Bridge-Seton Water Use Plan

Seton River Habitat and Fish Monitor

Implementation Years 1 and 2

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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 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. The data collected on juvenile and adult fish populations will, over time, allow us to identify trends and patterns that will enable us to make inferences about the effect of flow on habitat, species abundance and diversity.

In 2014, we collected data through habitat (depth, velocity) surveys, which allowed us to quantify useable habitat for Rainbow Trout, Coho and Chinook juveniles in the Seton River. Repeating the surveys at established sites enabled us to monitor the effects of flows on each habitat type. In 2014, habitat surveys were completed at four different discharges: 12, 15, 25 and 27 m^3/s. Overall, it appears that as flows increase, useable habitat decreases. However, this change is not consistent between habitat types and species. River channel characteristics may also play a role in response variability. For example, riffle habitat units in reach three responded positively to an increase in flow, showing an increase in useable habitat, whereas in all other reaches, the response was negative. In cases where flow increases resulted in positive habitat gains, there is likely an optimal discharge after which higher flows may have a negative effect on habitat. A discharge increase from 12 to 15 m^3/s had a positive effect on some habitats in all reaches, but it is unknown up to what discharge this positive responses will continue. At a discharge increase from 15 to 25 m^3/s, a negative effect was observed in all reaches.

Through monthly juvenile surveys in 2014, valuable data were collected on juvenile growth rates for resident and anadromous life stages in the Seton River. Thirteen species of fish were observed, including seven species of salmonids [Rainbow trout (*Oncorhynchus mykiss*), Bulltrout (*Salvelinus confluentus*), Coho (*O.* kisutch), Chinook (*O. tshawytscha*), Pink (O. gorbuscha), sockeye (O. nerka) and white fish (*Prosopium williamsoni*)] and six species of non-salmonids [bridgelip sucker (*Catostomus columbianus*), prickly sculpin (*Cottus asper*), coastrange sculpin (*C. aleuticus*), longnose dace (*Rhinichthys cataractae*), red-sided shiner (*Richardsonius balteatus*) and northern pike minnow(*Ptychocheilus oregonensis*)]. Of these

species, only Rainbow trout and Coho were caught in sufficient numbers to show the presence of discrete age classes. Four distinct age classes of Rainbow trout were observed (0+, 1, 2, and 3+). Two age classes of Coho were identified, age one (1) fish in the spring and young of the year (0) throughout the rest of the year.

A two level sampling strategy using electrofishing and snorkel surveys was used to estimate juvenile fish abundance in the Seton River. This includes Rainbow Trout, Coho, Chinook, Bull Trout and Mountain Whitefish. Electrofishing surveys and a mark-recapture study were completed in September. Snorkel surveys and mark recapture studies to estimate abundance and capture probabilities of larger, older fish (all species) could not be completed in September (2014), due to limited water visibility. These surveys will be completed in the spring of 2015. The electrofishing, mark-recapture study completed in September (2014) to estimate capture probability was used to expand the counts of the various index sites sampled through single pass electrofishing. A hierarchical Bayesian model (HBM) was used to estimate abundance estimates for age 0 Rainbow Trout only. Young of the year Coho, Chinook and Mountain Whitefish were also captured, but catches were not high enough to create abundance estimates.

Mean abundance of age 0 Rainbow trout across all the index sites sampled was 36 individuals (0.7 fish/m) and ranged from 5 to 87 individuals (0.1 - 1.7 fish/m). Low sample sizes in some sites (Site 4, reach 1 and Site 29, reach 3) resulted in broader credible intervals as high as 120% of mean estimate.

Efforts to enumerate all species of adult salmonids spawning in the Seton River in 2014 were completed through radio-telemetry, visual counts, and PIT telemetry. These methods worked with varying success. Fifteen Steelhead adults were tagged at the Seton-Fraser confluence but only three fish remained in the Seton River (20%). No Steelhead were observed during the stream walks. Chinook adult enumeration proved to be a challenge; although extensive angling effort was applied, there were none captured. Only two Chinook were observed holding in the Seton River during stream walks. Low numbers of fish were also observed for adult Coho. Only one adult captured and PIT tagged, and 21 observed during the stream walks. Of the 21 observed, 15 were observed in the spawning channels, the other six were observed holding near Seton Dam. However, we cannot be sure if they spawned in the Seton River or moved up past the dam. Other adult salmonids (e.g. Bull Trout and Mountain Whitefish) were observed in the system, but are believed to use the river as a feeding ground or migratory corridor rather than for spawning.

In 2014, three PIT antennas were installed in the Seton River watershed. These antennas were installed at the Seton Dam fishway, Cayoosh Creek near confluence with Seton River and the outflow of the lower spawning channel. Due to budget and equipment constraints a PIT antenna could not be installed in the upper spawning. This antenna will be installed in 2015. These antennae will allow us to track movements of individual fish, and inform us if fish move in and out of the Seton River to spawn or rear in other systems. Data collection is ongoing.

On April 1, 2014, the impacts of the annual maintenance shutdown of the Seton Generating Station were monitored. The shutdown of the generation station resulted in a 19% reduction in flow in the Fraser River at Water Survey of Canada's Texas Creek gauge downstream of the Fraser-Seton confluence. The average rate of stage reduction was below DFO guidelines (<0.5 m/h). At site one, the rate of stage reduction was 0.30 m/h, and at site two, the rate of reduction was 0.15 m/h. Fish stranding surveys identified one stranded sculpin but no others.

To monitor the effects of the Seton hydrograph influence on the short term and long term availability of gravel suitable for use by anadromous and resident species, a river bed topographical survey was completed in September, 2013. This survey was completed at the location where most fish have been observed to spawn (downstream of the dam, 135 m). Future surveys at the same location will allow for direct comparison of the bed elevation and thus allow us to make inferences about gravel movement or deposition. The next survey is scheduled for the fall of 2015.

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INTRODUCTION

1.1 Background

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 18 m 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, and from that point the two flow together as the Seton River. A small run-of-the-river generating station operates on Cayoosh creek and as a result, flows in the Creek are largely unregulated and can vary greatly on a seasonal basis.

The Seton corridor has high fisheries and wildlife value for the local community. The Seton 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), Bulltrout (Salvelinus confluentus), mountain whitefish (Prosopium williamsoni), and various species of minnows (Cyprinids).

Since the construction of the dam, the flows of the Seton River have been regulated. In 1999, the Bridge River Water Use Plan consultative process was initiated and was completed in 2001. A critical environmental concern expressed throughout the development of the Bridge-Seton Water Use Plan (BRG 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. Seton River is well known to provide spawning and rearing habitat to several anadromous (Chinook, Coho, Pink salmon, and Steelhead trout) and resident species [Bulltrout (rearing only), whitefish, and Rainbow trout]. However, there are relatively limited data to describe the biological characteristics of these populations in terms of the abundance, productivity, and life history. Very little information is available that links changes in flow to changes in habitat and fish populations.

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. Performance measures were developed in a phased manner. Initially, physical habitat simulation models developed in earlier efforts to resolve instream flow issues at Seton were applied to investigate the effect of the in stream flow regime on the rearing and spawning phases of key anadromous species. Discussion of model output 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. There was consensus that the physical habitat modeling was flawed because: 1) it did not account for all physical or biological factors influencing the productivity of the fish populations, and 2) there was insufficient spatial resolution to confidently extrapolate habitat conditions to the entire river. This uncertainty 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 central 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 simple measures did ultimately allow trade-off decisions to be made to select the final alternative (N2-P). The BRG CC expressed concern about uncertainty about how habitat changes would influence fish abundance and diversity. Given poor baseline data on habitat and populations in

Seton River, the BRG CC recommended implementation of 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 (summarized in Higgins 2010). The effects of Seton operations on Fraser River discharge are greater at low Fraser River discharge (typically Dec to Mar). Thus, concern was focused on the effects of Seton Generating Station operations during winter, and operations during this period are now managed to mitigate potential impacts. 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). This monitoring program will further investigate these potential impacts in the Fraser River and provide additional physical and biological information to help reduce uncertainty on the effects to fish and fish habitat.

1.2 Management Questions

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

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?

2) How does the proposed Seton hydrograph influence the hydraulic condition of juvenile fish rearing habitats 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.

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

H1: The amount of hydraulic habitat that can be inhabited by juvenile fish is independent of discharge from Seton Dam.

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.

H2: The selected Seton River hydrograph does not result in dewatering of salmon or Steelhead redds.

H3: 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; however, they could not be resolved during the WUP. Technical data evaluate answers to these hypothesis do not exist at present and there is expected to be some inter-annual variation in the hydrograph, which could not be predicted with power modeling studies. Data from this program will be collected to explicitly test these null hypotheses.

1.3 Key Water Use Decision Affected

Seton Dam and generating station are a ‘hydraulic bottleneck’ in the Bridge-Seton system, and changes in the operation of the dam (i.e., in stream flow release) have considerable upstream impact on the management of Carpenter and Downton Reservoir. This hydraulic characteristic has two practical consequences. First, there are periodic high flows in the river that are necessitated by water management concerns. For example, in high inflow years water is managed in the system to prevent excessive flow releases from Terzaghi Dam which result in power generation losses as well as environmental impacts in the Bridge River. Because 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 that are greater than that thought to be beneficial for fish. 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 are believed to reduce the productive capacity of the habitat. 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 expected riparian performance in Carpenter Reservoir. This trade-off was pervasive during the development of the BRG WUP. There was great uncertainty in making this trade-off so this monitoring program directly addresses this uncertainty. Follow-up monitoring was recommended by the BRG CC so that better estimates of the impacts of alternative flow regimes could be made and this would support more informed decisions about this trade-off in the future.

2. METHODS

2.1 Objectives

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

2.2 Monitoring Approach

The general approach to this monitoring program will be to conduct field studies to provide three critical pieces of information improving the capability to make wise decisions regarding flow management at Seton Dam. First, field studies will provide direct observation of key uncertainties about the impacts of the hydrograph on the quality of juvenile habitats, redd dewatering, and gravel scour in the river channel. Second this collection of habitat and population data simultaneously will allow more reliable judgments about the short term impacts of habitat alteration on population abundance and diversity. Finally, the monitoring studies will provide the time series data on juvenile and adult populations that 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 1) index population abundance and distribution in relation to habitat conditions 2) quantify red dewatering; and 3) quantify/map changes in spawning gravel location and quantity. Stream walk surveys of the Seton River are being continued annually following methodologies developed and implemented previously by Tisdale Environmental Consulting Inc. (from here on referred to as TEC Inc.). These methods are used to estimate the abundance, distribution and biological characteristics of the populations of salmon and Steelhead adults. The visual survey area extends from the Seton Dam to the confluence with the Fraser River.

Radio telemetry offers a means to address spawner distribution as highlighted above. For the first time, radio tags were applied to Steelhead in the spring of 2014 and will be continued in the spring of 2015. Radio tracking relies on a sub-sample of a spawner population to identify key spawning areas and evaluate residence time, migration flow and timing (Brown and Mackay 1995, Bison 2006, McCubbing and Melville 2000). The approach provides representative data on localized habitat use.

Standardized data management and base mapping is being developed to determine the linkage between spawner survey program 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 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. Discharge-habitat suitability curves can be used to determine the area of suitable habitat 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, K.D. 1986). Data requirements for this methodology include cross-sectional surveys and habitat suitability criteria. The transect sites identified by Tisdale Environmental Consulting Inc. (TEC) were suitable for the work completed by IFR, but the individual transect data collected in 2013 could not be used as the data collected was not consistent with BC Instream Flow Guidelines and useable depth and velocity cut-offs used were not consistent with the available HSI curves for each species.

2.3.1 Site selection:

Tisdale Environmental Consulting Inc. (TEC) identified the survey sites on lower the Seton River. This was completed through field surveys in 2013. The full length of the Seton River was surveyed from the Seton Dam to the confluence with the Fraser River. Hydrological habitat units (riffles, glides and pools) were identified and measured for length. Depending on accessibility and safety, transect sites were identified within each individual unit. In total, 125 sites were identified; 76 on river right and 49 on river left.

All transect sites were geo-referenced using a hand-held GPS receiver accurate to within 10 m. The GPS coordinates of each site were recorded in UTM format and the location of each transect was clearly marked (Figure 3). TEC Inc. marked the sites with flagging tape and InStream began marking sites using a 5/8” diameter rebar pin, which was placed above the point of rooted vegetation (bankfull) in order for depth and velocity transect to capture the wetted width over a range of flows.

Study sites were located throughout the Seton River with at least one site assigned per hydrological habitat unit (where access was safe). After linking sites on river right with the corresponding sites on river left, a total of 81 cross-sectional sites were identified. These sites were attempted to be sampled at various flows throughout 2014.

Along with the identification of the individual hydrological units in the Seton River, the river was divided into three reaches. These reaches were identified using Google maps and through the data collected during site selection surveys. Reaches were defined as homogeneous sections of the river as defined in Johnston and Slaney (1996).

Reaches were numbered in ascending order from Seton Dam to the confluence with the Fraser River (Figure 9).

Reach one extends 1100 m (down main thalwag of river) downstream to the confluence with Cayoosh creek (Lat 50.668884 N, Long -121.961335 W). This reach is a lower gradient comprised of long glide and riffle, pool sections.

Reach two extends 1246 m downstream from the Cayoosh confluence to 50.672083° N, -121.946417° W (just downstream of the intake to the lower spawning channel). Reach 2 is higher in gradient and is composed of primarily riffles and glide and very few pools. Water velocities in this reach are usually a bit higher due to the channelization (due to road armoring) of the reach.

Reach 3 is 1654 m long and extends downstream from reach two break to the confluence with the Fraser River. Like reach one, this reach is low gradient with wide bankfull widths. This reach is made up of long glides and long riffles and very few pools.

2.3.2 Surveys:

Surveys were conducted as per methods described in “The B.C. Instream Flow Guidelines” (Lewis et al. 2004). At each transect site (river cross section) depth, velocity, and substrate measurements were recorded along a series of verticals along the transect line. A detailed substrate survey was completed at base low flow (12 m^3/s), and included the identification of the distribution of substrate type (fines, sand, small gravel, large gravel, small cobble, large cobble, boulder and bedrock) to the nearest 5% within a 1 m^2 section of river bed along the entire length of the transect line from bank pin to bank pin or to a point of safe access. This was completed once to identify the dominant substrate using the Wentworth Scale at each transect site.

The depth-velocity transect consisted of running a measuring tape or marked line across the width of the river, from bankfull pin to bankfull pin, where possible. Depending on the wetted width of the site, depth, velocity and substrate measurements were recorded. Velocities were taken at 60% of the total depth (mean column velocity-V60) where depths were less than one meter. When depths exceeded one metre, velocities were taken at 80% and 20% of total depth. A Swoffer (Model 2100) current velocity metre was used to measure velocities and the top set wading rod of the Swoffer was used to measure depth. Depth was measured to the nearest centimetre.

2.3.3 Data Analysis:

Collected data was analyzed using a model developed by Ptolmey et al (1994), which is based on Habitat Suitability Index (HSI) scores. The Ministry of Environment provided species and life stage-specific HSI scores corresponding to depth, velocity, and substrate preferences (Appendix 1). This model estimates the amount of suitable habitat for different species and life stages at a given discharge. Each parameter is weighted by a Habitat Suitability Index score ranging from 0 (unsuitable) to 1 (optimal habitat suitability). The amount of suitable habitat is quantified as the product of HSI scores for each habitat value (e.g. water depth, velocity and substrate) plus the wetted width of the transect. Using these data two metrics were calculated: 1) % Weighted Useable Width (WUW) and 2) Weighted Useable Width in metres (with respect to the bankfull width). Each transect vertical (point) represents an area of stream bed half way to the neighboring vertical points and to the up and downstream boundaries of the transect (Mosley 1985). The WUW values can then be expanded by the length of the unit to create a % Weighted Useable Area (WUA) and total WUA. In sections of the river where a cross-section survey is completed, along with the WUA and useable width values, a metered discharge value is calculated. Once the WUA and WUW are calculated habitat discharge relationship are created.

Due to the size, depth and velocities of the Seton River, whole river cross sections were not completed at many sites. This was not a concern as the distribution of juvenile fish is mostly limited to shoreline areas. In cases where whole river cross-sections could not be completed, transects along the same line were completed on each shoreline. The middle sections of the river where velocities were too fast or too deep were deemed unsuitable to juveniles according to HSI curves. In sections where a transect was completed only on one shoreline and the river channel was uniform, the measurements/data from one shoreline were mirrored on the opposing shoreline for analysis.

Discharge data was obtained from the Water Survey of Canada Gauge at Seton River near Lillooet (08ME003) and the Water Survey of Canada Gauge at Cayoosh Creek (08ME002).

2.4 Juvenile Growth Sampling

Fish growth and distribution was assessed through monthly open site electrofishing surveys using a Smith-Root LR-24 backpack electrofisher. Fish were captured by one-pass electrofishing various sites within the river. Crews consisted of two or three members, with one person (crew leader) equipped with the backpack electrofisher and one or two dip netters to collect and sample fish. Fish collected from the surveys were placed in buckets of fresh water and held for sampling at the end of each site. Once the pass was completed, the fish were scanned for PIT tags and sampled.

In order to reduce handling stress, fish that were marked and/or sampled were anaesthetized with a diluted solution of clove oil, dissolved 1:10 in ethanol. Once a month (or every sampling session), a minimum of 30 fish per species were sampled for fork length (mm), weight (g) and scales. 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 from each fish were collected from the area above the lateral line and immediately below the dorsal fin. Scale samples were placed in coin envelopes marked with appropriate data for cross-reference. After a period of air-drying, scales were processed in two ways. They were either pressed on to plastic and the imprints analyzed using a microfiche reader following the methods of Mackay et al. (1990) or they were directly placed on glass slides and read under a microscope. Age was determined by the methods outlined in Ward and Slaney (1988), in which two persons independently determined age without knowledge of the size, time and location of capture of the sampled fish. Samples were discarded when a consensus between both persons could not be reached. The age data was then used to create an age-length relationship that in turn was used to create a length-age key and assign ages to the entire sample of fish. The age-length key was constructed by methods described in Isermann and Knight (2005) and the FSA package in R (Ogle, 2013).

In addition to the biological data collected, all Rainbow trout, Bull Trout and whitefish above 75 mm in length were tagged with a 12 mm PIT tag. These tags were inserted into the body cavity using a 12 gauge needle. If the fish were less than 150 mm in length the PIT tag was inserted into the ventral stomach cavity. If the fish were larger than 150 mm, the PIT tag was inserted into the dorsal sinus of the fish. The recapture of these fish would allow for the observation of growth and movement of each individual fish and help verify size/age classes of the other fish collected in each successive sampling survey.

The majority of sites were selected in the mainstem of the Seton River along with some sites within the two spawning channels (lower and upper). Although it was not within the scope of BRGMON-9 to sample the spawning channels, we thought it important to compare species presence and growth rate of fish between the two habitat types. Data from the two spawning channels was combined to compare against the main-stem fish. Electrofishing within the spawning channels would also provide the opportunity to PIT tag juvenile fish and asses any movement in and out of the spawning channels.
In total 14 sites were sampled on the Seton River main stem. These sites were selected according to their appearance to hold fish, as the main purpose of these surveys was to sample as many fish as possible. The spawning channels were sampled throughout their entire lengths (Figure 4).

2.5 Juvenile Abundance

A Juvenile standing crop survey was conducted in September 2014. This survey followed the methods outlined in Korman (2010a; 2010b). In short, this methodology combines open-site electroshocking and snorkel surveys for estimating species specific standing crop of juvenile salmonids present in the Seton River (i.e. Coho, Chinook, Rainbow trout/Steelhead, Bull trout, Mountain whitefish). These two methods work well together as they maximize detection capture probability across juvenile life stages and habitat types. For example, capture probabilities of small juvenile Rainbow trout (<60 mm) using electrofishing are high but low for larger juveniles (>60 mm) whereas the opposite is true for snorkel surveys (Korman et al., 2010a). Furthermore, capture probabilities differ for each method by water depth, with shallow water favouring electrofishing and deeper water favouring snorkel surveys (Korman et al., 2010a). A hierarchical Bayesian model was used to estimate fish abundance from these two methods (Korman 2010a and Wyatt 2002). This is a powerful modeling approach that allows for a mixture of enumeration methods and accounts for variation in detection probabilities among sites.

2.5.1 Site selection:

Sites along each shoreline were selected from the pool of hydrological units that were identified during the WUA surveys. These sites were further classified into riffle, shallow and deep habitats (Korman 2010b). These different type of habitats would be sampled by different gears depending on discharge and life stage of fish. The method/gear selected for sampling each habitat type was based on the gears limitations and method specific seasonal restrictions (turbid waters in the fall prevent snorkel surveys). Given the above criteria. The fall abundance surveys were based solely on electrofishing. Spring abundance estimates will be based on both the electrofishing data and snorkel surveys. At the time of writing this report the snorkel surveys hadn’t been completed.

In the fall of 2014, 25 index sites and 6 mark recapture sites were sampled by electro-fishing, accounting for a total of 991 m (approximately 12%) of shoreline sampled. Snorkel surveys could not be completed in the fall of 2014 due to the high turbidity and low visibility of the water (high amounts of glacial till) in the Seton River, but will occur in the early spring of 2015. Index electrofishing sites were selected at random from pre-existing riffle and shallow glide sites (these sites were selected from the 125 WUA sites – Figure 3). Mark recapture sites were selected to represent a shallow glide and riffle sections in each reach (3 reaches). Mark-recapture studies consisted of a capture survey where all fish of interest caught at a site (by electrofishing or snorkel surveys), were marked and released for recapture 24 hours later (Korman, 2010a). For snorkel surveys mark-recapture studies will be conducted as per methods described in Hagen et al. (2010). Briefly, a single diver traverses the site in an upstream direction searching for fish with the help of underwater lights fixed to the forearm and mask of the diver. This allows the divers hands to be free and use two aquarium nets (27 x 27 cm) fixed to handles to capture/collect fish. These two methods would provide a precise estimates of detection probability that are used in the Hierarchical Bayesian model.

2.5.2 Data Analysis

The hierarchical Bayesian model consisted of two levels. The first level of the model, the observation model, used data from the mark-recapture studies to estimate site-specific and hyper-distributions for capture probability (figure 5). Capture probability is the number of fish marked divided by the number recaptured in the second pass at mark recapture site *i* (Table 1). The hyper distribution for capture probability was then used in the second level of the model, the population model, to estimate abundance for index site *j* using catch data collected from the single pass. Abundance was calculated by multiplying capture probability by total catch at site *j*. The only species/life stage with enough data to produce reliable estimates of capture probability was for 0+ Rainbow trout.

The number of marked fish recaptured from a single pass in mark recapture site *i* were assumed to be binomial distributed and capture probabilities were assumed to follow a beta distribution. Catches were assumed follow a Poisson distribution and the abundance was assumed to follow a normal distribution. All priors used in the observation model were uninformative (Table 2). 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.

2.6 Radio Telemetry

2.6.1 Tag Application and Bio-sampling

Attempts to capture fish were conducted by skilled anglers fishing throughout the Seton River and Seton-Fraser Confluence. In 2014 Steelhead were radio tagged using the same methodologies used for Coho and Chinook on the Lower Bridge System (McCubbing et. al. 2013):

- A MCF2-3A radio tag (Lotek Engineering Inc.) was gastrically implanted in the stomach of each fish (Figure 6).

For all species double external spaghetti tag was attached through the dorsal muscle mass so that technicians could visually identify radio tagged fish during stream walks and thus determine observer efficiency.

Fork length and gender were recorded during tagging and scale samples were taken from all adults for ageing. After tagging, the 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 was proposed to be distributed throughout the migration period of the three species. Efforts to ensure even distribution of tags between sexes was made, as migration behaviour and run timing of males and females differs (Korman et al. 2010b; Troffe et al. 2010). The tagging schedule was adaptive in nature as suitable capture locations proved to be limited on the Seton River, and thus application timing depended on capture success, angler conditions, and fish behaviour.

2.6.2 Mobile Tracking

Weekly mobile tracking with a hand held Lotek W31 radio receiver was conducted throughout the four kilometers of the Seton River. Tracking occurred during the period tags were known to be present in the area (based on fixed station analysis) and co-incided with weekly stream walks. Manual tracking was completed by vehicle or foot and in isolation of the technicians conducting the visual count to avoid observer bias, i.e. searching for known tags in the area. Fish location and tag code were recorded as well as visual sighting of tagged and untagged individuals by species. Dates for tracking included the periods from April 21st to June 4th for Steelhead, only one Coho and no Chinook were caught in the summer and fall of 2014 and thus the radio telemetry component for those species was abandoned for the year.

2.6.3 Fixed Station Telemetry Receivers

Fixed station logging was conducted at two sites (Figure 7) with Lotek W31 receivers linked to two Yagi 6-prong directional aerials oriented upstream and downstream. These stations were powered by 12v deep cycle (110amp hour) lead acid batteries. The fixed stations were operated from April 6th through to June 20th when the migration of Steelhead had ceased.

Locations included:
Site 1: 200 m upstream of lower spawning channel outflow and Seton River Confluence (River Kilometer - RK 1.3 from confluence with Fraser River.)
Site 2: Cayoosh Creek confluence with the Seton River (RK 3 from the confluence with the Fraser River)

Fixed station data was used to corroborate fish location (during mobile tracking), identify entry and exit timing of each fish into each reach , and collect basic data on Steelhead adult migration and spawning behaviour in the Seton River.

2.7 Visual Counts

Visual stream bank counts were undertaken for spawning Steelhead, Rainbow, Chinook and Coho salmon weekly throughout the whole extent of the Seton River. The Spawning Channels were also surveyed in attempts to identify their use by adult Salmonids. Methods replicated those utilized in BRGMON3 surveys (McCubbing et. al. 2013) and data collected is an index of abundance rather than total counts. Briefly, two observers walked in a downstream direction on the riverbank looking for visible signs of fish. Fish were classified by species and location and recorded in field notebooks. Viewing conditions, cloud cover and lateral water visibility were also recorded. Surveys commenced on April 22nd for the enumeration of Steelhead and were completed on June 18th, when the Steelhead migration and spawning had completed. Chinook surveys commenced on September 4th and were completed on the 30th of September. Coho surveys began on October 28th and were completed on November 25th.

2.8 Model Used to Estimate Escapement from Visual Count and Telemetry Data

An Area-Under-the-Curve (AUC) method was proposed to estimate escapement for Steelhead salmon based on repeat visual counts from stream walks, combined with estimates of observer efficiency (o.e) and survey life from radio telemetry. Estimates were created by maximum likelihood using Hilborn et al.'s (1999) approach where spawn timing is modelled using a beta distribution,

1) $$S_t = E\frac{t}{T}^{(\alpha-1)}\left(1-\frac{t}{T}\right)^{(\beta-1)}$$

where S_t is the number of spawners in week t in the survey area (with a maximum week T), E is the total number of spawners over the spawning season (i.e., escapement), and α and β are parameters of the beta distribution that determine the proportion of the total spawners present on each week. We use a convenient re-parameterization of the beta distribution where the week of peak spawning (γ, the mode of the beta distribution) and the relative precision in spawn timing (α) are estimated, and β is computed from $\beta = \frac{\alpha-1}{\gamma} + 2 - \alpha$.

The predicted number of spawners present on each model week (s_t) is calculated as the difference between the cumulative number of spawners that have entered through week t (Eqn. 1) and the cumulative number that have died or left from,

2) $$s_t = \left(\sum_t S_t - \sum_t D_t\right)$$

where, D_t is number that died or left the survey area on week t, and is computed from $D_t = S_{t\text{-}surv}$, where surv is the survey life in weeks. Thus, we assume that survey life is constant over the spawning season.

The number of spawners that are observed on any survey date ($\hat{c}_t$) is computed from

3) $$\hat{c}_t = s_t * o.e$$

where, o.e is the observer efficiency. The model is then fitted to the data by minimizing the negative log likelihood (NLL) of a Poisson probability distribution whose kernel is,

(4) $$NLL = \sum_t \hat{c}_t - c_t \log(\hat{c}_t)$$

where, c_t is the observed count of spawners on a survey in week t.

Observer efficiency was calculated as the number of externally tagged fish observed in each visual enumeration stream walk divided by the total number of fish calculated as being present through manual and fixed station telemetry records. Each externally tagged fish was fitted with a radio tag so that the number of externally tagged fish in the count area was known on each survey date, through a combination of mobile tracking, generally on the day of visual count and through evaluation of fixed station downloads. Fish which were evaluated as deceased were not used in observer efficiency calculations as only live counts were used in AUC estimates. The date of each tagged fish's death was evaluated as the first day of which a significant (>1km) downstream movement was made or the day that the fish remained stationary in one location for the rest of the study period as recorded either by fixed station records or mobile tracking or the day that the fish ceased.

Residence time was estimated as the time period in which a live spawning fish was located within the visual counting zone and was calculated as an average by species and survey year of all tagged fish which were marked either outside of the visual count zone or at the lower portion of the count zone, (within 50m of the lower boundary). Briefly, residence time was calculated as the number of days post tagging that a fish was observed moving in an upstream direction followed by a large (>1km) directional downstream movement. Fish which exhibited little or no upstream movement post tagging or during periods of extended residency in one location without directional movement (post spawning) were not used for calculations unless visually verified as live at the time of the survey.

The first day of survey life was evaluated as the week that historically fish have been observed as being present in the survey count zone, while the total survey days was calculated as the difference in days between the first zero count following peak spawning and the initial survey day as described.

2.9 Passive Integrated Transponder Tagging

An intensive Passive Integrated Transponder (PIT) tagging operation has been taking place in the Seton River since the initiation of the BRGMON-9 project. Each adult or juvenile salmonid of a suitable size captured (juveniles > 70 mm and all adults), either through angling or electrofishing was implanted with a 12 mm or a 32 mm PIT tag. This mark recapture technique will allow for the tracking of movement and growth rate of individual fish in the Seton River system.

Movement of fish was assessed through the installation of three fixed PIT antenna arrays in the Seton River System. Fixed PIT (Figure 7). One of the PIT antennas is located in the fish-way of Seton Dam. Another antenna is located at the outflow of the lower spawning channel. These two stations are powered by mains power and therefore are able to operate all year round. The third antenna was installed in Cayoosh Creek, approximately 650 m upstream of the confluence with the Seton River. It was powered by a 12v deep cycle (110amp hour) lead acid battery. The Cayoosh Creek station was operated from October 8th through to December 3rd when the migration and spawning of Coho had finished.

Fixed station data will be used to corroborate fish location, identify movement of each fish into each region, and collect basic data on fish migration and spawning behavior in the Seton River. The data collected will also be used to assess fish abundance through proportional distribution analysis.

This method for evaluating abundance, using data collected at the Seton fishway and proportional distribution, will account for fish that move through the visual survey area and are likely to be counted by that method but do not spawn in the Seton River. This is a short-coming of the method described above because Coho, Chinook and Pink Salmon spawn in other areas of the Seton-Anderson Watershed; such as the lower and upper Seton River spawning channels, Cayoosh Creek, and upstream of the Seton Dam in Portage and Gates Creeks (H. O'Donaghey pers. comm.). The Seton fishway resistivity counter (BRGMON-14 funded) will provide an accurate estimate of the number of salmon that move above the dam and data collected by PIT tag arrays at key locations throughout the watershed will be used to calculate the relative proportion of fish that leave the mainstem and spawn elsewhere. This is a similar approach to coho enumeration currently being conducted on the Bridge River (BRGMON-3) by InStream Fisheries Research Inc.

To achieve sufficient sample sizes an additional 30-50 coho will be tagged with 32mm PIT tags and external Peterson disc tags. Data from PIT tags will used to determine the distribution of spawners throughout the entire Seton-Anderson watershed.

The abundance of coho spawning below the dam will be calculated as follows:

$$E_{lower} = E_{ft} - E_{ft} \cdot P_{dam}$$

where Elower is the number of salmon sp. spawning below the dam,

E_{ft} is the number of spawners through the fishway, and

P_{dam} is the proportion of PIT tagged fish that moved through the fishway.

To generate Seton River spawner abundance we must remove fish that spawn in the spawing channels and Cayoosh Creek. The Seton River salmon spawner abundance will be calculated as follows:

$$E_m = E_{lower} - E_{lower} \cdot P_{channels}$$

where E_m is the number of salmon spawning in the mainstem Seton River, and

$P_{channels}$ is the proportion of PIT tagged fish that enter and spawn in the lower and upper spawning channels as well as Cayoosh Creek.

Estimates of salmon abundance for the two spawning channels and Cayoosh Creek can also be derived from these data.

This approach assumes that no tags leave the river to the Fraser prior to spawning; radio tag data will confirm this assumption as the lower river is too large for efficient operation of a PIT antenna. We will compare the estimates of spawner abundance from both methods.

2.10 Fraser River Fish Habitat

Methods for assessing the effects of Seton Generating Station discharge reductions on the Fraser River fish and habitat were consistent with those used by TEC Inc. TEC Inc. provided technical support in 2014 and identified two locations of interest on the Fraser River (Figure 8). These sites were identified as critical sites (Higgins, 2010) due to the river channel properties for example these sites are gravel bar areas of low gradient that are susceptible to high surface area of dewatering.

Each site was visited the morning before the shutdown, and a portable staff gauge was installed. During ramp down the water depth was measured at the staff gauge every five minutes. After the shutdown the dewatered gravel bar was surveyed for stranded fish.

2.11 Gravel Mobilization

TEC Inc. contracted Bennett Land Surveying LTD. to conduct a riverbed topographical survey of the section of the Seton River where a large portion of the salmon spawning occurs. This area is approximately 135 m downstream of the Seton Dam. The survey consisted of measuring bed elevations at 19 cross-sections across the Seton River at 10 m intervals. The initial survey was conducted in the fall of 2013. In combination with future surveys this method will track bed elevation and characterize changes in gravel volume.

3. RESULTS

3.1 Juvenile Rearing habitat

3.1.1 Study sites

To better understand the variation in effects of discharge on fish habitat, results were broken down by reach and habitat type (riffles, pools and glides). Each of these habitat types and reaches experience different hydrological responses during different discharges.

Due to the influence of Cayoosh creek on the Seton River below their confluence, the discharge data for reach one was taken from Water Survey of Canada gauge (08ME003), which is located on the Seton River upstream of the confluence. For reaches two and three the discharge data from gauge 08ME003 was combined with Water Survey of Canada gauge (08ME002) located in Cayoosh Creek.

3.1.2 Surveys

Four depth, velocity surveys were completed on the Seton River in 2014 under four different discharges. Survey one was completed between March 18th and April 4th. During this time discharge at the Water Survey of Canada gauge (08ME003) was 11.63 m^3/s. Discharge at Cayoosh Creek was 1.55 m^3/s, which when combined with Seton River discharge summed to 13.18 m^3/s. Juvenile Rainbow Trout, Bull Trout, Coho Salmon, Chinook Salmon, Mountain Whitefish are all present at this time. During survey one, all of the 81 transect sites were surveyed. Survey two was completed between July 16th to 19th and July 31st, at which time flows in reach one and reaches two and three were 27.26 and 33.07 m^3/s (reaches 2 and 3 have same discharge) respectively. All juvenile species discussed above are present at this time as well. Survey three was completed between August 8th and September 11th. A total of 75 sites were sampled during survey this survey when discharges were 25.74 and 27.43 m^3/s (reach 2 & 3) in reach one and reaches two and three respectively. Survey four was conducted in September from the 15th to the 26th. At that time discharge at Seton gauge 08ME003 and downstream of Cayoosh Creek was 14.76 m^3/s 16.78 m^3/s respectively (Figure 10 & Figure 11). These surveys were conducted at sites where the juvenile abundance sampling had occurred and thus only 31 sites were surveyed.

Not all sites were represented in each of the four surveys, therefore only discharges from survey one (discharge = 12 m^3/s) and survey three (discharge = 25 m^3/s) will be directly compared, a similar number of sites were surveyed during each of those surveys and total weighted useable areas can be directly compared.

3.1.3 Rainbow Trout Fry

Rainbow trout fry useable habitat decreases with increased discharge (Figure 12).

In reach one when flows increased from 12 m^3/s to 25 m^3/s, total wetted usable area decreased for glides, riffles, pools. Total weighted useable (WUA) area for glides decreased from 776.2 m^2 to 395 m^2. A decrease of 49 %. Riffle WUA decreased by 942.8 m^2 (47 %) from 1991.8 m^2 to 1049 m^2 and WUA for pools decreased from 335.9 m^2 to 193.4 m^2 (42%). Although overall there was a decrease in WUA for each habitat type it is clearly visible from figure 13 that the percent change can be highly variable among habitat types and individual units. In reach one for example, some riffles appear to be more sensitive to flow changes (Figure 13b).

In reach two useable area decreased with the increase in discharge. Glides appear to be more sensitive to an increase of discharge (Figure 12b and 13d). Total WUA for glides decreased from 6907.7 m^2 to 1820.8 m^2, which is a drop of more than 5000 m^2or 74 %. Figure 12b shows that this drastic change may be caused by a large change in one or two glides where total WUA for them is absent at 25 m^3/s. The change in total WUA for riffles was not as large as for glides, but still decreased from 3431.2 m^2 to 1709.9 m^2 (50 %). Only one pool was sampled in this reach and its total WUA area decreased by 128.9 m^2 to 148.3 m^2.

In Reach three, wetted useable area also decreased with an increase in discharge. Glide total WUA decreased from 2793.55 m^2 to 1688.1 m^2 (40 %) and % WUA showed a similar magnitude of change across all glides (Figure 13g). The change in WUA for riffles in reach three was unlike any of the results from the other reaches. Riffles in reach three increased in the total amount of WUA (4811.5 m^2 to 6031.1 m^2 or 25 %). Like the glides in Reach two, this affect may be driven by a few riffle units in the reach (Figure 12c &13h). Only one pool was surveyed in reach 3 and total WUA area for that pool decreased from 2.27 to 0.9 m^2.

3.1.4 Rainbow Trout Parr

Rainbow trout parr WUA did not change to same magnitude of fry, but a decrease in area was still observed in all three reaches.

When discharge was increased by 13 m^3/s in reach one, total glide WUA area decreased from 1872.9 m^2 to 747.8 m^2 (Figure 14). This large decrease in WUA was likely driven by the single glide habitat in that reach (Figure 14a); most other glides exhibited only small changes in percent WUA (Figure 15a). Parr total WUA area in riffles decreased with increasing discharge (578 m^2) but did not show as large a change as in glides. The total WUA area of pools decreased from 553.2 m^2 to 215.15 m^2.

In Reach 2, total WUA for glides decreased from 5626 m^2 to 3720.1 m^2. Riffles saw a similar magnitude of change as total WUA area decreased from 3867 m2 to 2667.6 m^2. Only one pool was surveyed and parr WUA decreased from 326 m^2 to 181 m^2.

The smallest change in parr WUA was observed in Reach 3. Total parr WUA for glides decreased from 1000 m^2 to 2379 m^2. A smaller change was observed in riffles with total WUA decreasing from 5580 m^2 to 4929 m^2. The one pool that was surveyed in Reach 3 did not have any habitat suitable for parr at either discharge.

3.1.5 Juvenile Coho

Juvenile Coho habitat suitability show a similar response to Rainbow trout fry. In Reach one, total WUA for glides decreased from 1040.5 m2 to 612 m2 (Figure 16). Riffles were more sensitive to a increases in discharge and saw a decrease in Coho WUA from 2448.9 m2 to 1163.3 m2.Total pool WUA decreased by 554 m2 to 240.9m2.

In Reach two WUA decreased for all habitat types (Figure 16b). Coho WUA in glides decreased from 7776.3 m^2 to 2707.5 m^2. This large decrease may be driven by one or two glide units within the reach as shown in figure 16b and figure 17d. A smaller change was observed in riffles. WUA decreased by approximately 100 m^2. The WUA in the one pool that was surveyed decreased from 614 m^2 to 348 m^2.

WUA in reach three did not vary as much in reach two and an increase in WUA was observed in some riffles (3906.5m^2 to 4552.3 m^2) (Figure 16c and 17h). WUA in the one pool surveyed also increased from 79.8 m^2 to 90 m^2. Glides were more sensitive to an increase in discharge and total WUA declined from 2943.6 m^2 to 2126 m^2.

3.1.6 Juvenile Chinook

In reach one, Chinook WUA of glides and riffles showed similar results as Coho juveniles, with some units showing a decrease in %WUA and others an increase (Figure 19a, b & c). Overall a decrease was observed in total WUA (Figure 18). Glides declined from 5077.9 m^2 to 3090.3 m^2 and riffles decreased from 4106.32 m^2 to 3174.4 m^2. Overall the % WUA for each individual units was quite varied (Figure 19).

Reach two did not exhibit the same overall individual variation within habitat types observed in Reach one (Figure 19d, e & f). Glides were more sensitive to an increase in discharge and WUA decreased from 8685 m^2 to 5141.4 m^2. WUA for riffles also decreased (5738.8 m^2 to 4040.3 m^2), along with that of the one pool sampled (599.5 m^2 to 327.3 m^2).

In Reach three, WUA for Chinook in glides decreased from 5726.5 m^2 to 4314.02 m^2. Total WUA for riffles declined from 9149.8 m^2 to 8227.8 m^2 and there was little variability in % change of WUA. Total WUA for the single pool surveyed decreased from 267.8 m^2 to 30.8 m^2.

3.2 Juvenile Growth Sampling

Juvenile fish growth surveys commenced on April 15, 2014 and continued on a monthly basis through to October 26, 2015. In total 7 surveys were completed. The main-stem Seton River sites were sampled in all months from April to October, except for May and the spawning channels were sampled from April to July and then again in October.
In total, 13 species of fish were observed (Table 3). Seven species of salmonids (Rainbow trout, Bull trout, Coho, Chinook, Pink, sockeye and white fish), and six species of non-salmonids (bridge lip sucker, prickly sculpin, coastrange sculpin, longnose dace, red-sided shiner and northern pike minnow). Of these species only Rainbow trout and Coho were caught in sufficiently high numbers to show the presence of discrete size classes. Smaller fish, most likely young of the year, had a higher and more consistent capture rate than large fish and thus provided a larger sample size for analysis.

3.2.1 Rainbow Trout:

A total of 1096 Rainbow trout were sampled in the Seton River main-stem throughout the sampling series and their length ranged from 21 to 184 mm (Table 4). Length distributions show multiple modes in the histograms indicating multiple age classes are present throughout the year (Figure 20). In April two distinct modes are visible, one ranging from 75 to 120mm and the other representing fish larger than 125 mm. In July three distinct modes are apparent, one in the range from 25-65 mm, another in the 90 to 135 mm and a few fish greater than 135 mm. The length patterns observed in August are consistent with the patterns observed in July (i.e. three modes), although the mode of the largest group of fish is not as clearly defined. The September survey data is sparse for larger fish and thus is hard to identify any modes from the larger size classes. However, the larger fish sampled appear to be split evenly into three size classes (100-120 mm, 120-140mm and >145 mm). There is a clear mode for young of the year that ranges from 40 to 90mm (Figure 20). In October four distinct modes were clearly visible, with smaller size class between 45 and 110 mm, another possibly between 110 to125 mm, one from 130 to 150 mm and the last made up of fish greater than 155mm.

In the spawning channels 295 rainbow trout were sampled. Their lengths ranged from 32 to 228 mm (Table 4). Like in the mainstem river, the spawning channel histograms from the monthly sampling surveys indicate a similar distribution of size classes (Figure 21). The histogram from the spawning channels in April shows three possible size classes. A size class ranging from 75 mm to 120 mm, another from 125 to 165 mm and a size class of fish with fork lengths greater than 170 mm. In May the three distinct modes are not as clearly visible, but the data shows a similar spread or range. A distinct peak is observed at 115 mm another at around 140 mm and few larger fish greater than 165 mm. In June two modes are visible, one ranging from 110 to 140 mm and the other from 145 mm to 185 mm. In July a smaller size class is visible (25 mm to 55 mm), along with the larger three size classes that range from 100 to 130 mm, 135 to 160 mm and 165mm to greater than 200 mm. In October when the spawning channels were once again sampled, few fish were captured. This resulted in weak representation of the size classes however the data indicate modes between 60 to 80 mm, 110 to 130mm, 135 to 160 mm and 165 to 195 mm. This is consistent with the July and October size distributions.

Fish in the spawning channel were consistently larger than those sampled from the mainstem (t-test; p-value<0.05). This pattern was consistent for all the months where both areas were sampled (Table 5).

Scale/Age Analysis:

For the purpose of scale analysis all of the scales from the spawning channel fish and those of the mainstem river were pooled to increase sample sizes. Analysis from the scale data corroborate with the different modes observed in the length frequency histograms of each month. Data is presented for April, July, August and September. In May, June and October no scales were sampled.

In April, scale analysis showed three distinct age classes present. These ages represent fish that are one, two and three years old (Figure 22). All the Rainbow trout that have survived a winter were classified as age 1 +. In April these fish have not shown any scale growth to classify them as "+" fish but for graphical purposes they were classified as such. This was done for age 2 + and 3 + as well.

The length, age histogram for April shows an overlap of sizes between the age one and age two fish between 95 and 110 mm and age two and age three fish between 135 and 155 mm (Figure 22). The mean size at age for age one fish was 93 mm with a range from 75 to 109 mm, age two fish had a mean length of 123 mm (97 - 162 mm) and age three fish had an average length of 183 mm (135 – 228) (Figure 23). In July, when scales were once again sampled, the analysis showed three distinct age classes (0, 1 and 2) with a distinct new age class for young of the year Rainbow trout that had recently emerged from the gravel (Figure 24). Some of the fish were quite small and had not yet formed scales or developed annuli, scales were not collected from fish smaller than 45mm. It was assumed that these fish were age zero or young of the year. The age zero fish had a mean fork length of 38mm that ranged from 27 to 63 mm. The mean size for age one fish in July was 114mm (93 – 136 mm), while age two fish had a mean fork length of 144 mm (116 – 193 mm) (Figure 25). There were no age three fish sampled in July.

In August only three fish were sampled for scales and thus an age key could not be created. These fish were all age one fish with fork lengths of 113, 125 and 125 mm. The histograms from

July and August show very similar distributions and thus suggest the same age classes are present. These age classes would be age zero, age one and age two fish.

During the September sampling series, only six juvenile Rainbow were sampled for scales. These fish were all age zero fish with a mean fork length of 64mm (21 – 78 mm). Very few fish larger than 100 mm were sampled in September and therefore it is hard to estimate age classes of those fish. The dominant age class sampled in September were the age zero fish (Figure 20).
In October, three distinct age classes were identified (Figure 26). These were the same age classes observed in previous months. They were age zero, age one and age two fish. Age zero fish had a mean length of 71 mm and with a minimum of 55 mm and a maximum of 103 m. Age one fish had a mean fork length of 133 mm (112 – 174 mm) and age two fish had a mean length of 171 mm (150 – 267 mm) (Figure 27). An overlap between age one and age two fish still exists between 145mm to 175 mm.

Growth Analysis:

Although scales were not collected in all months, one can follow the common modes to assess growth rates through time. , Age data collected along with the length frequency histograms are used to assess growth rates of the different age classes in the Seton River main-stem. For young of the year fish both data are used. For age one and two fish, because sample sizes were not large enough, only data from the April, July and October sampling series is used. During those surveys enough samples were collected to create a length key and apply an age to non-sampled fish. Length, weight analysis showed a strong relationship between length and weight for Rainbow trout of all sizes within the Seton River (R2=0.969) (Figure 28).

Rainbow trout Age 0+

As expected, young of the year Rainbow were not observed until the July sampling survey. This was the case for sites in the main-stem river and spawning channels. During this survey the fish in the main-stem had a mean fork length of 37.6 mm with a range from 27 to 63 mm. Average weight was 0.8 g with a range from 0.10 to 3.9 g. In August these fish had grown to a mean length of 48.6 mm (31 to 67 mm) and a mean weight of 1.5 g. Growth continued into September with a mean fork length of 57 mm (21 – 82 mm) and a mean weight of 2.3 g. From September to

October the largest growth was observed. Mean fork length increased by 13 mm to 70 mm (46 – 103 mm) and a mean weight of 4.4 g (Figure 29 and 30). In total young of the year grew an average of 32.4 mm (0.36 mm/day) from July to October.

Rainbow trout Age 1+

Age one fish were represented in all months of the year where samples were collected. In April, the mean fork length of these fish (as reported previously) was 93 mm (75-109 mm) and had a mean weight of 9.5 g. By July these fish had grown by 21 mm to 114 mm and a mean weight of 18.6 g. From July to October growth remained constant and the fish had grown to a mean fork length of 133 mm and a mean weight of 24.3 g (Figures 31 and 32,). Age one fish grew an average of 40 mm (0.25 mm/day and 0.10g /day) in six months, from April to October.

Rainbow trout Age 2+

Age two fish like age one fish, were represented in all months where samples were collected. In April, age two fish had a mean fork length of 123 mm and a mean weight of 22.3 g. By July these fish had grown to a mean length of 145 mm and a mean weight of 38.8 g. From July to October age two fish mean length had increased by 26 mm to 171 mm. Mean weight had also increased from 38.8 g to 45.0 g, an increase of 6.3 g (Figures 32 & 33). Age two fish grew an average of 48 mm (0.3 mm/day) from April to October.

Rainbow trout Age 3+

Age three fish were only observed during the first sampling session. As they were only observed once throughout the year a growth pattern could not be assessed. This may be due to limitations of the sampling gear. Larger faster fish are more difficult to capture through open site electrofishing.

PIT Recaptures

Throughout the sampling year a number of Rainbow Trout that had been PIT tagged were recaptured. In total 22 PIT tagged Rainbow Trout were recaptured, sixteen of these fish could be retraced to original tag date (Table 6). The amount of time passed between catches varied from

30 – 126 days. Mean length and weight of the recaptured fish was 111 mm (90 – 143 mm) and 17.2 g (7.5 – 38.6 g). Based on the size and age we assume they are age one fish. On average these fish grew 0.24 mm/day and 0.11 g/day, this corresponds with the growth rates observed for the age one fish (0.25 mm/day and 0.10 g/day).
The PIT data also showed that there is some movement of juvenile fish throughout the river. Nine of the 16 fish tagged remained in the same location they were tagged. Three of them were originally tagged at site GS-3 and were recaptured at site GS-5 downstream about 1.3 km. Two of the fish were recaptured twice. They were originally sampled at GS-3 (July 23rd) then GS-5 (August 22nd) and the last time they were caught they were sampled at GS-3 again on October 22nd. The other fish was originally sampled at GS-5 then recaptured upstream at GS-3. The last fish was first sampled in the lower spawning channel on June 16th, 35 days later it was sampled at GS-8, meaning it migrated out of the spawning channel then moved upstream about 200m (Figure 4).

3.2.2 Juvenile Coho

A total of 466 Coho were sampled in the Seton River main-stem throughout the sampling series and their length ranged from 32 to 124mm. Results from the length distributions show two modes in the histograms suggesting multiple age classes present during certain times of the year (Figure 35). In April two distinct modes are visible, one single peak in the 30 to 35 mm range (young of the year) and the other with a peak at 100 to 105 mm representing larger older fish. In May the main stem was not sampled and in June, very few Coho were sample and it was not possible to identify modes in the histogram. In July fish length distribution was unimodal with a peak at 60 to 65 m. This is what is expected as the larger, older fish have most likely migrated downstream to the ocean. Length distributions in August are consistent with July length distributions with only a single size class is apparent. This same trend was observed in the September and October with only one age class present in the 65 to 95 mm range.

In the spawning channels a total of 208 Coho were sampled throughout the sampling period. Results from the length frequency distributions mirror those of the main-stem river (Figure 26). In April two size classes are observed. A smaller class 30 to 40 mm range and another in the 90 to 125 mm range. In May the smaller size class was not observed and only the larger 100 to 125 mm fish were captured. In June the larger size class was not present and the length frequency histogram was unimodal. This was also the case in the following sampling periods in July and October. During both those surveys a unimodal distribution of fish lengths are observed with ranges of 45 to 85 mm and 60 to 10 mm respectively.

There was no difference in the mean fork lengths between the mainstem coho and those of the spawning channels (p-value > 0.05, & t-stat < 2). This was consistent in all the months where both areas were sampled (Table 5).

Scale/Age Analysis:

Similar to the data of Rainbow trout, all of the scales from the spawning channel fish and those of the main-stem river were pooled to make a stronger sample size. Analysis from the scale data corroborate the modes observed in the length frequency histograms of each month.

Coho life history in the Seton River differs from Rainbow Trout in that they only spend their first year in fresh water then migrate to the ocean to rear for one and a half years. Therefore age zero (young of the year) fish would be encountered throughout the year and age one fish encountered only in the early spring.

This was the case with the sampling completed in 2014 in the Seton River. In April two age classes were identified. Age zero fish and age one fish (Figure 37). Mean length for age zero fish was 33 mm (32 - 35 mm). Age one fish had a mean fork length of 106 mm (83 – 124 mm) (Figure).

In May there were no scales taken from Coho. There were very few Coho captured and the age structure would not have significantly changed from the previous month. The larger fish observed in the length frequency histogram are most likely Coho smolts getting ready to migrate to the ocean.

Coho juveniles were not sampled for scales from June to September. The histograms show the same unimodal distribution suggesting that the fish sampled were most likely the age zero fish rearing in the system. The data collected in October affirms this assumption. All of the Coho that were sampled for scales in October were age zero fish. Their mean length was 78 mm with a range from 61 to 99 mm (Figure 38).

Growth Analysis:

Although scales were not collected in all months, common frequency modes are present throughout the sample period to assess growth rates through time. Age data collected along with the length frequency histograms are used to assess growth rates of age zero fish in the Seton River.

Length, weight analysis showed a strong relationship between length and weight for Coho Salmon of all sizes within the Seton River (R2=0.856) (Figure 39).

Age Zero fish were first encountered in April. They had a mean length of 33 mm with a range from 32 mm to 35 mm. By June they had grown by a length of 15 mm to a mean length of 48 mm (37 – 57 mm). From June to July the fish grew another 15 mm to a mean length of 63 mm (44 – 89 mm) and a mean weight of 3.4 g (0.1 – 10.2 g). In August growth had slowed and mean fork length of age zero fish was 68 mm (45 – 88 mm) and mean weight was 4.0 g (1.0 – 8.9 g). From August to September the growth continued to slow with only a growth of 3 mm to 71 mm (48 – 90) and a mean weight of 4.5 g (1.5 – 9.2 g). September to October saw an increase in growth by 7 mm to a mean length of 78 mm (61 – 99 mm) and weight of 5.7 g (2.5 – 11.5 g) (Figure 40).

3.3 Juvenile Abundance

Only 0+ (young of the year) Rainbow Trout were captured in high enough numbers to estimate abundance. Rainbow trout were sampled in all but one of the index sites (Site 1, nearest Seton Dam). A total of 1029 fish were caught during electrofishing surveys of index sites. Discharge of the Seton River during the time of the survey was 15 m^3/s from the dam. During the time of the survey, mean fork length for 0+ rainbow trout was 57 mm and ranged from 21 – 82 mm.

Through mark-recapture studies, a total 321 Rainbow trout were marked and 99 of them were recaptured resulting in an overall capture probability of 0.3, with a range of 0.23 to 0.38 between sites. Figure 5 shows the posterior distribution of the capture probability of Rainbow trout at the six different mark recapture sites.

Abundance estimates for 0+ rainbow trout in the Seton River were quite varied (Figure 41) ranging from 5 to 87 fish or 0.1 to 1. 7 fish/m (Figure 42). Overall, Reach 1 (Sites 2-11) appeared to have lower abundance of rainbow fry (0.18 fish/m – 0.62 fish/m) , except for Sites 8 and 9 where juvenile abundance estimates were 87 and 62 (1.74 and 1.24 fish/m). A wider range of abundances were observed in Reach 2 (Sites 12 – 24) ranging from 14 to 80 fish (0.28 – 1.6 fish/m) . In Reach 3 (sites 25-31), abundances were intermediate ranging from 16 to 79 fish (0.32 – 1.58 fish/m), with the exception of site 29, where only 5 fish were estimated (0.1 fish/m).

3.4 Adult Salmonids

3.4.1 Steelhead

Tag Application and Bio-sampling

Anglers in teams of 2 attempted to capture 40 Steelhead adults and apply internal radio tags into the stomach and external spaghetti tags in the Seton River in 2014. Fish capture attempts commenced in the first weeks of March and continued until the end of May when migration was believed to have ended. Attempts to capture fish were made at the Fraser confluence and at various locations of the Seton River. Fifteen (4 male and 11 female) were captured and tags applied over a 50 day period; March 14 to May 3rd (Table 6). Mean length for male and female Steelhead captured on the Seton River in 2014 was 868mm (range 820-910mm) and 762mm (range 620-870) respectively (Table 6).

Fixed and Mobile Tracking

Tags were detected by the series of fixed telemetry stations and by mobile tracking by vehicle and on foot. Eleven of the fourteen fish tagged were detected in locations upstream of the tagging location at the Spawning channel outflow confluence post tagging. The 3 remaining fish tagged were not located after tagging and possibly moved upstream in the Fraser River to another system (Table 7). There were issues with background noise at the fixed station near Cayoosh Creek and no codes were detected. Eight of the 11 fish observed in the Seton left the

Seton River and were observed in the Bridge River system (BRGMON 03, Ramos-Espinoza et. al. 2014).

Although tags were detected in the Seton River, it is hard to make assumptions on whether fish spawned or remained in the system as the fish were only detected on one antenna array and thus any further movement upstream cannot be verified. As discussed above, telemetry stations on the Lower Bridge River confirmed this.

Data from mobile tracks suggests that three fish made it past the Cayoosh Creek Confluence. One of the fish (code 68) was tagged on April 5th and later observed on April 21st at Cayoosh Creek confluence. The last observation of this fish was on May 12th near the Seton Dam (river km 3.4). Fish 48 was tagged on May 2nd and first observed on May 6th in the section of the river near the lower spawning channel. It was observed near Seton Dam on May 12th and then again on May 21st. Fish 53 was tagged on May 3rd and later observed on May 12th near the Cayoosh confluence. The last observation of this fish was made on May 21st near the Seton Dam.

Visual Counts – Streamwalks

Stream walks on the Seton River were conducted on a weekly basis, from April 22nd to June 18th. During this period no Steelhead adults were observed.

3.4.2 Coho Salmon

Tag Application and Bio-sampling

Efforts to capture 30 Coho salmon adults commenced the week of October 1st, 2014 and continued through to the end of November. Only one fish was captured and PIT tagged on October 17th. This fish was a male with a length of 565 mm and was caught at the Seton Bridge near Lillooet.

Fixed tracking – PIT tags

The one Coho that was PIT tagged was not observed at any of the fixed PIT antenna stations. Suggesting that either the fish remained in the Seton River or moved out of the Seton into the Fraser and onward.

Visual Counts – Streamwalks

Stream walks for Coho were conducted from October 28th to November 25th. During this time a total of 21 Coho were observed. Most of these fish were observed in the spawning channels (6 in upper spawning channel and 9 in lower spawning channel). The remaining six fish were observed near Seton Dam during the first survey. Along with the live fish observed in the lower spawning channel during the last survey, seven dead Coho were observed (Table 8).

3.4.3 Chinook Salmon

Efforts to catch and PIT tag adult Chinook Salmon were unsuccessful and thus the results focus on visual counts completed.

Visual Counts

Visual counts of Chinook salmon were conducted from September 4th through to September 30th, 2014 at which time spawning was assessed to be complete.
During the first survey on September 4th, one Chinook was observed holding in the section downstream of the Cayoosh confluence. The only other Chinook observed was on September 30th and it was located near the Seton Dam.

3.4.4 Resident fish

Adult resident fish species (Rainbow and Bull Trout) were sampled and tagged throughout the year. These species in most part were captured as by catch through other sampling efforts such as growth sampling (electrofishing) and angling for adult tagging

Rainbow Trout

In 2013 TEC captured and sampled a total of 274 Rainbow trout (Table 9). These fish were sampled through electrofishing and angling efforts. Of these fish 215 of them were implanted with PIT tags. Mean length of PIT tagged fish was 230 mm with a range from 100 – 527 mm. Mean weight for these fish was 194.4 g with a range from 11.3 – 1257 g.

In 2014, 28 adult resident trout were captured. In total 26 of them were implanted with PIT tags. Mean fork length was 268 mm with a range from 152 – 430 mm. Only ten of these fish were sampled a mean weight of 432.8 g with a range from 85 – 1361 g was observed. The large discrepancy between the two years numbers is due to the amount of effort (TEC put in more effort) applied and the lack of gear (Instream was waiting on PIT tags in the spring to tag resident fish).

Bull Trout

In 2013 TEC Inc. sampled a total of 43 Bull trout, all of which were implanted with a PIT tag (Table 9). Mean length and weight for the sampled Bull trout was 465 mm (212 – 675 mm) and 1332.7 g (106.6 – 4145.0g) respectively.
In 2014 a total of 12 Bull trout were sampled. Mean length of the Bull trout sampled in 2014 was 385 mm (280 – 570 mm). Mean weight for the fish sampled was 578 g with a range from 230 g to 1814 g. Again, the amount of effort dedicated to angling was the main reason for the reduction of fish tagged in 2014.

Mountain Whitefish

TEC Inc. sampled a total of 79 Mountain Whitefish in 2013, 61 of these fish were implanted with a PIT tag. Mean fork length was 281 mm (32 – 422 mm). Mean weight for these fish was 404.9 g (0.3 – 1178 g).
In 2014 only one Mountain Whitefish was caught, it was not PIT tagged but length and weight for the fish were 340 mm and 503 g respectively

3.5 Fraser River Habitat

The shutdown of Seton Generating Station (SONGS) occurred on April 1, 2014. At the time, Fraser River discharge was 530 m^3/s at Texas Creek gauge (08MF040). After the shutdown was completed, discharge at Texas Creek gauge had decreased to 425 m^3/s (Figure 43). Due to some maintenance requirements the SONGS had to remain shutdown for an extended period of time.

At site one, located approximately 1.7 km downstream of SONGS, the effects of the shutdown were first observed at 10:00:00 am. At that time the gauge read 0.83 m. From that time gauge level decreased for about an hour till they stabilized at 11:15:00 am and the gauge read 0.528 m. Overall the reduction in water level elevation was 0.302 m (Figure 44). The rate of stage reduction was 0.3 m/h. After the water levels had stabilized a survey of the dewatered area was conducted to look for any stranded fish. There were no fish identified at site one.

At site two, located 10.9 km downstream of SONGS, the effects of the shutdown were not observed until 10:30:00 am. Before the change was noticed the stage reading was 0.702 m. Water level elevation decreased for an hour and 50 minutes until they stabilized at 12:20:00 at 0.396 m. Overall reduction in water level elevation was 0.306 m, very similar to what was observed at station 1 (Figure 45). The rate of stage reduction at station two was approximately 0.15m/h. During the stranding survey at site two, a single sculpin measuring 130 mm was identified and returned to the flowing river.

3.6 Gravel mobilization

Results from the topographic surveys conducted are reported in figure 45. This figure shows the bed elevation of the known section of Seton River to be of high spawning consequence. Instream Fisheries is in the process of acquiring the raw data from the surveys, so that when future surveys are completed, the results can be compared. This will continue to be an on-going process.

4. DISCUSSION

The primary objective of this monitoring program is to monitor the response of fish habitat and fish populations to Seton Dam operations. Data collected in 2014 is a good start to the process of understanding the current state of fish habitat and fish populations in the river.

Depth velocity transects were conducted with various degrees of success at four different flows. Due to safety concerns not all sites were surveyed at the various flows and as a result, total WUA could not be compared between all the surveys. Total WUA was compared between 12 and 25 m3/s and showed that in most cases and for most juvenile species and life stages, there was a decrease in useable area and that specific habitat units depending on their size can have a big effect on reach totals. As surveys continue it will be important to identify these habitat units as they 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.

Percent weighted useable area were compared between all the sites at all the measured flows and also showed a decreasing trend. Percent weighted area also showed that the same type of habitat units within a reach can have varying degrees of change depending on the species and life stage in question. Identifying the life stage of a species that is limiting or a species that is at risk will be important for the management of flows at Seton River. What is also interesting is the observed response of some habitat units from 12 m3/s to 15m3/s. Some riffles showed an increase of WUA for all species and life stages, but then decreased again when flows increased to 25 m^3/s. This raises the question of whether WUA continues to increase to a certain inflection point between 15 and 25m^3/s. Future transects will enable us to better understand if this is the case.

In 2014, valuable baseline data was collected to identify the species present in the Seton River. Important life history information was collected, identifying four age classes of Rainbow trout, and two age classes of juvenile Coho. A few juvenile Chinook were observed, but no age data was collected. The Known life history of Chinook (stream type), allows us to assume a similar age structure as Coho. Continued monitoring will allow us to develop an index of juvenile salmon in the Seton River. Continued PIT tagging will also to track the growth and movement of individual fish and serve as a check on our ageing methods.

Juvenile abundance surveys were completed for age 0 Rainbow trout in September 2014. Mark recapture experiments resulted in a mean recapture probability of 0.30. Results from the HBM showed a broad range of abundances throughout the river. Due to limited sample size at some sites, broad credible intervals were observed. Some were as large as 120% of mean estimate. This may be because there are very few Rainbow trout in the area or alternately, our sampling methods were not suitable. The completion of the snorkel surveys in March of 2015 will allow us to get a better understanding of the status of the larger older fish.

Adult salmonid abundance and distribution proved difficult to observe. Fifteen adult Steelhead were radio tagged, only three Steelhead were believed to have moved and stayed in the Seton River. The last time the fish were observed in the system (mid to end of May) is close to peak spawning time, which may suggest they spawned in the river. This data is consistent with what was observed by Webb, S. et. al. (1999). If adult Steelhead do spawn in the Seton River, what is their spawning success? To date, no data has been collected to try to identify juvenile densities and use of the Seton River. A microchemistry study, similar to the one carried out by Korman et. al. (2010) on the Cheakamus River would allow to differentiate between anadromous and resident *O. mykiss.*

Very few adult Chinook and Coho were observed and sampled. This made it very difficult to proceed with our proposed methods of enumerating them and understanding their spawning distribution. A stronger effort in capturing adults, or a change in methods will be required to get a sample size that is adequate for the study. Methods to consider would be tangle netting or beach seining. Continuation of stream walks (Visual counts) is also important as it will us to continue collecting index data.

Adult Bull trout and whitefish were observed in the Seton River, but may not be using the river to spawn. This is corroborated by the juvenile data collected, where very few juvenile Bull Trout and Mountain Whitefish were captured . Instead these two species may be using 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). Work completed by Taylor & Yau (2013) on the Peace River allowed them to trace genetic differences of Bull trout and Mountain Whitefish amongst localities for each species and infer movements of fish between localities. Verifying this migratory behavior would allow agencies to better manage these species. Continuing the efforts of PIT tagging will allow us to see some of this movement, as some of the other BRGMONs have PIT antennas installed in other systems (Lower Bridge River, and gates creek). For example an adult Bull Trout that was PIT tagged in the Seton River was observed at the fixed PIT station at Gates Creek (Pers. Comm. BRGMON 14). Collaborating with the other monitors will be very important collecting this valuable data.

In April of 2014, the maintenance shutdown of the Seton Generating Station (SONGS) was monitored. During that time, the Fraser River discharge was low and a decrease in discharge of 19% was observed at Texas Creek Water Survey of Canada gauge. Ramping rates did not exceed DFO thresholds of <0.5m/h. At the site nearest SONGS stage decrease occurred at a rate of 0.3 m/h and at the site 10.9 km downstream the rate of decrease was only 0.15 m/h. During stranding survey, only one sculpin was identified and was returned to the river. In future monitoring, we plan to link stage decrease to a value of area dewatered at each site, therein further quantifying the effects of the SONGS shutdown.

There was no work completed in 2014 to monitor gravel mobilization. Attempts to obtain and analyze data collected by TEC Inc. were made and are on-going. Having a baseline riverbed elevation for the spawning area downstream of Seton Dam is a good start, as future surveys will tell us if there has been any change/movement of gravel out of the area.

5. SUMMARY, CHALLENGES and RECOMMENDATIONS

In summary, the work undertaken in 2014 to begin to quantify juvenile habitat, fish abundance and distribution in the Seton River was successful. Adult salmonids proved to be a bigger challenge.

A number of recommendations are provided that may improve estimates of adult spawner escapement and habitat use are provided. These include:

1) Continue with WUA surveys, to evaluate habitat responses at different discharges (between 15 and 25 m^3/s and higher)

2) Increase angling effort to capture and tag more adult salmon

3) Modify methods of capturing adult salmon for tagging (Seining, tangle netting or use of fish fence)

4) Continue increased frequency of mobile tracking and visual stream walks around peak spawner abundance to improve o.e. estimates.

5) Continue with opportunistic PIT tagging of all adult Rainbow trout, Bull trout and whitefish encountered during salmon tagging to evaluate their movements within the Seton River watershed.

6) Continued operation of PIT tag arrays (installed in 2014) to delineate spawner distribution.

7) Microchemistry analysis of juvenile *O. mykiss* to identify the presence of anadromous Steelhead juveniles in the Seton River.

6.0 TABLES

Table 1. Definitions of variables used in hierarchical model

Variable	Definition
Data	
m_i	Marks released at mark recapture site *a*
r_i	Recaptured marked fish at mark recapture site *i*
c_j	Fish caught a 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*
Hyper parameters	
μ_θ	Mean of beta hyper-distribution for capture probability
τ_θ	Precision of beta hyper distribution for capture probability
Derived variables	
N_j	Estimated abundance at index site *j*

Table 2. 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
$\theta_j \sim dbeta(\alpha, \beta)$
$c_j \sim dbin(\theta_j, N_j)$
$N_j \sim dnorm(30, 20^{-2})$
Priors and transformations
$\mu_\theta \sim dunif\,(0, 1)$
$\sigma_\theta \sim dunif\,(0.05, 1)$
$\tau_\theta = \sigma^{-2}$
$\alpha \sim \mu_\theta\, \tau_\theta$
$\beta = (1 - \mu_\theta)\, \tau_\theta$

Table 3. Total number of fish caught during 2014 juvenile growth sampling surveys, 2014.

Species	Seton River	Spawning Channels
Bridgelip Sucker	2	28
Bull Trout	2	2
Coast-range sculpin	88	50
Prickly Sculpin	34	8
Chinook	15	7
Coho	466	208
Sculpin	2	NA
Longnose Dace	335	65
Northern Pike Minnow	1	NA
Pink	14	22
Rainbow Trout	1096	272
Red sided Shinner	7	52
Sockeye	6	NA
White fish	14	NA
Grand Total	2082	714

Table 4. Mean length of Rainbow trout sampled during juvenile growth sampling surveys at Seton River and Seton River spawning channels.

Sites	Month	N	Mean	sd	Min	Median	Max
USC	**April**	62	131.9	31	95	120.5	228
LSC	**April**	43	126.7	34.1	76	124	225
Seton River	**April**	20	96.6	17.1	75	90	134
USC	**May**	28	127.1	27.1	90	124	212
LSC	**May**	21	126.9	26.3	88	123	180
USC	**June**	16	140.9	16	119	141.5	170
LSC	**June**	21	135.1	19.5	105	136	170
Seton River	**June**	11	112.5	21.7	75	114	144
USC	**July**	23	77.4	54.7	32	44	193
LSC	**July**	33	102.7	38.5	35	117	170
Seton River	**July**	204	50.4	30.4	27	38	166
Seton River	**August**	263	54.9	22.4	31	50	152
Seton River	**September**	489	58.4	13.5	21	56	172
USC	**October**	23	77.4	54.7	32	44	193
LSC	**October**	25	128.7	37.8	65	146	184
Seton River	**October**	109	78	25.5	46	72	184

Table 5. Results of simple t-test comparing length of main-stem Seton River fish with spawning channel fish in 2014.

Species	Month	t-stat	df	p value
Rainbow trout	April	6.37	49.19	2.01E-08
Rainbow trout	June	3.5	14.367	0.00342
Rainbow trout	July	6.31	68.04	2.37E-08
Rainbow trout	October	6.37	29.18	5.61E-07
Rainbow trout	April	0.94	28.44	3.50E-01
Coho	June	-1.09	2.02	3.90E-01
Coho	July	1.68	208.03	9.30E-02
Coho	October	-0.22	11.78	8.30E-01

Table 6. Biological data of adult Steelhead captured in 2014

CAPTURE DATE	CAPTURE LOCATION	CAPTURE METHOD	FREQUENCY	CHANNEL	CODE	FORK (mm)	WEIGHT	SEX	ANGLER
14-Mar-14	Seton Confluence	angle	150.500	5	43	760	14 lbs	F	CJ/SP
17-Mar-14	Seton Confluence	angle	150.500	5	36	870	16.5 lbs	M	CJ/SP
20-Mar-14	Seton Confluence	angle	150.500	5	33	770	15.5 lbs	F	CJ/SP/ES
26-Mar-14	Seton Confluence	angle	150.500	5	37	670	8 lbs	F	CJ
26-Mar-14	Seton Confluence	angle	150.500	5	51	910	15 lbs	M	RJ/TC
3-Apr-14	Seton Confluence	angle	150.680	6	61	825	16.5 lbs	F	CJ/SP
3-Apr-14	Seton Confluence	angle	150.680	6	64	870	16 lbs	M	RJ/TC
5-Apr-14	Seton Confluence	angle	150.680	6	68	830	11 lbs	F	RJ/TC
8-Apr-14	Seton Confluence	angle	n/a	n/a	n/a	775	10 lbs	F	CJ
9-Apr-14	Seton Confluence	angle	150.680	6	56	820	10.5 lbs	M	SP
21-Apr-14	Seton Confluence	angle	150.500	5	49	870	16.1 lbs	F	RJ
25-Apr-14	Seton Confluence	angle			72	780	10.5 lbs	F	SP
2-May-14	Seton Confluence	angle			48	620	7 lbs	F	CJ
2-May-14	Seton Confluence	angle			59	680	8 lbs	F	CJ/TR
3-May-14	Seton Confluence	angle	150.680	6	53	800	9.5 lbs	F	CJ

Table 7. Seton River Steelhead mobile tracking

Date	Species	Frequency	Channel	Code	River KM	Location/ stream walk section
21-Apr-14	SHA	150.680	6	68	n/a	Cayoosh
21-Apr-14	SHA	150.500	5	43	n/a	Seton/Fraser Confluence
22-Apr-14	SHA	150.680	6	68	0.5	Seton River
22-Apr-14	SHA	150.500	5	43	n/a	Seton/Fraser Confluence
29-Apr-14	SHA	150.680	6	68	0.5	Seton Dam-Inclined Plane Trap
6-May-14	SHA	150.680	6	68	0.5	Seton Dam-Inclined Plane Trap
6-May-14	SHA	150.500	5	48	3.5	Seton River beside LSCH
12-May-14	SHA	150.500	5	48	0.0	Seton Dam (Below)
12-May-14	SHA	150.680	6	68	0.6	Seton Dam-Inclined Plane Trap
12-May-14	SHA	150.680	6	53	1.6	Cay. Conf.-Halfway
21-May-14	SHA	150.680	6	53	0.2	Seton Dam-Inclined Plane Trap
21-May-14	SHA	150.500	5	48	0.2	Seton Dam-Inclined Plane Trap
28-May-14	*	150.680	6	*51		Seton River beside LSCH
4-Jun-14	*	150.680	6	*28		LSCH
4-Jun-14	*	150.680	6	*15		LSCH-Seton Bridge
						* Most likely not a SHA tag/code

Table 8. Seton River Coho visual count data – 2014

Date	Observers	% Cloud Cover	Air Temp	Water Visibility (m)	Untagged Seton Dam to IPT	Tagged Seton Dam to IPT	Untagged Upper Spawning Channel	Tagged Upper Spawning Channel	Untagged Lower Spawning Channel	Tagged Lower Spawning Channel	MORTS	Total
28-Oct-14	CJ/RJ	90	N/A	1 m	6	0	1	0	0	0	0	7
04-Nov-14	SP/RJ	95	5	<.5	0	0	0	0	4	0	0	4
19-Nov-14	CJ/RJ/SP	100	N/A	.5 m	0	0	3	0	2	0	0	5
25-Nov-14	ES/CJ/SP	100	N/A	N/A	0	0	2	0	3	0	7	5

Table 9. Summary of fish sampled by TEC Inc. in 2013

Species	Total	# PIT tagged	Mean FL (mm)	Min FL	Max FL
Bull Trout	43	43	465	212	675
Coastrange Sculpin	2	2	52	47	56
Chinook	69	26	48	33	109
Coho	129	20	60	32	133
Mountain Whitefish	79	78	281	32	442
Rainbow trout	274	215	190	22	527
Sockeye	5	1	109	90	152
Steelhead	2	2	701	675	727
Grand Total	603	387			

Table 10. Summary table for recaptured Rainbow trout in Seton River 2014.

Date	Site Recaptured	Species	Length (mm)	Weight (g)	Catch type	PIT #	Site marked	Original Length	Original Weight	Date Marked	Length diff.	weight diff.	# of days	mm/day	g/day
Unknown	usc	rb	152	36.8	r	585068	not marked by ifr								
Unknown	usc	rb	117	18.4	r	584541	not marked by ifr								
Unknown	lsc	rb	176	58.5	R	585180	not marked by ifr								
2014-05-15	usc	rb	103	10.9	R	584754	usc	95	9.7	2014-04-15	8	1.2	30	0.27	0.04
2014-05-15	usc	rb	127	22.1	R	586207	usc	122	19.3	2014-04-16	5	2.8	29	0.17	0.10
2014-07-22	gs8	rb	129	25.5	R	650713	lsc	110	13.8	2014-06-17	19	11.7	35	0.54	0.33
2014-07-23	gs3	rb	127	26	R	584804	gs3	90	7.5	2014-04-17	37	18.5	97	0.38	0.19
2014-07-24	usc	rb	147	39.4	R	650691	usc	125	23.3	2014-06-19	22	16.1	35	0.63	0.46
2014-07-24	usc	rb	141	36.6	R	584774	usc	105	11.4	2014-04-15	36	25.2	100	0.36	0.25
2014-07-24	lsc	rb	124	27.9	R	586108	lsc	116	16.2	2014-04-16	8	11.7	99	0.08	0.12
2014-08-21	gs8	rb	139	31.5	R	586215	gs8	95	9.2	2014-04-17	44	22.3	126	0.35	0.18
2014-08-21	gs8	rb	145	36.5	R	650508	gs8	143	38.6	2014-07-22	2	-2.1	30	0.07	-0.07
2014-08-22	gs5	rb	130	25.3	R	650737	gs3	121	27.1	2014-07-23	9	-1.8	30	0.30	-0.06
2014-08-22	gs5	rb	115	18.6	R	650672	gs3	112	17.3	2014-07-23	3	1.3	30	0.10	0.04
2014-10-22	gs3	rb	116	18	R	650672									
2014-08-22	gs5	rb	120	20.7	R	650566	gs3	119	19.9	2014-07-23	1	0.8	30	0.03	0.03
2014-08-22	gs5	rb	104	14.7	R	650582	gs3	100	13.3	2014-07-23	4	1.4	30	0.13	0.05
2014-08-22	gs5	rb	102	12.8	R	650532	gs3	99	12.5	2014-07-23	3	0.3	30	0.10	0.01
2014-10-22	gs3	rb	103	12		650532									
2014-10-22	gs3	rb	115	16	R	650625	gs3	106	15.2	2014-07-23	9	0.8	91	0.10	0.01
2014-10-22	gs3	rb	117	19	R	650442	gs5	119	20.2	2014-08-22	-2	-1.2	61	-0.03	-0.02

7.0 FIGURES

Figure 1. Bridge & Seton Watersheds

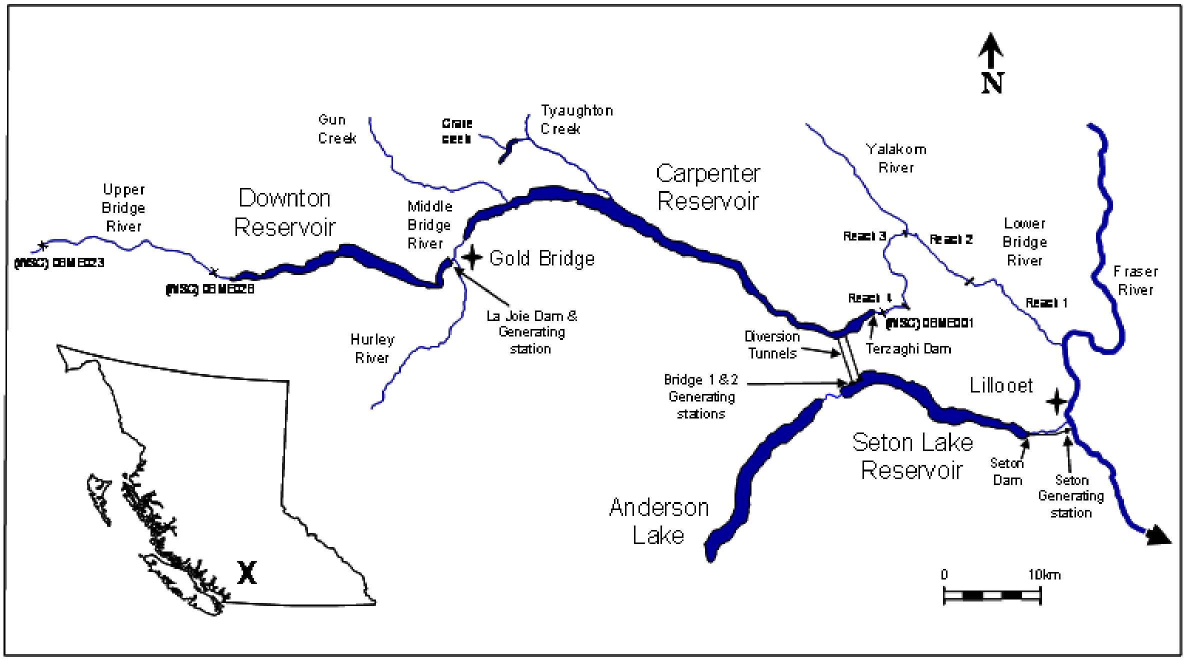


Figure 2. Seton River Study Area showing diversion canal and Cayoosh Creek

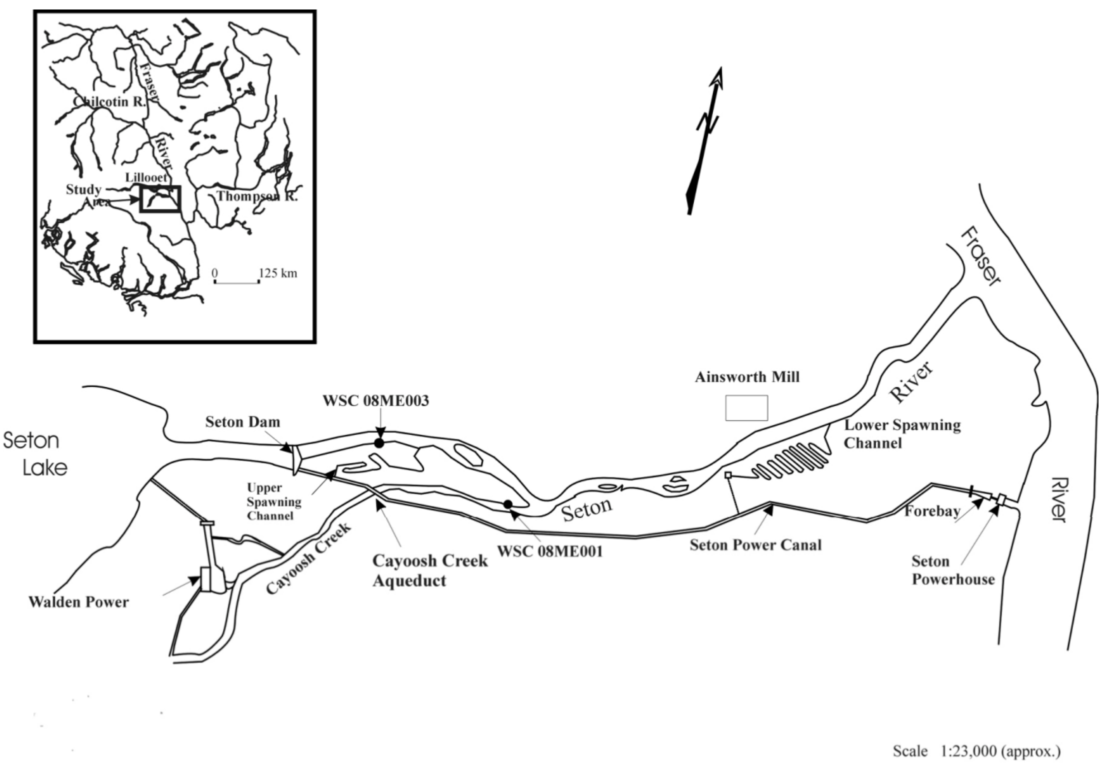


Figure 3. Location of Weighted Useable Area transect sites in Seton River

Figure 3, cont…

Figure 3. Cont….

Figure 4. Location of juvenile growth sampling sites, Seton River, 2014.

Figure 4. Cont…

Figure 4. Cont…

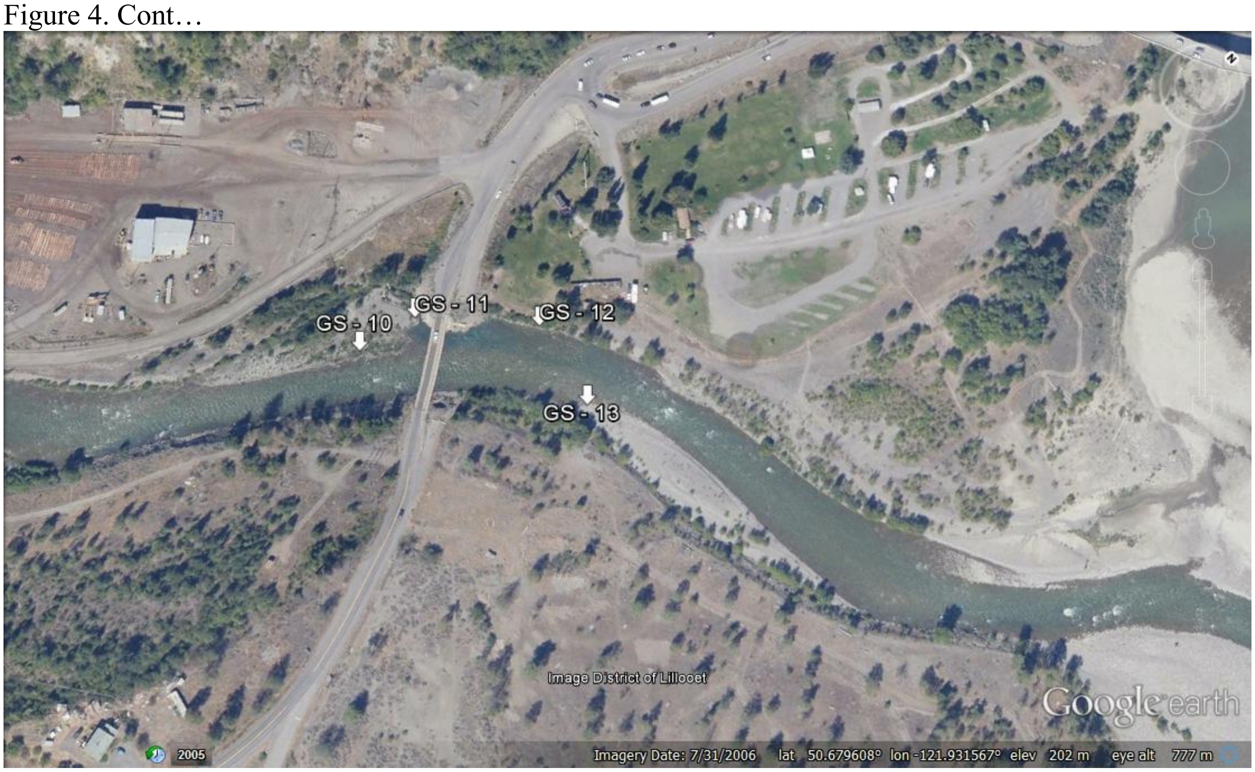


Figure 5. Posterior distributions for capture probability at mark recapture sites, Seton River 2014

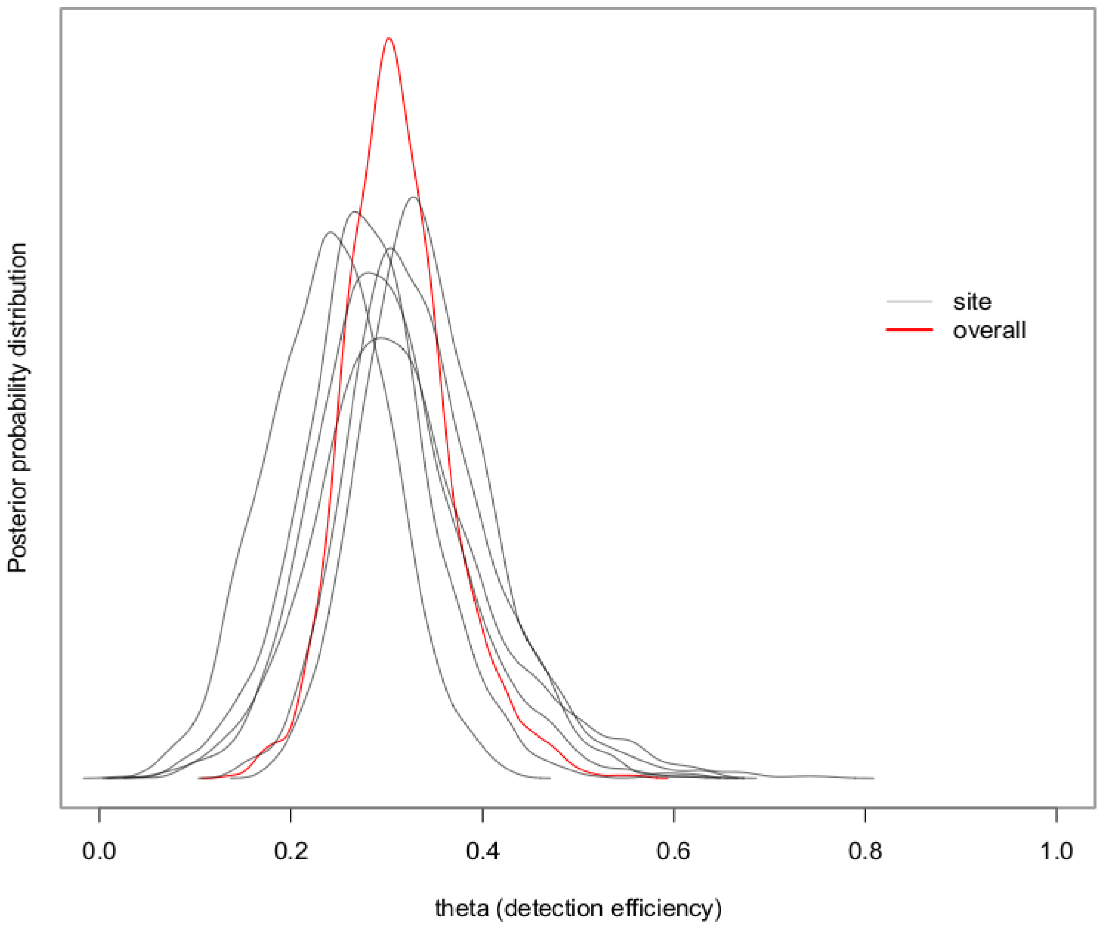


Figure 6. Diagram of gastrically implanted radio tag, dorsal PIT tag and dorsal Spaghetti tag in adult fish.

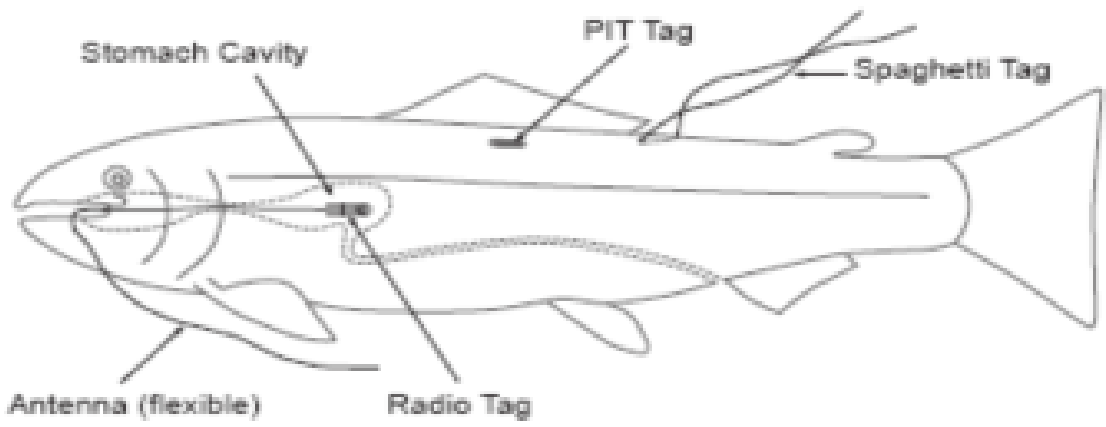


Figure 7. Location of fixed radio telemetry stations and fixed PIT station, Seton River 2014

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

Figure 9. Location of Seton River reaches (reach breaks)

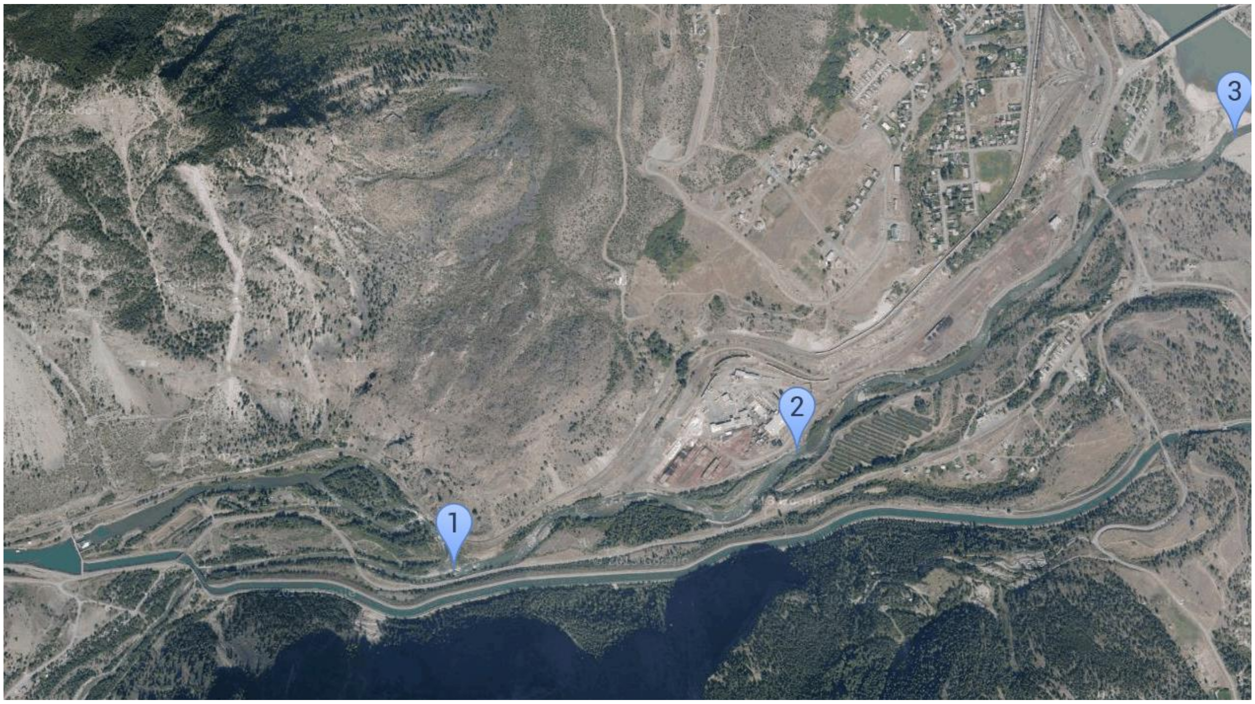


Figure 10. Discharge curve for reach 1 of Seton River at Water Survey of Canada gauge (08ME003) 2014

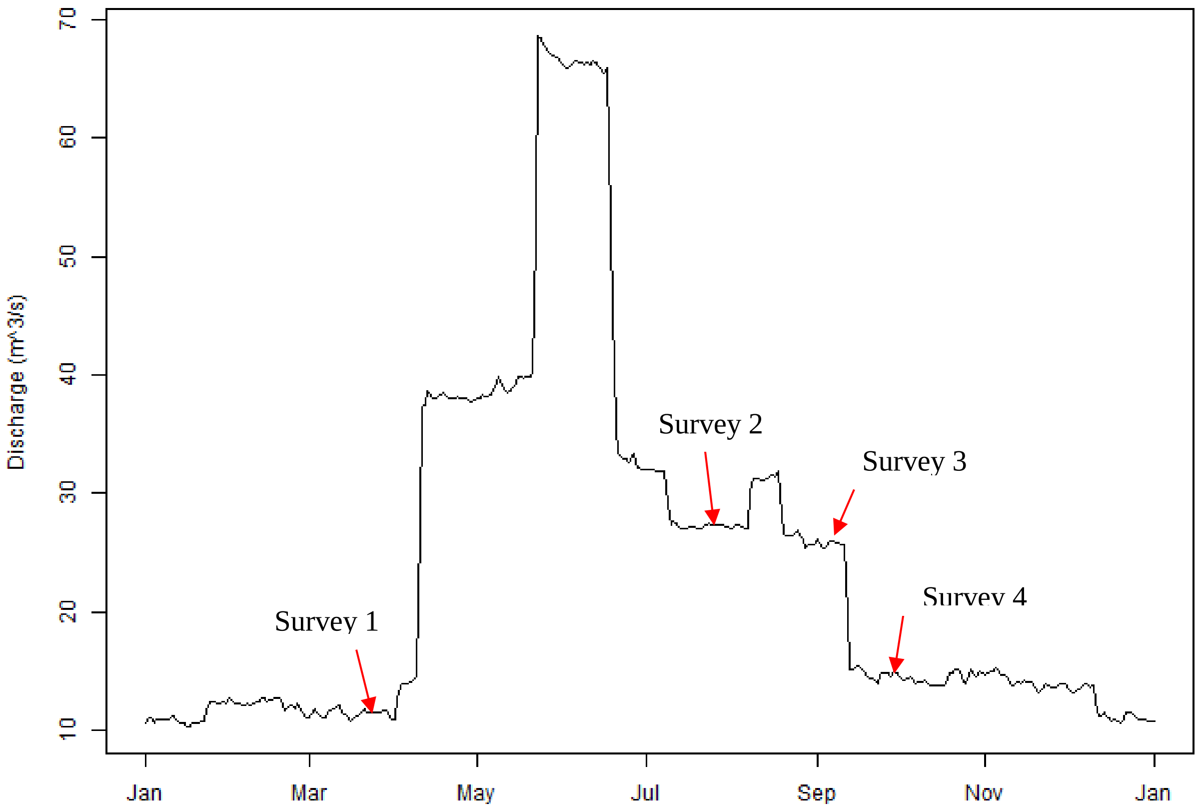


Figure 11. Discharge curve for reaches 2 and 3 of Seton River. Combine discharges of WSC gauges 08ME003 & 08ME002

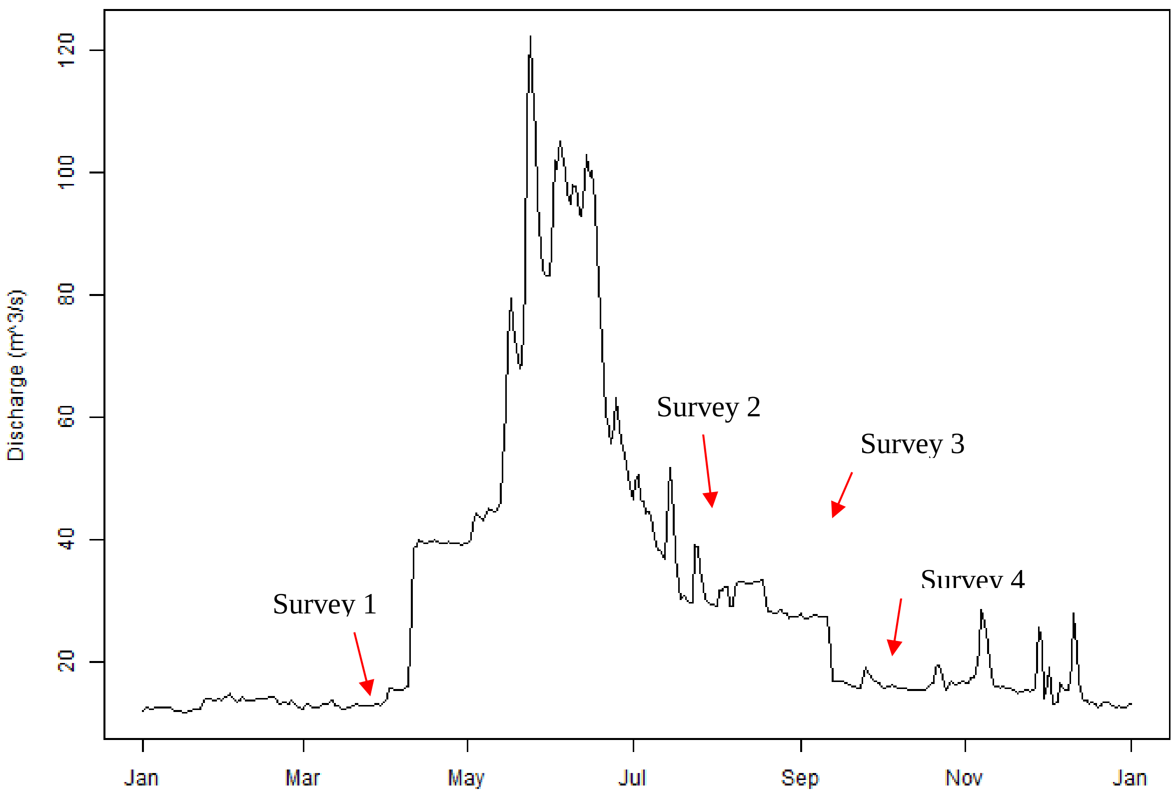


Figure 12. Rainbow trout fry total Weighted Useable Area (WUA) in glide, pool and riffle habitats of reach 1 (a), reach 2 (b) and reach 3(c) of Seton River at 12 and 25 m^3/s (2014). Dark lines represent the mean of all points, the modes represent the distribution of the data and the small white lines represent individual data points.

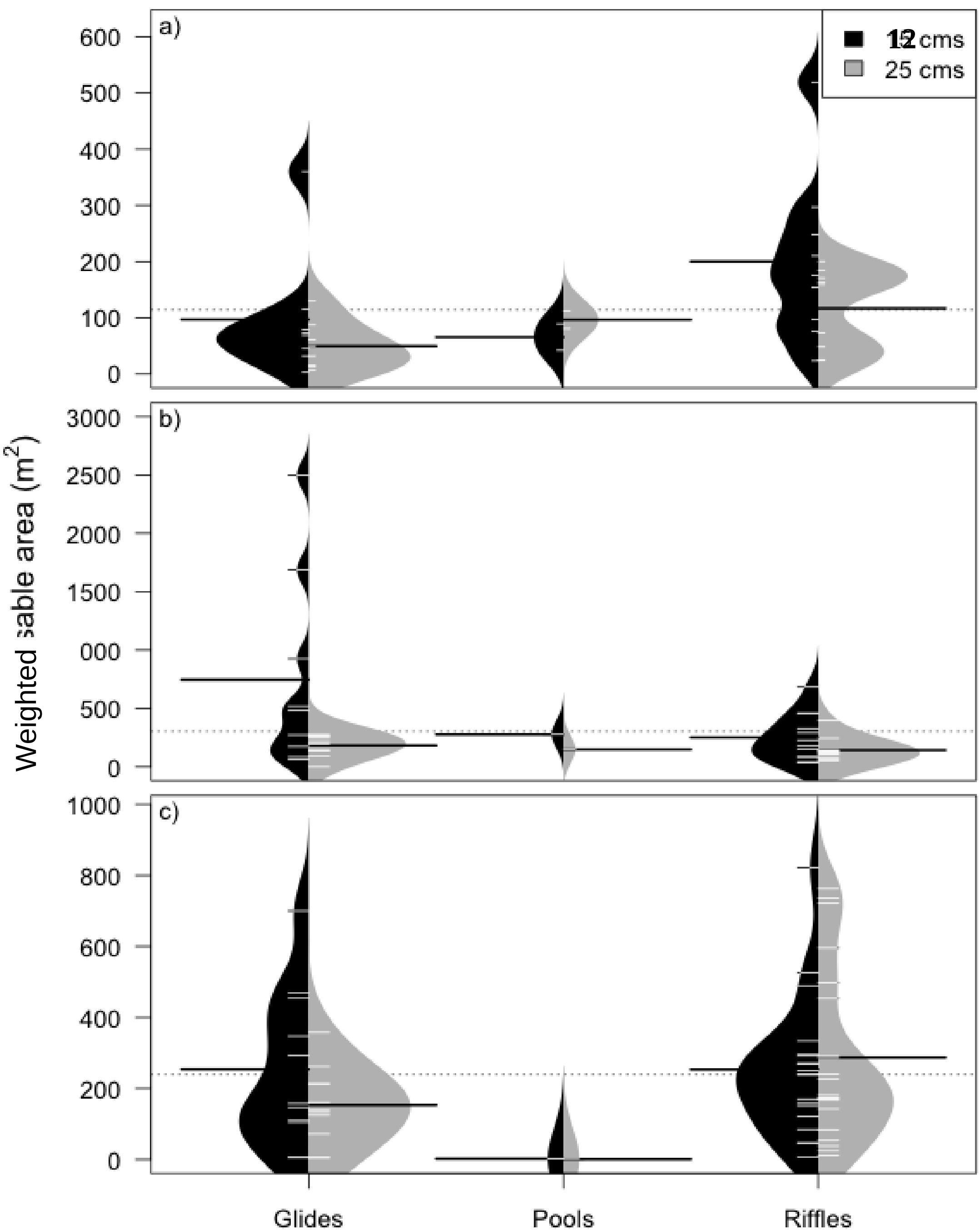


Figure 13. Rainbow trout fry % WUA of glide, pool, riffle habitat in reaches 1 (a, b & c), 2 (d, e & f) and 3 (g, h & i) of Seton River 2014 at various discharges.

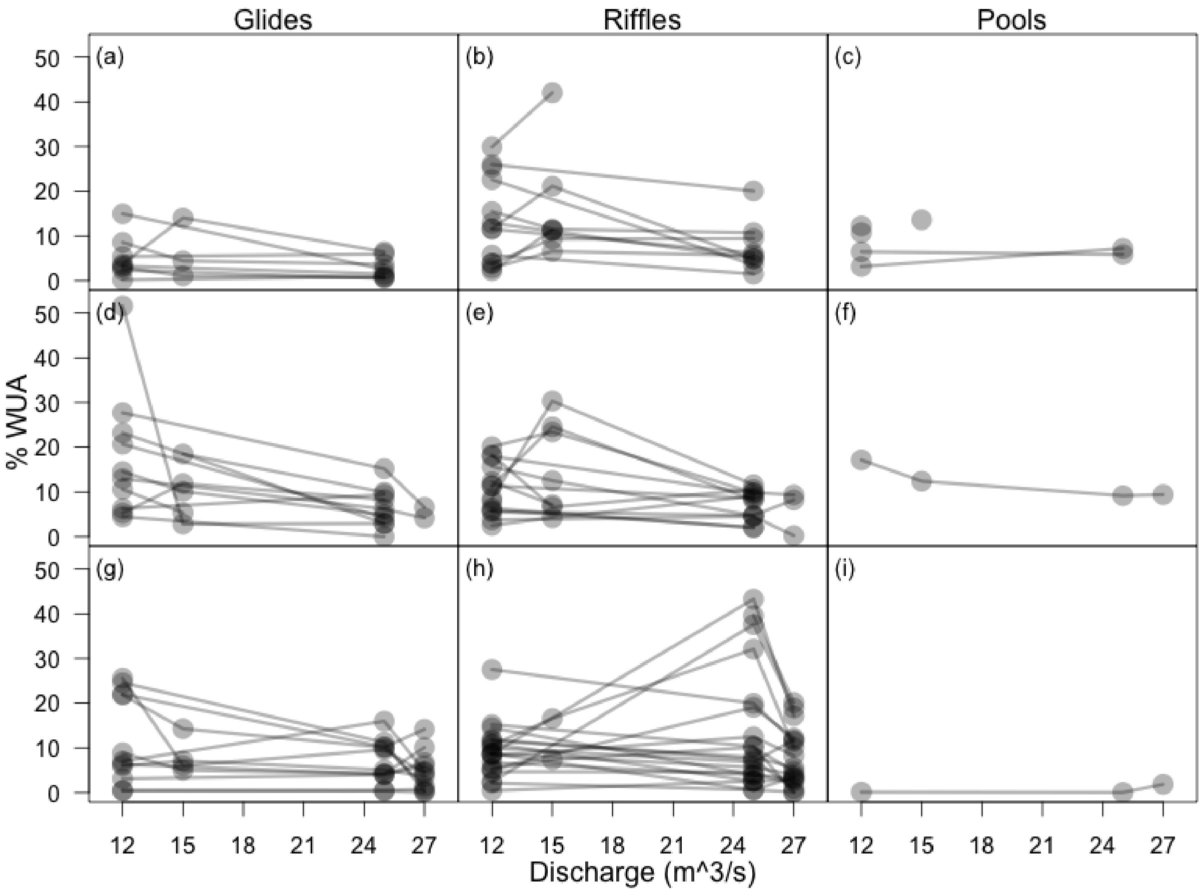


Figure 14.Rainbow trout parr total Weighted Useable Area (WUA) in glide, pool and riffle habitats of reach 1 (a), reach 2 (b) and reach 3(c) of Seton River at 12 and 25 m3/s (2014). Dark lines represent the mean of all points, the modes represent the distribution of the data and the small white lines represent individual data points.

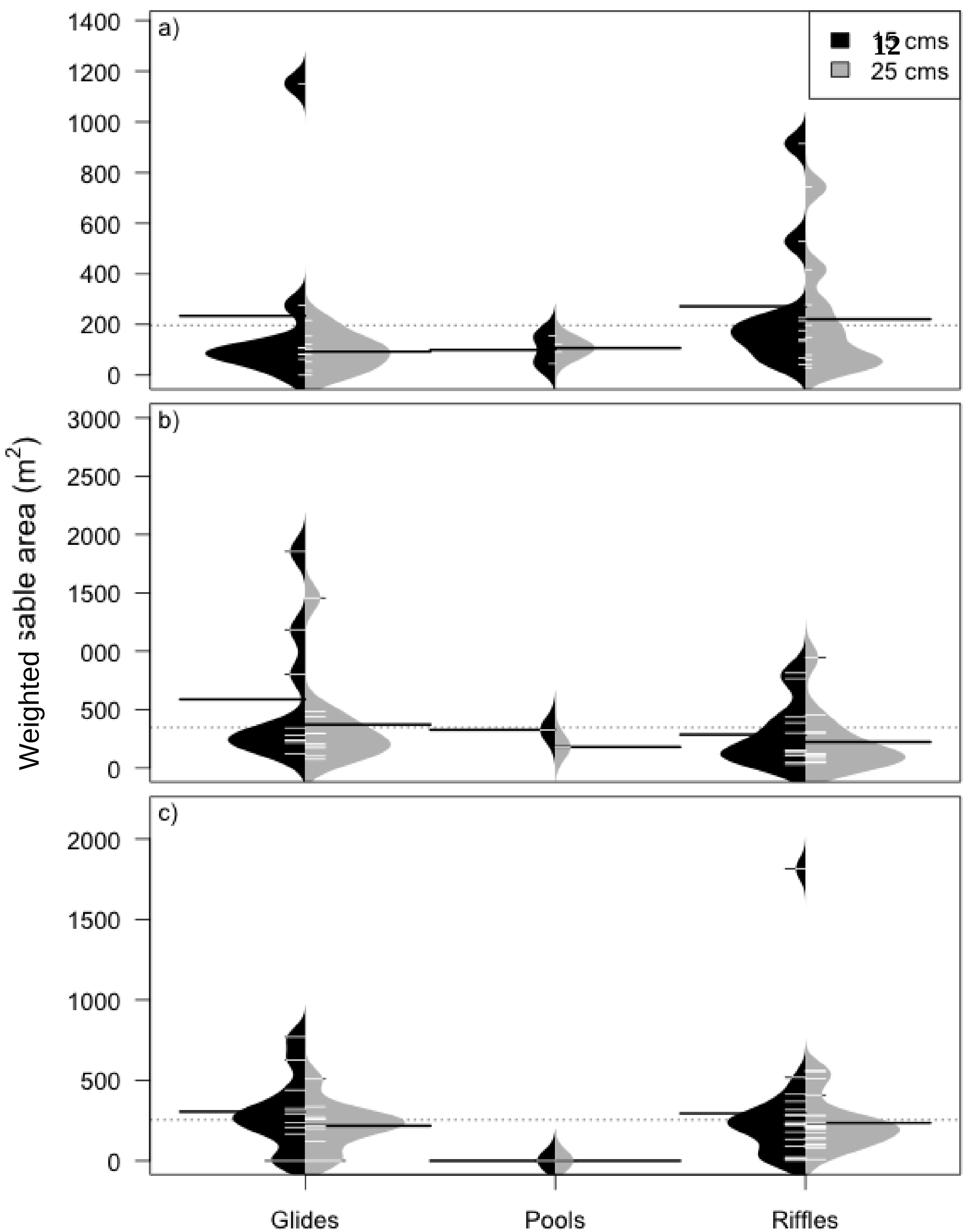


Figure 15. Rainbow trout parr % WUA of glide, pool, riffle habitat in reaches 1 (a, b & c), 2 (d, e & f) and 3 (g, h & i) of Seton River 2014 at various discharges.

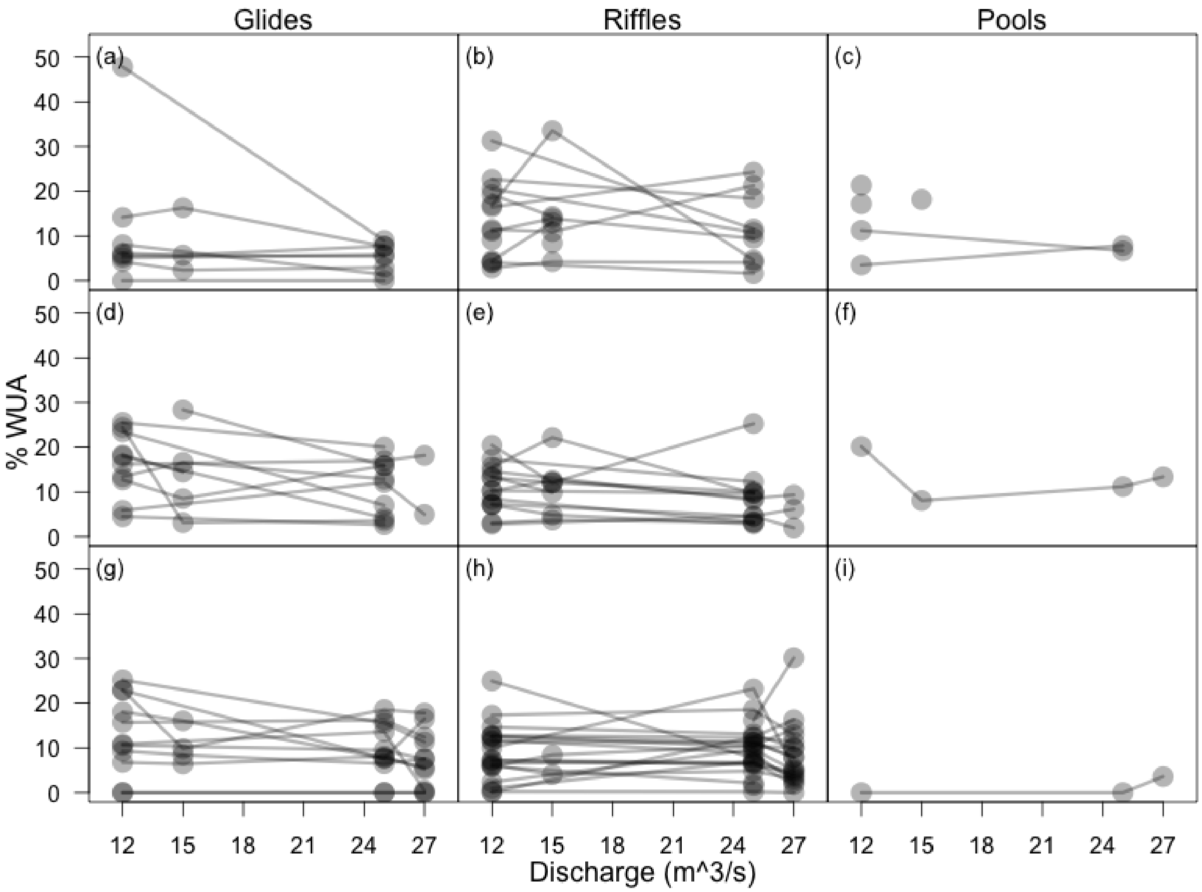


Figure 16. Coho juvenile total Weighted Useable Area (WUA) in glide, pool and riffle habitats of reach 1 (a), reach 2 (b) and reach 3(c) of Seton River at 12 and 25 m3/s (2014). Dark lines represent the mean of all points, the modes represent the distribution of the data and the small white lines represent individual data points.

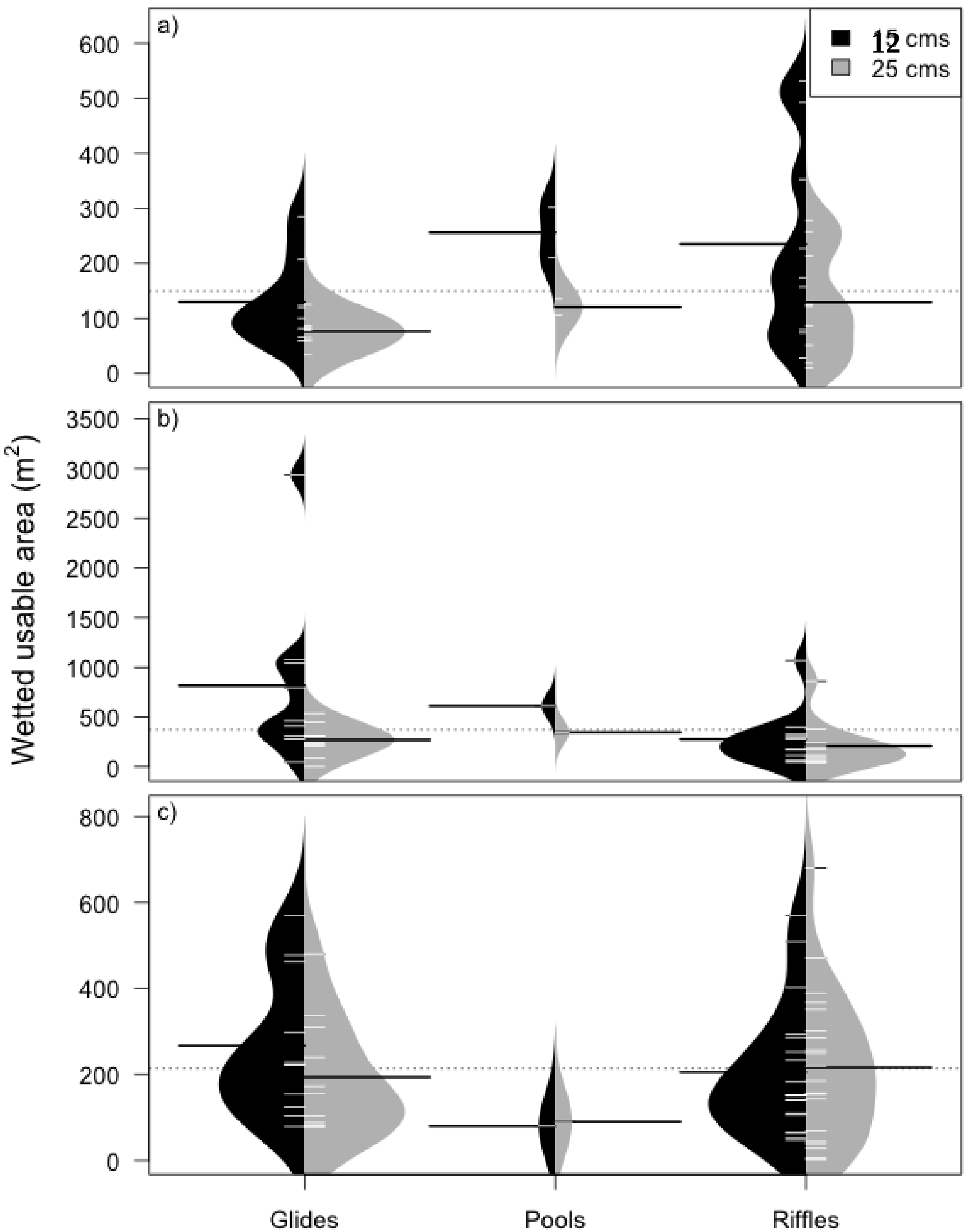


Figure 17. Coho juvenile % WUA of glide, pool, riffle habitat in reaches 1 (a, b & c), 2 (d, e & f) and 3 (g, h & i) of Seton River 2014 at various discharges.

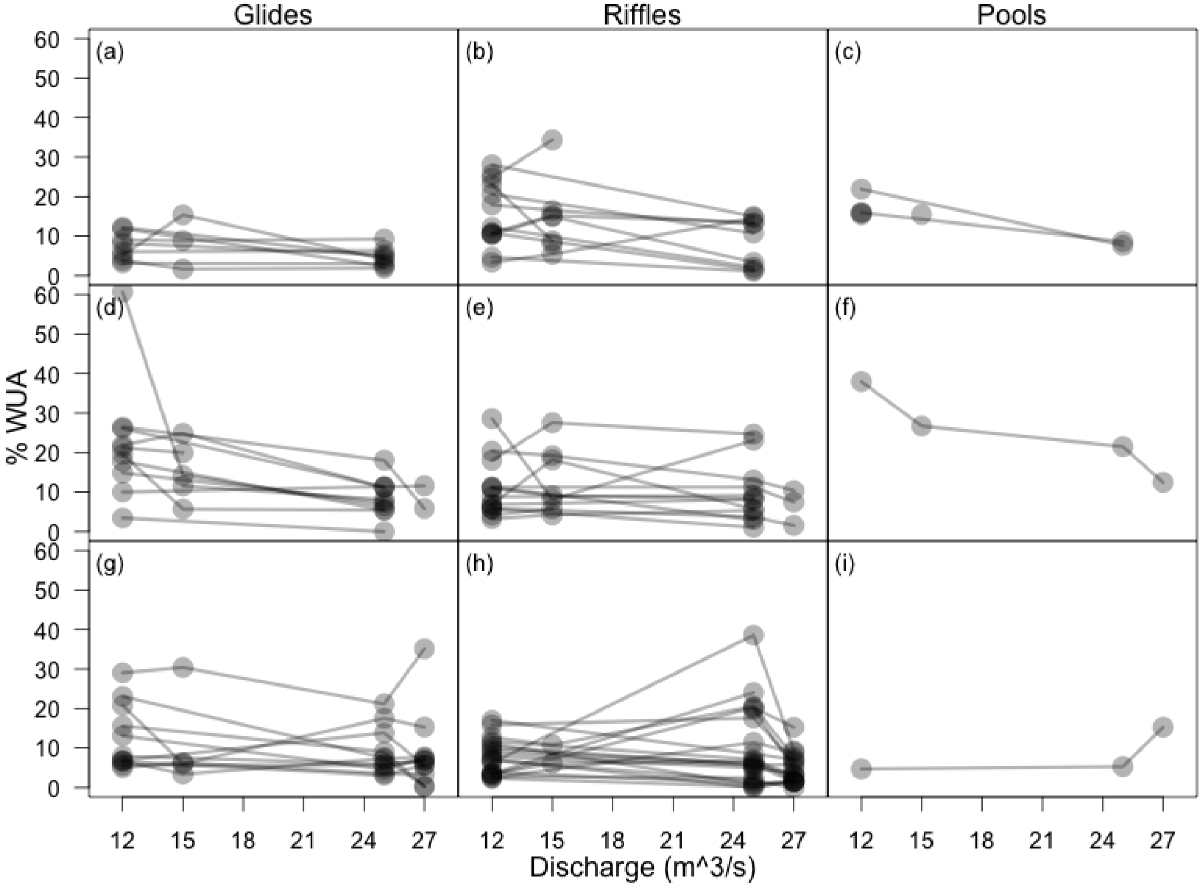


Figure 18. Chinook juvenile total Weighted Useable Area (WUA) in glide, pool and riffle habitats of reach 1 (a), reach 2 (b) and reach 3(c) of Seton River at 12 and 25 m3/s (2014). Dark lines represent the mean of all points, the modes represent the distribution of the data and the small white lines represent individual data points.

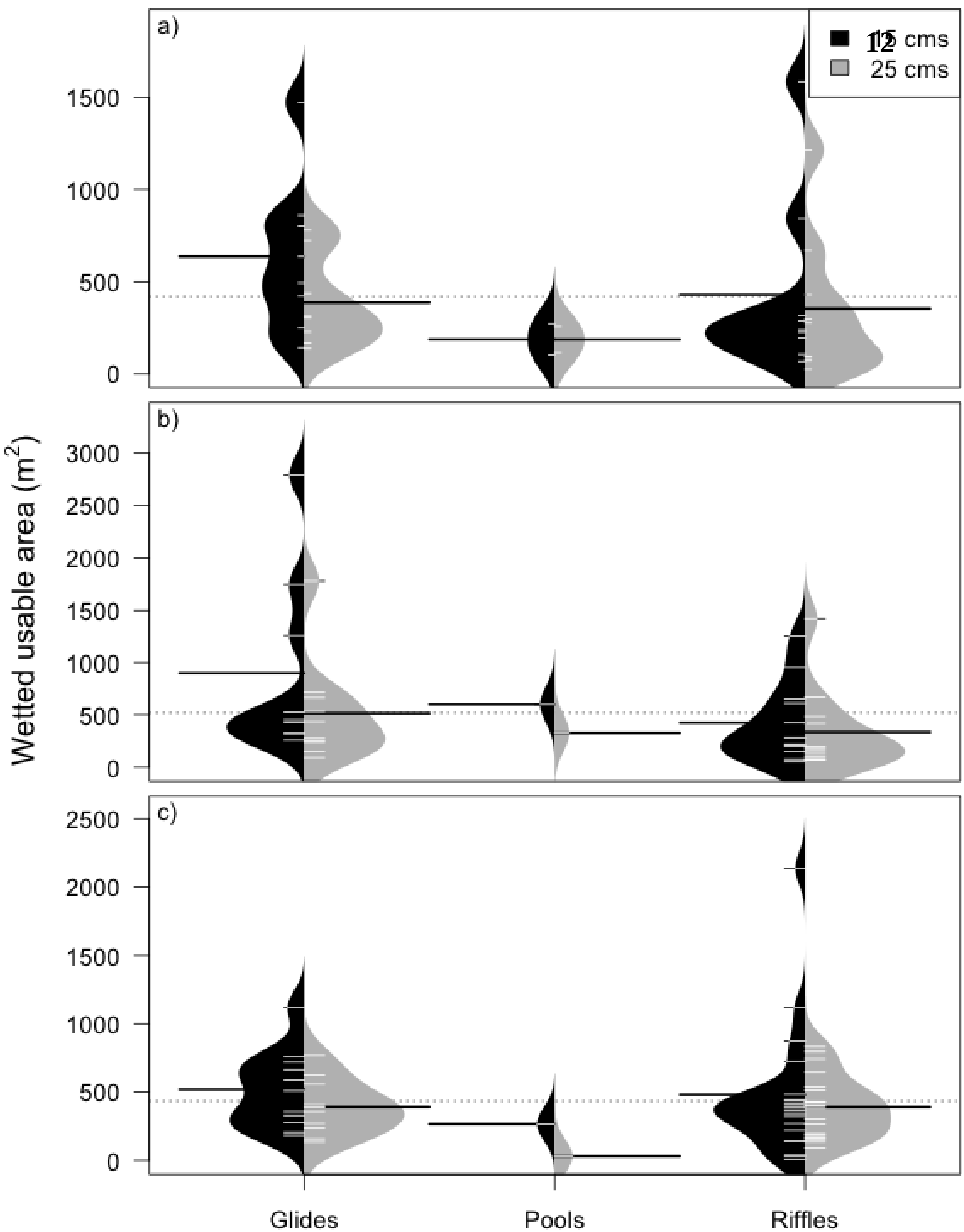


Figure 19. Chinook juvenile % WUA of glide, pool, riffle habitat in reaches 1 (a, b & c), 2 (d, e & f) and 3 (g, h & i) of Seton River 2014 at various discharges.

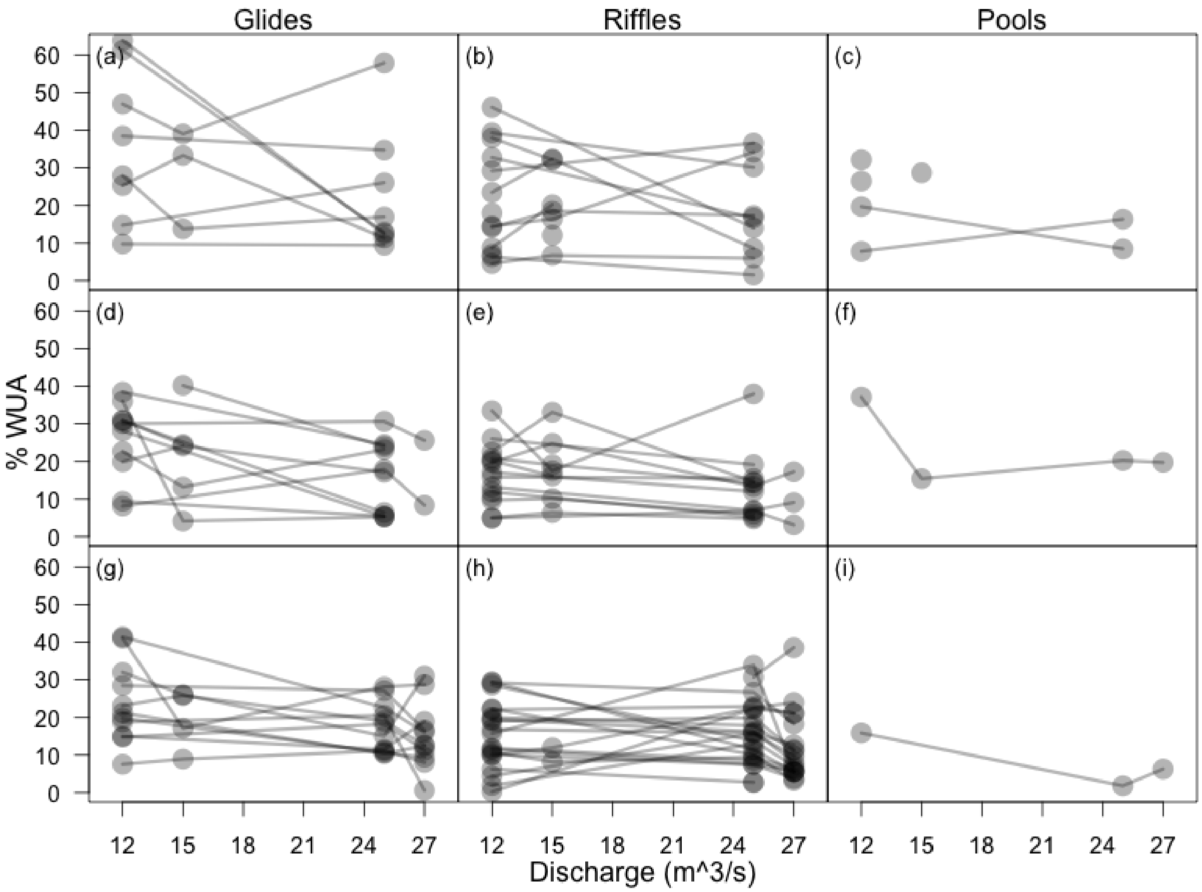


Figure 20. Length frequency histograms of juvenile Rainbow trout sampled in Seton River 2014

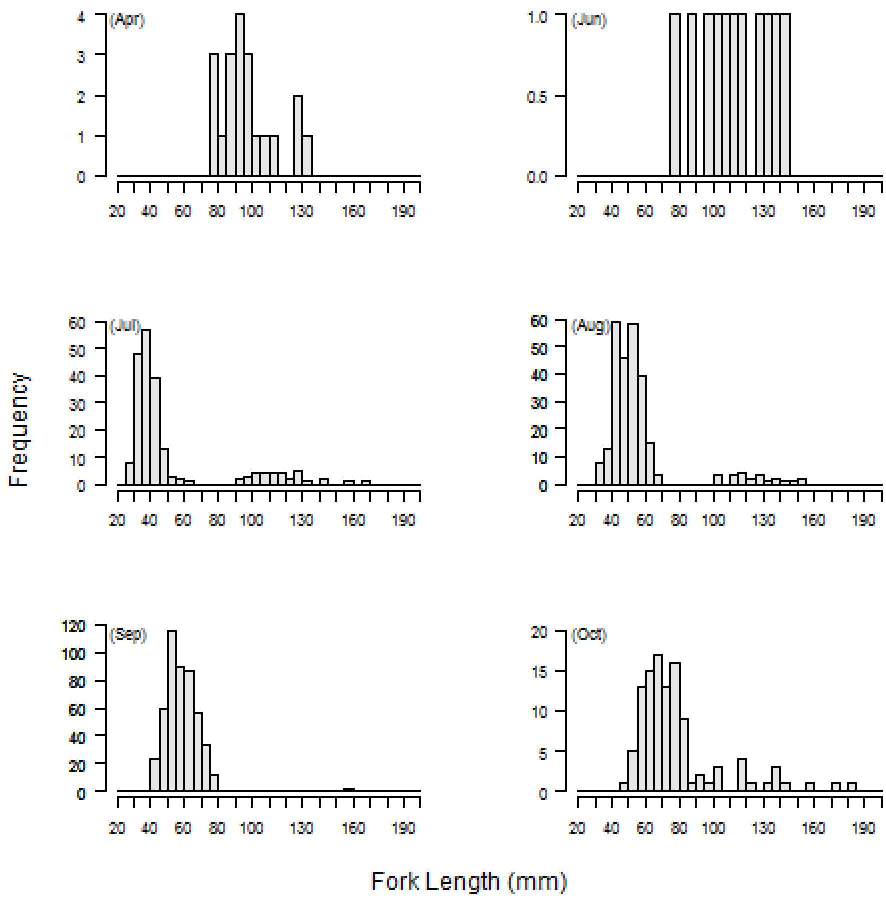


Figure 21. Length frequency histograms of juvenile Rainbow trout sampled in Seton River spawning channels in 2014

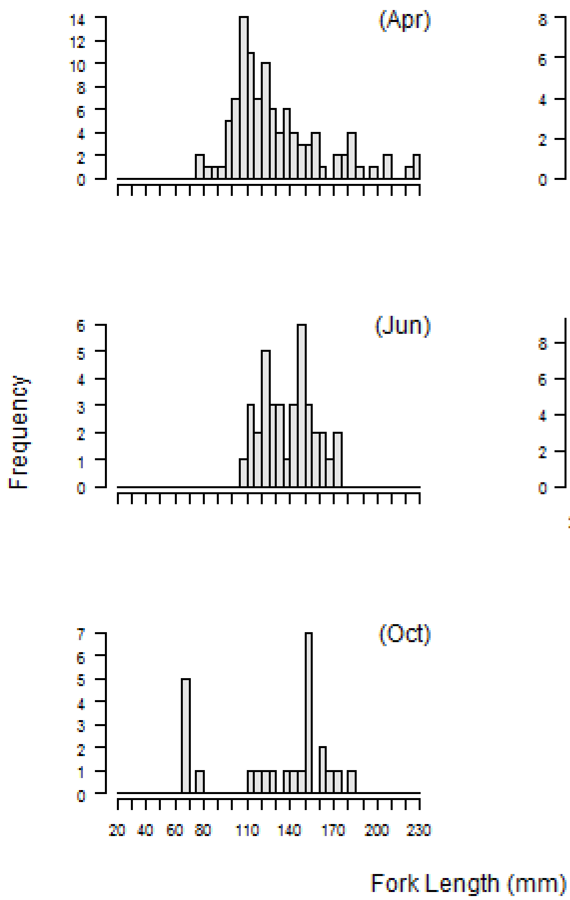


Figure 22. Length frequency for Seton River Rainbow trout in April 2014, Red = 1, Green = 2 and Blue = 3 year old fish

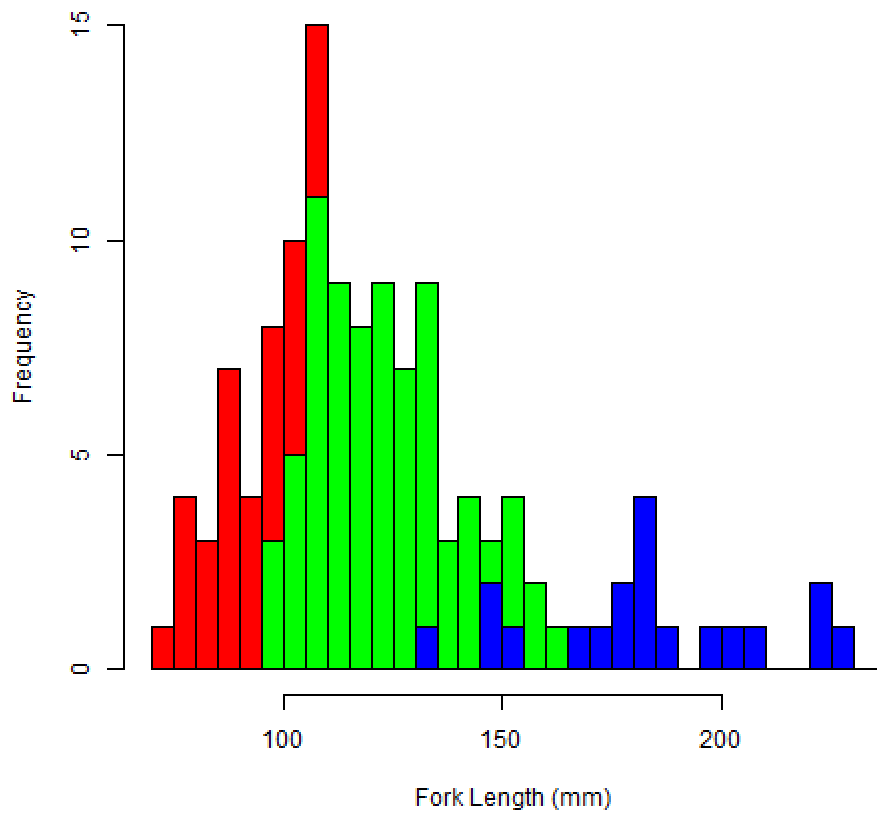


Figure 23. Length-at-age for Seton River Rainbow trout sampled in April 2014. Mean lengths-at-age connected by blue line.

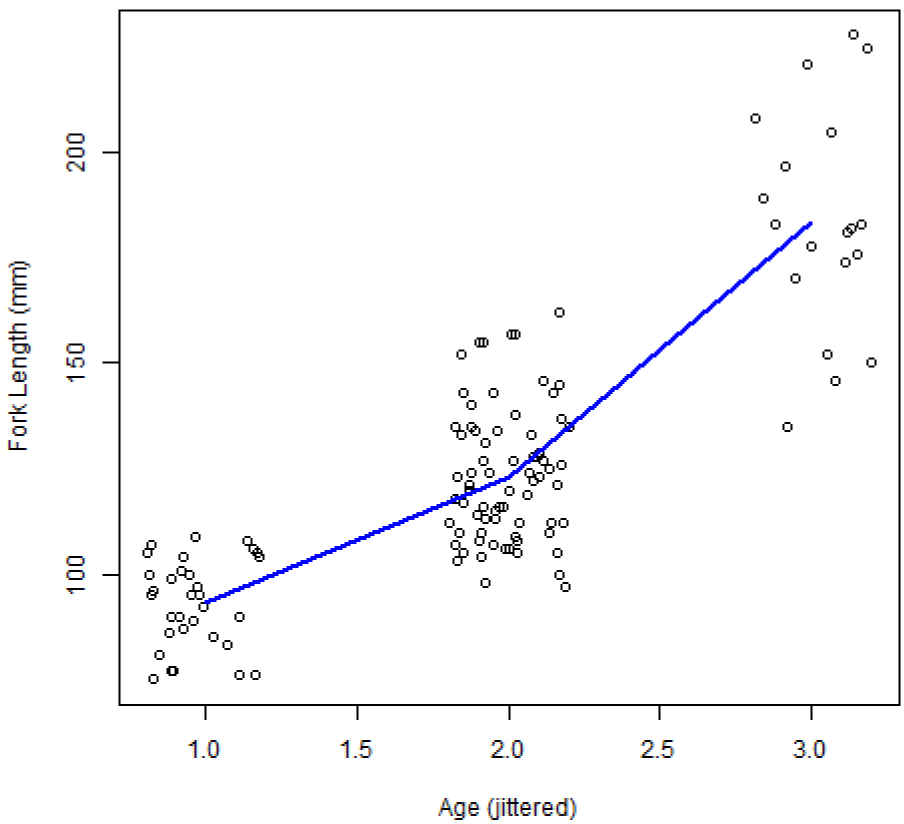


Figure 24. Length frequency for Seton River Rainbow trout in July 2014, Red = 0, Green = 1 and Blue = 2 year old fish

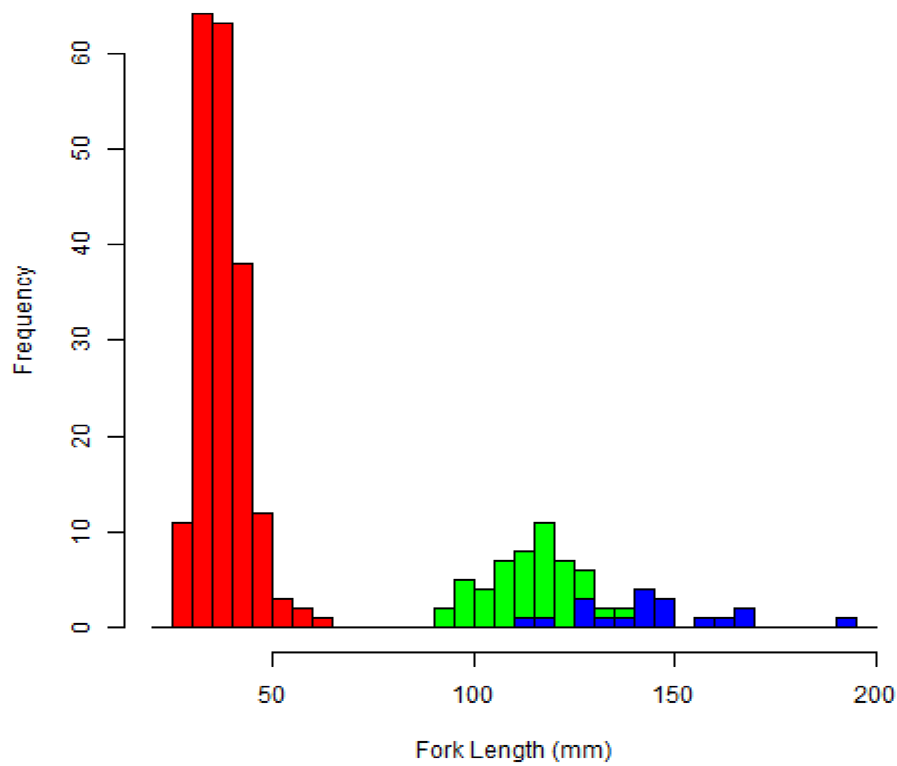


Figure 25. Length-at-age for Seton River Rainbow trout sampled in July 2014. Mean lengths-at-age connected by blue line.

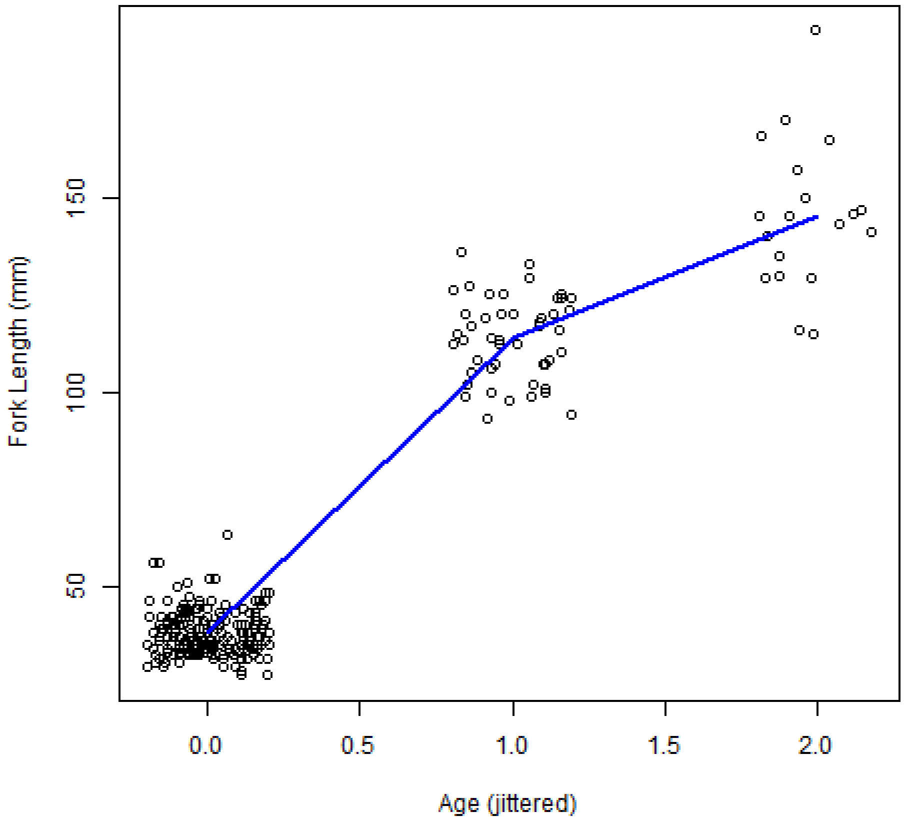


Figure 26. Length frequency for Seton River Rainbow trout in October 2014, Red = 0, Green = 1 and Blue = 2 year old fish.

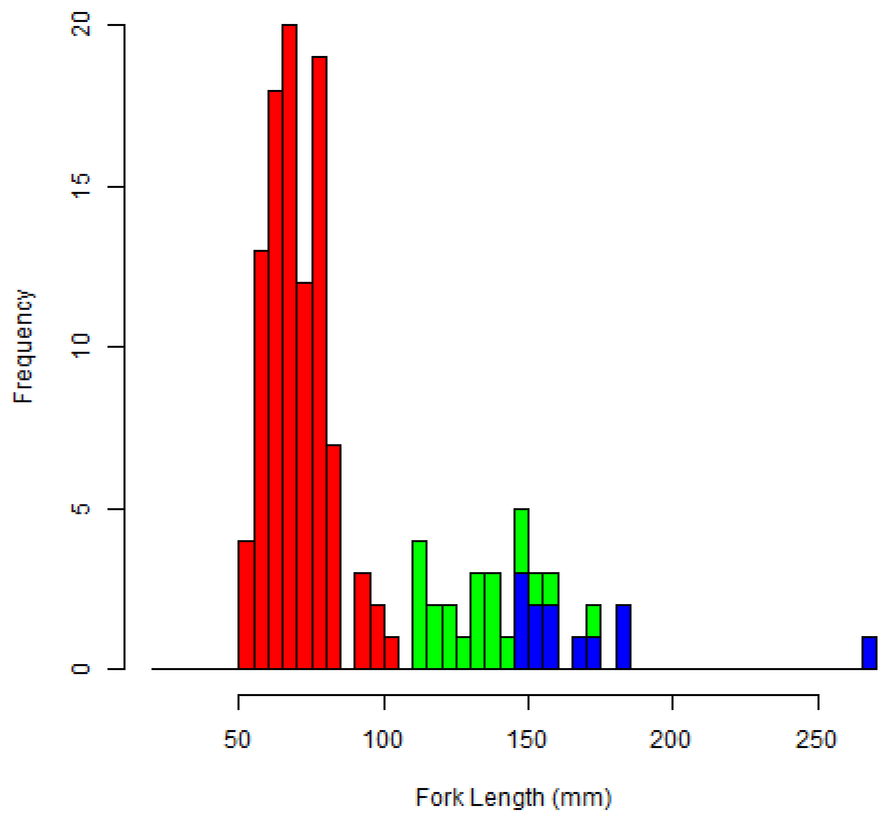


Figure 27. Length-at-age for Seton River Rainbow trout sampled in October 2014. Mean lengths-at-age connected by blue line.

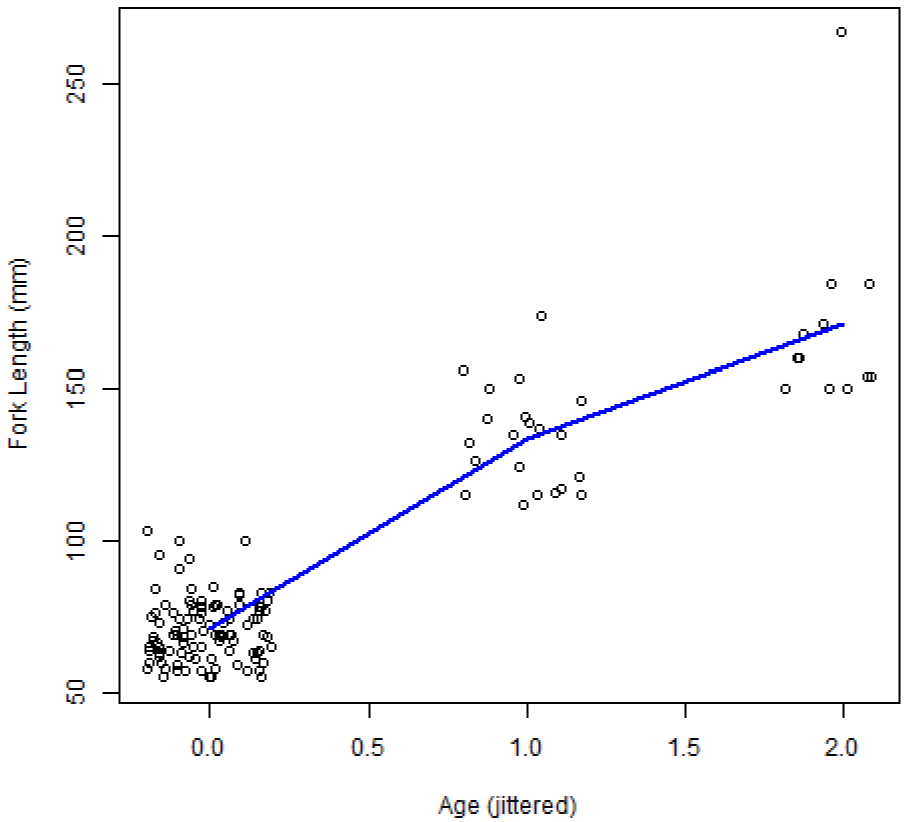


Figure 28. Weight, length relationship for Seton River Rainbow trout sampled in 2014

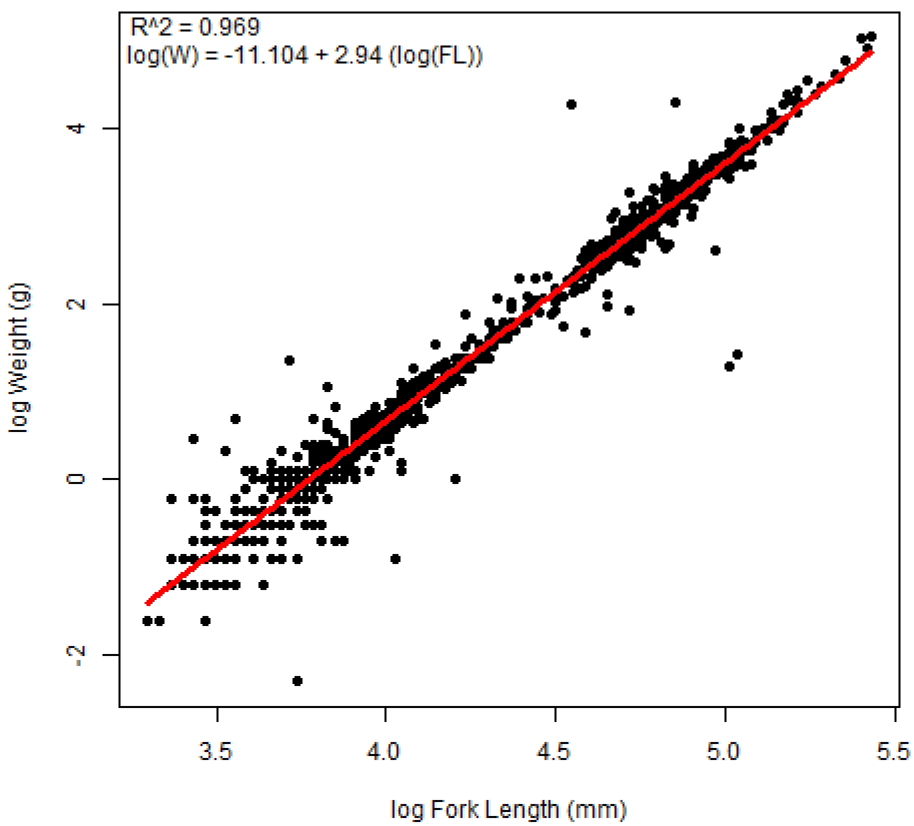


Figure 29. Length boxplot of Seton River age 0 Rainbow trout from July -October 2014

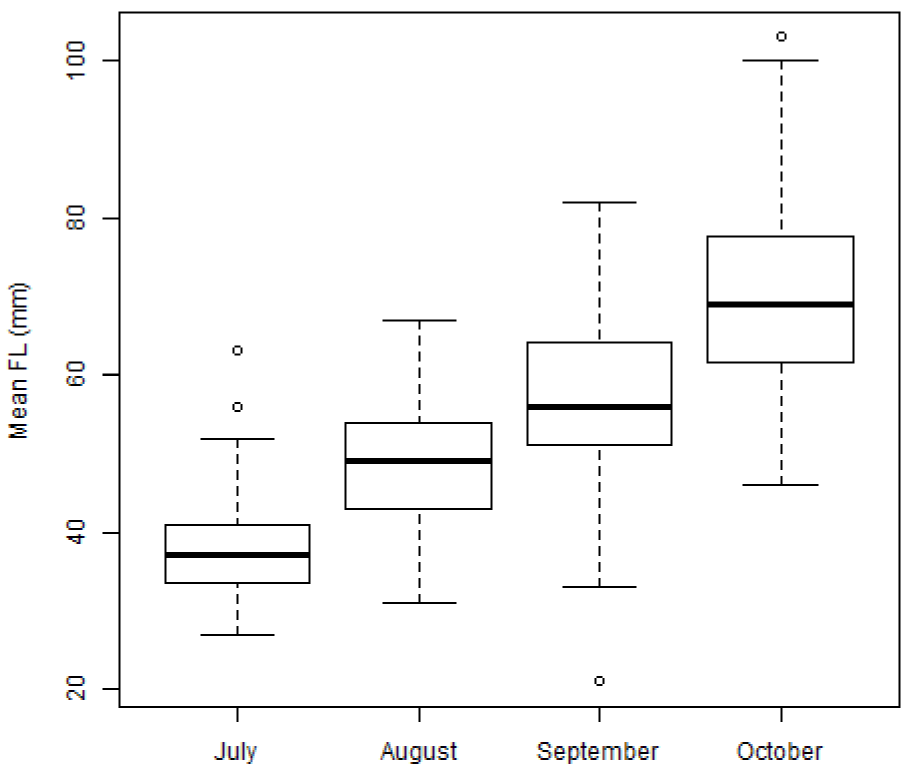


Figure 30. Weight boxplot of Seton River age 0 Rainbow trout from July -October 2014

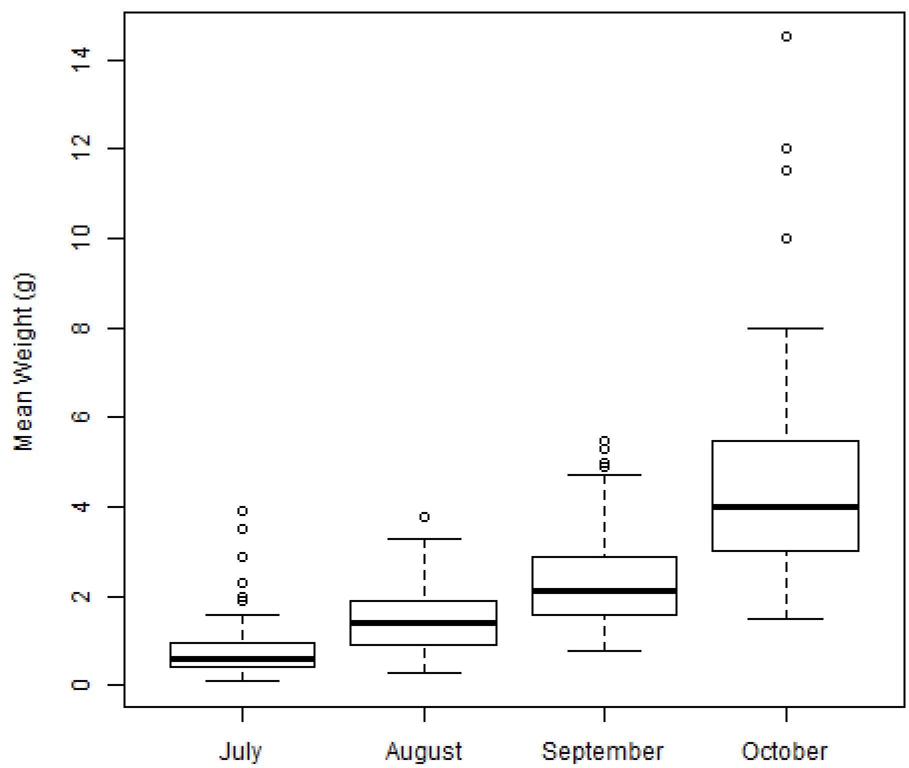


Figure 31. Length boxplot of Seton River age 1 Rainbow trout from July -October 201

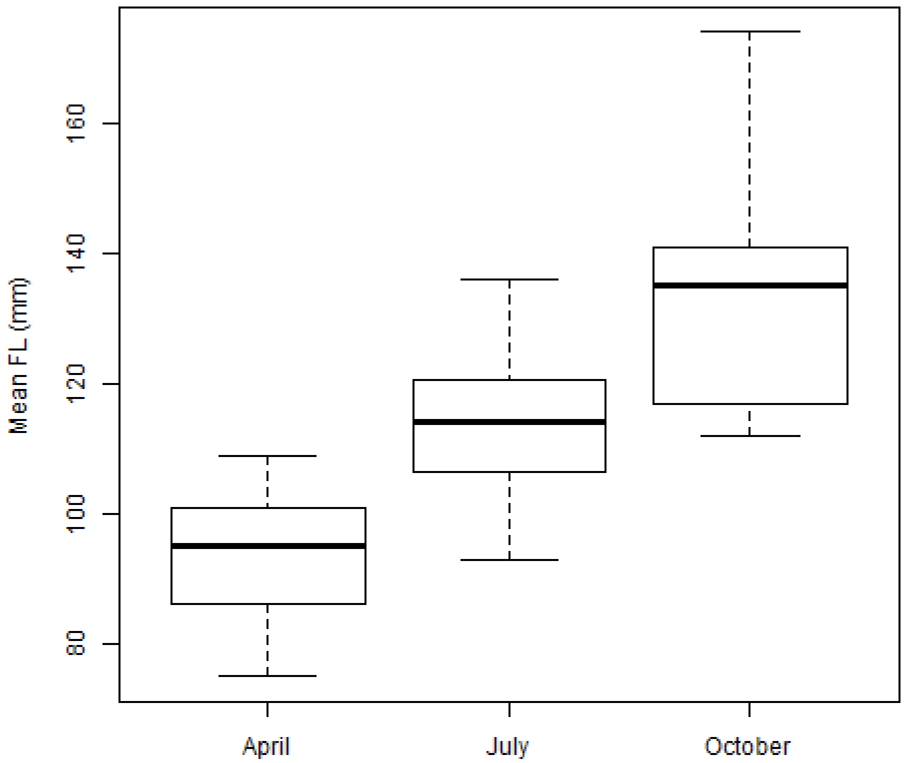


Figure 32. Weight boxplot of Seton River age 1 Rainbow trout from July -October 2014.

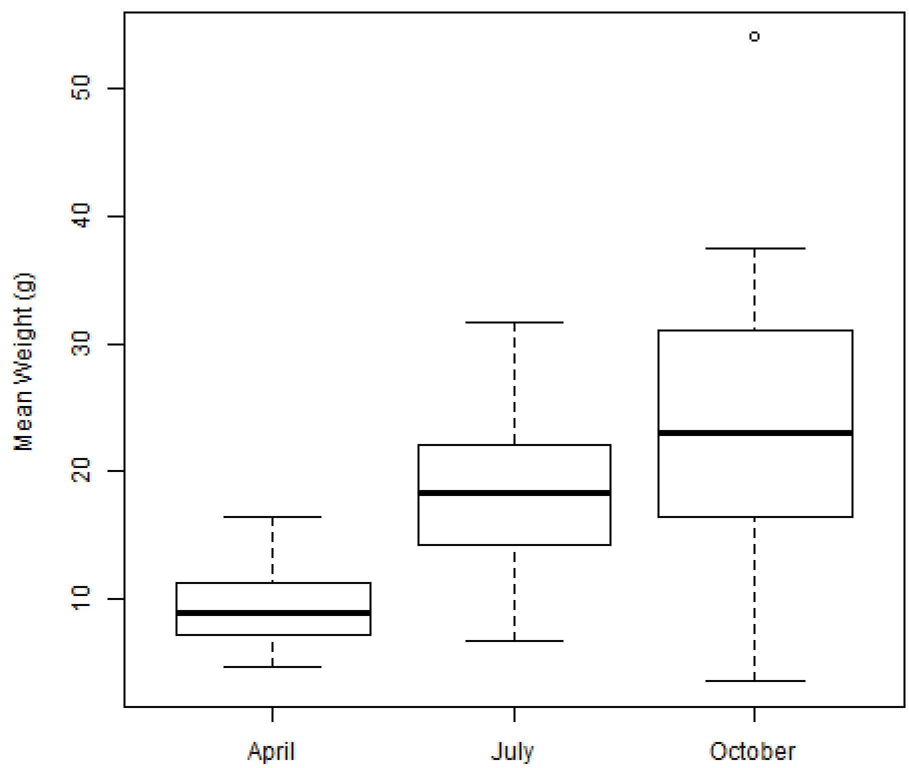


Figure 33. Length boxplot of Seton River age 2 Rainbow trout from July -October 2014.

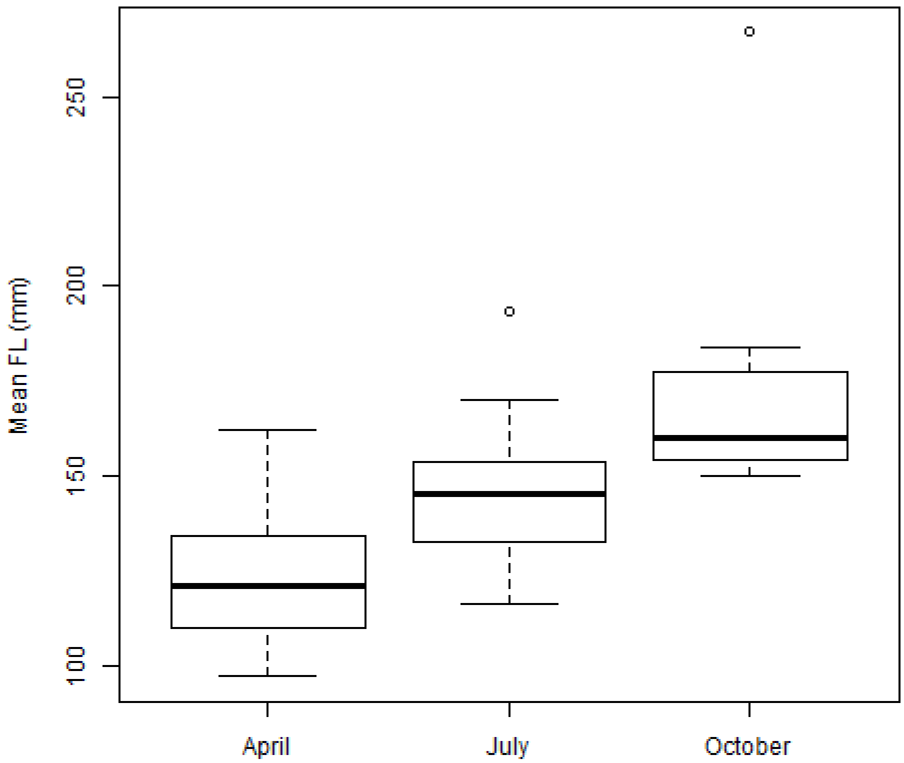


Figure 34. Weight boxplot of Seton River age 2 Rainbow trout from July -October 2014.

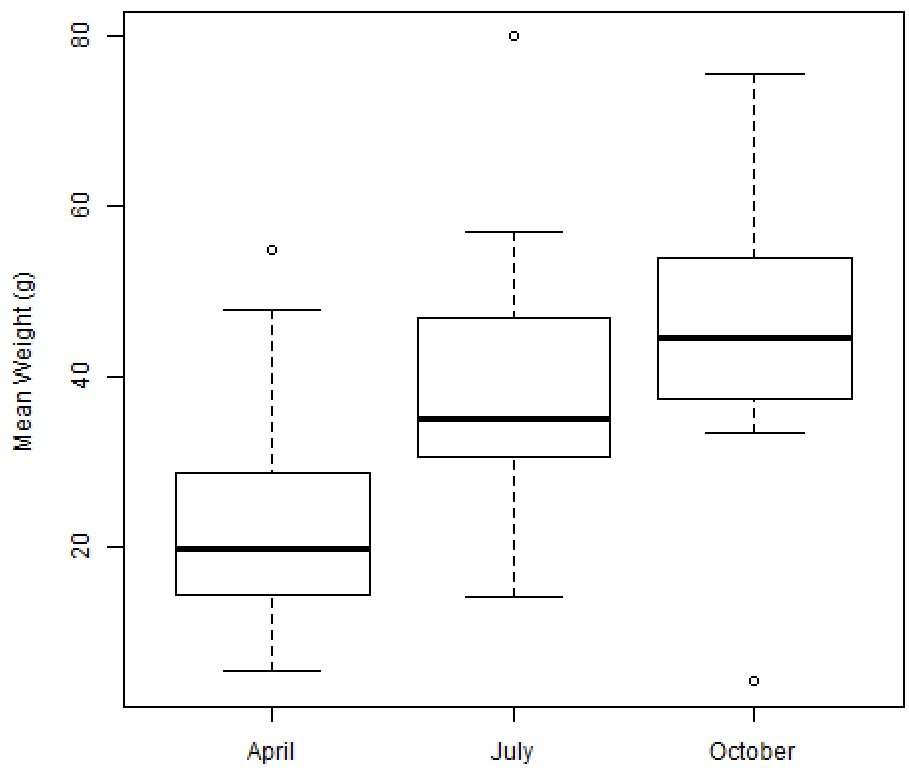


Figure 35. Length frequency histograms of juvenile Coho sampled in Seton River 2014.

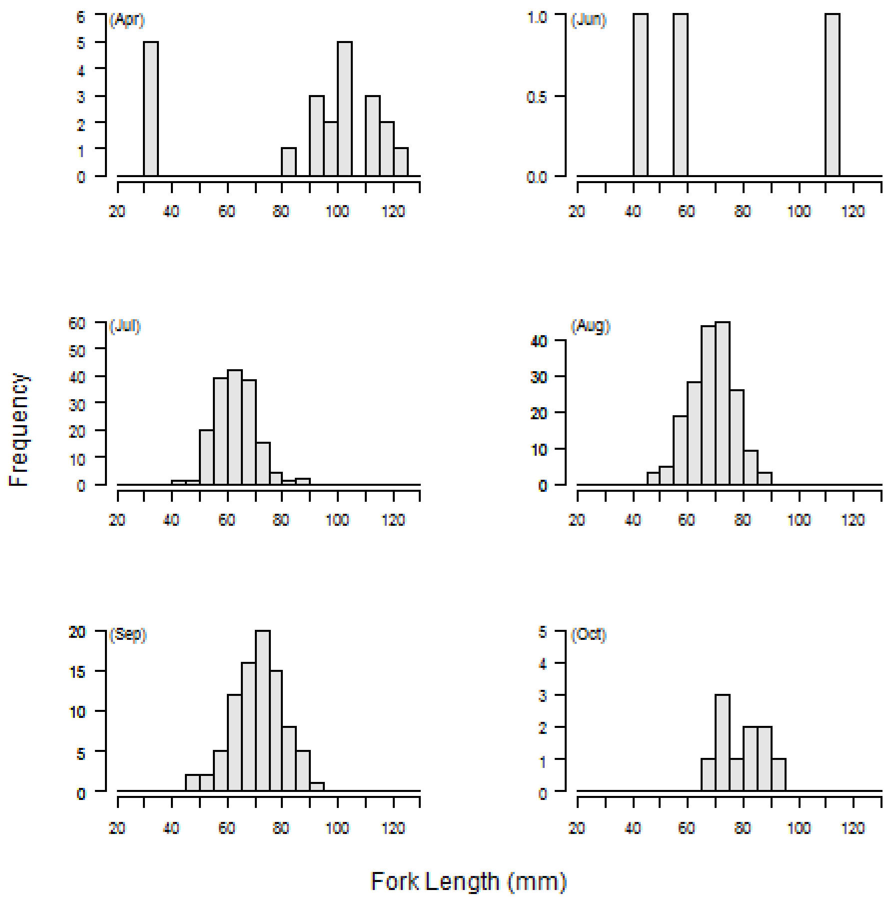


Figure 36. Length frequency histograms of juvenile Coho sampled in Seton River spawning channels 2014.

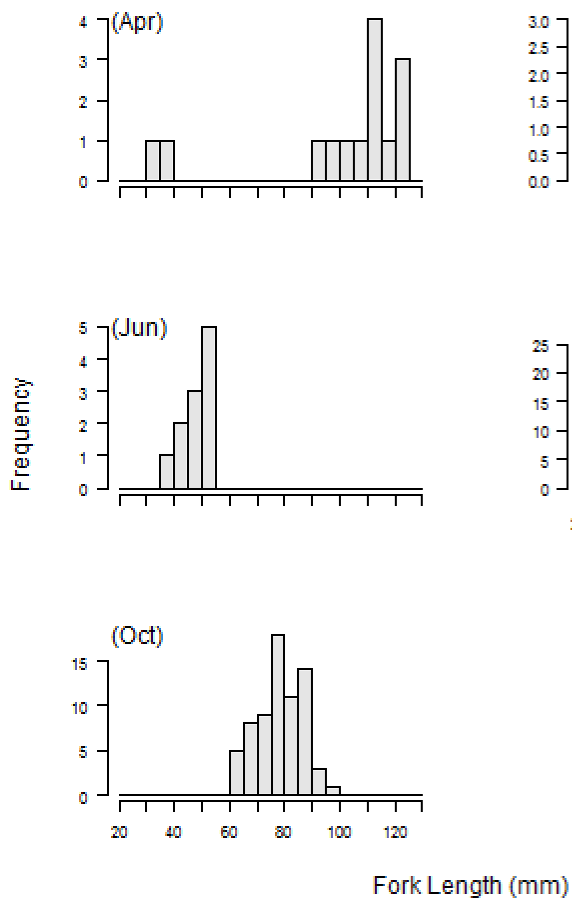


Figure 37. Length frequency for Seton juvenile Coho in April 2014, Red = 0 and light blue = 1 year old fish.

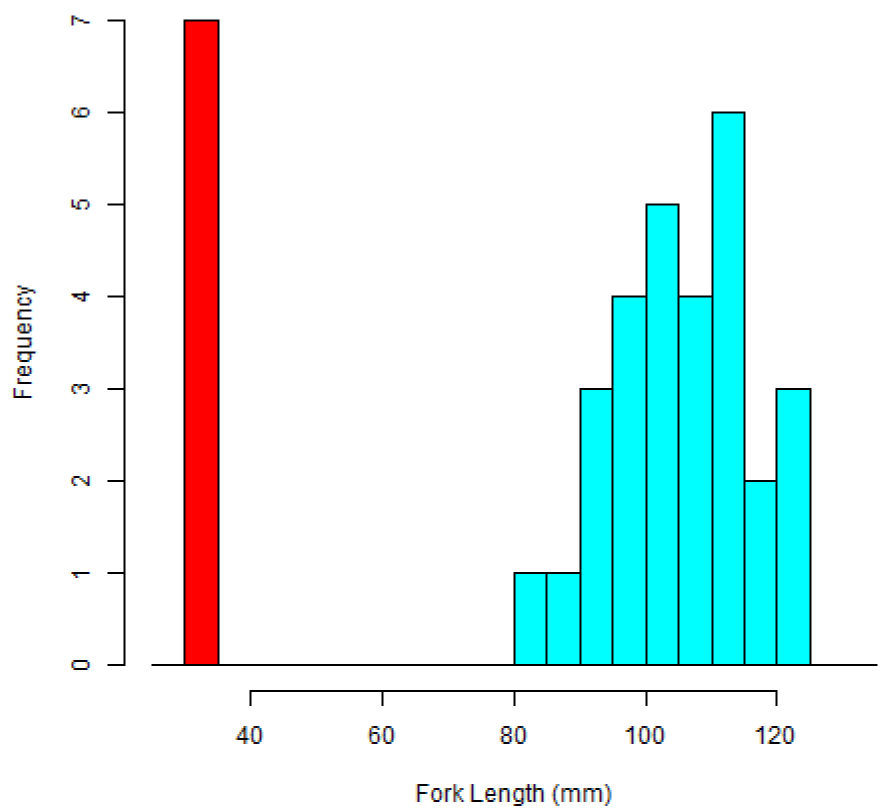


Figure 38. Length frequency for age 0 Seton juvenile Coho in October 2014.

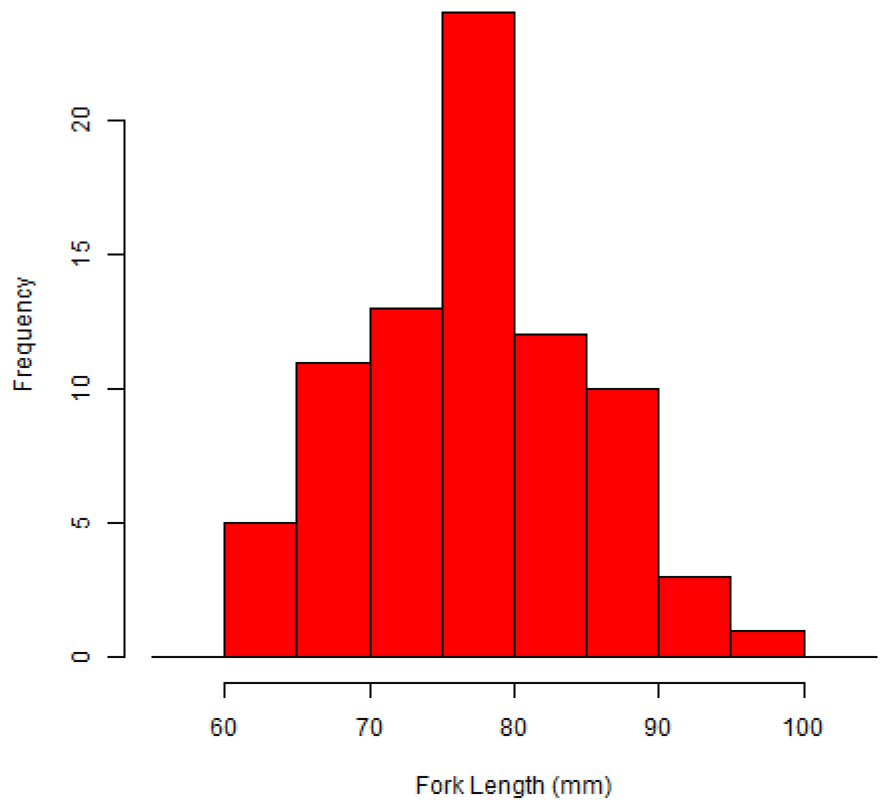


Figure 39. Weight, length relationship for Seton River juvenile Coho salmon sampled in 2014.

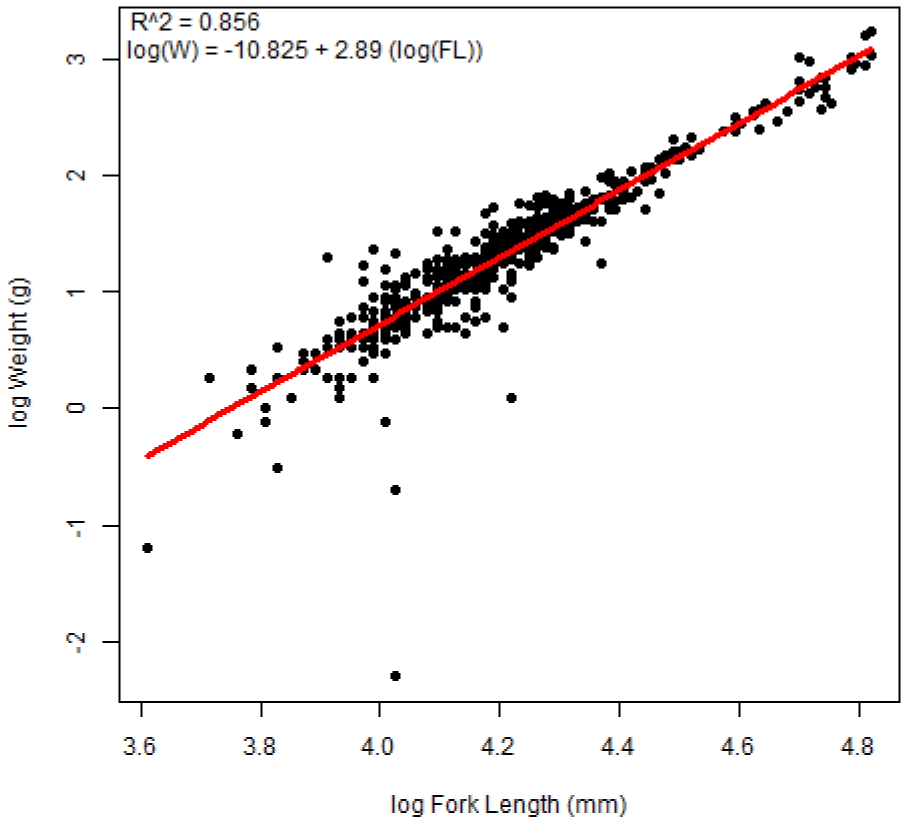


Figure 40. Length boxplot of Seton River age 0 Coho from April -October 2014.

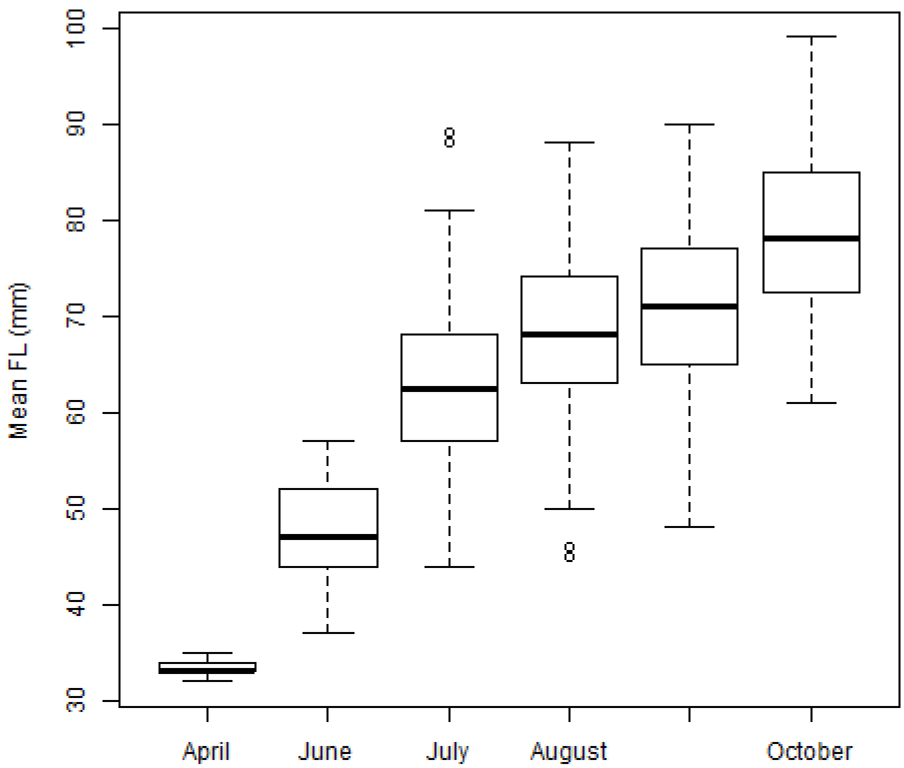


Figure 41. Posterior distributions of Seton River age 0 Rainbow trout abundance estimates at index sites - Fall 2014.

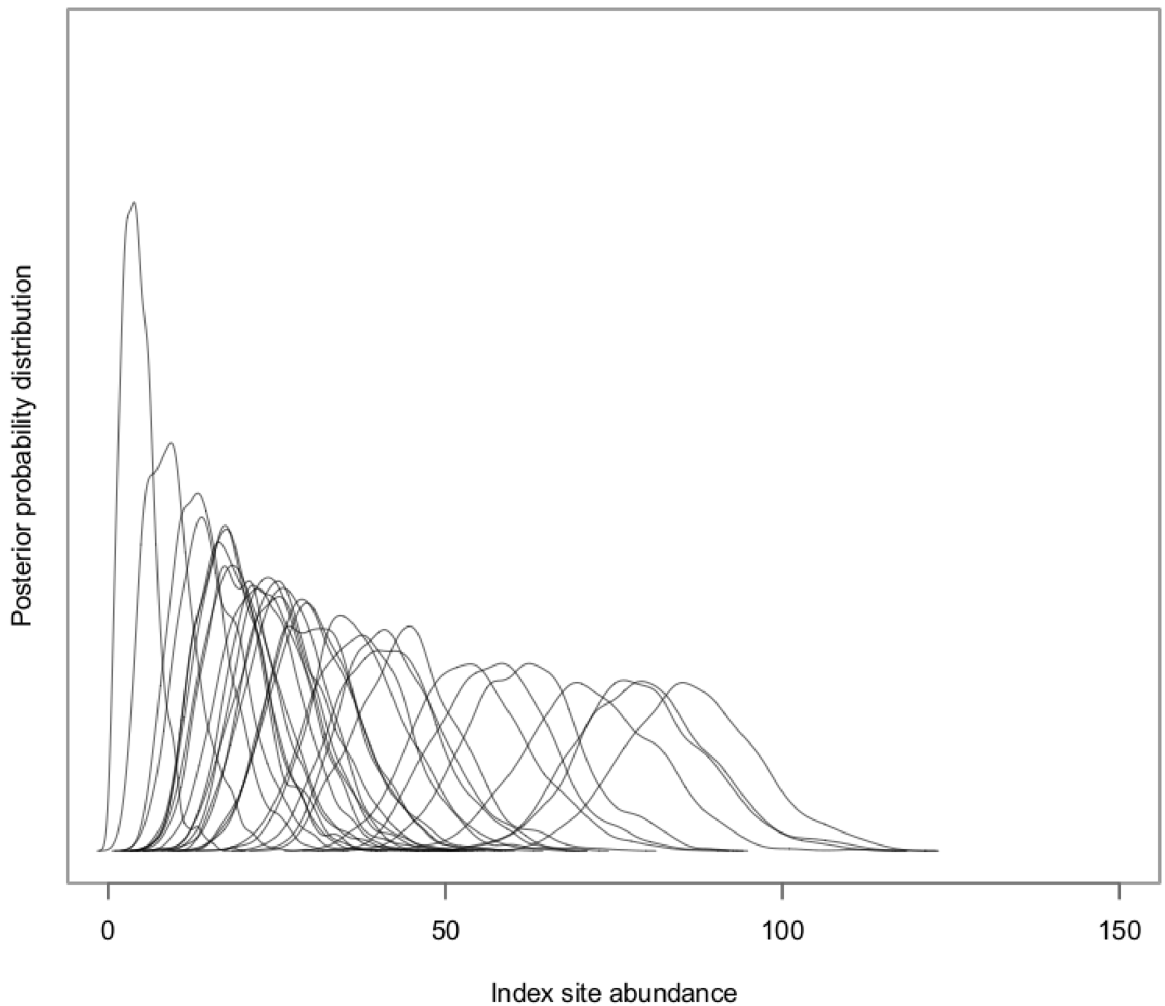


Figure 42. Seton River age 0 Rainbow trout abundance estimates - Fall 2014

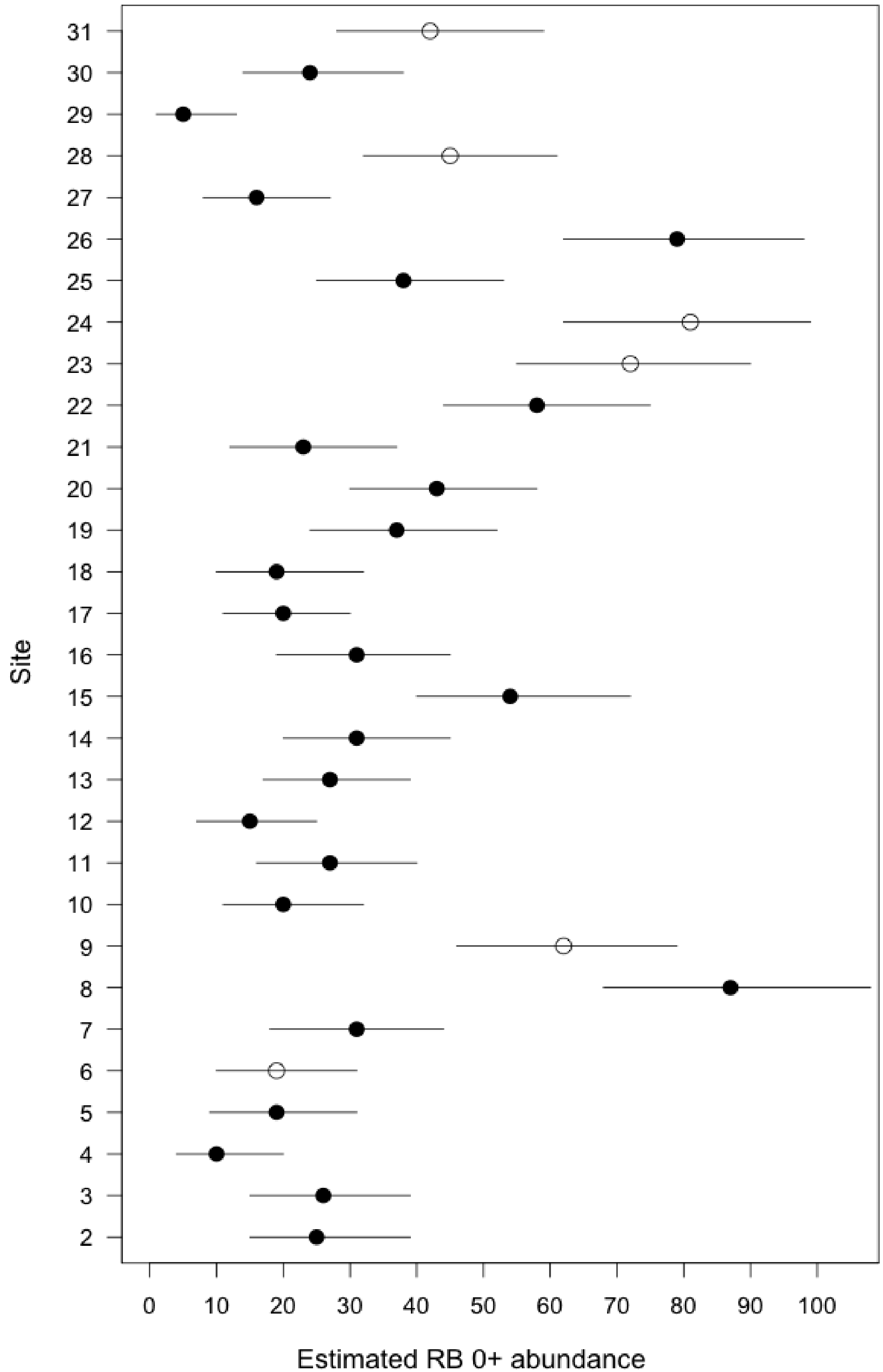


Figure 43. Fraser River discharge at Water survey of Canada Texas Creek gauge (08MF040) - April 1, 2014

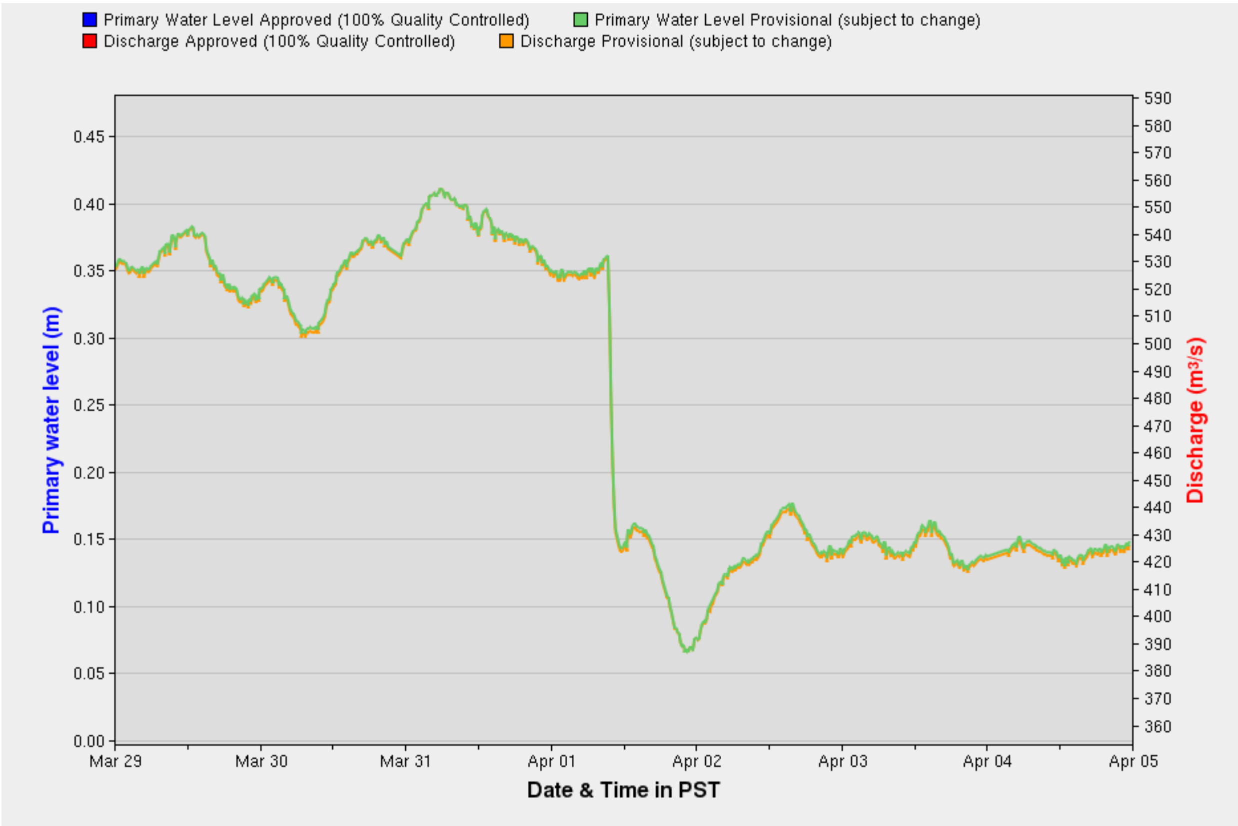


Figure 44. Stage level at Fraser River Stranding site 1. April 2014.

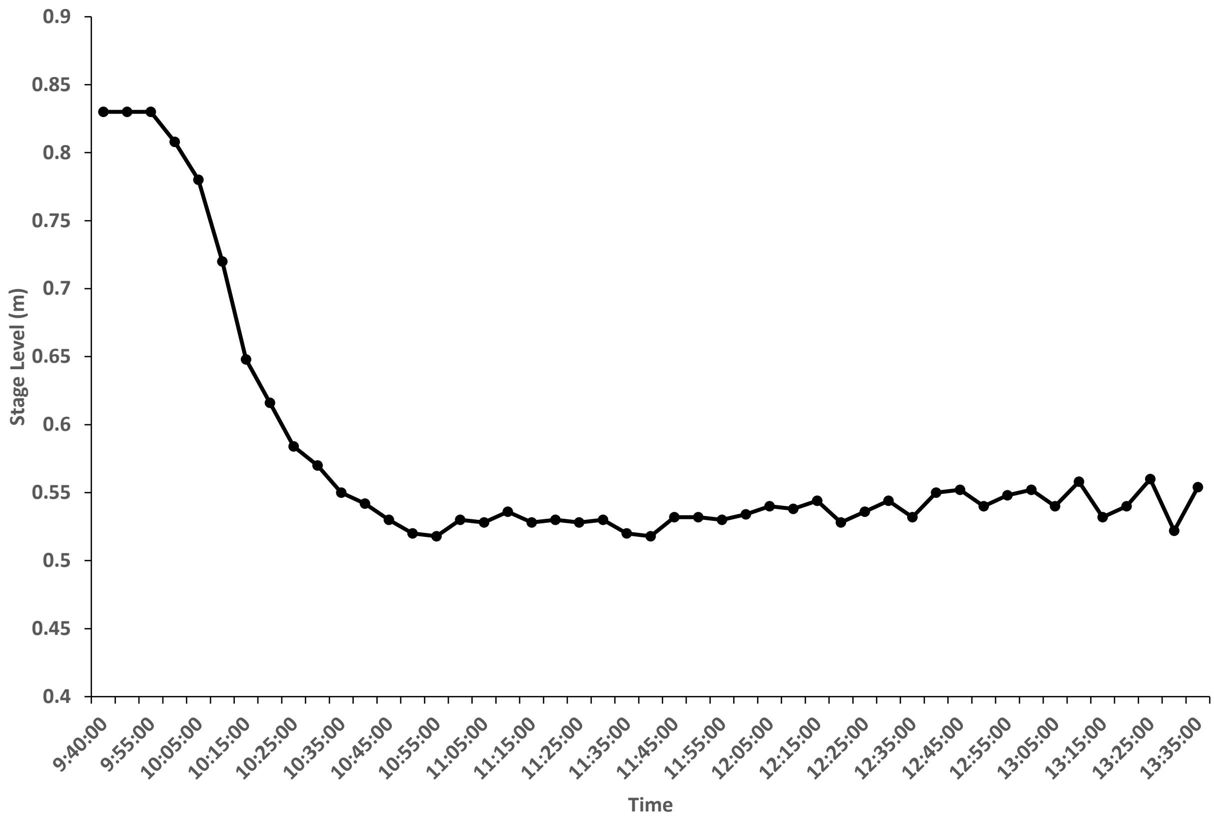


Figure 45. Stage level at Fraser River Stranding site 2. April 2014.

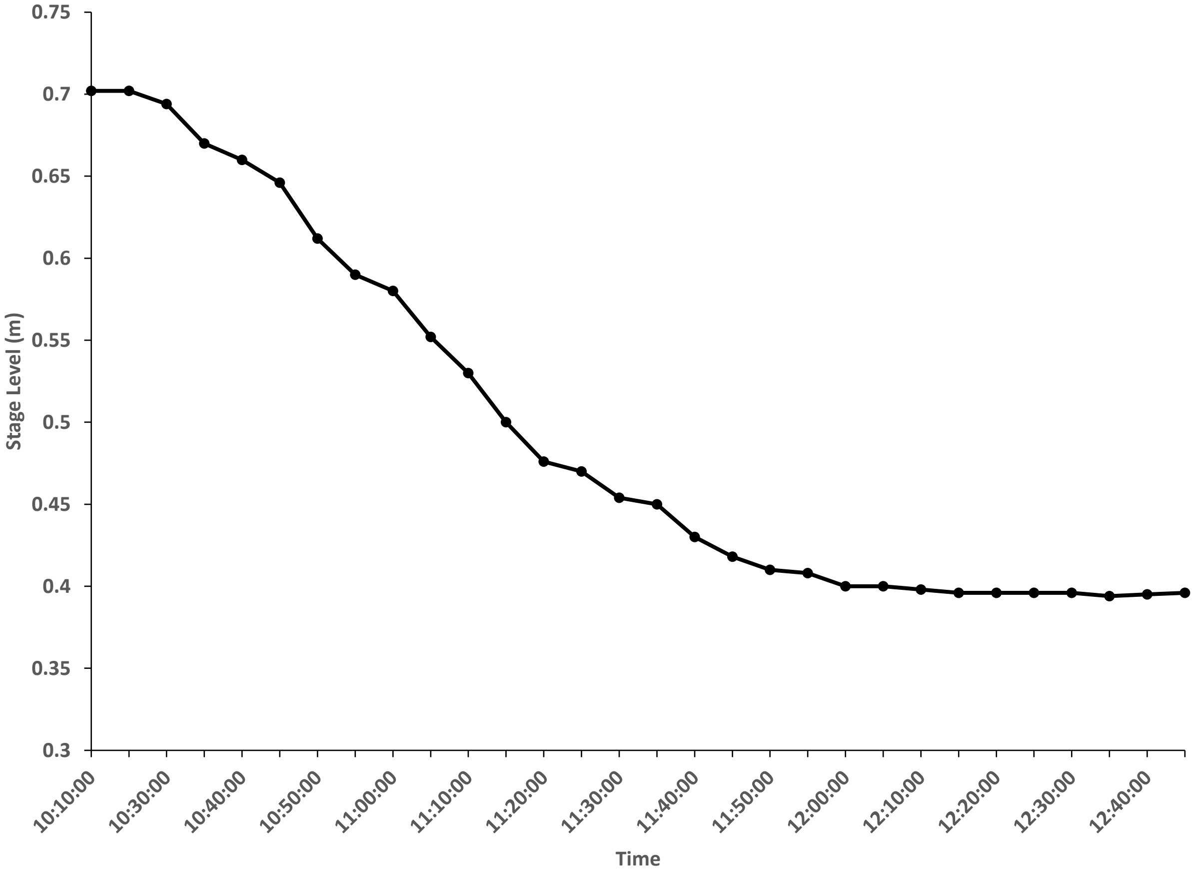
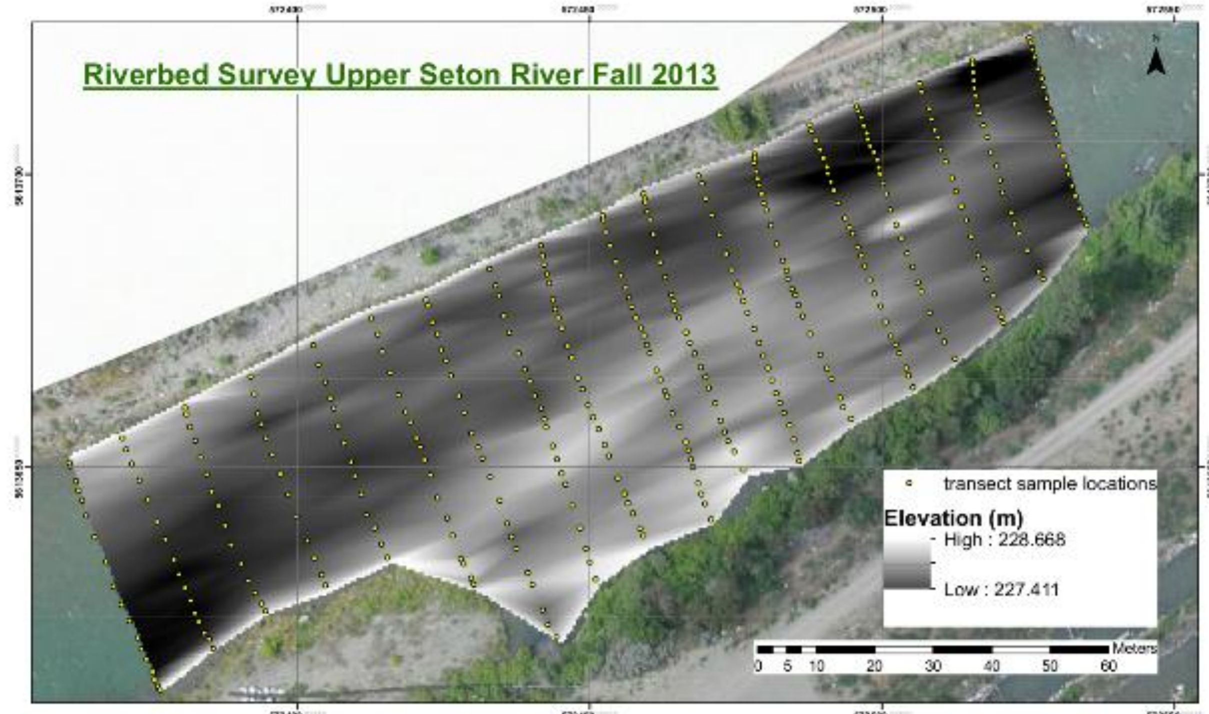


Figure 46. Seton riverbed elevation. Fall 2013



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9.0 APPENDIX

Habitat Suitability