Bridge River Water Use Plan

Seton River Habitat and Fish Monitor

Implementation Year 3

Reference: BRGMON-9

Bridge-Seton Water Use Plan Monitoring Program: Seton River Habitat and Fish Monitor, 2015

Study Period: March 1 to December 31, 2015

Daniel Ramos-Espinoza, Douglas Braun, Nicholas Burnett and Caroline Melville

InStream Fisheries Research Inc.
Unit 215 – 2323 Boundary Rd.,
Vancouver, BC.
V5M 4V8
T: 1 (604) 428 - 8819

December 23, 2016

Bridge-Seton Water Use Plan

Implementation Year 3 (2015):

Seton River Habitat and Fish Monitor

Reference: BRGMON-09

Daniel Ramos-Espinoza, Douglas Braun, Nicholas Burnett and Caroline Melville

Prepared for:

St'át'imc Eco-Resources

10 Scotchman Road

PO Box 2218

Lillooet, BC V0K 1V0

Prepared by:

InStream Fisheries Research Inc.

215 – 2323 Boundary Road

Vancouver, BC V5M 4V8

Seton River Habitat and Fish Monitor

2015

MON-09 STATUS of OBJECTIVES, MANAGEMENT QUESTIONS and HYPOTHESES after Year 3

Study Objectives	Management Questions	Management Hypotheses	Year 3 (2015-2016) Status
1. Monitor the response of fish habitat and fish populations to Seton Dam operations (implemented hydrograph).	1. What are the basic biological characteristics of the rearing and spawning populations in Seton River in terms of relative abundance, distribution, and life history?	H1: The amount of hydraulic habitat that can be inhabited by juvenile fish is independent of discharge from Seton Dam.	Partially answered. Habitat suitability surveys have been completed to identify available juvenile habitat at various discharges. Adult spawner abundance estimates have been difficult to calculate and more data is needed to assess use of Seton River for spawning by anadromous species. Methods will continue to be refined for assessing each individual species.
2.	2. How does the proposed Seton hydrograph influence the hydraulic condition of juvenile fish rearing habitats downstream of 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.	Partially answered. Juvenile standing crop surveys have been completed (2014-2015). Further surveys will continue to add to data series and aide in providing relationship between standing crop biomass and discharge. Juvenile Weighted Useable Area and discharge relationship curves have been created for 6 discharges.

---	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?	H2. The selected Seton River hydrograph does not result in dewatering of salmon or Steelhead redds.	Partially addressed. No red dewatering events have been observed to date. Data collected through visual surveys will continue to add to data series if Seton Dam operations change.
	4. How will the Seton hydrograph influence the short term availability of gravel suitable for use by anadromous and resident species for spawning and egg incubation?	H3. The selected Seton River hydrograph does not result in mobilization of gravel or net loss of gravel from the system.	Partially answered. Requires further analysis of substrate data collected in 2016 and more riverbed topographic surveys.
	5. Does discharge from Seton Generating Stations impact fish habitat in the Fraser River above and beyond natural variation in Fraser River discharged?		Partially answered. Requires further analysis of data collected in 2016 and additional surveys to document total area dewatered during specific events.

Executive Summary

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

This monitor is in year 3 of 10 years and combines old and new approaches to better understand the status of the Seton River fish populations and how different life histories may be affected by Seton Dam operations. 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.

Data collected through habitat surveys in 2014 and 2015 (i.e. depth, velocity and substrate measurements), allowed us to quantify useable habitat for Rainbow Trout, Coho and Chinook juveniles in the Seton River at various discharges. Repeating the surveys at established sites enabled us to monitor the effects of these different flows on each habitat type. To date, habitat surveys have been completed at six different discharges: 12, 15, 25, 27, 60 and 100 m^3/s. At the time of these surveys, the three species discussed above were present in the river. Overall, when flows increase from 12 to 27 m^3/s, useable habitat decreases; however, this change is not consistent between habitat type and species. River channel characteristics may play a role in response variability. For example, riffle habitat in reach three responded positively to increased flow (i.e., there was an increase in fish 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 15m^3/s had a positive effect on some habitats, but at this point in the monitoring program it is unknown up to what discharge this positive response will continue. As discharge increased to 60 m^3/s, weighted useable area for all species decreased substantially (about a third of what was observed at 12m^3/s). These changes were most evident in reaches one and three, the wider and lower gradient reaches. At 100 m^3/s, habitat decreased to the lowest levels measured to date.

Through monthly juvenile surveys, valuable data continued to be collected on juvenile growth rates for resident and anadromous life stages in the Seton River. Twelve species of fish were observed, including six species of salmonids [Rainbow Trout (*Oncorhynchus mykiss*), Bull Trout (*Salvelinus confluentus*), Coho (*O.* kisutch), Chinook (*O. tshawytscha*), Sockeye (O. nerka) and Mountain Whitefish (*Prosopium williamsoni*)], and seven species of non-salmonids [Bridgelip Sucker (*Catostomus columbianus*), Prickly Sculpin (*Cottus asper*), Coastrange Sculpin (*C. aleuticus*), Longnose Dace (*Rhinichthys cataractae*), Redside Shiner (*Richardsonius balteatus*) , Peamouth Chub (*Mylocheilus caurinus*)and Northern Pikeminnow (*Ptychocheilus oregonensis*)]. Of these species, only Rainbow Trout, Coho and Chinook were caught in sufficient numbers to show the presence of discrete age classes. Four distinct age classes of Rainbow Trout were observed (0+, 1, 2, and 3+), while two age classes were identified for Coho and Chinook: 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 Rainbow Trout abundance in the Seton River. In September of 2014 and 2015, electrofishing surveys and mark-recapture studies were completed. Mark-recapture studies were conducted to estimate capture probability, which was then used to expand counts from index sites sampled using single-pass electrofishing to un-sampled habitat units. A Hierarchical Bayesian Model (HBM) was used to estimate abundance of age-0 Rainbow Trout. Rainbow Trout densities for age 0 fish decreased in 2015. Densities ranged from 0.1 to 1.0 fish/m, compared to densities of 0.1 – 3.7 fish/m in 2014. Young-of–the-year Coho and Chinook were also observed, but not at densities high enough to estimate abundance. In March 2015 we completed snorkel surveys of all species for indexing and mark-recapture purposes. Results indicate that parr/larger fish occur at low densities in the Seton River. Mark-recapture modeling for snorkel survey data could not be completed due to the low number of fish observed.

Attempts to enumerate all species of adult salmonids spawning in the Seton River using radio-telemetry, visual counts, and PIT tagging continued in 2015. Eighteen steelhead adults were PIT tagged at the confluence of the Seton and Fraser River. Five fish remained in the Seton River while 11 were observed in the Bridge River (BRGMON -03) and two were unaccounted for. Two of the fish that moved in to the Seton River were observed (through PIT telemetry) moving into the lower spawning channel, where they most likely spawned (residence time of 10 days). One Steelhead was observed moving through the fishway and past the dam. The remaining two fish either spawned in the Seton River or moved back to the Fraser to continue their migration to upstream tributaries. Two Steelhead were observed during the streamwalks that occurred weekly from March to June.

We were unable to capture any adult Chinook, and no individuals were observed in the Seton River during stream walks.

An attempt was made in 2015 to enumerate adult Pink salmon through mark-recapture and proportional distribution methods, but capture efforts produced few fish to tag. The low sample size was insufficient to produce meaningful recapture /distribution data thus a confident/reliable mark-recapture estimate could not be produced. In the absence of a mark-recapture estimate, residence time data collected through these methods and a mean observer efficiency from existing literature was used to create an Area Under the Curve (AUC) estimates for the upper and lower spawning channels; 6,117 (95 % CI, 0 and 47,540) and 12,433 (95 % CI, 7,551 and 17,315) individuals respectively and mainstem of Seton River; 2,541 (95 % CI, 1,122 and 3,960).

Forty-eight Coho were captured and PIT tagged in the Lower Bridge River as part of BRGMON-03. Of these 48 fish, five individuals were detected on the PIT readers in the Seton River corridor. One fish entered the lower spawning channel, two entered the upper spawning channel and the remaining two fish moved through the fishway and past the dam. Eighteen Coho were observed during the visual surveys all in the upper and lower spawning channels.

Other salmonids (e.g. Bull Trout and Mountain Whitefish) were PIT tagged opportunistically in 2015. These fish were caught as bi-catch through other angling efforts and are believed to use the Seton River as a feeding ground and migratory corridor and likely use other areas of the watershed for spawning and rearing. This is corroborated by the very few juveniles (<10) observed during the growth sampling surveys. The series of

PIT antennas installed in the Seton River corridor and lower Bridge River will provide valuable information on resident fish migratory behavior as this monitor progresses.

On March 23, 2015, we monitored the impacts of the shutdown of the Seton Generating Station on fish stranding in the Fraser River. The shutdown resulted in a 2.3% flow reduction in the Fraser River (Water Survey of Canada, Texas Creek gauge) downstream of the Fraser-Seton confluence. The average rate of stage reduction was below DFO guidelines of <0.5 m/h, and there were no fish identified during the stranding survey.

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 and 2015. This survey was completed at the location where most fish have been observed to spawn (135 m downstream of the dam,). Analysis of data collected to date shows that some elevation changes have occurred, but these changes were variable within and between transects. The most upstream (transects 1 - 4) and downstream (transects 16 -18) sections surveyed showed little or no change while the middle section (transects 5-15) saw an overall decrease in elevation. The river left section of the middle area where the main thalweg of the river flows became more uniform in depth and overall saw a decrease in elevation. The river right section saw different results with the marginal areas seeing an increase in elevation and the rest of the area seeing little change or becoming deeper.

Acknowledgments

St'át'imc Eco Resources (SER) staff provided administrative support for this project. Ed Serruol, Candice Jack, Avaleen Adolph, Ron James, and Storm Peters (SER) provided essential field services.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

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 (BC Hydro 2011). 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 and provide information on the most suitable shape of the hydrograph for fish production.

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, as identified in WUP, 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 to test these hypotheses 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 which is optimal 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 could 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 is to conduct field studies to provide three critical pieces of information improving the capability to make 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 redd dewatering; and 3) quantify/map changes in spawning gravel location and quantity.

Standardized data management, analysis and base mapping continues to be developed to determine the linkage between fish use and abundance observations and habitat inventories.

2.3 Juvenile Rearing Habitat

To determine how the Seton River hydrograph influences the hydraulic conditions of juvenile fish rearing habitats downstream 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 point where suitable habitat area begins to decrease rapidly and are based on the principle that habitat features such as depth and velocity are directly related to discharge (Jowett 1997). At the core of these methods, are Habitat Suitability Index (HSI) curves. These suitability curves may be defined by different criteria, including species, life stage, and seasonal requirements (Bovee 1986). 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. Surveys completed in 2015 supplemented the IFR data collected in 2014.

2.3.1 Site selection:

TEC identified the habitat survey sites on 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 marked the sites with flagging tape and in 2014 InStream began marking sites using a 5/8" diameter rebar pin, which was placed above the point of rooted vegetation (bankfull) to ensure depth and velocity measurements for each transect were being measured at the exact location and to capture the wetted width over a range of flows.

The 125 transect sites were located throughout the Seton River with at least one site assigned per hydrological habitat unit (where access was safe). Sites on river right were matched with the corresponding sites on river left and a total of 81 cross-sectional sites were identified. These sites were sampled where practical at various flows throughout 2014 and 2015.

To better understand the variation in effects of discharge on fish habitat, data collected in 2014 and 2015 was stratified by reach and habitat type (riffles, pools and glides). Each habitat type and reach experiences different hydrological responses to different discharges. These reaches were identified using Google maps and through the data collected during site selection surveys (Figure 2). 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. In March 2015 a modified level 1 habitat assessment (Johnston and Slaney, 1996) was completed at low base flows to ground truth the reaches identified in 2014 and verify the hydrological units identified by TEC in 2013 (hydrological units identified by TEC were not assessed at low flows).

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 (Figure 3).

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, or to a point of safe wading access. 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.

Surveys were conducted at six different discharges but not all transect sites were represented during each of the surveys. Only discharges from survey one (discharge = 12 m^3/s), three (discharge = 25 m^3/s) and five (discharge ~ 60 m^3/s) were directly compared, as a similar number of sites were surveyed during each of those surveys and total weighted useable areas can be directly compared.

A detailed substrate survey was completed in March of 2014 at base low flow (12 m^3/s), to identify the dominant substrate type at each transect. Substrate type was classified using the Wentworth scale (Wentworth, 1922), which splits substrate into 7 categories (fines, sand, small gravel, large gravel, small cobble, large cobble, boulder and bedrock). Within a transect, each substrate type was estimated to the nearest 5% within a 1 m^2 section of river bed along the entire length of the transect line or to a point of safe access.

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 bankful 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 relationships are created.

Due to the size, depth and velocities of the Seton River, whole river cross sections were only completed at a few sites. In cases where whole channel cross-sections could not be completed, transects along the transect line were completed from each shoreline until wading became unsafe due to depth and velocity. This is not a concern when using the HSI model to determine the distribution of juvenile fish in Seton River, as the middle sections of the river where velocities are too fast or too deep for safe data collection are also unsuitable for juveniles according to HSI curves (velocities and depths too great). In sections where a transect was completed on only one shoreline and the river channel was uniform, the measurement/data from one shoreline was mirrored rather than measured 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). Due to the influence of Cayoosh Creek on the Seton River below the 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. The two spawning channels also provide additional inflow throughout the year, but their contribution is constant all year round (~2 cms).

2.4 Juvenile Growth Sampling

Fish growth and distribution was assessed through monthly (April through October) open site electrofishing surveys using a Smith-Root LR-24 backpack electrofisher. Fish were captured by one-pass electrofishing at a number of sites distributed from the dam to the Fraser confluence. At each site 50 m of shoreline was sampled. 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. In total 7 sites were sampled on the Seton River main stem. These sites were selected based on the results from the 2014 sampling surveys. The two spawning channels were spot sampled randomly throughout their entire lengths (Figure 4).

In order to reduce handling stress, fish were placed in aerated buckets of fresh water until the electrofishing was completed for the site. Fish that were sampled were anaesthetized with a diluted solution of clove oil, dissolved 1:10 in ethanol. During each 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 removed from the envelopes and placed directly 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 Mountain Whitefish above 75 mm in length are scanned for PIT tags and if not present were tagged with a 12 mm PIT tag. These tags were inserted into the body cavity using a 12 gauge needle. Fish <150 mm were tagged in the ventral stomach cavity and fish >150 mm were tagged in the dorsal sinus. Measurements from recaptured fish are analyzed for growth and movement of each individual fish between captures. This data assists in verifying the size/age classes of untagged fish collected in successive sampling surveys.

The majority of the survey sites were selected in the mainstem of the Seton River along with some sites within the two spawning channels (lower and upper). Data from the two spawning channels was combined to compare against the main-stem fish. Electrofishing within the spawning channels also provided the opportunity through PIT tagging to further assess movement of fish between the spawning channel and mainstem habitats.

2.5 Juvenile Abundance

A Juvenile standing crop survey was conducted in September 2015. This survey followed the methods outlined in Korman et al. (2010a; 2010b) and Hagen et al. 2010. 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 modeling approach 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). The method/gear selected for sampling each habitat type was determined by discharge, the life stage of fish and method specific limitations (i.e. turbid waters in the fall prevent snorkel surveys). Given these criteria, the fall abundance surveys were based solely on electrofishing and spring abundance estimates of larger/older fish were based on snorkel surveys. The sites sampled in the fall surveys (electrofishing) were shallow riffles and glides, while shallow and deep riffles and deep glides and pools were sampled in the spring (snorkel surveys).

Sites were selected at random from the 125 WUA sites assessed during the habitat survey described in Section 2.3 – Figure 3. Electrofishing index and mark-recapture sites were selected from shallow riffle and glide habitats while snorkel surveys included deeper riffle, glide and pool habitats. Electrofishing sites were sampled during the day by a three-person crew using a Smith-Root LR-24 backpack electrofisher. Each site (50 m in length) was sampled systematically by traversing the site in an upstream direction and capturing all the fish that were observed. The sites were not enclosed and sampling was conducted as far into the river as safely possible. Side-channels or narrower sections of the river were sampled from bank to bank. Snorkel survey sites were surveyed as per methods in Decker et al. (2009). Sites were surveyed at night and involved a single diver navigating the site in an upstream direction searching for fish with the assistance of an under-water light. 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).

2.5.2 Data Analysis

The hierarchical Bayesian model consists of two levels. The first level; the observation model, used data from the mark-recapture studies to estimate site-specific and hyper-distributions for capture probability. The hyper distribution for capture probability estimated from mark-recapture site *i* was then used in the second level of the model; the population model, to estimate density for index site *j* using catch data collected from the single pass, the site length, and the capture probability (Table 1).

Capture probability is the proportion of marked fish recaptured in the second pass at mark recapture site *i* (Table 1). 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. The only species/life stage with enough data to produce reliable estimates of capture probability was for 0+ Rainbow Trout/Steelhead.

Catches from index sites were assumed follow a binomial distribution and the abundance at index sites was assumed to follow a Poisson distribution. Densities were assumed to be lognormal-distributed. Densities for 2014 and 2015 are presented together for comparison.

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 2015, no Coho or Chinook adults were captured thus only Steelhead adults (n = 18) were radio tagged by gastrically implanting an MCF2-3A radio tag (Lotek Engineering Inc.) using the same methods described for the Lower Bridge System (Burnett et. al. 2016).

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. 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, angling conditions, and fish behaviour.

2.6.2 Mobile Tracking

Weekly mobile tracking with a hand held Lotek W31 radio receiver was conducted from March 23rd to May 29th for Steelhead 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 coincided 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.

2.6.3 Fixed Station Telemetry Receivers

Fixed station logging was conducted from April 6th to June 5th at one site located 200 m upstream of the lower spawning channel outflow and Seton River Confluence (River Kilometer - RK 1.3 from confluence with Fraser River) (Figure 5) with a Lotek W31 receiver linked to two Yagi 6-prong directional aerials oriented upstream and downstream. In previous years a station was located near the confluence with Cayoosh Creek but was not operated in 2015 as the noise created by the overhead power lines confounded the reliability of the receiver.

Fixed station data was used to corroborate fish location (during mobile tracking), identify entry and exit timing into the Seton River, 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 Seton River. The spawning channels were also surveyed to assess use by adult salmonids. Methods replicated those utilized in BRGMON3 surveys (Burnett et al. 2016) and the 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 March 4th for Steelhead and were completed on June 15th. Chinook and Pink migration overlapped and surveys for both species commenced on August 4th and were completed on the 30th of September. Coho surveys began on October 6th and were completed on December 15th.

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

An Area-Under-the-Curve (AUC) method was proposed in 2015 to estimate escapement for Pink salmon in the spawning channels based on repeat visual counts from stream walks, combined with estimates of observer efficiency (o.e) and survey life from PIT telemetry.

In previous years AUC analysis was proposed for adult salmonids as described in Hilborn et al. (1999), but due to the lack of fish observed, estimates were not produced. In the methods described in Hilborn et al. (1999), abundance is modelled as a quasi-Poisson distribution with arrival timing characterized by a beta distribution. We found that a normal distribution adequately described arrival timing of salmon in the Lower Bridge River (Burnett et al. 2016) and resulted in a simpler AUC model compared to the beta distribution version of the model. Consequently, abundance of Pink Salmon in the Seton

River in 2015 were modelled using a quasi-Poisson distribution with normally distributed arrival timing (described in Millar et al. 2012). Both methods were evaluated using maximum likelihood (ML), and differ only in the distribution of arrival timing. Abundance estimates were thus insensitive to this change in analysis, and consequently, we used the methods described below from Millar et al. (2012).

With abundance modelled as a quasi-Poisson distribution with normally distributed arrival timing (Millar et al. 2012), the number of observed spawners at time t (C_t) is

(1) $$C_t = a\ exp\left[-\frac{(t-m_s)^2}{2\tau_s^2}\right]$$

where *a* is the maximum height of the spawner curve, m_s is the time of peak spawners, and τ_s^2 is the standard deviation of the arrival timing curve.
Because the normal density function integrates to unity, the exponent term in Equation 1 becomes $\sqrt{2\pi\tau_s}$ and Equation 1 can be simplified to

(2) $$C_t = a\sqrt{2\pi\tau_s}$$

A final estimate of abundance ($\hat{E}$) is obtained by applying observer efficiency (v) and survey life (l) to the estimated number of observed spawners

(3) $$\hat{E} = \frac{\hat{C}_t}{l * v}$$

$\hat{E}$ in Equation 3 is estimated using ML, where $\hat{a}$ and $\hat{\tau}$ are the ML estimates of *a* and τ_s in Equation 2 ($\hat{C}_t = \hat{a}\sqrt{2\pi\hat{\tau}_s}$).
The AUC estimation in Equation 1 can be re-expressed as a linear model, allowing the estimation to be performed as a simple log-linear equation with an over-dispersion correction factor. Correction for over-dispersion accounts for instances where the variance

of the observations exceeds the expected value. The log-linear model is computationally simple and can be completed using standard generalized linear modelling software. 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 fixed PIT telemetry station records. Residence time in the spawning channels was estimated as the time period in which a live fish moved into the counting/spawning zone, spawned then proceeded to leave the channel where they would be recorded by the PIT antenna.

2.9 Passive Integrated Transponder Tagging

Passive Integrated Transponder (PIT) tagging has been taking place in the Seton River since the initiation of the BRGMON-9 project in 2013. 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 detailed tracking of movement and growth rate of individual fish in the Seton River system.

Movement of tagged fish was assessed through the installation of four fixed PIT antenna arrays in the Seton River System (Figure 5):

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

Fixed station data was analyzed to assess fish location, identify movement of each fish into each region, and collect basic data on fish migration and spawning behavior in the Seton River. The detection data for tagged Pink salmon was used to assess fish abundance through proportional distribution analysis.

This method for evaluating abundance, using data collected at the Seton fishway and proportional distribution from the other antenna sites, accounts for fish that move through the visual survey area and are likely to be counted but do not spawn in the Seton River. This is a short-coming of the AUC method described above because 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) provides 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 can be used to calculate the relative proportion of fish that leave the mainstem and spawn elsewhere.

The abundance of Pink spawning below the dam is calculated as follows:

$$E_{lower} = E_{ft} / P_{dam}$$

where E_{lower} 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 spawning channels and Cayoosh Creek. The Seton River salmon spawner abundance is 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.

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 and two locations on the Fraser River have been identified for monitoring (Figure 6). 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 during the shutdown events.

Each site was visited the morning before the scheduled shutdown of the generating station. A portable staff gauge was installed and during the ramp down the water depth was measured every five minutes. After the shutdown the dewatered gravel bar was surveyed for stranded fish.

2.11 Gravel Mobilization

Bennett Land Surveying Ltd. was contracted to conduct riverbed topographic surveys of the Seton River downstream of Seton Dam in September 2013 and September 2015 (Figure 7). Briefly, surveyors measured streambed elevation using a single-base real-time kinematic (RTK) Global Navigation Satellite System (GNSS) following the Guidelines for RTK/RTN GNSS Surveying in Canada (Donahue et al. 2013). Surveyors setup a RTK base station on a static point with fixed coordinates, and the change in northing, easting and elevation between the base station and rover was recorded. The rover was moved along 18 transects spaced approximately 10 m apart, recording up to 30 elevation measurements in a single transect. Accuracies of horizontal (northing and easting) and vertical (elevation) data were $\pm$ 2 cm and $\pm$ 4 cm, respectively.

Data were managed, analyzed and visualized in R (Version 3.2.3; R Core Team 2014). Streambed elevation data were plotted on both a transect and riverine scale by year.

3. RESULTS

3.1 Juvenile Rearing habitat

3.1.1 Study sites

From the modified level 1 FHAP assessment conducted in 2015, three reaches with 48 distinct hydrological habitat units were identified on the Seton River mainstem, along with two side-channels (Figure 8 and Table 3).

Reach one extends 1432 m from the dam (down main thalwag of river) downstream to the confluence with Cayoosh Creek (50.668884 N -121.961335 W). This reach is comprised of 17 habitat units. Riffles were most common making up 47% of total length (667 m), followed by pools at 28% (407 m) and glides at 25 % (358 m). Mean bankfull width and wetted width at base flows were 30.1 and 27.0 m respectively.

Reach two extends 1109 m downstream from the Cayoosh confluence to just downstream of the intake to the lower spawning channel (50.672083° N -121.946417° W). This reach is made up of 9 habitat units and has the highest gradient of the 3 reaches. It is composed of primarily riffles; 67% of habitat units observed and 750 m of the reach length. Glides made up 23% of the reach (260 m) and the single pool 9 % of the reach (99 m). Mean bankfull and wetted widths for the reach were 37 and 32 m respectively.

Reach 3 is the largest of the reaches measuring 1796 m and is comprised of 22 habitat units. It extends downstream from the reach two break to the confluence with the Fraser River. Similar to reach one, this reach is low gradient with wide bankfull widths (mean 37 m). Glides are the most abundant habitat type making up 45 % of the habitat units measured, but only make up 708 m of the total length (37 %). Riffles made up 41% of the habitat types and are 874 m (46%) of the total length of the reach. Pool habitat is sparse (3 units) and was 12% (214 m) of the reach.

3.1.2 Surveys

Depth and velocity surveys have been completed at six different discharges on the Seton River in 2014 and 2015: Juvenile species of Coho, Chinook and Rainbow Trout were present during all the surveys.

- Survey one was completed between March 18th and April 4th of 2014 (all 81 transect sites were surveyed). During this time discharge, the sum of the WSC Seton River at Lillooet gauge (08ME003) and WSC Cayoosh Creek at Lillooet (08ME002) (reach 2 & 3), was 13.18 m^3/s [11.63 m^3/s (reach 1) and 1.55 m^3/s respectively].
- Survey two was completed between July 16th to 19th and July 31st of 2014, at which time flows in reach one and reaches two and three were 27.26 and 33.07 m^3/s respectively (reaches 2 and 3 had same discharge). In total 36 sites were surveyed.
- Survey three was completed between August 8th and September 11th of 2014 A total of 75 sites were sampled during 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 between September 15th and 26th of 2014. At that time, discharge at Reach 1 and Reaches 2 and 3 was 14.76 m^3/s and 16.78 m^3/s respectively. These surveys were only conducted at juvenile abundance sampling sites and thus only 31 sites were surveyed.
- Survey five was started in June 16th to the 18th and completed in July 2nd-3rd and 6th of 2015 Due to BC Hydro operations (discharge changes) at the dam the survey could not be completed all at once and also resulted in a small difference in the discharge between the dates. Mean daily discharge during these dates at Seton gauge ranged from 59.80 (June 16-17th) to 87.84 m^3/s (June 18th) most of the sites were completed at ~60 m3/s in the period from the 16th to the 18th before the flows

were ramped up on the 18th. The remaining sites were surveyed on July 2nd – 3rd and 6th after the flows were ramped down from ~100 m^3/s. Mean discharge for these days was 75 m^3/s. Discharge at Cayoosh ranged from 10.77 to 12.46 m^3/s (Figure 9 & Figure 10). In total 65 sites were sampled, the remaining sites could not be sampled due to safety concerns (too fast and deep) and thus are assumed to be unsuitable for juvenile fish.

- Survey six was completed between June 29th and July 1st. A total of 62 sites were surveyed during this time when discharge from Seton Dam and Cayoosh Creek was 99 m^3/s (reach 1) and 14.3 m^3/s (total of 113.2 m^3/s for reach 2 and 3) respectively (Figure 9 & Figure 10). Due to the short time period the flows were held at ~100 m^3/s, we were unable to assess if all the sites were accessible (safe) or to survey them and thus, not all sites were surveyed.

3.1.3 Rainbow Trout Fry

Based on weighted useable area (WUA) analysed for Survey one (12m^3/s), three (25 m^3/s) and five (60 m^3/s) Rainbow Trout fry useable habitat decreased in all three reaches of the Seton River when discharge increased. (Figure 11 and Table 4).

In reach one, total WUA for glides decreased from 776.2 m^2 to 395 m^2 (50% decrease) when flows increased from 12 m^3/s to 25 m^3/s. When flows were increased to 60 m^3/s, WUA decreased a further 45% to 176 m^2. Riffle WUA decreased by 942.8 m^2 (47 %) from 1991.8 m^2 to 1049 m^2 with a change in discharge from 12 to 25 m^3/s. When flows were increased to 60 m^3/s, riffle WUA saw a dramatic change, with WUA decreasing from 1049 m^2 to 367 m^2 (65% decrease). For pools, when flows went from 12 to 25 m^3/s, WUA decreased from 335.9 m^2 to 193.4 m^2 (42%) and at 60 m^3/s remained relatively unchanged at 203.3 m^2 (Figure 11a & Table 4).

In reach two glides were the most sensitive habitat type to increases in discharge (Figure 11b and 12d). Total WUA for glides decreased from 6568.4 m^2 to 1820.8 m^2 (12 m^3/s to 25 m^3/s) and then to 1128.8 m^2 when flows were increased to 60 m^3/s. This equates to a decrease of 72% when discharge increases to 25 m^3/s and a further 10% when discharge increases to 60 m^3/s. This change is likely caused in 3 large glides where total WUA decreased from a combined area of 5112 m^2 to about 550 m^2 at 25 and 60 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 %) when discharge was increased to 25m^3/s. When flows were increased to 60 m^3/s WUA in riffles decreased to 1207.1 m^2, a further 15% (Figure 11b and 12e). Only one pool was sampled in this reach and its total WUA decreased by 128.9 m^2 to 148.3 m^2 and 70.41 m^2 when flows were increased to 25 and 60 m^3/s respectively (Figure 11b and 12f).

In reach three, glide WUA decreased from 2793.55 m^2 to 1688.1 (40 %) when flows were increased from 12 to 25 m^3/s. A further decrease of 1174 m^2 (a further 18%) was observed when flows increased to 60 m^3/s. Percent WUA showed a similar magnitude of change across all glides (Figure 11c and 12g). The change in WUA for riffles in reach three differed from that of reach 1 & 2; when flows increased from 12 to 25 m^3/s WUA increased from 4811.5 m^2 to 6031.1 m^2 (25 %). As the flows increased to 60 m^3/s total WUA decreased to 1160.2 m^2, a drop of 80%. Like the glides in Reach two, this effect may be driven by a few riffle units in the reach where total WUA went from 2816 m^2 to 114 m2 when discharge increased to 60 m^3/s (Figure 11c &12h). Only one pool was surveyed in reach 3 and total WUA area for that pool decreased from 2.27 to 0.9 m^2 (12 to 25 m^3/s). When discharge was increased to 60 m^3/s the pool habitat surveyed saw an increase in WUA of 2.4 m^2 (Figure 11c and 12).

Overall, increase in discharge resulted in a decrease in WUA for each habitat type, however, the change at lower discharges, i.e. 12-25 m^3/s, can be highly variable among habitat types and individual units (Figure 12). For example, in reach one, some riffles appear to be more sensitive to flow changes than others (Figure 12b). When flows reached 60 m^3/s this variability is less obvious and the general trend is for a decrease in useable habitat in all habitat types and in individual units (Figure 12). For the entire Seton River WUA for Rainbow Trout fry decreased by 7591 m2 (37%) between 12 and 25 m3/s and a further decrease of 8206 m2 when increased to 60 m3/s (Figure 13 and 14).

3.1.4 Rainbow Trout Parr

Rainbow Trout parr WUA decreased in all reaches of the Seton River for all three discharges surveyed although the magnitude of change was not as high as Rainbow Trout fry (Table 4)

In reach one when discharge was increased from 12 m^3/s to 25 m^3, total glide WUA decreased from 1872.9 m^2 to 747.8 m^2 (60%). When discharge was increased to 60 m^3/s, glide WUA decreased to 257.2 m^2, a drop of a further 26%. This large decrease in WUA was likely driven by a single glide habitat in that reach where WUA decreased from 1151 m2 to 110 m2; most other glides exhibited only small changes in percent WUA (Figure 15a and 16a). WUA area in riffles decreased from 2571 to 1993 m^2 (22%) with the discharge increase from 12 to 25 m^3/s. A larger change was observed when discharge increased from 25 to 60 m^3/s with a loss of 1429.9 m^2 (56%) of WUA for parr (Figures 15a & 16b). Total WUA for pools decreased from 553.2 m^2 to 215.15 m^2 and remained relatively unchanged (201.5 m^2) when the flows were increased to 60 m^3/s (Figures 15a &16c).

In reach two as discharge increased from 12 m^3/s to 25 m^3/s, total WUA for glides decreased from 5472.0 to 3720.1 (32%) and to 1089.9 m^2 a further 48% reduction when discharge increased to 60 m^3/s (Figure 15b & 16d). Riffles saw a similar magnitude of change as total WUA decreased from 3867.0 to 2667.6 (31%) when discharge increased from 12 m^3/s to 25 m^3/s and to 1406.9 m^2; an additional 32% reduction when discharge increased to 60 m^3/s (Figure 15b & 16e). Only one pool was surveyed and parr WUA at that habitat decreased from 326 to 181 and 161.2 m^2 respectively as discharge was increased from 12 to 60 m^3/s (Figure 15b & 16f).

In reach three total parr WUA for glides decreased by 1000 m^2 to 2379 m^2 (29%) as flows increased to 25m^3/s from 12 m^3/s. As flows increased to 60 m3/s a reduction in WUA of 70 % (1680 m2) was recorded (Figures 15c & 16g). Similar to Rainbow Trout fry riffle habitat in reach three increased by 17% (4226.5 to 4929.2 m^2) when discharge increased from 12 to 25 m^3/s, and a large decrease from 4929.2 to 1632.0 (61% reduction) was observed as discharge increased to 60 m^2/s (Figure 15c &16h). The one pool that was surveyed in Reach 3 did not have any habitat suitable for parr at any of the three discharges measured.

As was observed for Rainbow Trout fry an overall, increase in discharge resulted in a decrease in WUA for each habitat type as flows reached 60 m3/s., however, the change at lower discharges, i.e. 12-25 m^3/s, can be highly variable among habitat types and individual units (Figure 16). For example, in reach one, various riffles increased in %WUA, while others decreased (Figure 16b). When flows reached 60 m^3/s this variability is less obvious and the general trend is for a decrease in useable habitat in all habitat types and in individual units (Figure 16). For the entire Seton River WUA for Rainbow Trout parr decreased by 5418 m2 (24%) between 12 and 25 m3/s and a further decrease of 10822 m2 when increased to 60 m3/s (Figure 17 and 14).

3.1.5 Juvenile Coho

Juvenile Coho habitat suitability showed a similar response to discharge increases as Rainbow Trout fry. WUA decreased in all habitat types and all reaches as discharge increased for Coho juveniles from 12 m^3/s to 60 m^3/s (Table 4).

In reach one, total WUA for glides decreased from 1040.5 m^2 to 612 m^2 (41% decrease) and 443.8 m^2 (a further 16% decrease) as flows increased from 12 to 25 and 60m^3/s respectively (Figure 18a & 19a). Riffle WUA was more sensitive to increases in discharge and decreased 52 % from 2448.9 m2 to 1163.3 m^2 when discharge increased from 12 m^3/s to 25 m^3/s. Coho WUA decreased a further 742.6 m^2 (18%) to 420 m2 as the flows increased to 60m^3/s (Figure 20a & 21b). Total pool WUA decreased by 554 m^2 to 240.9m^2 (57% reduction) and remained relatively unchanged (271 m^2) as the flows increased to 60 m^3/s (Figure 18a and 19c).

In reach two, WUA in glides decreased from 7092.6 m^2 to 2707.5 m2 (62 %) as flows increased from 12 to 25 m3/s and continued to decrease as flows increased from 25 to

60m^3/s (2707.5 to 1136.5 m2) (Figure 18b and 19d). The large decrease may be driven by one or two glide units that decreased from 2940.3 m2 to 231.5 m2 within the reach as shown in figure 20b and figure 21d. A smaller change was observed in riffles. WUA decreased by 28.7 % (3527.4 to 2513.5 m2) as flows increased from 12 to 25 m3/s and as flows increased to 60 m3/s WUA decreased to 1472.5 m2. The WUA in the one pool that was surveyed decreased from 614 to 348 and to 69.3 m^2 as flows increased from 12 to 25 and 60m3/s respectively (Figure 18b and 19i).

In reach three, total glide WUA showed a decline from 2943.6 m^2 to 2125.9 m^2 (28 %) as the flows increased from 12 m^3/s to 25m^3/s (Figure 18c & 19g). As flows increased, WUA decreased to 1137.5 m2. In contrast to reaches 1 and 2, an increase in WUA of 30 % was observed in riffles (33481.0.5m^2 to 4552.3 m^2) as the flows increased from 12 to 25 m^3/s. That increase shifted to a large decrease as the flows increased to 60 m^3/s and WUA was calculated at 1033.3 m^2; a 77% decrease (Figure 18c and 19h). WUA in the one pool surveyed increased slightly from 79.8 m^2 to 90 m^2, but decreased to 59.8 m^2 at 60 m^3/s.

Overall, an increase in discharge resulted in a decrease in WUA for each habitat type as flows reached 60 m3/s, however, the change at lower discharges for riffles in reach three, i.e. 12-25 m^3/s, can be highly variable (Figure 19h). For example, various riffles increased in %WUA, while others decreased (Figure 19h). When flows reached 60 m^3/s this variability is less obvious and the general trend is for a decrease in useable habitat in all habitat types and in individual units (Figure 19). For the entire Seton River WUA for Coho juveniles decreased by 7674.1 m2 (34.8 %) between 12 and 25 m3/s and a further decrease of 6044.5 m2 when increased to 60 m3/s (Figure 20 and 14).

3.1.6 Juvenile Chinook

Juvenile Chinook habitat suitability showed a negative response to discharge increases. WUA decreased in all habitat types and all reaches as discharge increased for Chinook juveniles from 12 m^3/s to 60 m^3/s (Table 4).

In reach 1, glide WUA declined from 5077.9 m^2 to 3090.3 (39 %) then to 890.0 m^2 (further 71%) as flows increased from 12, 25 and 60 m3/s respectively (Figure 21a and 22a). Riffles showed a similar magnitude of change, with WUA decreasing from 4106.32 m^2 to 3174.4 (22.7 %) then to 762.7 m^2 (decrease of 76 %) (Figure 21a). The large decrease WUA was likely driven by the change in two units, one glide and one riffle. These two units decreased from 1473.7 (glide) and 1584.9 m2 (riffle) to 148.7 and 122.9 m2 respectively (Figure 21a and 22a&b). Pool WUA decreased from 909.6 to 372.3 m2 (59 %) when flows increased from 12 to 25 m3/s and remained relatively stable as flows increased to 60 m3/s (359.0 m2) (Figure 21a and 22).

Reach two glides decreased from 8472.2 m^2 to 5141.4 m^2 (39 % decrease) and then to 1682.0 m^2 (67.3 %) as flows increased to 60m^3/s (Figure 21b and 22d). WUA for riffles also decreased by 29.6 % (5738.8 m^2 to 4040.3 m^2) and then further by 45.4 % (2203.5 m2) as flows increased from 12 to 25 and to 60m3/s (Figure 21b and 22e). The one pool sampled decreased from 599.5 m^2 to 327.3 then to 226.3 m^2as flows increased from 12 to 25 and 60 m3/s (Figure 21b and 22f).
In Reach three, WUA for Chinook in glides decreased from 5726.5 m^2 to 4314.0 and to 1591.6 m^2 as flows increased to 12, 25 and 60m^3/s respectively (Figure 21c and 22g) Total WUA for riffles increased from 7555.2 m^2 to 8227.8 m2 when flows increased from 12 to 25 m3/s, but a marked decrease to 2311.7 m2 (72 %) was observed when flows increased to 60m3/s (Figure 21c and 22h). Total WUA for the single pool surveyed decreased from 267.8 m^2 to 30.8 m2 but then increased again to 136.3 m^2 when flows were 12, 25 and 60m3/s respectively (Figure 21c and 22i).

Total WUA for juvenile Chinook in the Seton River decreased by 25 % (from 38454.4 to 28718.5 m2) when flows were increased from 12 to 25 m3/s. When flows increased to 60m3/s a further reduction of 64% to 10163.1 m2 was observed (Figure 23 and 14).

3.2 Juvenile Growth Sampling

Juvenile fish growth surveys commenced on April 23, 2015 and continued on a monthly basis through to October 20, 2015. In total 7 surveys were completed. The mainstem Seton River and the spawning channels sites were sampled during all surveys. In total, 12 species of fish were observed (Table 5). Six species of salmonids (Rainbow Trout, Bull Trout, Coho, Chinook, Sockeye and Mountain White fish), and six species of non-salmonids (Bridgelip Sucker, Prickly Sculpin, Coastrange Sculpin, Longnose Dace, Red-sided Shiner and Peamouth Chub). Of these species only Rainbow Trout, Coho and Chinook were caught in sufficient numbers to show the presence of discrete size classes. Smaller fish, (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 659 Rainbow Trout were sampled in the Seton River and lower spawning channels throughout the sampling series and their length ranged from 27 to 235 mm (Table 6).

Scale/Age Analysis:

For the purpose of scale analysis all of the scales from the spawning channel fish and those of the main-stem river were pooled to increase sample sizes. Data is presented for each of the 7 sampling sessions; April through to October. These ages represent fish that are one, two and three years old (Figure 24). 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.

In April, scale analysis showed three distinct age classes as described in the methods section. The length, age histogram for April shows an overlap of sizes between the age one and age two fish and age two and age three fish (Figure 24). The mean size at age for age one fish was 80 mm with a range from 55 to 120 mm, age two fish had a mean length of 120 mm (70 - 170 mm) and age three fish had an average length of 170 mm (160 – 195) (Figure 25).

May age data showed the same age classes present (age 1, 2 and 3), but little overlap between age one and age two fish and no overlap between age 2 and age 3 fish.

In June two distinct age classes were identified, age one and age two fish. These fish had a mean size at age of 96 and 128 mm respectively (Figure 24).

In July, 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 these fish were quite small and scales were not collected from fish <45mm (designated as 0 aged fish) as they have not yet formed scales or developed annuli. The age zero fish had a mean fork length of 42 mm that ranged from 27 to 66 mm. The mean size for age one fish in July was 107.4 mm (73 – 160 mm), while age two fish had a mean fork length of 131 mm (130 – 132 mm) (Figure 26). There were no age three fish sampled in July. In August, the same three age classes (0, 1 and 2) were observed. Mean size for age zero, one and two fish was 57, 111, and 137 mm respectively (Figure 24).

During the September sampling series, the dominant age class sampled was the age zero fish (Figure 24). Mean length for age zero fish was 69 mm with a range from 41 to 112 mm. Age one and two fish were also sampled, their mean size at age was 132 and 205 mm respectively.

In October, only two distinct age classes were sampled (Figure 24). They were age zero, and age one fish. Age zero fish had a mean length of 72 mm (45 - 84 mm) while age one fish had a mean fork length of 132 mm (86 – 170 mm) (Figure 27). An overlap between age zero and age one fish was not evident.

As was observed in 2014, Rainbow Trout in the spawning channels were consistently larger than those sampled in the mainstem (t-test; p-value$<$0.05). This pattern was consistent for all the months where both areas were sampled (Table 7).

Growth Analysis:

Age and length data collected throughout the sampling periods is used assess growth rates of the different age classes in the Seton River main-stem.

Length, weight analysis showed a strong relationship between length and weight for Rainbow Trout of all sizes within the Seton River (R2=0.953) (Figure 28).

Rainbow Trout Age 0+

As in 2014, young of the year Rainbow were not observed until the July sampling survey in both the main-stem and spawning channels. During the July survey fish had a mean fork length of 42 mm with a range from 27 to 66 mm. Average weight was 1.2 g with a range from 0.20 to 7.0 g. In August these fish had grown to a mean length of 57 mm (38 to 76 mm) and a mean weight of 2.5 g. Growth continued into September with a mean fork length of 67 mm (45 – 112 mm) and a mean weight of 4.5 g. From September to October the growth rate observed was not as high. Mean fork length increased by 5 mm to 72 mm (45 – 84 mm) and a mean weight of 5.1 g (Figure 29 and 30). In total young of the year grew an average of 30 mm (0.31 mm/day) from July to October, this is similar to the rates observed in 2014 (0.36 mm/day)

Rainbow Trout Age 1+

Age one fish were represented in all 7 surveys (April through October). In April, the mean fork length of these fish was 80 mm (59-118 mm) and had a mean weight of 6.2 g. By July these fish had grown by 27 mm to 107 mm and a mean weight of 19.2 g. From July to August fish did not show much growth (107 To 111 mm). In September growth increased and fish grew by 20 mm to a mean of 130 mm. In October only 5 age 1 fish were sampled and mean length of those fish was 117 mm (mean weight = 24.2 g) (Figures 31 and 32) suggesting a decrease in growth. This is unlikely and may be a factor of the small sample size observed. Excluding Octobers' data (due to sample size), age one fish grew an average of 50 mm (0.33 mm/day and 0.16g /day) in five months, from April to September.

Rainbow Trout Age 2+

Age two fish were represented in all months surveyed except October. Sample sizes were small (1 - 6) in all months except April and May (18 and 9 respectively) and thus a confident growth analysis cannot be provided. In April and May, age two fish grew by 17 mm to a mean length of 145 mm (0.8 mm per day) and a mean weight of 36.8 g (Figures 33 & 34).

Rainbow Trout Age 3+

Age three fish were only observed during the May sampling session (4 fish). 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 2015 sampling year 206 Rainbow Trout were PIT tagged. In total 15 PIT tagged Rainbow Trout were recaptured, and could be retraced to original tag date (Figure 35). The amount of time between catches varied from 31 – 131 days. Based on the age analysis these fish were classified as age one (12) and age two fish (3). Mean length and weight of age 1 recaptured fish was 110 mm (81– 149 mm) and 18.9 g (7.0 – 42.4 g) (Table 8). On average these fish grew 0.3 mm/day and 0.16 g/day, this corresponds with the growth rates observed for the age one fish (0.33 mm/day and 0.16 g/day). Mean length and weight of age 2 recaptured fish was 157 mm (155– 159 mm) and 44.0 g (42.3– 45.6 g). On average these fish grew 0.6 mm/day and 0.27 g/day, this is similar to the growth rates observed for the age two fish (0.8 mm/day).

3.2.2 Juvenile Coho

A total of 466 Coho were sampled in the Seton River main-stem (288) and spawning channels (158) throughout the sampling series (Table 5). Coho fork length ranged from 32 to 124 mm.

In April, fork lengths of spawning channel fish were larger than those observed in the main-stem (p-value < 0.05 and t-stat > 2). There was no difference in the mean fork lengths between the mainstem coho and those of the spawning channels the rest of the year (p-value > 0.05, & t-stat < 2). This was consistent in all the months where both areas were sampled (Table 9).

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.
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 2015 in the Seton River. In April two age classes were identified. Age zero fish and age one fish (Figure 36). Mean length for age zero fish was 35.3 mm (31 - 44 mm). Age one fish had a mean fork length of 91 mm (82 – 102 mm). In May age 0 Coho had a mean length of 38 mm (30-82 mm). Age 1 Coho were also larger in May with a mean length of 103 mm and a range spanning from 97 to 110 mm. One of the fish sampled in May was aged as a 2 year old (fl = 101 mm). This is possible, but unlikely as the length of an age 2 fish is expected to be larger than 101 mm.
As expected in June through October only age 0 Coho were observed as the larger fish (age one) have left the system as ocean bound smolts. The histograms for these months show

the same unimodal distribution with an increase in length through time, suggesting that the fish sampled were age zero fish rearing in the Seton River and side channels Figure 36).

Growth Analysis:

Age data collected along with the length frequency histograms were used to assess growth rates of age zero Coho in the Seton River. Analysis showed a strong relationship between length and weight for Coho Salmon of all sizes within the Seton River (R^2=0.907) (Figure 37).

Age zero fish were encountered during the first survey conducted in April. They had a mean length of 35 mm with a range from 31 mm to 44 mm. By June they had grown by a length of 16 mm to a mean length of 51 mm (37 – 69 mm). From June to July the fish grew another 8.5 mm to a mean length of 60 mm (45 – 80 mm) and a mean weight of 2.9 g (1.1 – 5.5 g). From July to August mean fork length of age zero fish increased to 69 mm (51 – 84 mm) and mean weight was 4.0 g (0.5 – 7.6 g). From August to September an increase of 7 mm in fork length was observed. Mean length and weight in September was 76 mm (55 – 93) and 5.4 g (1.2 – 8.6 g) respectively. September to October had the same average growth rate of 7 mm to a mean length of 83 mm (53 – 100 mm) and weight of 7.7 g (2.0 – 12.8 g) (Figure 38 and 39).

3.2.3 Juvenile Chinook

In 2015, Chinook juveniles were observed in all sampling surveys (April to October). In total 196 Chinook were sampled. Nineteen fish were sampled in the spawning channels and 177 in the main-stem Seton River (Table 5).

Like Coho juveniles, one dominant size/age (age 0) class is consistent throughout the year (Figure 40). From April to June sample sizes were small (<10 fish) and distinct modes are not obvious. In April, three age zero (young of the year) and one age one Chinook were observed. This is expected and consistent with the stream type life history of Chinook. In May and June only age 0 fish were observed and fork length for those fish ranged from 30 to 65 mm. In July, the number of Chinook sampled increased considerably. All of the fish sampled in July were age zero fish and ranged in size (45 to 90 mm). Through July to October, 177 age 0 Chinook and one age 1 fish were observed. The histograms show the same unimodal distribution increasing in length, suggesting that the fish sampled were age zero fish rearing in the system (Figure 40).

Growth Analysis:

Age data collected along with the length frequency histograms were used to assess growth rates of age zero Chinook in the Seton River. Length, weight analysis showed a strong relationship between length and weight for Chinook salmon of all sizes within the Seton River (R^2=0.915) (Figure 41).

In April Chinook had a mean length of 43.5 mm with a range from 34 mm to 53 mm. In May a slight decrease in mean length for age zero fish was observed. Mean fork length was 40 mm (34 – 58mm). By June age zero fish had grown by a length of 12 mm to a mean length of 52 mm (40 – 65 mm). From June to July the second largest growth was observed; fish grew 14 mm to a mean length of 66 mm (49 – 90 mm) and a mean weight of 3.6 g (1.6 – 8.0 g). From July to August growth decreased slightly and mean fork length of age zero fish was 77 mm (67 – 94 mm) and mean weight was 5.5 g (3.9 – 9.6 g). In September, mean length and weight appeared to decreased and was 72 mm (60 – 95) and 4.7 g (2.4 – 8.6 g) respectively. September to October saw the largest increase in growth of 17 mm to a mean length of 89 mm (58 – 104 mm) and weight of 9.2 g (2.2 – 14.8 g) (Figure 42 and 43).

3.3 Juvenile Abundance

In March of 2015, 10 snorkel index and 1 mark-recapture site were surveyed, accounting for a total of 600 m (7.3 %) of shoreline sampled. In the September of 2015, 26 index sites and 4 mark recapture sites were sampled by electro-fishing, accounting for a total of 1497 m (approximately 18%) of shoreline sampled.

Snorkel Surveys

During the snorkel surveys in March 2015, five species of fish were observed at the index sites. The species observed include Coho Salmon, Rainbow Trout, Mountain Whitefish, Bull Trout and Redside Shiner (Table 10). Discharge at the WSC gauge (08ME003) during the surveys was 12.2 m^3/s (Figure 9).

The most abundant of the five species was Rainbow Trout with 102 fish observed. Mean fork length was 88.7 mm with a range from 60 mm to 170 mm. The number of Rainbow Trout observed at the index sites ranged from 1 to 25 individuals (Table 10). A mark-recapture experiment was attempted, but due to the low number of individuals marked and re-observed the mark-recapture modeling was not completed. At the mark-recapture site 7 Rainbow Trout and 12 Coho were marked; mean fork length was 140 mm (87 – 210 mm) and 98 mm (83 – 112 mm) respectively. Three Rainbow Trout and seven Coho were recaptured (re-observed) in the observation pass of the mark-recapture site, resulting in recapture rates of 0.43 and 0.58 respectively. Although these numbers seem reasonable, the low sample size creates the potential for larger margins of error, and thus modeling for age 1 and 2 Rainbow Trout was not completed.

Electrofishing Surveys

Only 0+ (young of the year) Rainbow Trout were captured in high enough numbers to estimate abundance. A total of 145 Rainbow Trout were sampled in 21 of the 30 index sites. Mean fork length for 0+ rainbow trout was 62 mm and ranged from 35 – 85 mm. Discharge in the Seton River during the survey was 21 m^3/s (September 22-23) and 12.7 m3/s (September 24-30) (Figure 9).

During mark-recapture studies, a total of 108 Rainbow Trout (0+) were marked and 16 were recaptured resulting in a capture probability of 0.15, with a range of 0.08 to 0.29 between sites. Figure 44 shows the posterior distribution of the capture probability of

Rainbow Trout at the four different mark recapture sites sampled in 2015. Age 0 Rainbow Trout were observed in 21 of the 31 sites sampled.

Density estimates in 2015 for 0+ rainbow trout in the Seton River were not as variable and appear to be lower than observed in 2014. Densities in 2015 ranged from 0.1 to 1.0 fish/m, compared to 0.1 – 3.7 fish/m in 2014. Reach 1 (Sites 2-11 and 34-39) appeared to have lower abundance of rainbow fry (0.18 fish/m – 0.28 fish/m). A wider range of abundances were observed in Reach 2 (Sites 12 – 24 and sites 41 to 47) ranging from 0.10 – 0.91 fish/m. In Reach 3 (sites 25-31), abundances were also variable ranging from 0.1 – 1.0 fish/m (Figure 45 & Table 11).

3.4 Adult Salmonids

3.4.1 Steelhead

Tag Application and Bio-sampling

In 2015, fish capture attempts commenced at the end of March and continued until the end of May when migration into the Seton has ended based on run-timing information from other Fraser systems (Braun et al. 2016). Eighteen steelhead trout (3 males and 15 females) were captured by angling at the Seton – Fraser and Bridge – Fraser confluences and radio tagged from February 27 to April 19, 2015 as part of a collaborative effort with BRGMON-3. Mean fork lengths of radio-tagged males and females were 874 mm (range: 835 to 935 mm) and 759 mm (range: 630 to 820 mm), respectively (Table 12).

Fixed and Mobile Tracking

Radio tags were detected by the series of fixed telemetry stations and mobile tracking on the Seton and Lower Bridge Rivers. Five of the 18 steelhead trout all tagged at the Seton – Fraser confluence were detected on a radio receiver located at the LSC confluence (1.42 km upstream of confluence) (Figure 5, Table 12). Migration rates for these five steelhead trout were computed by dividing the travel distance from capture location to LSC receiver (1.42

km) by travel time. Mean rate was 0.3 km/day and ranged from 0.1 to 0.7 km/day (Table 13).

Four of the five tags (Codes # 41, 46, 50, 67) that entered the Seton River were detected during mobile tracking surveys (Table 14). The remaining 13 fish tagged at the Seton–Fraser confluence did not enter the Seton River and continued their migration upstream. Eleven were observed in the Bridge River (BRGMON 03, Burnett et al. 2016) and two were unaccounted for and possibly continued an upstream migration to another watershed (Chilcotin River).

Adult Steelhead in 2015 were also tagged with PIT tags in order to track their movements into specific habitats (i.e. spawning channels, Cayoosh Creek and u/s of Seton Dam). Mobile radio tracking data was used to corroborate the PIT telemetry data by confirming that fish detected at the PIT antennas were in these locations. Of the five individuals detected on the radio receiver at the LSC, two (Codes #32, 46) were detected at the lower spawning channel PIT antenna. These fish entered the LSC on April 14th and 20th and they remained there for approximately 10 days (exited April 24 and 30th respectively) suggesting that they spawned in the channel. One of the five individuals (Code #67) was detected passing the Seton Dam fishway on April 29th. Code #67 entered the downstream end of the fishway at 06:56 and exited upstream at 07:32 – this constitutes a passage time of 36 min. Mobile radio tracking data corroborated this information and indicated that Code #67 was downstream of the Seton Dam on April 27 at 14:00.

Visual Counts – Streamwalks

Stream walks on the Seton River were conducted on a weekly basis, from March 4th to June 15, 2015 at which point spawning was assessed to be complete. Two Steelhead adults were observed in the Seton River Corridor; one on May 4th downstream of Seton Dam and one in the Lower Spawning Channel on June 15th. Water visibility was adequate (0.4 to 3.0 m) throughout the survey and mean daily discharge ranged from 12.5 to 38.7 m^3/s (Figure 9).

3.4.2 Coho Salmon

Tag Application and Bio-sampling

Efforts to capture Coho salmon adults in the Seton River were reduced in 2015 after the efforts in 2014 resulted in 1 fish being captured. By comparison, efforts to capture adult Coho for BRGMON03 were successful and forty-eight Coho salmon (20 males and 28 females) were captured by angling and PIT tagged in the Bridge River from October 15 to November 10, 2015. Mean fork lengths of PIT-tagged males and females were 599 mm (range: 460 to 715 mm) and 541 mm (range: 410 to 680 mm), respectively (Burnett et al, 2016)). The significance of these tagged fish are discussed below.

Fixed tracking – PIT tags

Of the 48 Coho salmon captured and tagged at the Bridge – Fraser confluence, 14 individuals moved to upstream reaches of the Bridge River. Of the 34 fish that did not enter the Bridge River, five individuals were detected on PIT readers in the Seton River (Table 15). Code #10015 entered the lower spawning channel on November 9 at 20:54 and exited on November 25 at 07:02 – this fish likely spawned in the channel, and had a residence time of 15.4 days. Two fish (Codes #183225801 and 183225445) passed Seton Dam on October 18 at 11:46 and October 20 at 00:56, respectively. Passage times for these two individuals were 41 and 37 min. Code #183227082 was detected at the entrance of the Seton Dam fishway on November 11 at 05:22 and later entered the upper spawning channel on November 11 at 16:25. Code #183225362 entered the upper spawning channel on October 28 at 23:12, this fish did not leave the spawning channel and was assumed to have spawned there.

Visual Counts – Streamwalks

Visual counts of Coho salmon were conducted from October 6th to December 15th, at which point spawning was assessed to be complete. All of the Coho that were observed were in the lower and upper spawning channels, 18 individuals, and 4 individuals respectively.

The majority of fish (14) were observed on November 23rd in the LSC. There were no adult Coho observed in the mainstem Seton River.

Water visibility was adequate (0.5 to 1.0 m) throughout the survey. (Table 16). Mean daily discharge remained stable with a range from 11 to 14.8 m^3/s (Figure 9).

3.4.3 Chinook Salmon

Efforts to catch and PIT tag adult Chinook Salmon were unsuccessful and therefore no distribution use data was collected in 2015.

Visual Counts

Visual counts of Chinook salmon coincided with surveys for Pink salmon and began on August 4th (in LSC only) and ceased on October 13th at which time spawning was assessed to be complete. Run timing data is based on information from BRGMON 3 and 14 (Burnett et al, 2016 and Casselman et al. 2016). Throughout this period there were no adult Chinook observed. Water visibility was adequate (0.5 to 1.5 m) throughout the survey and mean daily discharge ranged from 11 to 21.6 m^3/s (Figure 9).

3.4.4 Pink Salmon

Efforts to catch and tag Pink salmon with PIT and Petersen disk tags were moderately successful. It was proposed to tag 500 individuals, but the time and effort to tag this number of fish was underestimated and thus only 54 individuals (51 males and 3 females) were tagged between September 4th to the 25th.

Tangle netting to capture fish was done two times per week between Sept 4th and 25th at a location downstream of the lower spawning channel. Mean fork length of PIT-tagged males and females was 532 mm (range: 460 to 660 mm) and 487 mm (range: 480 to 500 mm), respectively (Table 17). Eight of the 54 PIT-tagged pink salmon were detected on PIT readers throughout the Seton River corridor. Of these eight fish, six (11% of 54) were detected entering and exiting the Lower Spawning Channel (LSC) and were assumed to have spawned there (Table 18). On average these fish had a residence time of 5.3 days. One fish (1.9%) likely spawned in Cayoosh Creek – this individual entered and exited the creek on September 18 at 10:51 and September 24 at 06:37, respectively. Residence time in Cayoosh Creek for this individual was 5.8 days. One fish (1.9%) was detected by a PIT reader passing the Seton Dam fishway. This fish entered and exited the fishway on September 27 at 00:02 and September 27 at 00:43, respectively – this constitutes a passage time of 41 min through the fishway.

Due to the limited number of PIT tags available to be distributed to the various spawning locations, using the proportional distribution method to assess population abundance produced inflated and unrealistic numbers. For example, only 1.9 % of the tags (1 fish) migrated past the dam. Using this proportion and knowing that 87,032 Pinks migrated past the dam (Casselman et al. 2016) the resulting estimate was over 4 million fish downstream of the dam. Due to the lack of confidence in the proportional estimate an AUC estimate using the visual count data was used to assess Pink abundance in the Seton River in 2015.

Visual Counts

Pink salmon visual counts were conducted from August 4th to October 13th. Pink salmon occurred in high abundance with a total of 6,562 live individuals observed in the spawning channels and main-stem Seton River. Peak live count was 4,347 fish on September 21st, and decreased to zero fish on October 13th. The majority of the spawning activity observed was located in the lower and upper spawning channels with 2888 and 2577 individuals observed respectively. In the main stem the highest abundance of pink salmon was observed on September 14th (500) between Seton Dam and the BRGMON-13 inclined plane trap site (500 m downstream). Water visibility was adequate (0.5 to 1.5 m) throughout the survey.

Area under the Curve Abundance Estimates

Seton Mainstem

Pink visual surveys on the Seton River mainstem did not begin until September 14th and thus a portion of the run was not counted. As no tags were seen during visual counts of the mainstem observer efficiency could not be calculated and thus the mean value of 0.66 (Perrin and Irvine 1990 and Bue et al. 1998) was used. The residence time of 5.3 days observed in the PIT tagged individuals from the lower spawning channel was adopted. Using these values and stream count data, a spawner abundance estimate of 2,541 individuals with 95% confidence intervals of 1,122 and 3,960 was calculated for the mainstem in 2015 (Figure 46 and Table 19). The estimate provided from this analysis should be considered a minimum number as the first two weeks of the migration were missed in the Seton mainstem.

Spawning channels

Visual count, PIT, and Peterson disk tag data was used to estimate the total number of spawners in each of the spawning channels. The visual count data provided weekly totals of fish observed. The PIT data provided estimates of an average residence time (5.3 days in LSC, no tagged fish entered the USC) and Peterson disk tag observations resulted in an observer efficiency of 33% in the LSC, (no tagged fish entered the USC). Due to the limited number (6 fish) of visual tags that were available to be seen in the LSC we felt that the observer efficiency was likely biased low and thus would inflate the AUC estimates. Therefore, instead of using the 33% value, the literature value of 66% was used (Perrin and Irvine 1990 and Bue et al. 1998). Spawner abundance for the lower spawning channel was estimated at 6,117 with lower and upper confidence intervals of 0 and 47,540 respectively Abundance for the upper spawning channel was estimated at 12,433 spawners with 95% confidence intervals from 7,551 to 17,315 (Figure 46 and Table 19).

3.4.5 Adult Resident fish

Adult resident fish species (Rainbow Trout, Bull Trout and Mountain Whitefish) were sampled and PIT tagged throughout the year. The majority of these fish were captured as by-catch through other species directed sampling efforts such as angling for adult anadromous fish and trash-rack salvage efforts.

Rainbow Trout

In 2015, 43 adult resident Rainbow Trout were captured as by-catch through the angling efforts to capture any of the anadromous salmon species and 7 were collected from the trash rack salvage that occurred March 23rd, 2015. In total, 44 were implanted with PIT tags. Six of the Rainbow Trout captured were fish that were captured and tagged previously in 2015. Mean fork length of the PIT tagged fish was 355 mm with a range from 280 – 546 mm. Mean length of these fish was 332 mm (286 – 410 mm).

Bull Trout

In 2015 a total of 92 Bull trout were captured and sampled. Eighty-three of these fish were implanted with PIT tags. Five fish were recaptures of fish captured and tagged earlier in 2015 and four fish were tagged in previous years or through other monitors (data currently under analysis). Two of the 92 fish were collected from the trash rack salvage completed on March 23, 2015. Mean length of the Bull Trout sampled in 2015 was 435 mm (257 – 710 mm).

Mountain Whitefish

In 2015, 12 Mountain Whitefish were sampled. The majority (11) of Whitefish sampled and tagged were collected from the trashrack salvage in March. Mean fork length of these fish was 327 mm (230 -440 mm).

One fish (fl = 340 mm) was captured through angling efforts at the Seton-Fraser confluence. The Whitefish sampled from the trashrack salvage were released at the Seton Lake boat launch.

3.5 Fraser River Habitat

A shutdown of Seton Generating Station (SONGS) occurred on March 23, 2015. At the time, Fraser River discharge was 2,300 m^3/s at Texas Creek gauge (08MF040). After the shutdown was completed, discharge at Texas Creek gauge had decreased to 2,246 m^3/s (Figure 47). The shutdown was scheduled to clean out the trash-rack at the penstock forebay area.

At site one, located approximately 1.7 km downstream of SONGS, the effects of the shutdown were first observed at 08:45:00 am. At that time the temporary gauge read 0.39 m. From that time, gauge level decreased for 50 minutes until the water level stabilized at 09:35:00 am and the gauge read 0.34 m. Overall the reduction in water level elevation was

0.05 m. The rate of stage reduction was approximately 0.05 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 stranded fish observed.

At site two, located 10.9 km downstream of SONGS, the effects of the shutdown were observed at 09:00:00 am. Before the change was evident the temporary stage reading was 0.5 m. Water level elevation decreased for an hour and 50 minutes until the water level stabilized at 10:00:00 at 0.40 m. Overall reduction in water level elevation was 0.10 m. This was two times the change observed at station 1. The rate of stage reduction at station two was approximately 0.1 m/h. There were no stranded fish observed.

3.6 Gravel mobilization

Analysis of the elevation data showed that elevation change was variable within and between transects (Figure 48 and 49). For example, on transect 12, changes in elevation were observed in both positive and negative directions between years. Elevation decreased by 0.57 m on a section of the transect while an increase of 0.17 m was observed elsewhere on the transect (Table 20). This trend is consistent in the majority of transects i.e. in T5-13 if a decrease in elevation (erosion) occurs on one side, then deposition tends to occur on other section (Figure 50). The top (Transects 1-4) and bottom (Transects 16-18) portions of the section surveyed saw little change in elevation (mean change = 0.01). The middle portion (transects 5 - 15) of the survey area also displayed a consistent elevation shift; the river right side (of middle section) appears to have decreased or leveled off in elevation (deeper/erosion) and the river left side became more uniform in depth (Figure 48).

4. DISCUSSION

The primary objective of this program is to monitor the response of fish habitat and fish populations to Seton Dam operations. Data collected in 2015 was the third year of the 10year program and continues to build on the knowledge of fish habitat and fish populations gained in 2013 and 2014.

Depth velocity transects were conducted with various degrees of success at six different flows (12, 15, 25, 27, 60 and 100 m^3/s). 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, 25 and 60 m^3/s. Results showed that in general, an increase from 12 to 25 m^3/s, resulted in a decrease in useable area for most juvenile species and life stages. In addition, changes in useable area in specific habitat units, depending on their size (area) can have a big effect on reach totals. When flows increased further to 60 m^3/s, WUA for all species and life stages decreased considerably, to about one third of what was available at base flows (12 m^3/s).

Percent weighted useable area was also compared between all the sites and at the 3 flows and showed a decreasing trend as discharge increased. Percent weighted area 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. Also of interest is the observed positive response of individual habitat units from 12 m^3/s to 15m^3/s. Some habitat types showed an increase of WUA for all species and life stages, but then decreased again when flows increased to 25 m^3/s and continued to decrease when flows were increased to 60 m^3/s. This raises the question of whether WUA continues to increase to a certain inflection point between 15 and 25m^3/s?

As surveys continue focus will shift to identify habitat units that are sensitive to flow changes in the 12 – 25 m^3/s range. These sites could be used:1) as indicators of habitat conditions during certain flows or 2) they could be identified as sites susceptible to stranding risks during ramp downs. Another factor to consider when making management decisions is the timing of the high flow releases. For example, in 2015, a high discharge event (>100 m3/s) occurred in the first week of July. Using information gathered through this monitor (when young of the year fish are first observed) and literature (McPhail 2007), this timing coincides with the beginning of Rainbow Trout fry emergence and potentially puts these fish at high risk at a vulnerable point in their life history. These emergent fry have the potential to be by displaced from the mainstem Seton River.

In 2015, valuable biological data continued to be collected to identify the species present in the Seton River. As was observed in 2014, four age classes of Rainbow Trout (0, 1, 2, and 3), and two age classes of juvenile Coho were observed (0 and 1). The number of juvenile Chinook sampled increased in 2015, and two age classes were identified (age 0 and 1). This result was unexpected as only one adult Chinook was observed in the Seton River in 2014. Further years observations will potentially confirm where these 0 aged juveniles are coming from i.e. are Chinook spawning in the Seton River or are 0 juveniles migrating into the Seton from other locations? Various studies (Murray & Rosenau 1989 and Daum & Flannery 2012) have shown that in some stream-type populations of Chinook, juveniles rear and sometimes over-winter in non-natal streams as they migrate to the ocean. This is certainly a possibility as the majority of the fish observed were age 0 fish, and sample sizes were relatively low until July when an increase in catches were observed. Future DNA analysis on 0 aged chinook will potentially identify their natal stream.

Juvenile Rainbow Trout growth in 2015 was 0.31 and 0.33 mm/day for age 0 and 1 fish respectively. In 2014, growth rates for same age groups was 0.36 and 0.25 mm/day. Future analysis will look to identify if the difference between years is statistically significant and look for the cause of the change. Sample sizes of larger older fish were low and thus growth could not be adequately tracked. This may be a factor of our capture method (electrofishing) as it has been shown that backpack electrofishing catch efficiency for larger fish is low (Korman et al. 2010b)

Juvenile abundance surveys were completed for age 0 Rainbow Trout in September 2015. Mark recapture experiments resulted in a mean recapture probability of 0.27 (mean from hyper distribution). In 2014 a recapture probability of 0.33 was observed. Results from the 2015 HBM showed a narrower range of abundances throughout the river (0.1 – 1.0 fish/m), compared to those of 2014 (0.09 – 3.71 fish/m). It should be noted that not all the sites sampled in 2014 were sampled in 2015 and vice versa, but all common sites sampled between the two years showed a decrease in fish densities. Due to limited sample size at some sites, broad credible intervals were observed. Some of the lower and upper credible intervals were as large as 20 to 400% of the mean estimate respectively. This is likely due to very few Rainbow Trout in the area or less likely, our sampling methods were not suitable. The snorkel surveys completed in March of 2015 indicated that larger/older fish occur at low densities. Consequently, not enough fish of the various size and age classes were captured to confidently model capture probability. The number of fish observed were low ranging from 1 – 25 for all species. For this reason, densities using the HBM were not produced. Continuing snorkel surveys in future years will provide an annual index of abundance for these age classes. Future surveys throughout the river may also reveal sites of higher abundances where mark recapture experiments could be completed.

Adult salmonid abundance and distribution continued to be difficult to assess, but progress was made. Through efforts made possible by collaboration with BRGMON-3, 18 adult Steelhead were radio and PIT tagged. Five of these fish were believed to have moved into and stayed in the Seton River, the remaining 13 fish were detected on PIT and radio telemetry stations on the Bridge River (Burnett et al. 2016). The combination of PIT and radio technology allowed us to collect more detailed information on their distribution and use of the Seton corridor. We can now conclude with more certainty that Steelhead are spawning in the lower spawning channel and are migrating past the Seton Dam to spawn in systems upstream. There is still some uncertainty on the use of the Seton mainstem river. Two of the five fish that entered the Seton were not observed in any of the other spawning locations (USC, LSC, Cayoosh, Seton Dam and Bridge River) and thus we could make the assumption that these fish remained and spawned in the mainstem Seton River. Conversely they may also have moved out of the Seton and migrated further up the Fraser. More years of tagging and distribution data will assist in strengthening our understanding of Steelhead adult use of the mainstem of the Seton.

There were no Chinook adults observed in the Seton River during visual counts or captured by angling and thus our proposed methods for assessing use and estimating abundance have not been possible. In 2015 age zero (young of the year) chinook juveniles were captured during growth sampling potentially indicating that Chinook are spawning in the Seton or conversely that they are coming from other locations and rearing/migrating. DNA assessment of these juvenile fish may inform their origin and will be conducted in future years of the monitor.

Pink salmon adults occur at higher densities than all other salmonid species in the Seton River. Unfortunately attempts to estimate the spawning population in 2015 were not as effective as anticipated. PIT tagging efforts were successful, but not to the extent that was intended. Two issues presented themselves that will be corrected in the future; 1) Tangle nets mesh size was too large allowing fish to escape the net and 2) capture effort needs to increase i.e. more fishing days. During 2015, the sample size was not large enough to create a confident estimate through the proportional distribution method originally proposed. Valuable residence time data was collected and used for the AUC estimates (5-6 days in LSC and Cayoosh Creek). An observer efficiency was calculated for the lower spawning channel, but the limited sample size that entered the channel (6 fish) would result in inflated estimates with large margins of error. Due to these uncertainties observer efficiencies of 66% (Perrin and Irvine 1990 and Bue et al. 1998) were used. Estimates suggest that the majority of Pink spawning is occurring in the lower and upper spawning channels with estimates of 6,117 and 12,433 individuals respectively. These numbers should be taken with consideration, as a surrogate value of observer efficiency was used and both estimates have large confidence limits around them. The observer efficiency value was created from coastal Pink populations where biotic and abiotic conditions may be different than those observed in the spawning channels. The broad confidence limits may be due to the migration timing of Pink and how it fits the AUC model. Only 2,541 Pinks were estimated in the mainstem Seton River. This value also needs to be taken with some considerations; the observer efficiency value used was a surrogate and a true zero visual count was not observed and was inserted for modeling purposes. The estimate created also does not take into account any fish that may have continued their migration upstream and past the dam i.e. individuals counted during the survey may have left the system but were included in the total count. This would result in an inflated estimate by an unknown number. Once the capture-tagging methods for tagging Pink salmon are refined and a larger number of fish are tagged the proportional distribution method will serve as a better method for enumerating Pink salmon numbers in the Seton River.

Coho, like Chinook, were difficult to observe/sample in the Seton River, but through the efforts of BRGMON-03 we were able to make more certain inferences about their migration patterns and behavior in the area. It was unexpected to observe fish tagged at the Bride River-Fraser confluence double back and moved up into the Seton River. In 2015, it appears that all of the Coho tagged and observed through visual surveys spawned in the spawning channels or migrated past Seton Dam to systems upstream. An increased effort will be made in 2016 to try to sample Coho at the Seton-Fraser confluence. This will add to the efforts of BRGMON03 and provide a larger sample of fish to be monitored and observed in the network of PIT antennas in the Seton-Bridge area. Continuation of stream walks (Visual counts) is also important as it will allow us to continue collecting valuable index data and help corroborate PIT distribution data.

As in 2014, adult Bull trout and whitefish were observed in the Seton River, but were caught as by-catch in efforts to collect anadromous species. These species likely don't use the Seton River for spawning and rearing as very few if any juveniles were observed in both years. Instead these two species likely use the river as a migratory and feeding corridor. Bull trout are known to be food driven migrators (Ladell et. al. 2010) as are Mountain Whitefish (Mcphail, 2007). 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 a number of other monitors in the watershed have PIT antennas installed in other areas (Lower Bridge River, and Gates Creek). For example, an adult Bull Trout that was PIT tagged in the Bridge River (at the Yalakom confluence) in the fall of 2014 and was detected at the fixed PIT telemetry station at the Lower Spawning Channel in March of 2015. Collaboration with the other monitors will be critical for collecting this valuable fish movement data.

In March of 2015, the scheduled shutdown of the Seton Generating Station (SONGS) was monitored. Freshet in 2015 began earlier in the year and during the time of the shut down the Fraser discharge was >2000 m^3/s and thus the decrease in discharge observed at Texas Creek Water Survey of Canada gauge was only 2% of the total. Ramping rates did not exceed DFO thresholds of <0.5m/h at either of the assessment sites. In future monitoring, we plan to link stage decrease to a value of area dewatered at each site, therein further quantifying the effects of SONGS shutdowns.

Results from the riverbed topographic surveys showed that elevation changes within the area monitored was variable within and between transects. Sections of the area monitored (top 4 and bottom 3 transects), saw little change in elevation (mean change = 0). The middle section of the area showed different results in general the river right portion appeared to have decreased in elevation (got deeper) while the river left side became more uniform in depth. An initial inference is that these sections got deeper or became more uniform in depth because there was movement of substrate through the area. Substrate surveys proposed for spring of 2016, will aim to quantify if the substrate composition has changed from when the surveys were first completed in 2013 and will begin to inform the uncertainties about substrate movement in the Seton River. Further review of data will also look into identifying if the rate of elevation change is within the natural variance expected within rivers.

5. SUMMARY, CHALLENGES and RECOMMENDATIONS

In summary, the work undertaken in 2015 continued to quantify juvenile habitat, fish abundance and distribution in the Seton River. Adult salmonid habitat use and abundance continued to be challenging to assess.

A number of recommendations are provided that may improve adult spawner escapement estimates 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 between 25 and 45 m^3/s)

2) Modify methods of capturing adult salmon (Pinks) for tagging (Use smaller mesh size tangle nets, and/or increase effort)

3) Continue increased frequency of mobile tracking and visual stream walks around peak spawner abundance to increase odds of seeing fish.

4) 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.

5) Continued operation of PIT tag arrays (installed in 2014 and 2015) to delineate spawner distribution. Possibly add another array in lower reach.

6) DNA analysis of juvenile Chinook to identify their origin/natal stream.

6.0 TABLES

Table 1. Definitions of variables used in hierarchical model

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

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

Table 3. Hydrological units identified in the Seton River through modified Level 1 FHAP, 2015.

Reach	Total length (m)	-	Total Length of Habitat Type (m)	-	Mean Bankfull width (m)
		G	P	R	
1	1154	358	342	455	30.7
2	1288	260	65	963	34
3	1895	708	313	874	36.8
Total	4337	1325.5	720	2292	

Table 4. Juvenile WUA (m2) by reach and habitat class during surveys completed in Seton River, 2014 and 2015.

Reach	Habitat	Survey	Rb Fry WUA (m2)	Rb Parr WUA (m2)	Co WUA (m2)	Chk WUA (m2)
1	G	1	776.23	1872.86	1040.53	5077.89
1	G	3	395.59	747.83	612.18	3090.29
1	G	5	176.28	257.24	443.76	889.91
1	P	1	340.26	553.49	799.95	909.6
1	P	3	193.36	215.15	240.87	372.28
1	P	5	203.3	201.46	270.95	359.03
1	R	1	1991.82	2570.85	2448.86	4106.62
1	R	3	1048.96	1992.5	1163.34	3174.37
1	R	5	367.23	562.61	420.76	762.69
2	G	1	6568.43	5472.03	7092.63	8472.22
2	G	3	1820.8	3720.11	2707.5	5141.37
2	G	5	1128.81	1089.9	1136.45	1682.04
2	P	1	277.24	325.9	614.06	599.8
2	P	3	148.32	181.1	348.1	327.32
2	P	5	70.41	161.2	69.34	226.25
2	R	1	3431.24	3866.95	3527.36	5738.83
2	R	3	1709.41	2667.58	2513.48	4040.34
2	R	5	1207.06	1406.89	1472.54	2203.54
3	G	1	2793.55	3361.64	2943.55	5726.46
3	G	3	1688.12	2379.07	2125.91	4314.02
3	G	5	514.1	698.82	1137.52	1591.61
3	P	1	2.27	0	79.8	267.75
3	P	3	0.9	0	90	30.75
3	P	5	3.32	0	59.82	136.31
3	R	1	4446.53	4226.48	3481.01	7555.19
3	R	3	6031.14	4929.18	4552.3	8227.79
3	R	5	1160.15	1631.98	1033.34	2311.72

Table 5. Total number of fish caught during juvenile growth sampling surveys, 2015.

Species	Site	N
Bridgelip Sucker	Seton River	23
Bridgelip Sucker	Spawning channel	24
Bull Trout	Spawning channel	1
Coast-range sculpin	Seton River	169
Coast-range sculpin	Spawning channel	43
Prickly Sculpin	Seton River	28
Prickly Sculpin	Spawning channel	38
Chinook	Seton River	177
Chinook	Spawning channel	19
Coho	Seton River	288
Coho	Spawning channel	158
Longnose Dace	Seton River	282
Longnose Dace	Spawning channel	203
Peamouth Chub	Seton River	1
Rainbow Trout	Seton River	541
Rainbow Trout	Spawning channel	118
Redside Shinner	Seton River	8
Redside Shinner	Spawning channel	5
Sculpin	Seton River	17
Sculpin	Spawning channel	7
Sockeye	Seton River	23
Sockeye	Spawning channel	1
Mountain Whitefish	Seton River	7

Table 6. Mean length of Rainbow Trout sampled during juvenile growth sampling surveys at Seton River and Seton River spawning channels

Site	Month	N	Mean	sd	Min	Median	Max
Seton River	April	60	84.6	19.7	55	83	164
Spawning channel	April	38	112.4	35.8	72	96.5	194
Seton River	May	51	84.5	20.3	57	82	155
Spawning channel	May	17	128.9	47.1	81	103	235
Seton River	June	7	84.6	17.3	56	88	104
Spawning channel	June	15	118.2	21.2	72	116	155
Seton River	July	69	57.9	31.3	27	42	156
Spawning channel	July	18	81.4	38.6	40	60.5	160
Seton River	August	37	64.4	23.8	38	57	142
Spawning channel	August	10	98.5	37.6	58	91	165
Seton River	September	281	76.7	26	41	70	205
Seton River	October	36	79.1	17.8	45	79	145
Spawning channel	October	20	122.7	48.7	64	118.5	204

Table 7. Results of simple t-test comparing length of main-stem Seton River fish with spawning channel fish in 2015.

Species	Month	t-stat	df	p.value
Rainbow Trout	April	4.4011642	51.454085	5.45E-05
Rainbow Trout	May	3.7692706	18.009945	0.0014032
Rainbow Trout	June	3.944818	14.327754	0.001407
Rainbow Trout	July	2.3839098	23.131929	0.025716
Rainbow Trout	August	2.7282835	11.021472	0.0196074
Rainbow Trout	October	3.8613971	21.861266	0.0008529

Table 8. Growth of PIT-tagged juvenile Rainbow Trout, 2015.

PIT ID	Age	First FL (mm)	Last FL (mm)	Growth (mm)	Rate of growth

		measurement	measurement		(mm day^{-1})
650261	1	112	114	2	0.065
650274	1	85	130	45	0.536
650301	2	142	155	13	0.236
650323	1	84	81	-3	
650352	1	108	149	41	0.313
650945	1	103	113	10	0.156
650953	1	81	111	30	0.469
657013	1	82	123	41	0.313
657016	1	75	112	37	0.282
657556	1	90	117	27	0.415
657584	1	86	97	11	0.115
657614	1	95	93	-2	
657700	1	77	85	8	0.119
657713	2	125	159	34	0.944
657716	2	115	157	42	0.646

Table 9. Results of simple t-test comparing length of main-stem Seton River Coho with spawning channel Coho in 2015.

Species	Month	t-stat	df	p value
Coho	April	6.452	32.635	2.70E-07
Coho	May	1.745	89.957	8.44E-02
Coho	June	-0.166	53.788	8.69E-01
Coho	July	-1.628	41.354	1.11E-01
Coho	August	0.569	30.739	5.73E-01
Coho	October	1.918	23.879	6.72E-02

Table 10. Summary of fish observed during juvenile snorkel surveys in Seton River, 2015

Site	Species	N	Mean FL ± SD (mm)
3	Rainow Trout	1	80
4	Rainow Trout	7	90 ± 24.5
7	Coho	2	45
7	Rainow Trout	3	90 ± 26.5
7	Redside Shiner	8	85
7.2	Rainow Trout	9	72.2 ± 10.9
19	Coho	4	NA
19	Rainow Trout	14	92.9 ± 35.4
19.2	Rainow Trout	25	92.4 ± 29.6
19.2	Mountain Whitefish	1	NA
22	Rainow Trout	9	80 ± 7.1
23	Coho	4	NA
23	Rainow Trout	12	77.5 ± 12.9
26	Coho	4	NA
26	Rainow Trout	16	105 ± 27.1
26.2	Bull Trout	1	180
26.2	Coho	13	NA
26.2	Rainow Trout	6	80 ± 39.5

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

Table 11. Seton River Rainbow Trout age 0 densities, 2014 -2015

	2014			2015		
Site	Density (fish/m)	5 % CI	95 % CI	Density (fish/m)	5 % CI	95 % CI
2	0.74	0.33	1.68			
3	0.20	0.07	0.53			
4	0.48	0.20	1.20	0.18	0.04	0.69
5	0.35	0.14	0.89			
7	0.77	0.35	1.68			
8	3.71	1.86	8.25			
9				0.28	0.08	0.79
11				0.27	0.08	0.84
14	0.59	0.27	1.34	0.52	0.19	1.39
15	2.03	0.97	4.57	0.91	0.34	2.36
16	0.75	0.34	1.73			
17	0.50	0.21	1.25	0.14	0.03	0.50
18	1.26	0.57	2.83	0.15	0.04	0.53
19	0.95	0.46	2.12	0.17	0.04	0.62
20				0.15	0.04	0.56
21	0.62	0.27	1.52			
22	0.09	0.02	0.31			
23	0.94	0.44	2.18	0.30	0.10	0.94
25	3.16	1.62	7.10			
27				0.11	0.02	0.51
28	0.73	0.33	1.77	0.21	0.06	0.71
34				0.11	0.02	0.45
38				0.18	0.04	0.69
39	0.44	0.19	1.08			
41	0.82	0.37	1.86	0.10	0.02	0.41
42	0.36	0.14	0.91	0.11	0.03	0.48
43	0.88	0.41	2.01			
44	0.52	0.22	1.30			
45				0.32	0.10	0.99

46	0.46	0.19	1.09	0.30	0.08	1.17
47	1.77	0.85	4.06	0.14	0.03	0.53
50				0.28	0.08	0.89
51	0.12	0.04	0.38			
53				1.04	0.41	2.61

Table 12. Seton River Steelhead and Coho catch data, 2015

Capture Date	Capture Location	Species	Sex	Length (mm)	Catch A/R	PIT Tag ID	Radio Frequency	Radio Code	Angler & Crew
20/03/15	Seton Con.	SHA	F	740	A	230000010008	150.500	32	ES
24/03/15	Seton Con.	SHA	F	800	A	183225159	150.680	67	ES
03/04/15	Seton Con.	SHA	F	724	A	230000010018	150.500	50	RJ
08/04/15	Seton Con.	SHA	F	630	A	183225150	150.500	41	ES
14/04/15	Seton Con.	SHA	F	760	A	183225279	150.500	46	ES
15/10/15	Bridge Con.	COA	F	540	A	183225362			
15/10/15	Bridge Con.	COA	F	495	A	183227082			
16/10/15	Bridge Con.	COA	M	650	A	183225801			
17/10/15	Bridge Con.	COA	F	530	A	183225445			
03/11/15	Bridge Pool	COA	M	610	A	230000010015			

Table 13. Seton River Steelhead fixed telemetry records at Lower Spawning Channel, 2015

Code	Sex	Days to migrate to LSC	Migration rate (km day^{-1})
32	F	15.5	0.1
41	F	2.0	0.7
46	F	5.2	0.3
50	F	7.9	0.2
67	F	10.9	0.1
		Mean	0.3
		Minimum	0.1
		Maximum	0.7

Table 14. Seton River Steelhead mobile tracking data, 2015

Date	Time	Section	Frequency	Code
04/13/15	10:40 AM	CC-HW	150.500	41
04/23/15	-	LSC	150.500	46
04/27/15	2:00 PM	HW-LSC	150.500	46
04/30/15	2:30 PM	LSC	150.680	46
05/07/15	8:50 AM	LSC	150.500	46
05/11/15	9:36 AM	LSC	150.500	46
05/14/15	9:30 AM	LSC	150.500	46
05/22/15	9:00 AM	INT-BRIDGE	150.500	46
05/29/15	8:45 AM	LSC	150.500	46
04/13/15	10:40 AM	INT-BRIDGE	150.500	50
04/17/15	9:00 AM	INT-BRIDGE	150.500	50
04/23/15	-	LSC	150.500	50
04/17/15	9:00 AM	HW-LSC	150.680	67
04/27/15	2:00 PM	S.DAM-IPT	150.680	67

Table 15. Seton River Coho PIT telemetry data – 2015

Code	Location	Date and time of entry	Date and time of exit
10015	LSC	2015-11-09 20:54	2015-11-25 07:02
183225801	Seton Dam	2015-10-18 11:05	2015-10-18 11:46
183225445	Seton Dam	2015-10-20 00:19	2015-10-20 00:56
183227082	Seton Dam	2015-11-11 05:22	-
	USC	2015-11-11 16:25	2015-11-12 05:49
183225362	USC	2015-10-28 23:12	Fish (or carcass) did not leave channel

Table 16. Seton River Coho visual count data – 2015

Date	Cloud Cover %	Water Vis. (m)	Air Temp.	S. Dam-IPT	IPT-Cay.Con	Cay.Con-Halfway	Halfway-Intake	Intake-S.Bridge	USCH	LSCH	Morts	Total	Comments
10/06/15	85	0.5		0	0	0	0	0	0	0	0	0	
10/13/15	0	0.5	8	0	0	0	0	0	0	0	0	0	
10/19/15			9	0	0	0	0	0	0	0	4	4	
10/26/15				0	0	0	0	0	2	3	0	5	
11/02/15				0	0	0	0	0	0	0	0	0	
11/09/15	40		8	0	0	0	0	0	0	0	0	0	
11/24/15	20	1		0	0	0	0	0	0	14	0	14	
12/01/15									2	1	0	3	Splitrock only
12/08/15									0	0	0	0	Splitrock only
12/15/15									0	0	0	0	Splitrock only

Table 17. Seton River Pink Salmon tagging data – 2015

Fish No.	Date	Location	Capture Method	Species	Sex	Length (mm)	Disk	PIT Tag ID
1	10-Sep-15	LSC	Tangle Net	PK	M	490	Blue	900_230000018002
2	10-Sep-15	LSC	Tangle Net	PK	M	495	Blue	900_230000018001
3	16-Sep-15	LSC	Tangle Net	PK	M	520	O	900_230000018092
4	16-Sep-15	LSC	Tangle Net	PK	M	520	O	900_230000018101
5	16-Sep-15	LSC	Tangle Net	PK	F	480	P	900_230000018104
6	16-Sep-15	LSC	Tangle Net	PK	M	500	O	900_230000018112
7	16-Sep-15	LSC	Tangle Net	PK	M	520	O	900_230000018105
8	16-Sep-15	LSC	Tangle Net	PK	M	560	O	900_230000018137
9	16-Sep-15	LSC	Tangle Net	PK	M	550	O	900_230000018165
10	16-Sep-15	LSC	Tangle Net	PK	M	550	O	900_230000018133
11	16-Sep-15	LSC	Tangle Net	PK	M	550	O	900_230000018140
12	16-Sep-15	LSC	Tangle Net	PK	M	610	O	900_230000018118
13	16-Sep-15	LSC	Tangle Net	PK	M	565	O	900_230000018149
14	16-Sep-15	LSC	Tangle Net	PK	M	500	O	900_230000018163
15	16-Sep-15	LSC	Tangle Net	PK	M	585	O	900_230000018166
16	16-Sep-15	LSC	Tangle Net	PK	M	535	O	900_230000018166
17	16-Sep-15	LSC	Tangle Net	PK	M	535	O	900_230000018161
18	16-Sep-15	LSC	Tangle Net	PK	M	487	O	900_230000018147
19	16-Sep-15	LSC	Tangle Net	PK	M	525	O	900_230000018186
20	16-Sep-15	LSC	Tangle Net	PK	M	530	O	900_230000018148
21	16-Sep-15	LSC	Tangle Net	PK	F	480	P	900_2300000181807
22	16-Sep-15	LSC	Tangle Net	PK	M	610	O	900_230000018011
23	16-Sep-15	LSC	Tangle Net	PK	M	615	O	900_230000018164
24	16-Sep-15	LSC	Tangle Net	PK	M	510	O	900_230000018117
25	17-Sep-15	LSC	Tangle Net	PK	M	520	O	900_230000018030
26	17-Sep-15	LSC	Tangle Net	PK	M	490	O	900_230000018008
27	17-Sep-15	LSC	Tangle Net	PK	M	480	O	900_230000018098
28	17-Sep-15	LSC	Tangle Net	PK	M	580	O	900_230000018062
29	17-Sep-15	LSC	Tangle Net	PK	M	460	O	900_230000018058
30	17-Sep-15	LSC	Tangle Net	PK	M	550	O	900_230000018034
31	17-Sep-15	LSC	Tangle Net	PK	M	530	O	900_230000018097
32	17-Sep-15	LSC	Tangle Net	PK	M	480	O	900_230000018070
33	17-Sep-15	LSC	Tangle Net	PK	M	460	P	900_230000018056
34	17-Sep-15	LSC	Tangle Net	PK	F	500	P	900_230000018048
35	17-Sep-15	LSC	Tangle Net	PK	M	520	P	900_230000018079
36	17-Sep-15	LSC	Tangle Net	PK	M	480	P	900_230000018023
37	17-Sep-15	LSC	Tangle Net	PK	M	510	P	900_230000018022
38	17-Sep-15	LSC	Tangle Net	PK	M	510	P	900_230000018010
39	17-Sep-15	LSC	Tangle Net	PK	M	580	P	900_230000018018
40	24-Sep-15	LSC	Tangle Net	PK	M	495	O	900_230000018145

41	24-Sep-15	LSC	Tangle Net	PK	M	578	O	900_230000018155
42	24-Sep-15	LSC	Tangle Net	PK	M	511	O	900_230000018025
43	24-Sep-15	LSC	Tangle Net	PK	M	508	O	900_230000018029
44	24-Sep-15	LSC	Tangle Net	PK	M	559	O	900_230000018009
45	24-Sep-15	LSC	Tangle Net	PK	M	539	O	900_230000018157
46	24-Sep-15	LSC	Tangle Net	PK	M	488	O	900_230000018035
47	24-Sep-15	LSC	Tangle Net	PK	M	589	O	900_230000018028
48	24-Sep-15	LSC	Tangle Net	PK	M	589	O	900_230000018014
49	24-Sep-15	LSC	Tangle Net	PK	M	509	O	900_230000018006
50	24-Sep-15	LSC	Tangle Net	PK	M	525	O	900_230000018027
51	30-Sep-15	LSC	Tangle Net	PK	M	479	O	900_230000018033
52	30-Sep-15	LSC	Tangle Net	PK	M	557	O	900_230000018007
53	30-Sep-15	LSC	Tangle Net	PK	M	660	O	900_230000018067
54	30-Sep-15	LSC	Tangle Net	PK	M	520	O	900_230000018066

Table 18. Seton River Pink Salmon PIT telemetry data (Lower Spawning Channel), 2015

Code	Date and time of entry	Date and time of exit	Residence time (days)
18161	2015-09-16 09:57	2015-09-23 15:36	7.2
18034	2015-09-17 00:32	2015-09-21 00:49	4.0
18062	2015-09-17 00:30	2015-09-17 00:48	-
18092	2015-09-17 06:36	2015-09-23 00:45	5.8
18098	2015-09-18 16:48	2015-09-23 01:00	4.3
18035	2015-09-27 00:00	Fish (or carcass) did not leave channel	-
		Mean	5.3
		Minimum	4.0
		Maximum	7.2

Table 19. Seton River Pink Salmon AUC estimates with confidence intervals, 2015.

Site	Observer Efficiency (OE)	SE - OE	Survey Life (SL)	SE - SL	Escapement	Escapement SE	Lower 95 CI	Upper 95 CI
LSC	0.664	0.031	5.3	0.74	6117	21134	0	47540
Mainstem	0.664	0.031	5.3	0.74	2541	724	1122	3960
USC	0.664	0.031	5.3	0.74	12433	2491	7551	17315

Table 20. Summary of riverbed topography surveys, 2013 - 2015

Transect	2015 elevation (m) ± sd	2013 elevation (m)	Mean Change (m)	Max erosion (m)	Max deposition (m)
1	228.04 ± 0.29	228.04 ± 0.28	0.00	-0.09	0.13
2	228.05 ± 0.28	228.04 ± 0.26	0.01	-0.16	0.22
3	228.11 ± 0.22	228.1 ± 0.23	0.02	-0.11	0.15
4	228.12 ± 0.18	228.1 ± 0.2	0.02	-0.09	0.18
5	228.17 ± 0.23	228.15 ± 0.23	0.02	-0.13	0.13
6	228.13 ± 0.19	228.14 ± 0.18	-0.01	-0.16	0.1
7	228.13 ± 0.18	228.13 ± 0.19	0.01	-0.09	0.19
8	228.1 ± 0.21	228.11 ± 0.22	-0.01	-0.12	0.11
9	228.12 ± 0.18	228.12 ± 0.17	0.00	-0.07	0.08
10	228.07 ± 0.19	228.07 ± 0.16	0.00	-0.16	0.16
11	227.94 ± 0.22	227.97 ± 0.2	-0.03	-0.22	0.09
12	227.96 ± 0.21	227.94 ± 0.26	0.02	-0.57	0.17
13	227.96 ± 0.18	227.96 ± 0.15	0.00	-0.14	0.12
14	227.88 ± 0.24	227.87 ± 0.25	0.01	-0.11	0.14
15	227.85 ± 0.20	227.86 ± 0.21	-0.01	-0.1	0.12
16	228.05 ± 0.31	228.04 ± 0.3	0.01	-0.1	0.07
17	227.97 ± 0.36	227.98 ± 0.36	-0.01	-0.16	0.08
18	228.03 ± 0.39	228.02 ± 0.36	0.01	-0.07	0.1

7.0 FIGURES

Figure 1. Bridge & Seton Watersheds

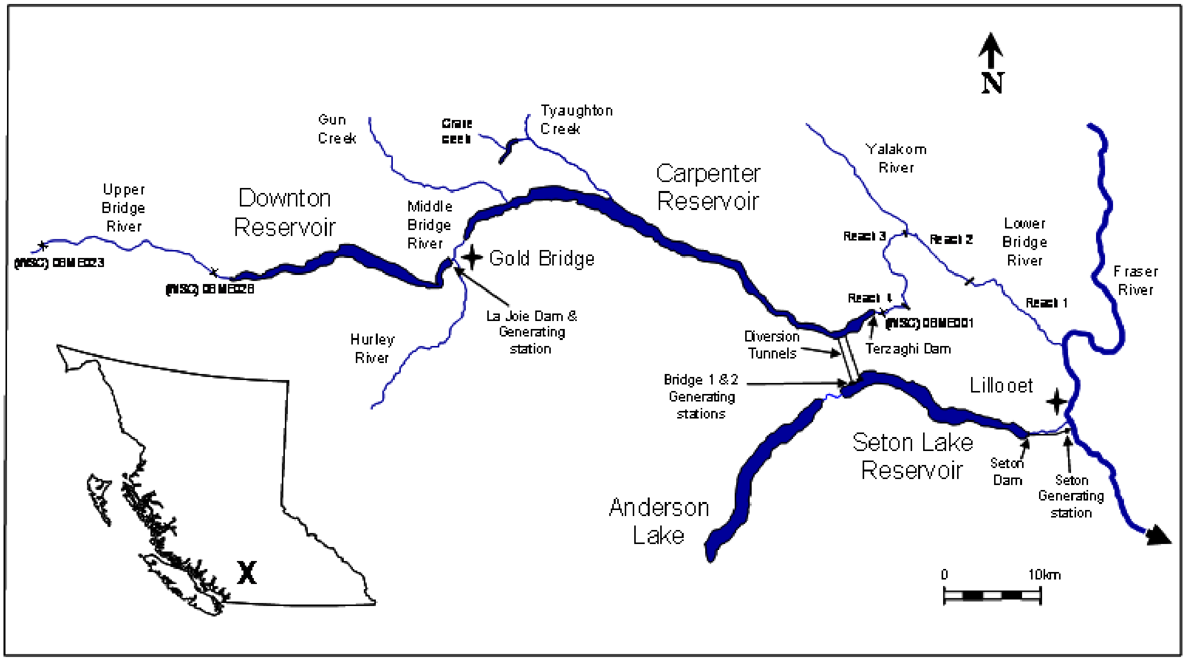


Figure 2. Seton River Study Area showing diversion canal and Cayoosh Creek.

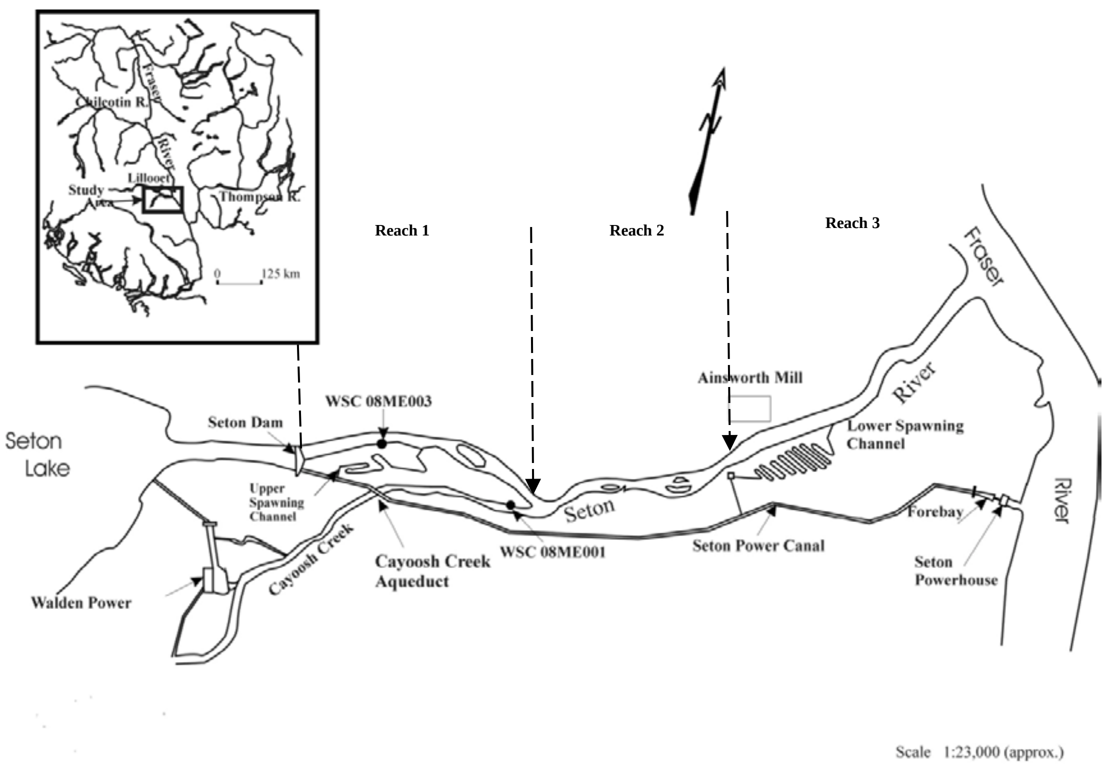


Figure 3. Location of Weighted Useable Area transect sites in Seton River

Figure 3, cont…

Figure 3. Cont….

Figure 4. Location of juvenile growth sampling sites, Seton River, 2014 - 2015.

Figure 4. Cont…

Figure 4. Cont…

Figure 5. Location of fixed radio telemetry stations and fixed PIT station, Seton River 2014 – 2015.

Figure 6. Location of Fraser River stranding sites (flow reduction monitoring)

Figure 7. Site of riverbed topographic surveys 2013 & 2015

Figure 8. Habitat classes identified in Seton River in 2015. P = Pool, R = Riffle and G = Glide

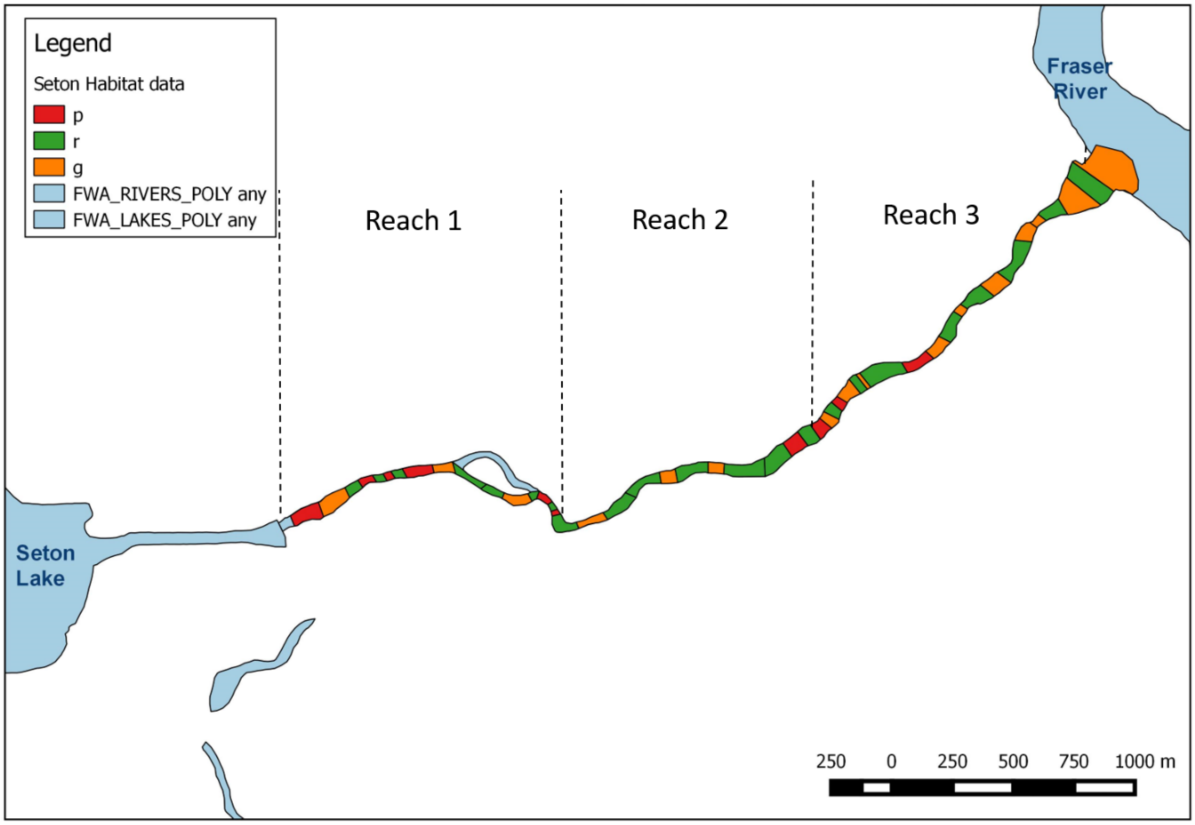


Figure 9. Discharge curve for reach 1 of Seton River at Water Survey of Canada gauge (08ME003) 2015. The different lines denote when surveys were completed. Blue and grey = 60 cms survey and red = 100cms survey.

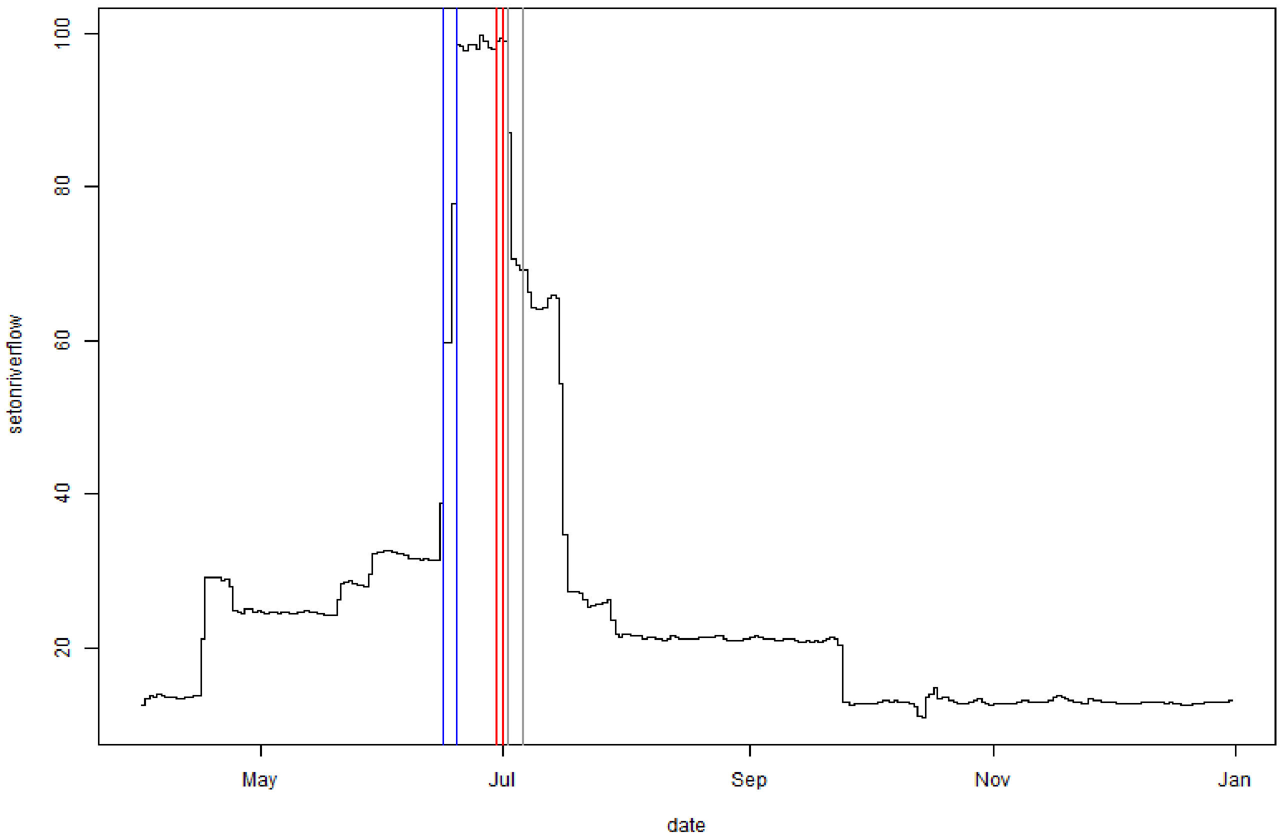


Figure 10. Discharge at Cayoosh Creek Water Survey of Canada gauge (08ME002) 2015. The different lines denote when surveys were completed. Blue and grey = 60 cms survey and red = 100cms survey.

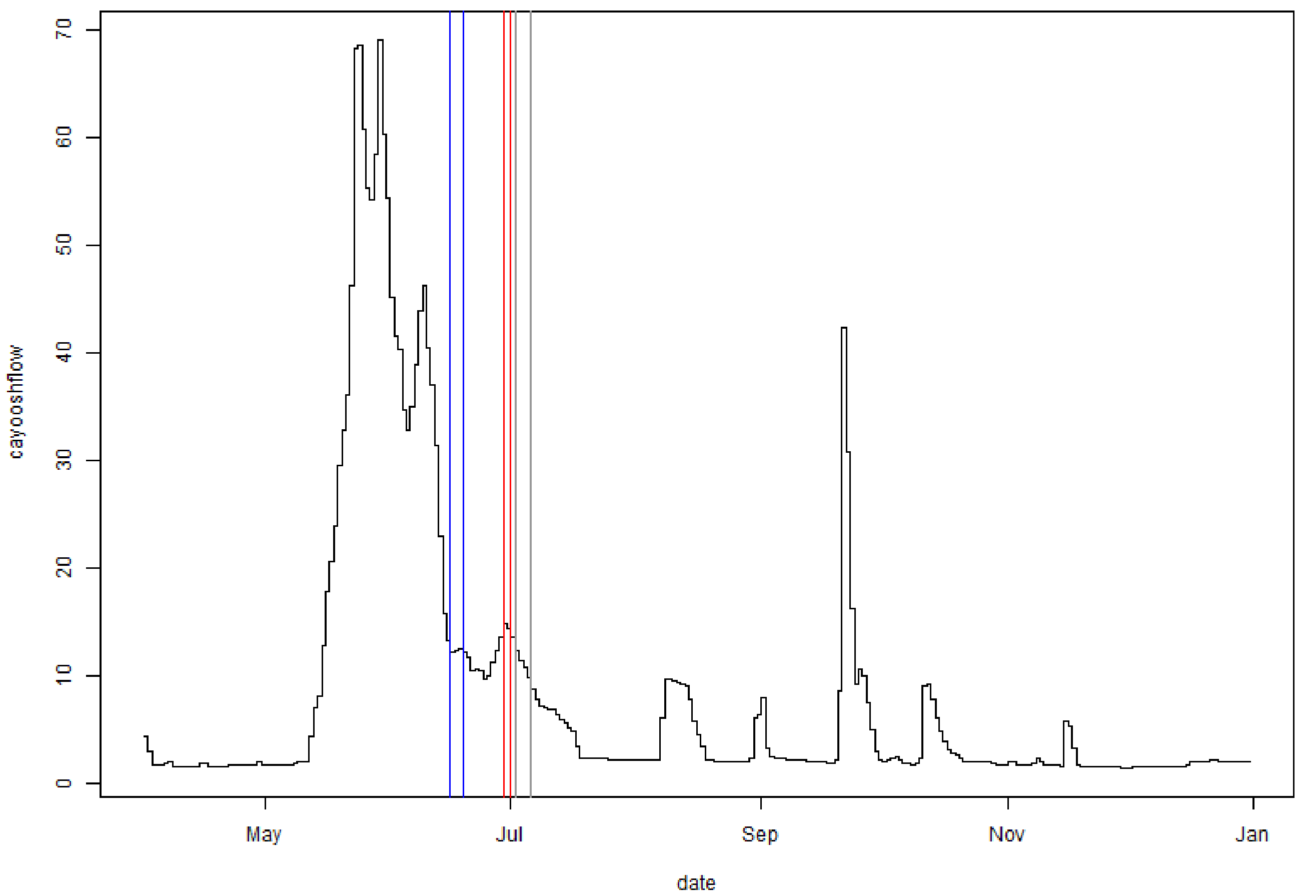


Figure 11. Rainbow Trout fry total Weighted Useable Area (WUA) in glide, pool and riffle habitats of reach 1 (a), reach 2 (b) and reach 3(c) of Seton River at 12, 25 and 60 m3/s (2014 & 2015). Black lines represent the mean of all points, the modes represent the distribution of the data and white lines are individual data points. The broken horizontal line represents the mean of all data points for each reach.

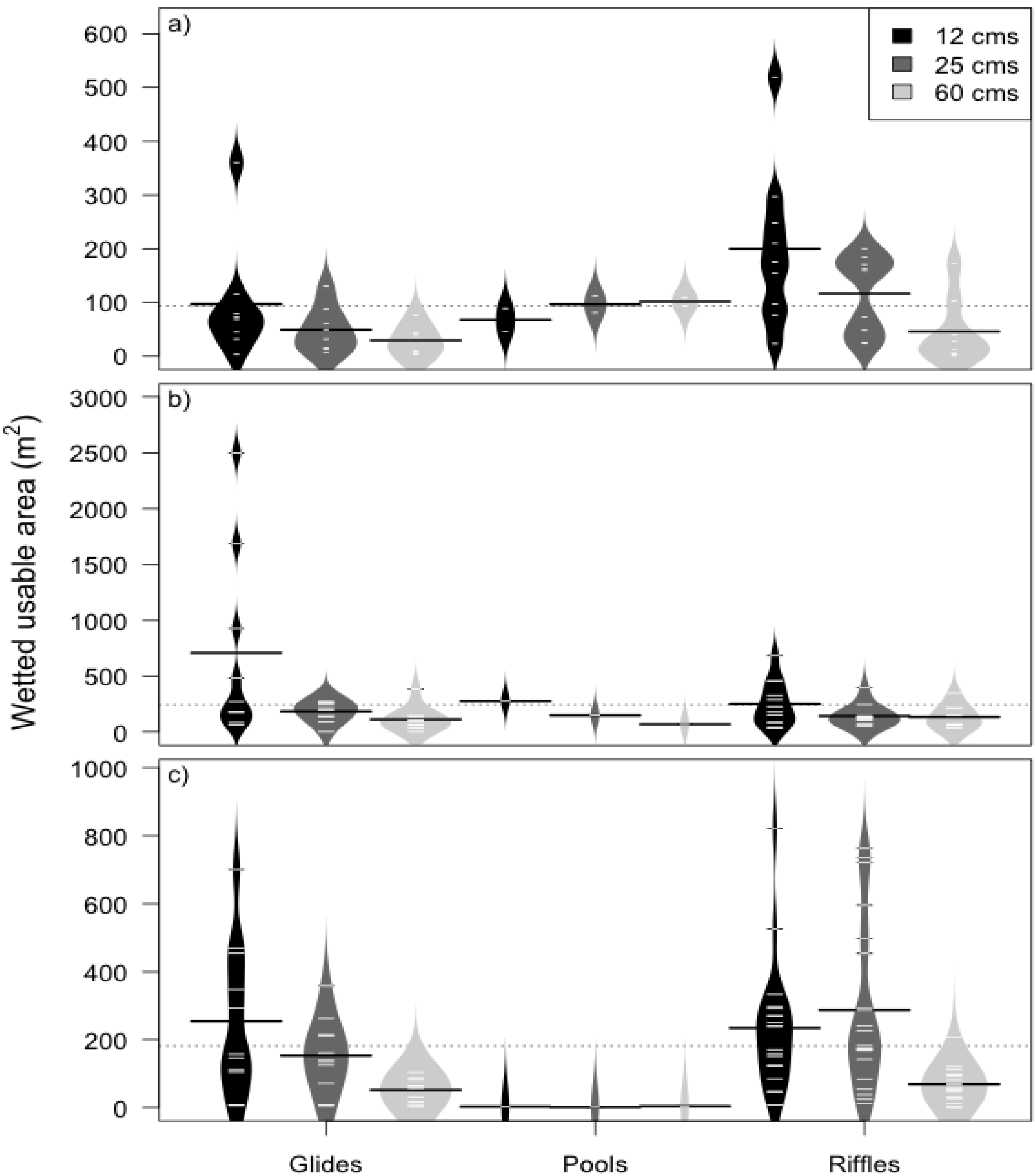


Figure 12. Rainbow Trout fry % WUA of glide, pool, riffle habitat in reaches 1 (a, b & c), 2 (d, e & f) and 3 (g, h & i) of Seton River 2014 and 2015 at various discharges.

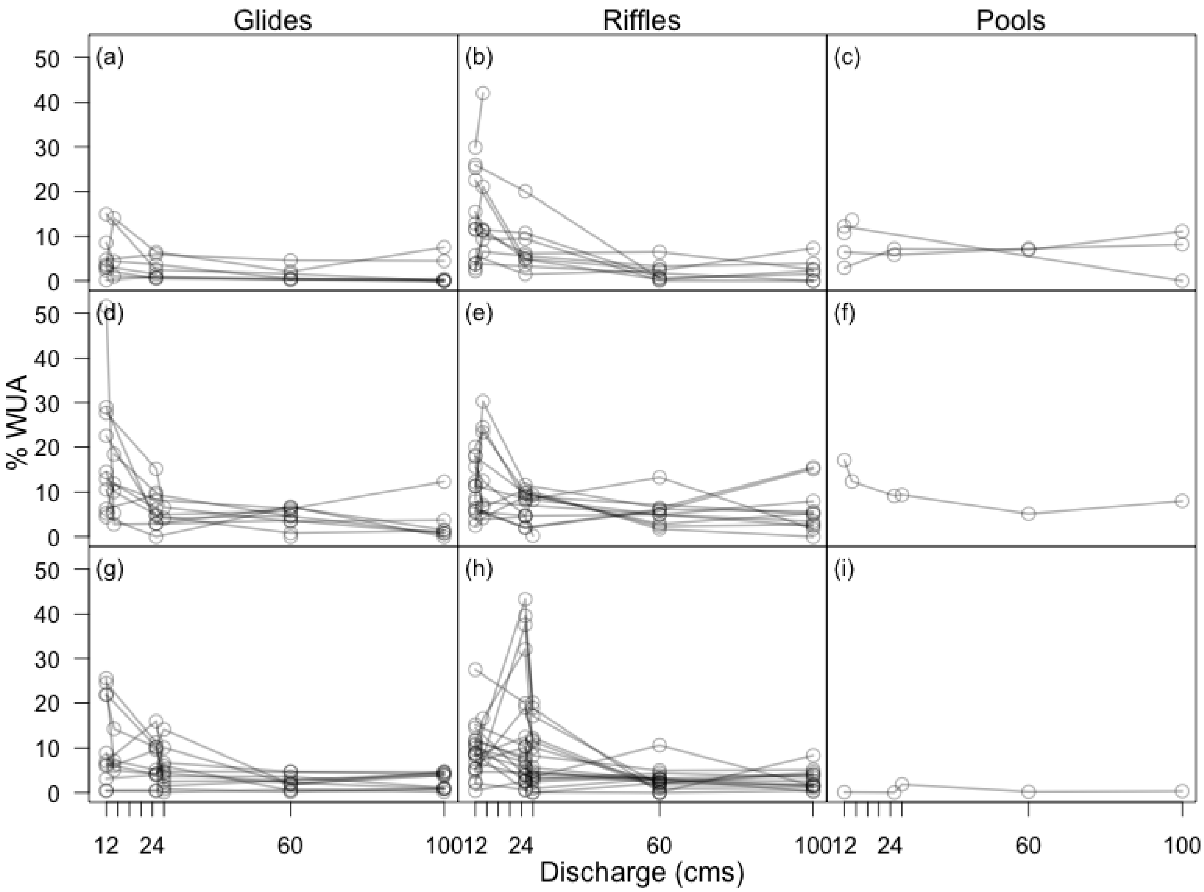


Figure 13. Seton River Rainbow Trout fry total Weighted Useable Area (WUA), 2014 & 2015. Black lines represent the mean of all points, the modes represent the distribution of the data and the white lines represent individual sites. The broken horizontal line represents the mean of all data points.

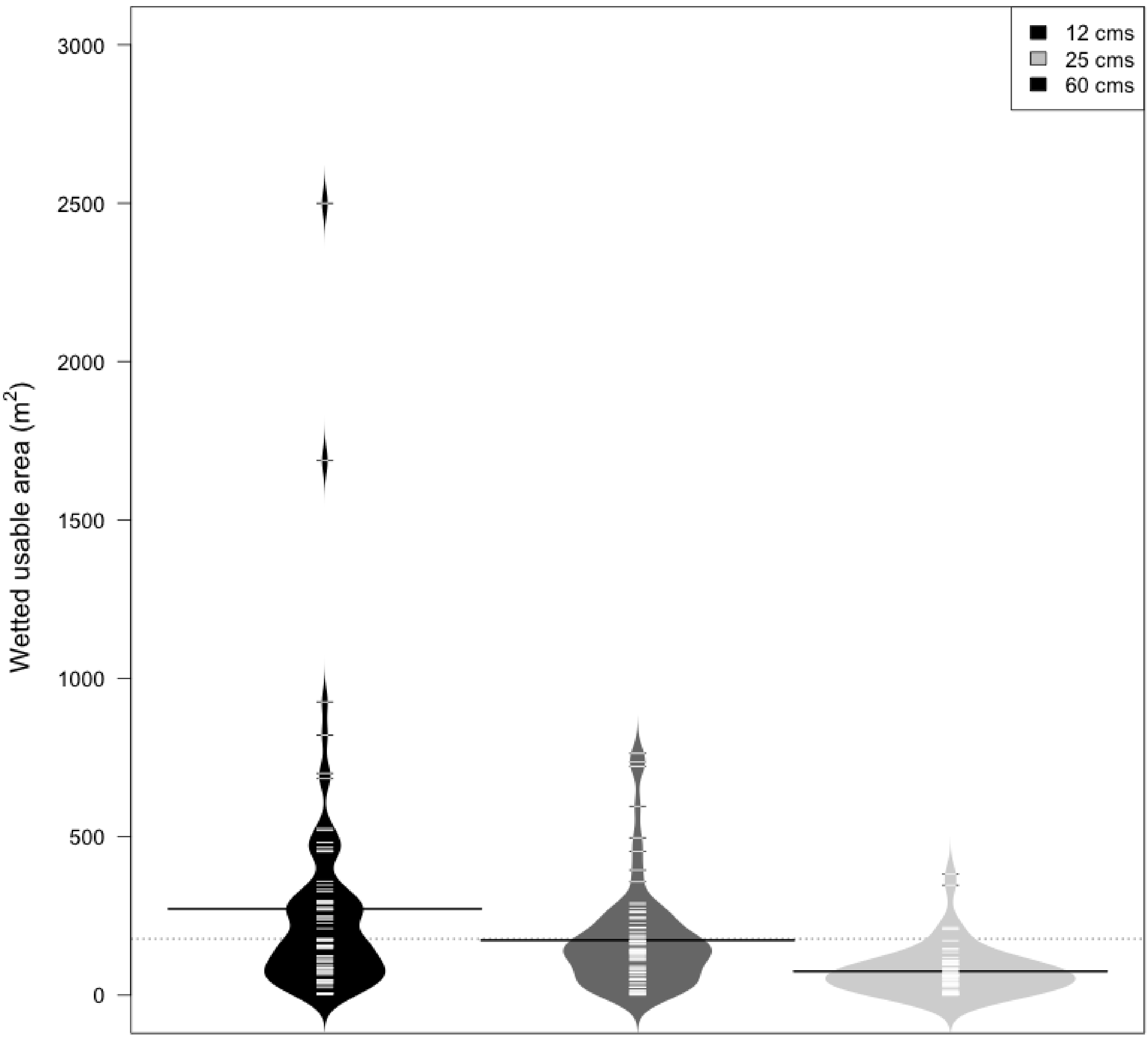


Figure 14. Seton River total Weighted Useable Area (m^2)for Rainbow fry (RBF), Rainbow parr (RBP), Coho (CO) and Chinook (CHK) at 12, 25 and 60 m^3/s (2014 and 2015).

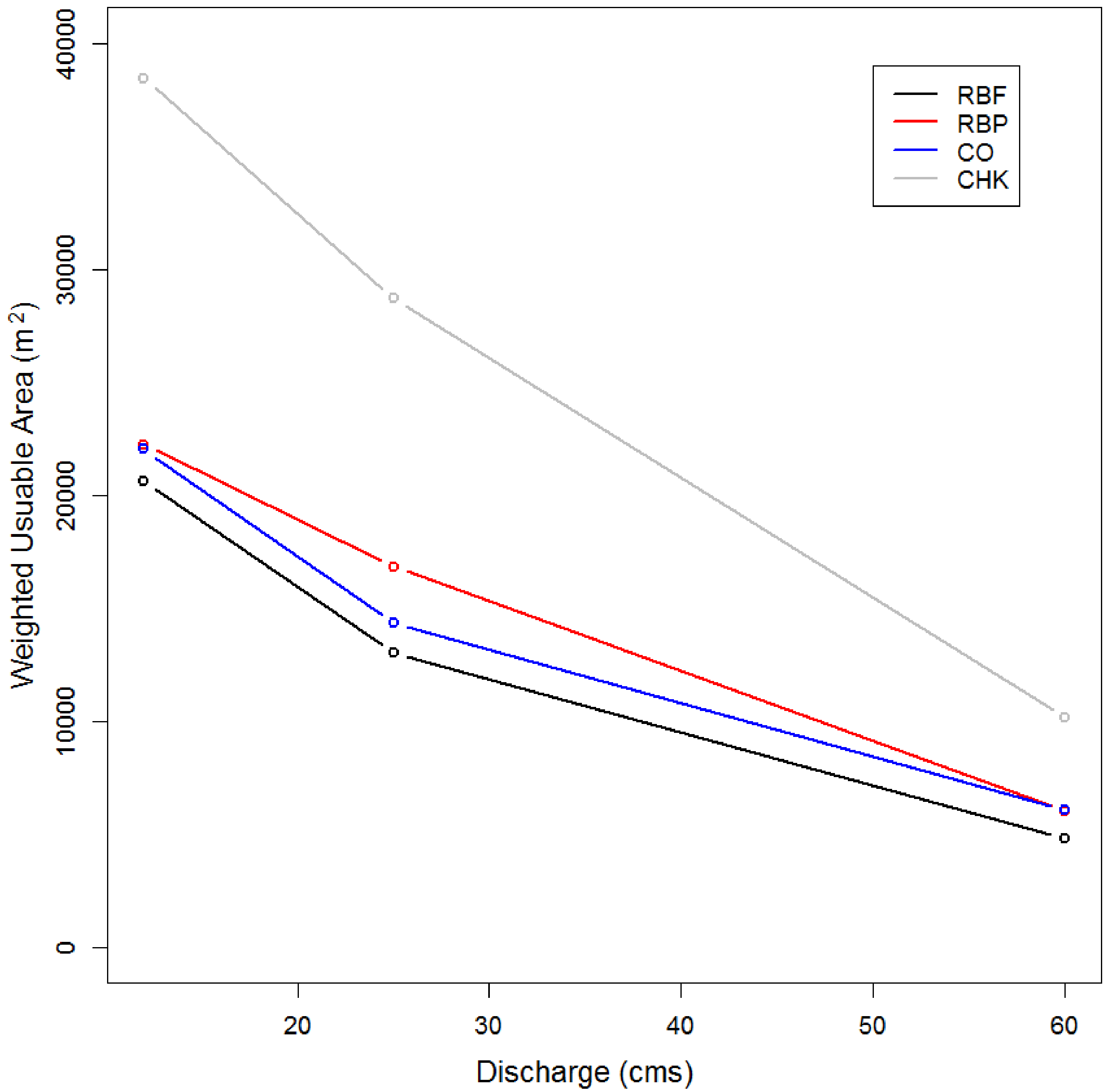


Figure 15. Rainbow Trout parr total Weighted Useable Area (WUA) in glide, pool and riffle habitats of reach 1 (a), reach 2 (b) and reach 3(c) of Seton River at 12, 25 and 60 m3/s (2014 and 2015). Black lines represent the mean of all points, the modes represent the distribution of the data and the white lines are individual data points. The broken horizontal line represents the mean of all data points for each reach.

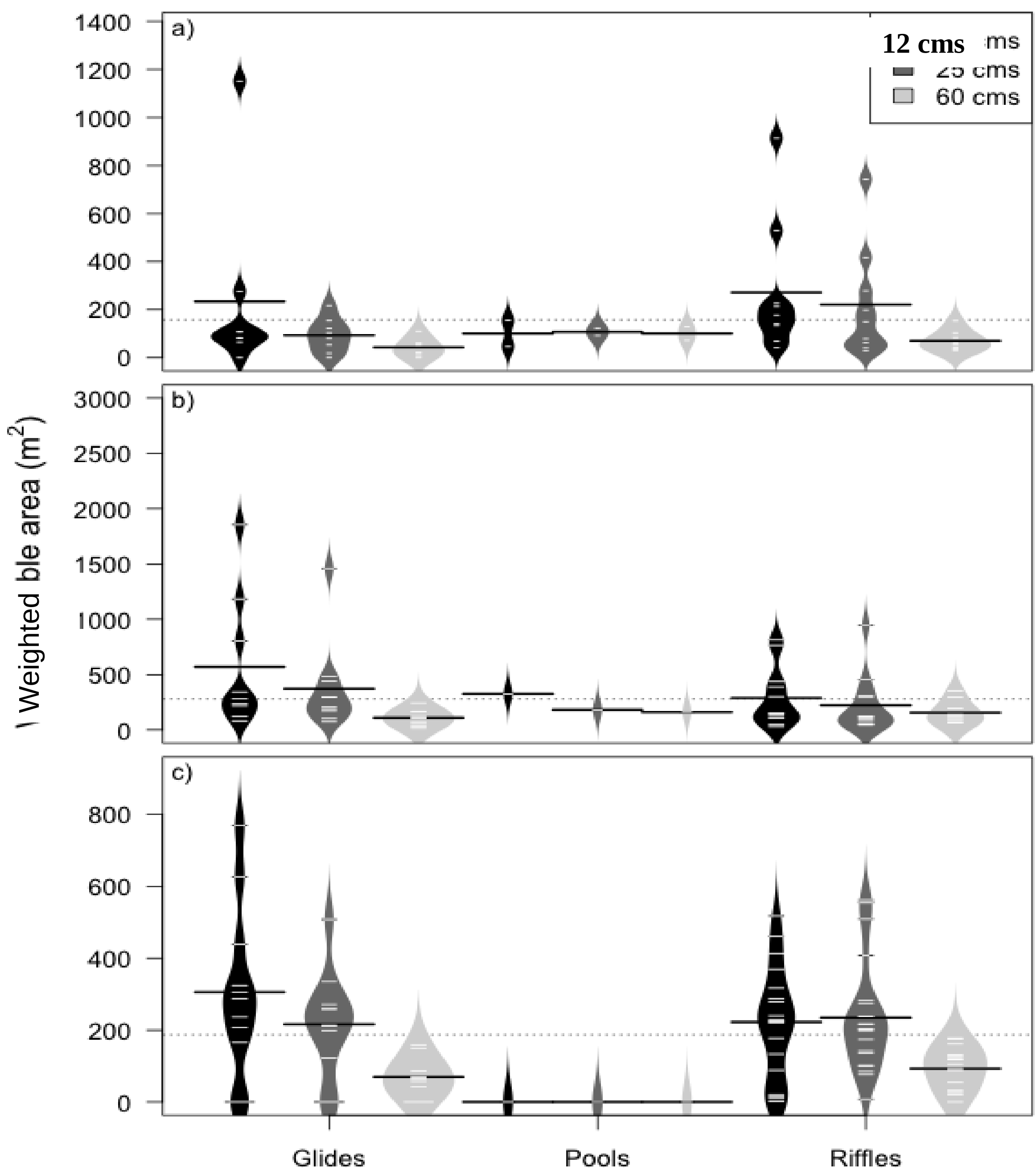


Figure 16. Rainbow Trout parr % WUA of glide, pool, riffle habitat in reaches 1 (a, b & c), 2 (d, e & f) and 3 (g, h & i) of Seton River 2014 and 2015 at various discharges.

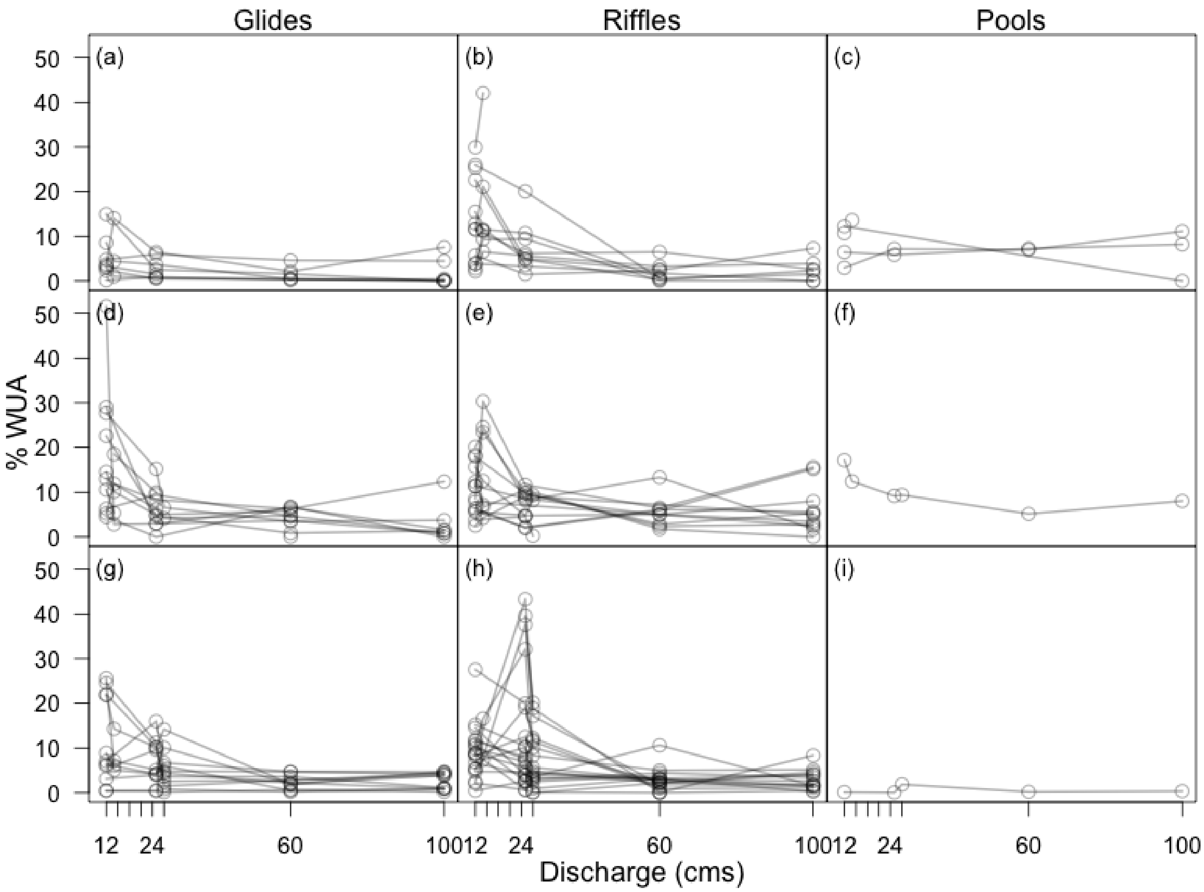


Figure 17. Seton River Rainbow Trout parr total Weighted Useable Area (WUA), 2014 & 2015. Black lines represent the mean of all points, the modes represent the distribution of the data and the white lines represent individual sites. The broken horizontal line represents the mean of all data points.

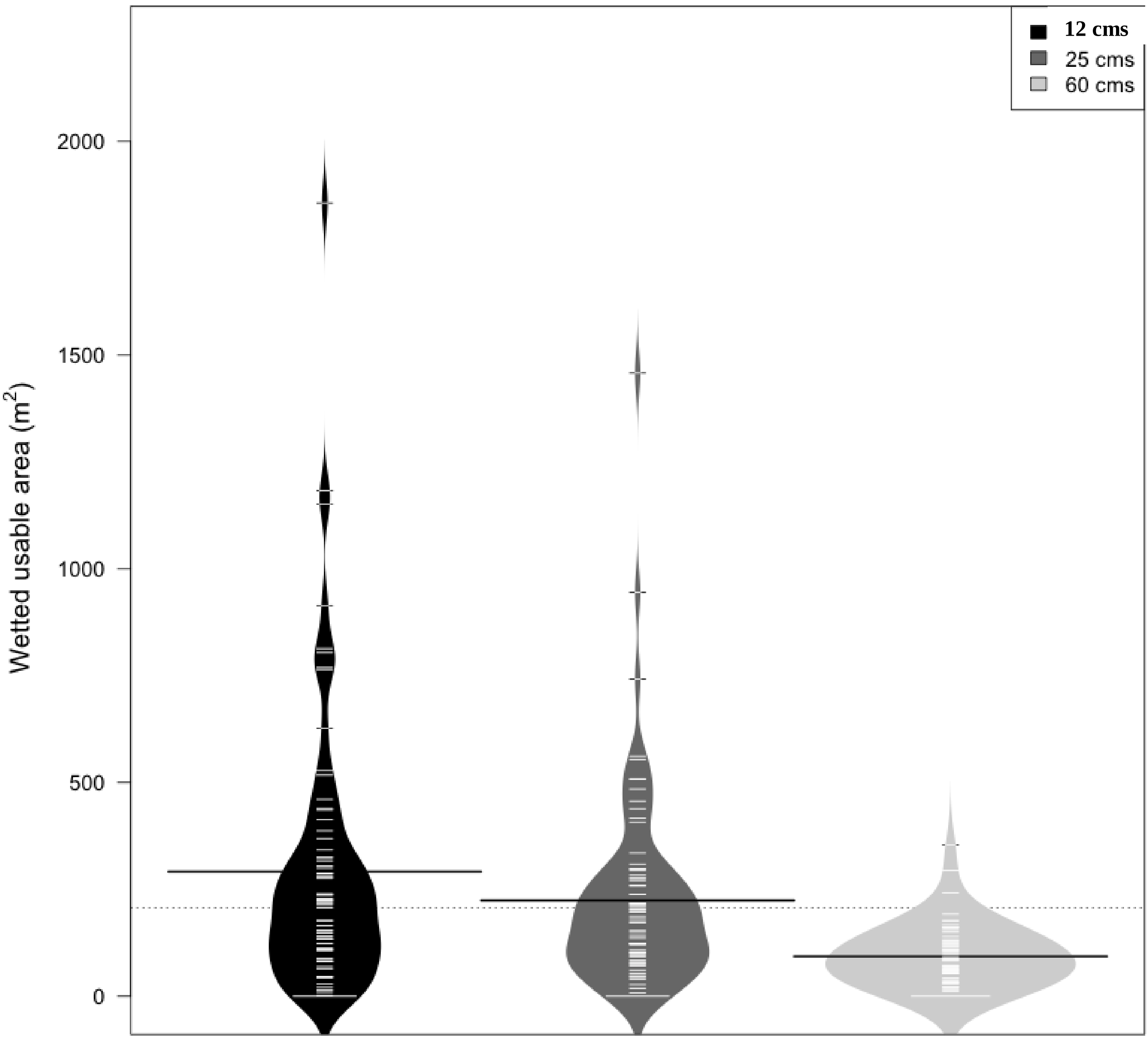


Figure 18. Coho juvenile total Weighted Useable Area (WUA) in glide, pool and riffle habitats of reach 1 (a), reach 2 (b) and reach 3(c) of Seton River at 12, 25 and 60 m3/s (2014 and 2015). Black lines represent the mean of all points, the modes represent the distribution of the data and the small white lines represent individual data points. The broken horizontal line represents the mean of all data points for each reach.

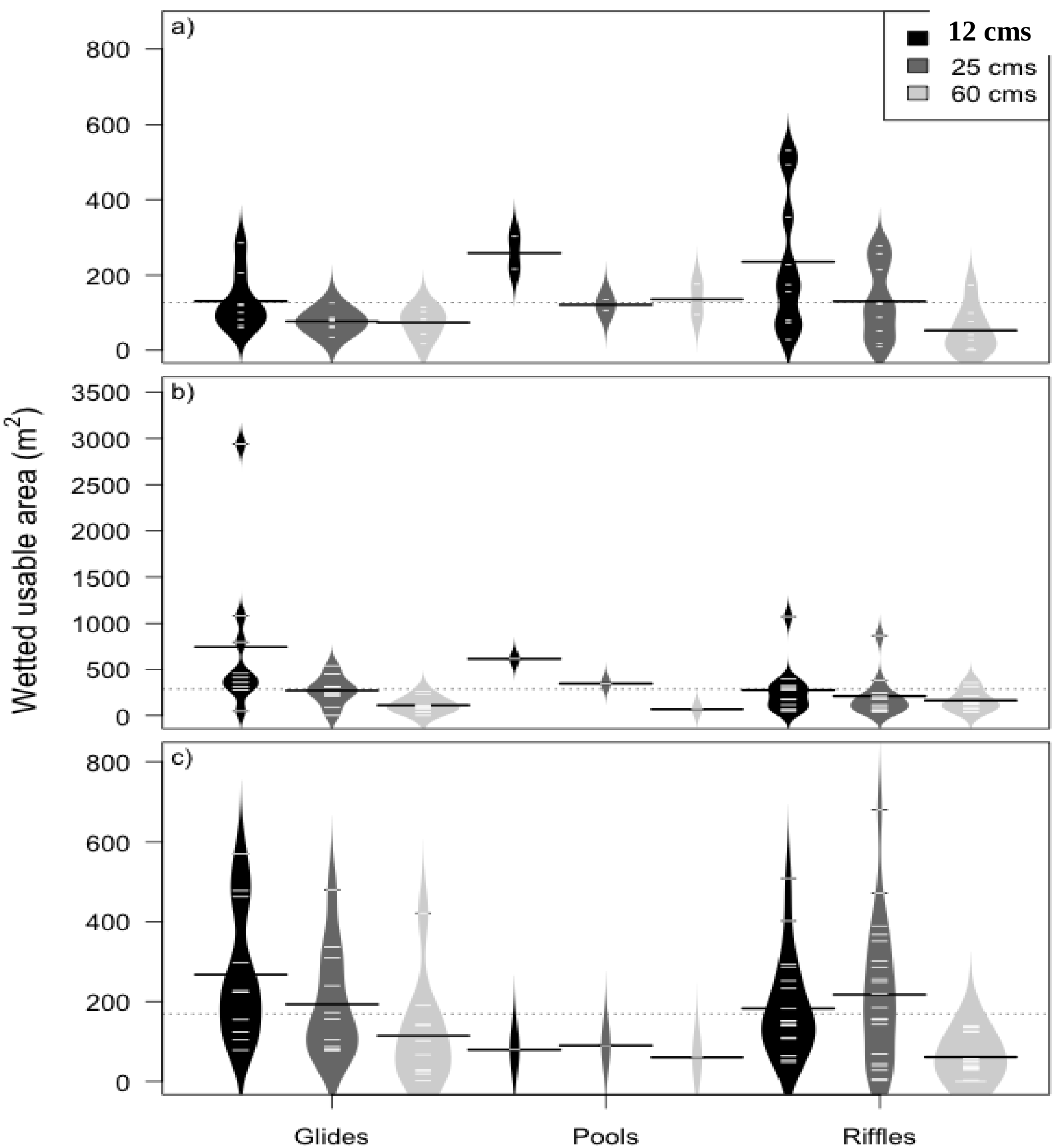


Figure 19. Coho juvenile % WUA of glide, pool, riffle habitat in reaches 1 (a, b & c), 2 (d, e & f) and 3 (g, h & i) of Seton River (2014 and 2015) at various discharges.

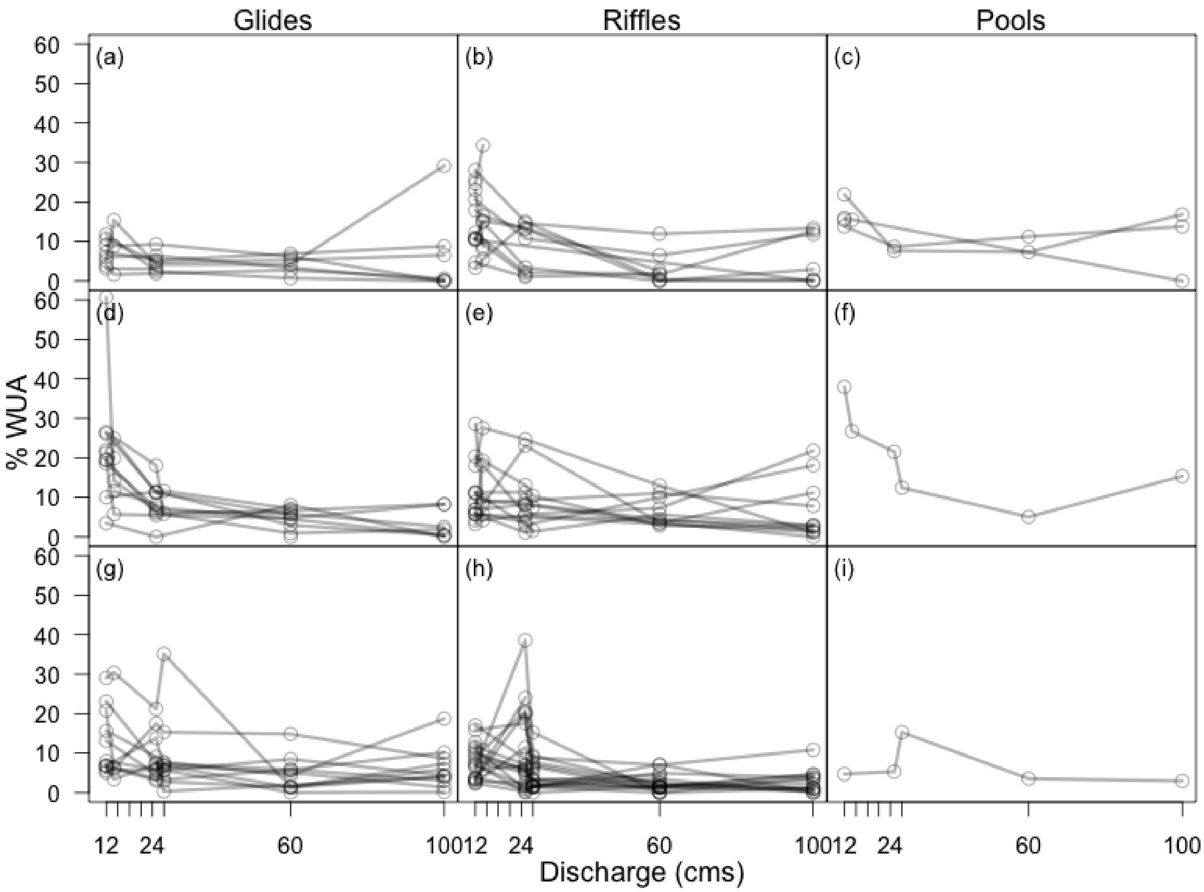


Figure 20. Seton River juvenile Coho total Weighted Useable Area (WUA), 2014 & 2015. Black lines represent the mean of all points, the modes represent the distribution of the data and the white lines represent individual sites. The broken horizontal line represents the mean of all data points.

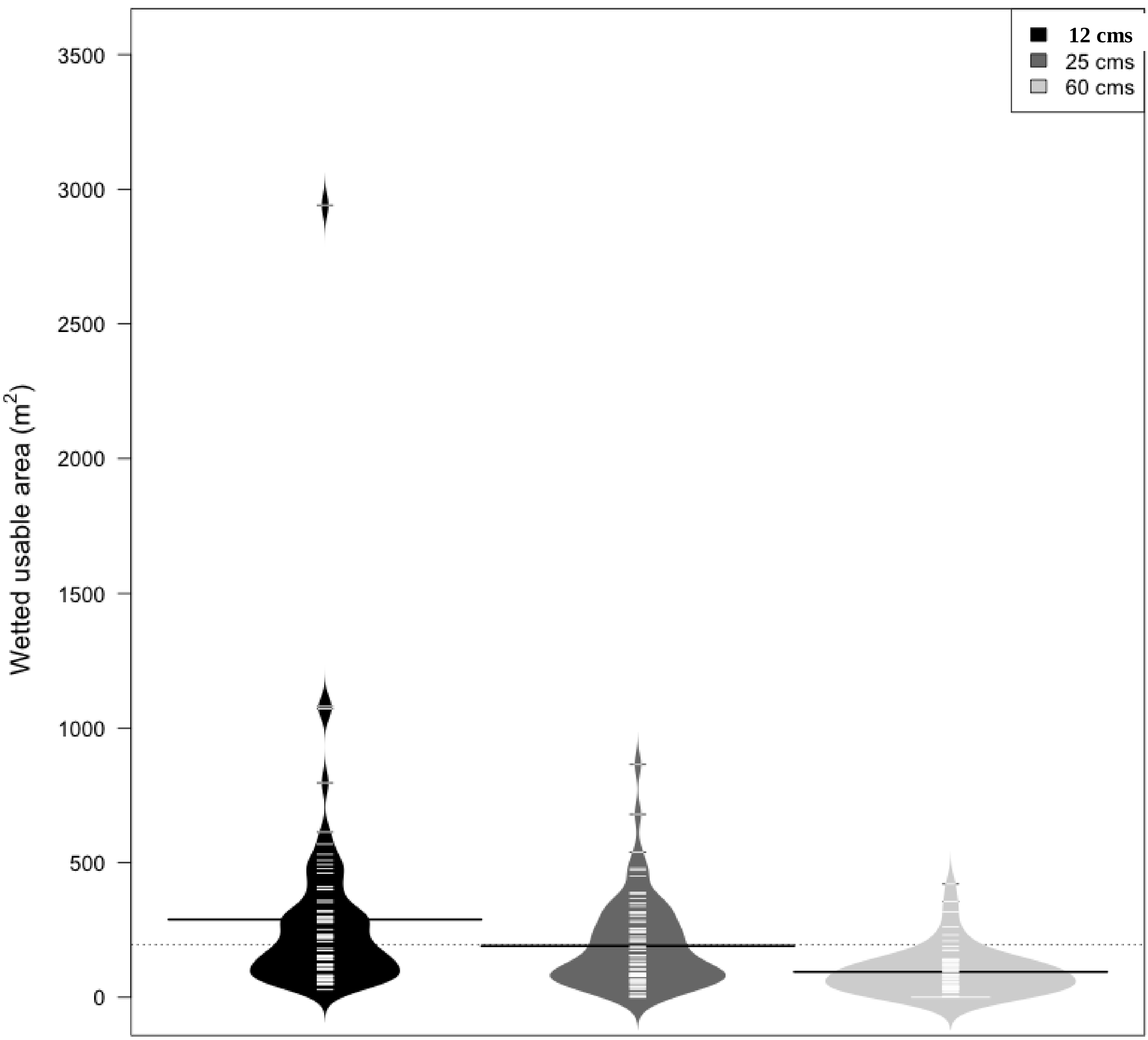


Figure 21. Chinook juvenile total Weighted Useable Area (WUA) in glide, pool and riffle habitats of reach 1 (a), reach 2 (b) and reach 3(c) of Seton River at 12, 25 and 60 m3/s (2014 and 2015). Black lines represent the mean of all points, the modes represent the distribution of the data and the small white lines represent individual data points. The broken horizontal line represents the mean of all data points for each reach.

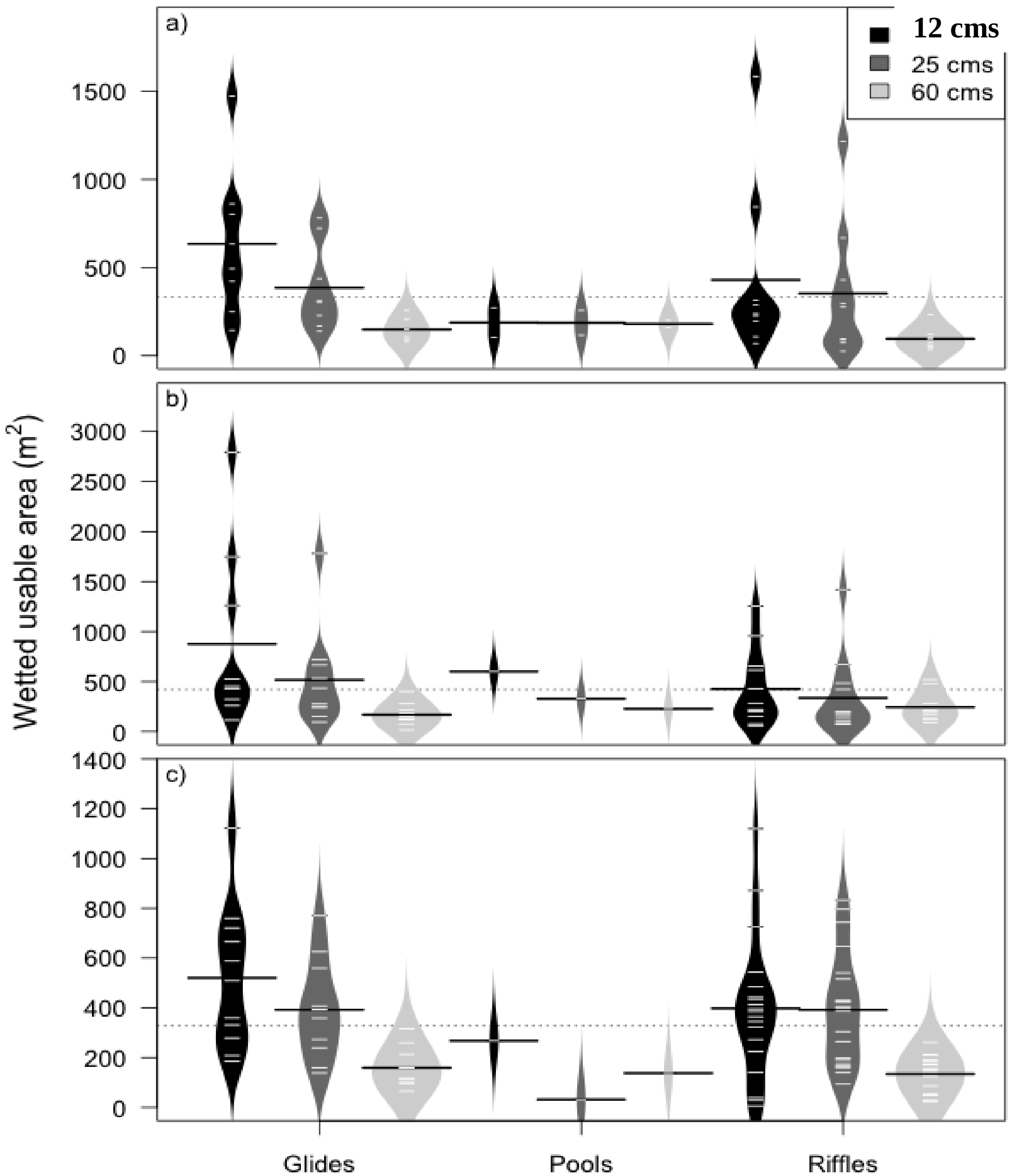


Figure 22. Chinook juvenile % WUA of glide, pool, riffle habitat in reaches 1 (a, b & c), 2 (d, e & f) and 3 (g, h & i) of Seton River (2014 and 2015) at various discharges.

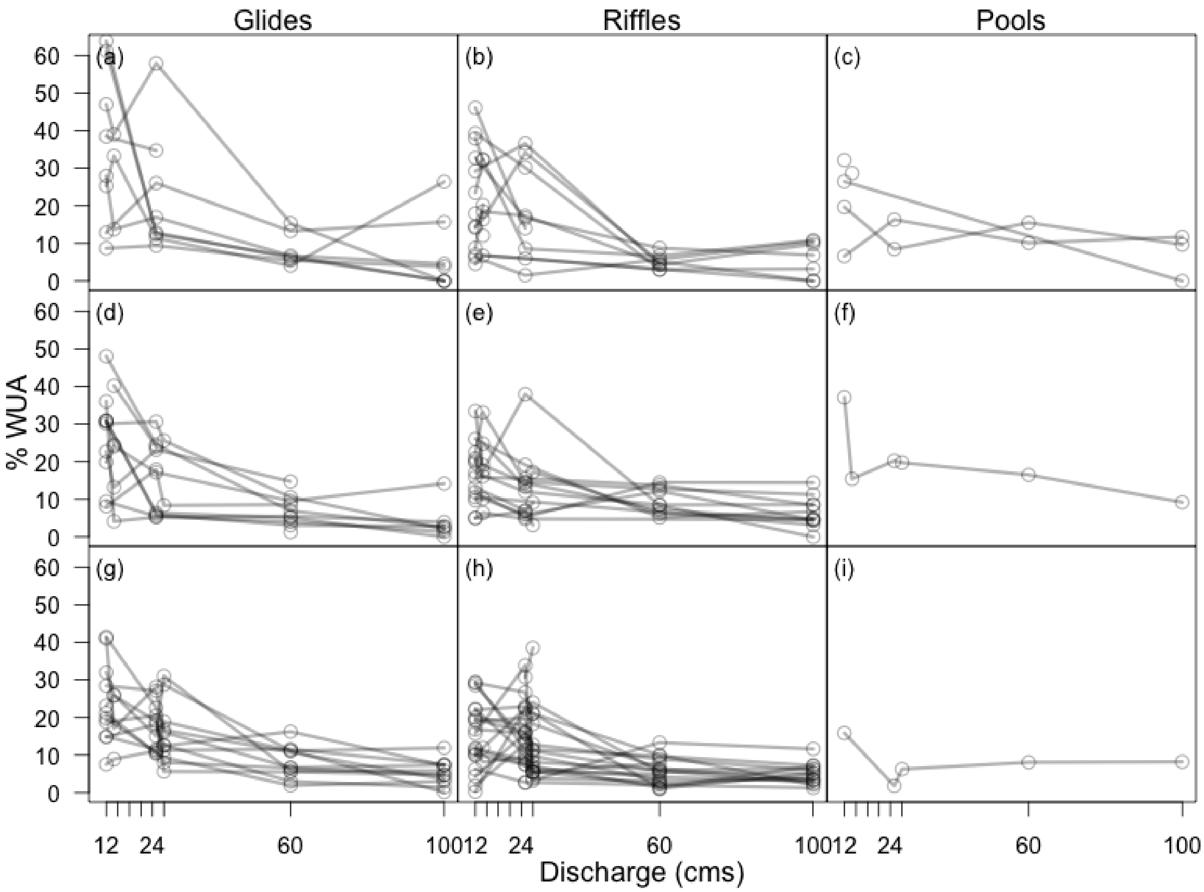


Figure 23. Seton River juvenile Chinook total Weighted Useable Area (WUA), 2014 & 2015. Black lines represent the mean of all points, the modes represent the distribution of the data and the white lines represent individual sites. The broken horizontal line represents the mean of all data points.

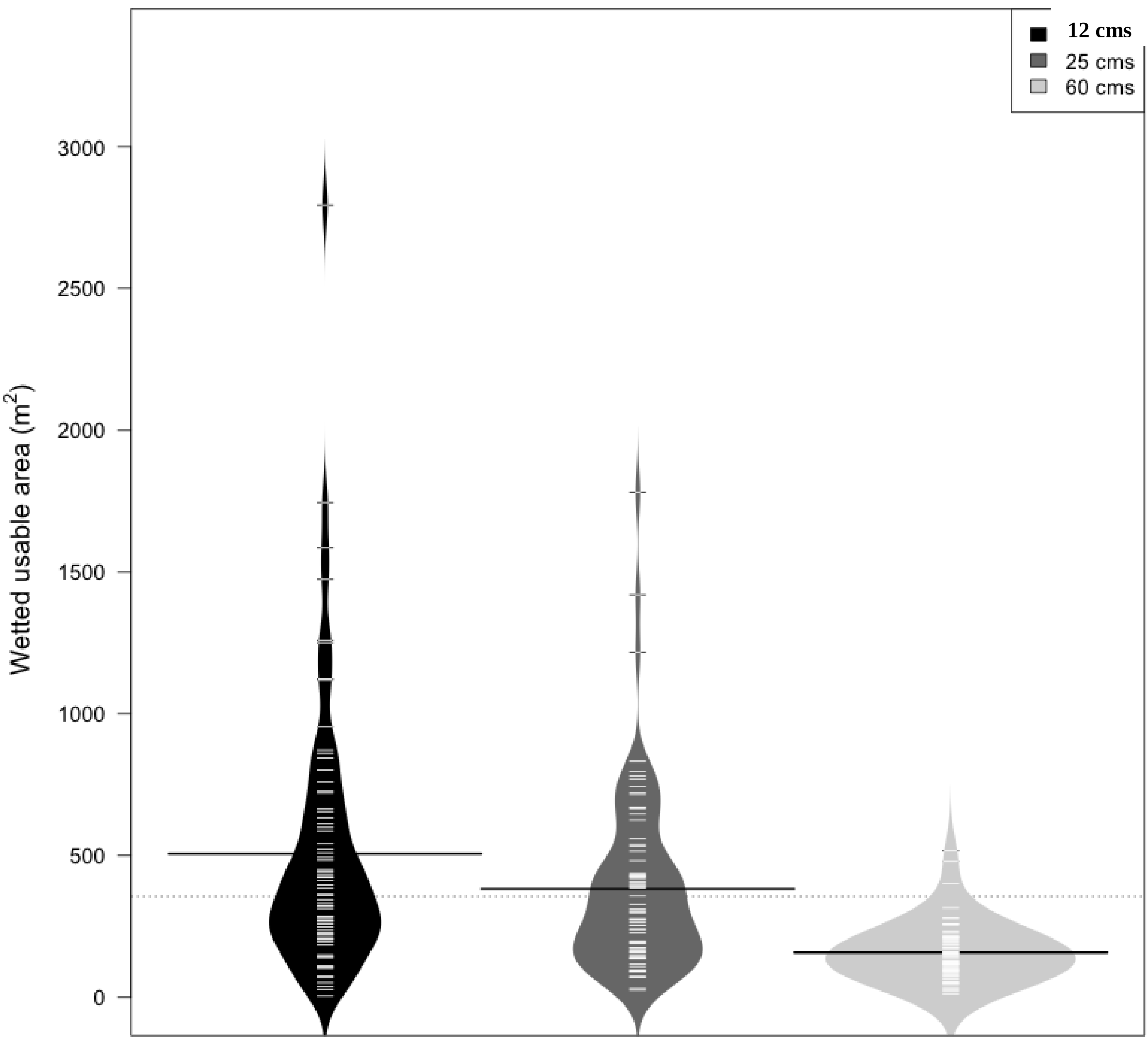


Figure 24. Length at age frequency distributions for Seton River Rainbow Trout April to October 2015.

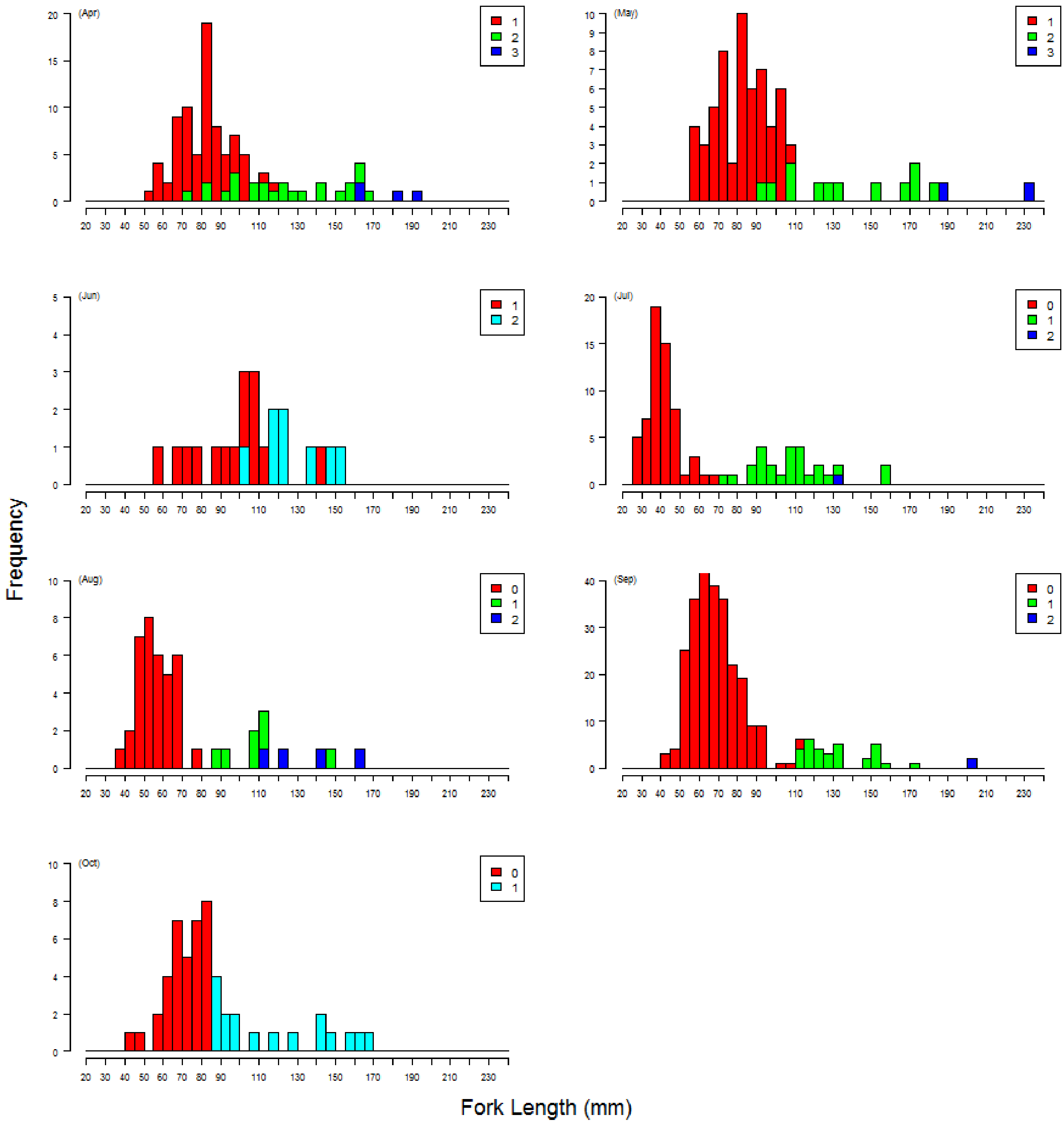


Figure 25. Length-at-age for Seton River Rainbow Trout sampled in April 2015. Mean lengths-at-age connected by blue line.

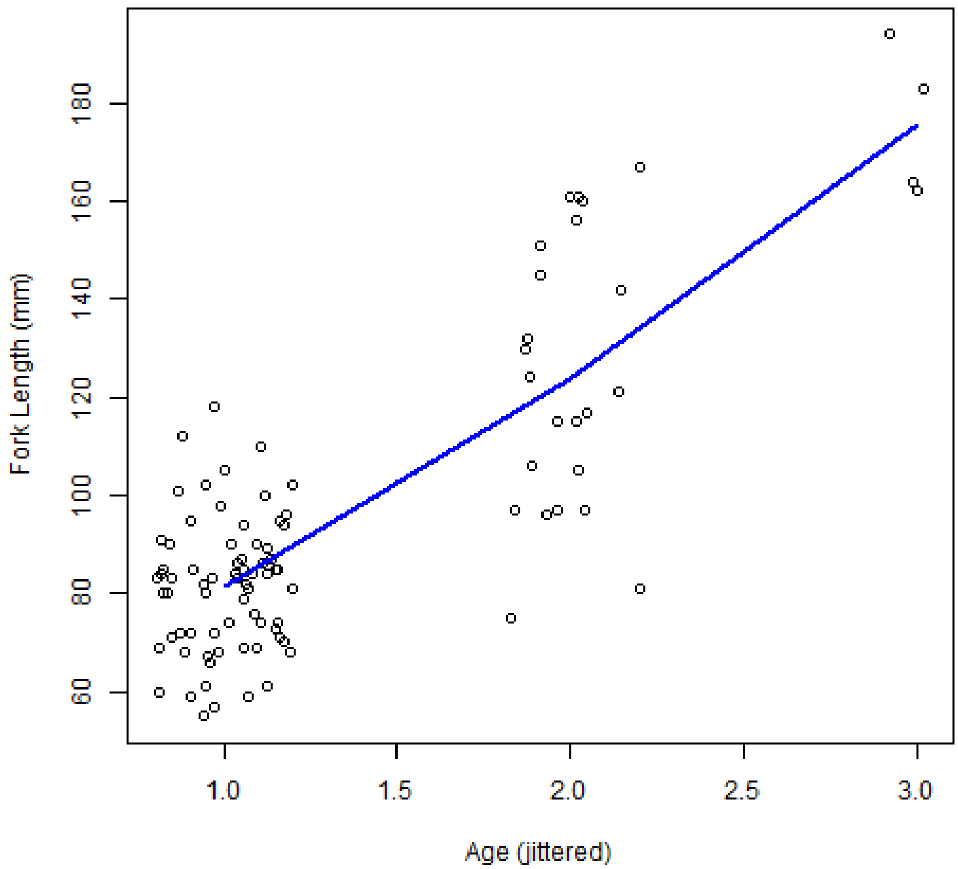


Figure 26. Length-at-age for Seton River Rainbow Trout sampled in July 2015. Mean lengths-at-age connected by blue line.

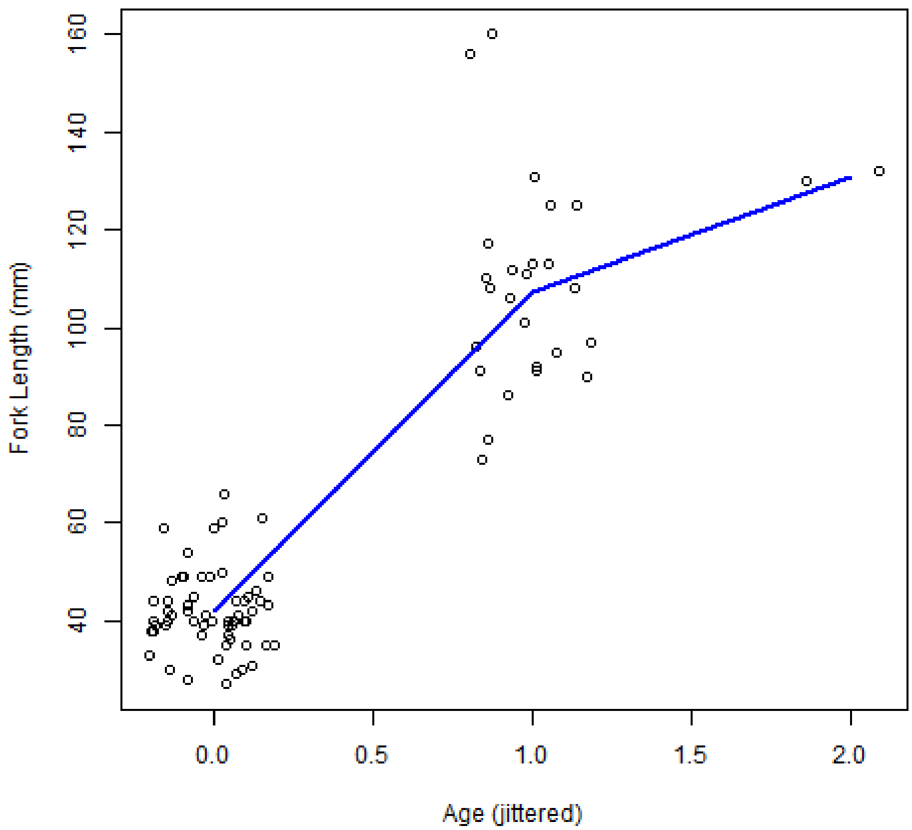


Figure 27. Length-at-age for Seton River Rainbow Trout sampled in October 2015. Mean lengths-at-age connected by blue line.

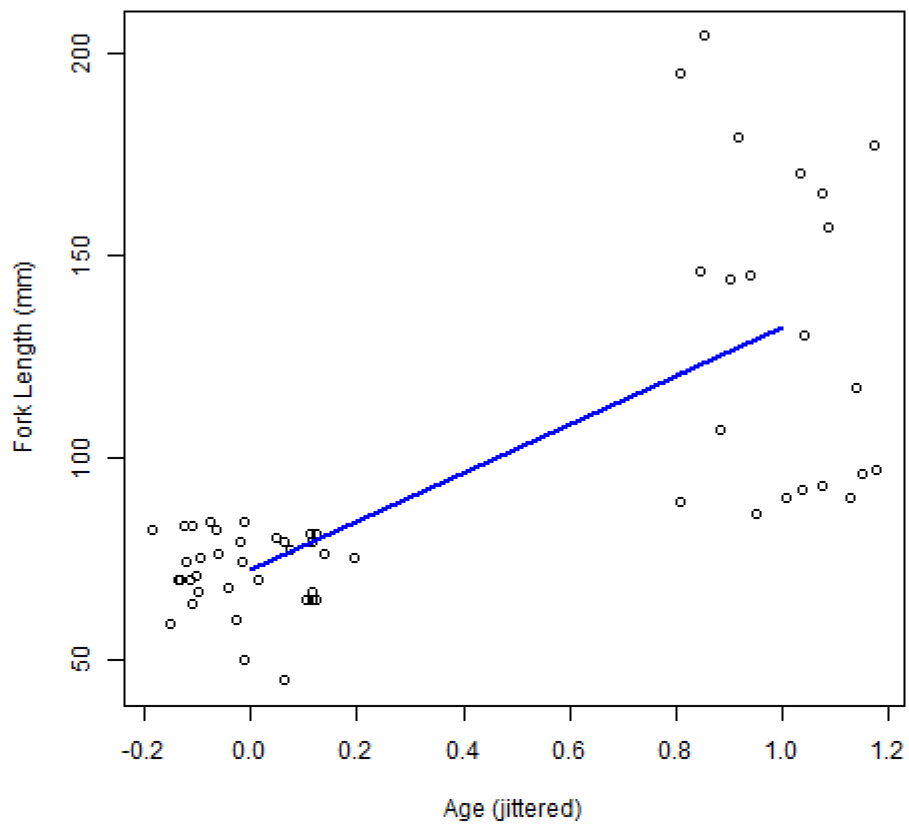


Figure 28. Weight, length relationship for Seton River Rainbow Trout sampled in 2015

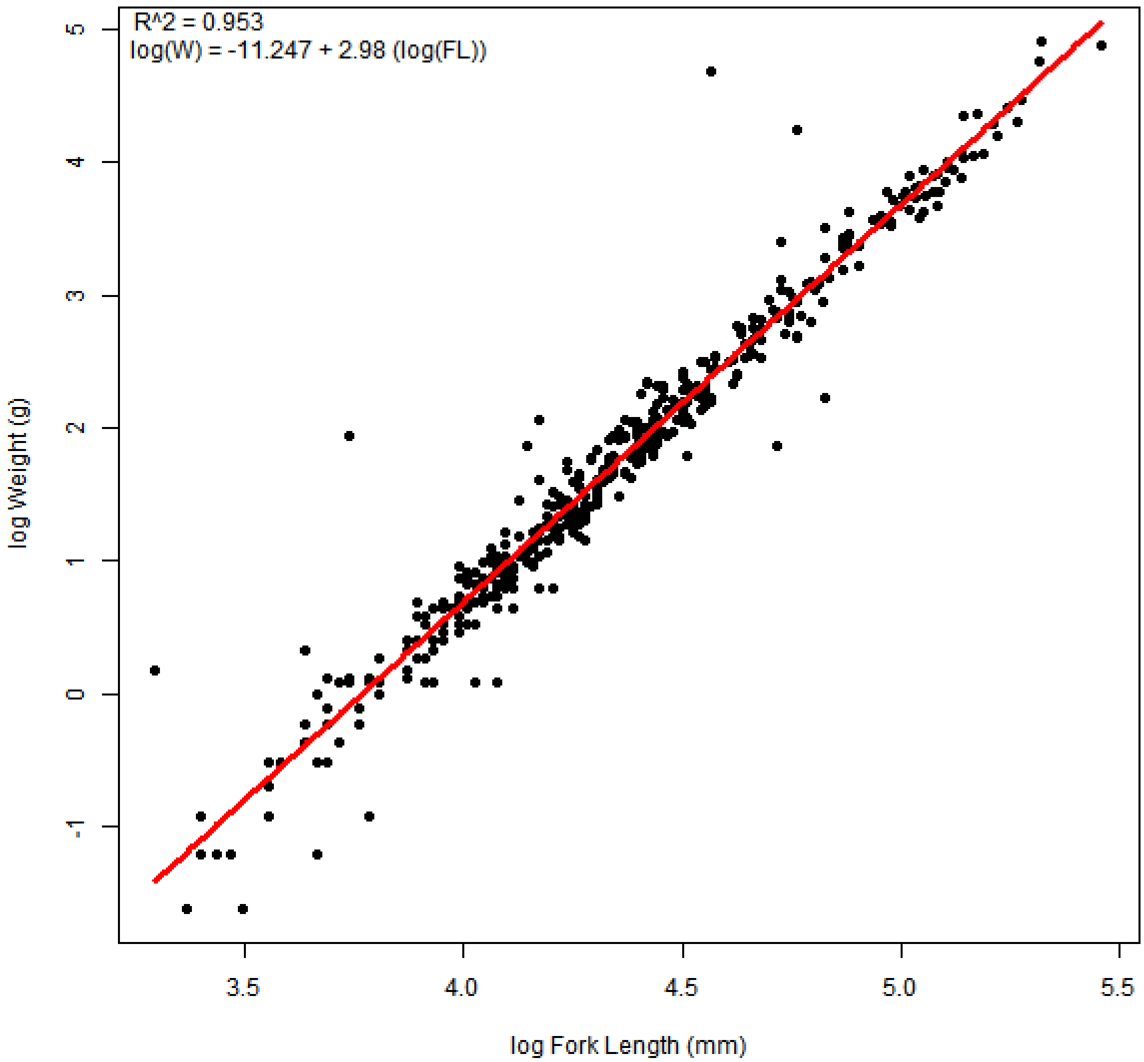


Figure 29. Length boxplot of Seton River age 0 Rainbow Trout from July -October 2015

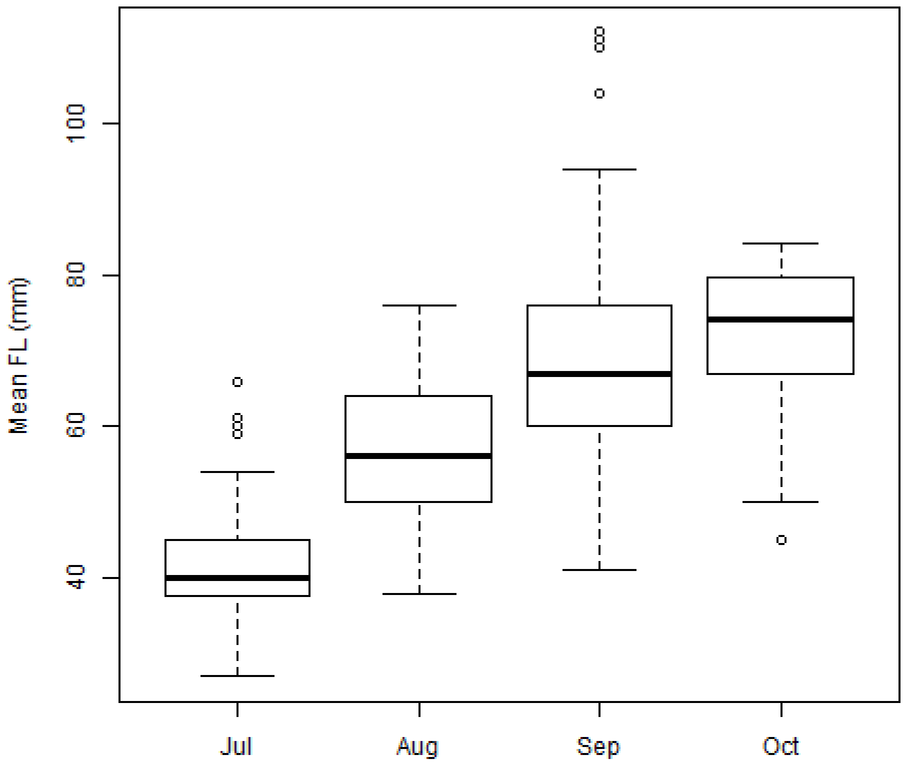


Figure 30. Weight boxplot of Seton River age 0 Rainbow Trout from July - October 2015

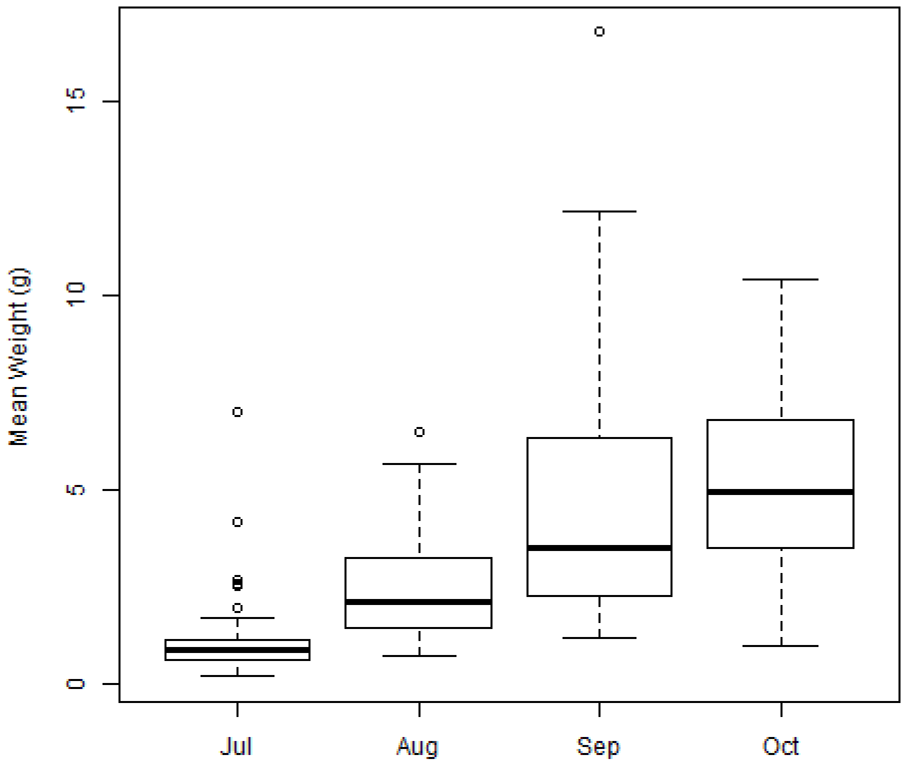


Figure 31. Length boxplot of Seton River age 1 Rainbow Trout from April -October 2015

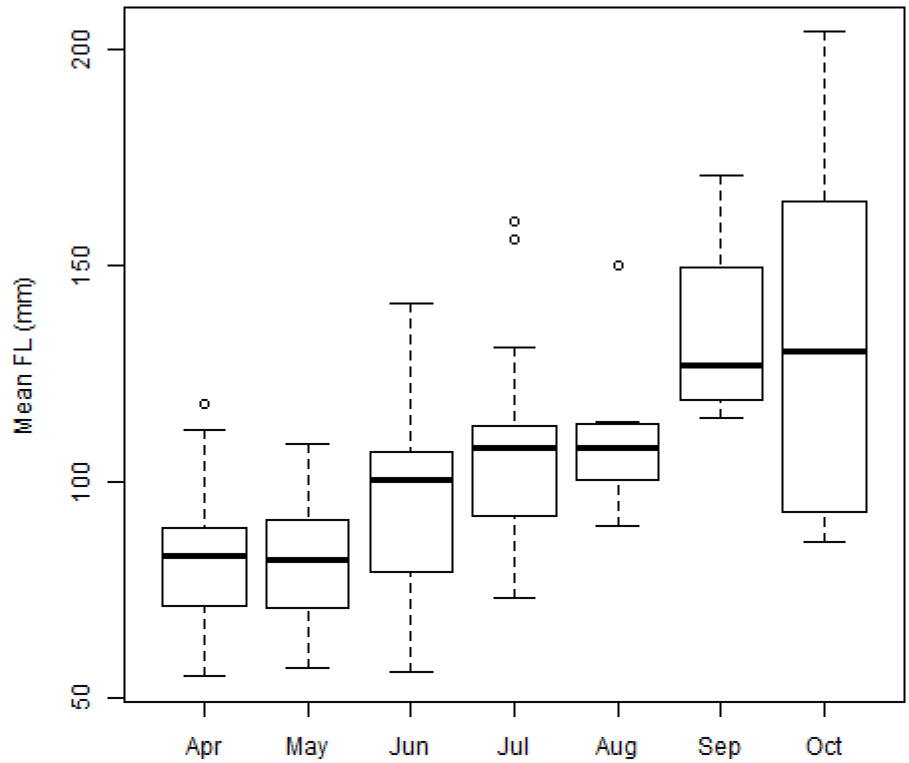


Figure 32. Weight boxplot of Seton River age 1 Rainbow Trout from April -October 2015.

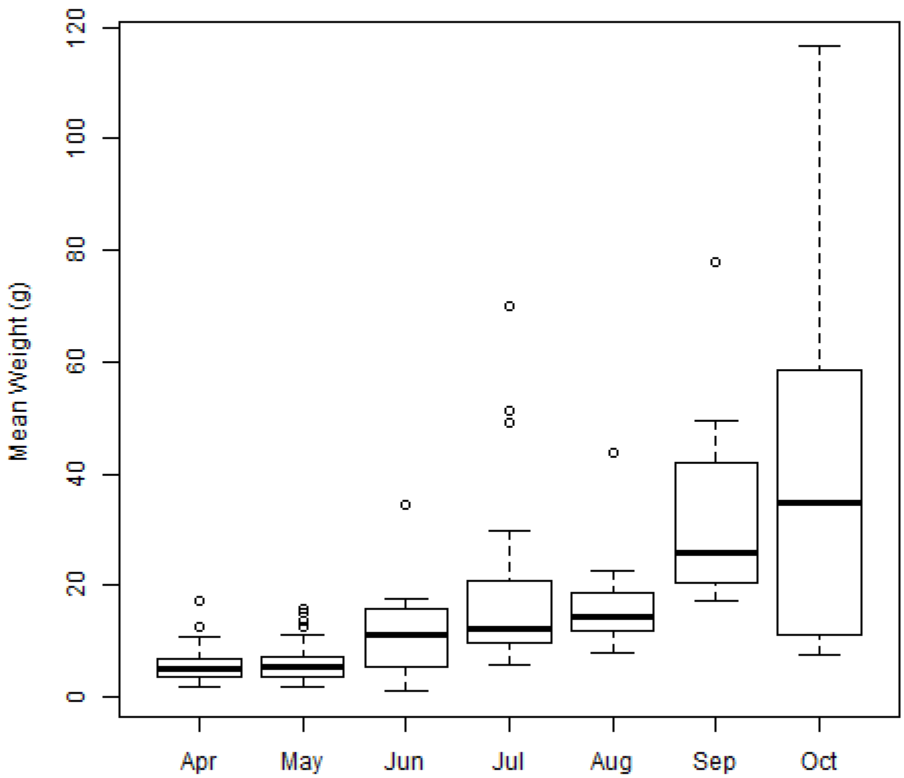


Figure 33. Length boxplot of Seton River age 2 Rainbow Trout, 2015.

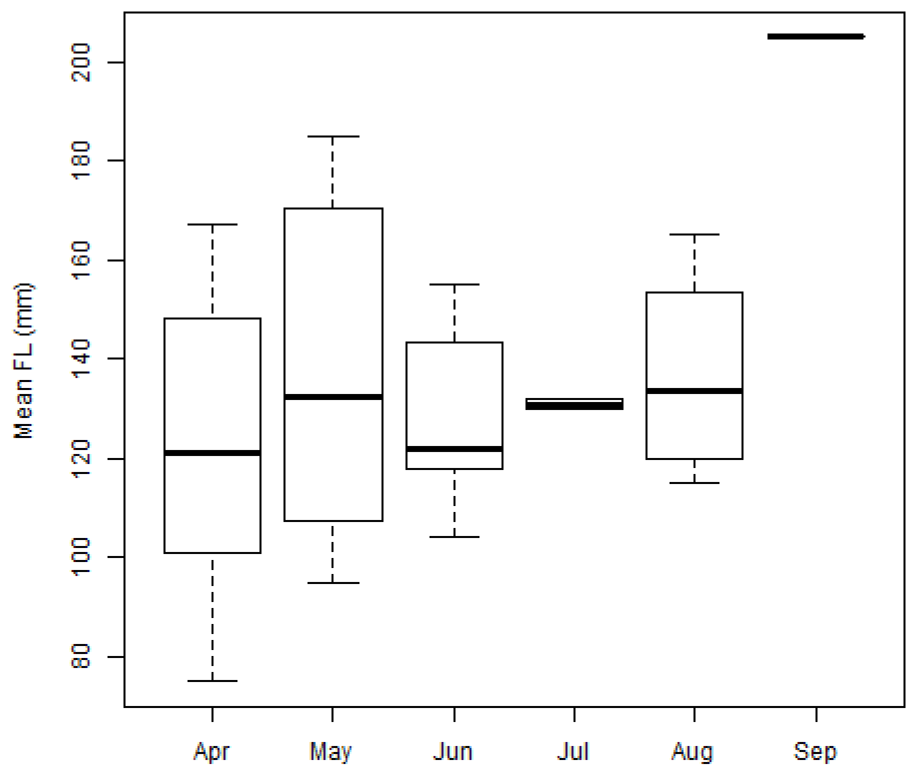


Figure 34. Weight boxplot of Seton River age 2 Rainbow Trout, 2015.

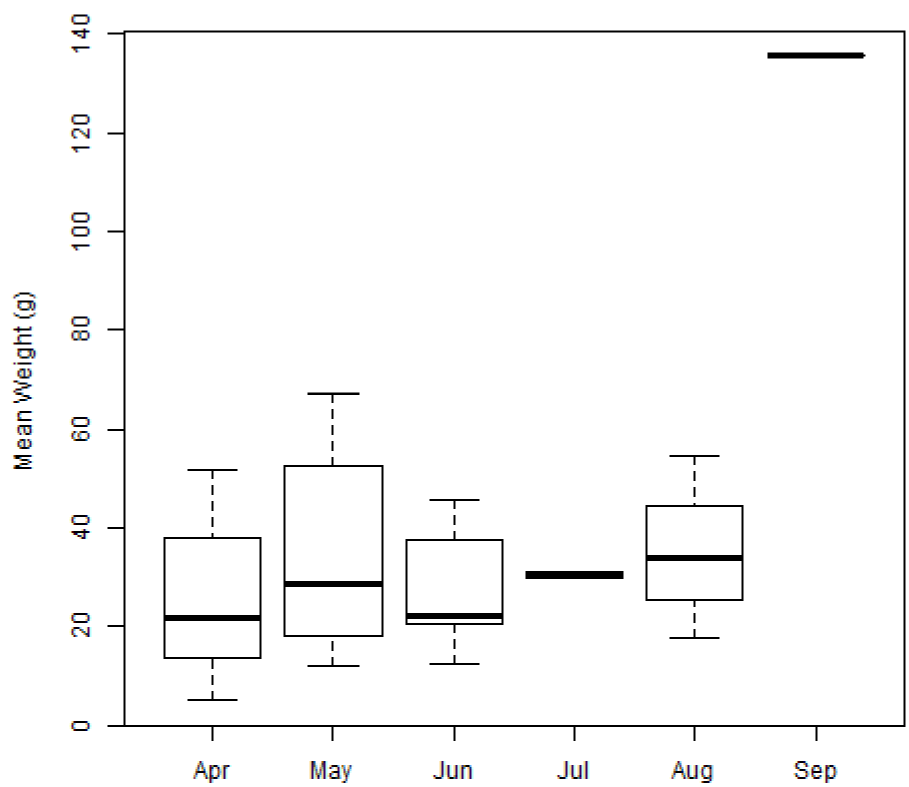


Figure 35. Growth of PIT-tagged juvenile rainbow trout from April to October 2015. Each panel represents the growth of an individual fish. LSC and USC are the Lower and Upper Spawning Channels, respectively.

Figure 36. Length and age frequency for Seton River juvenile Coho in 2015,

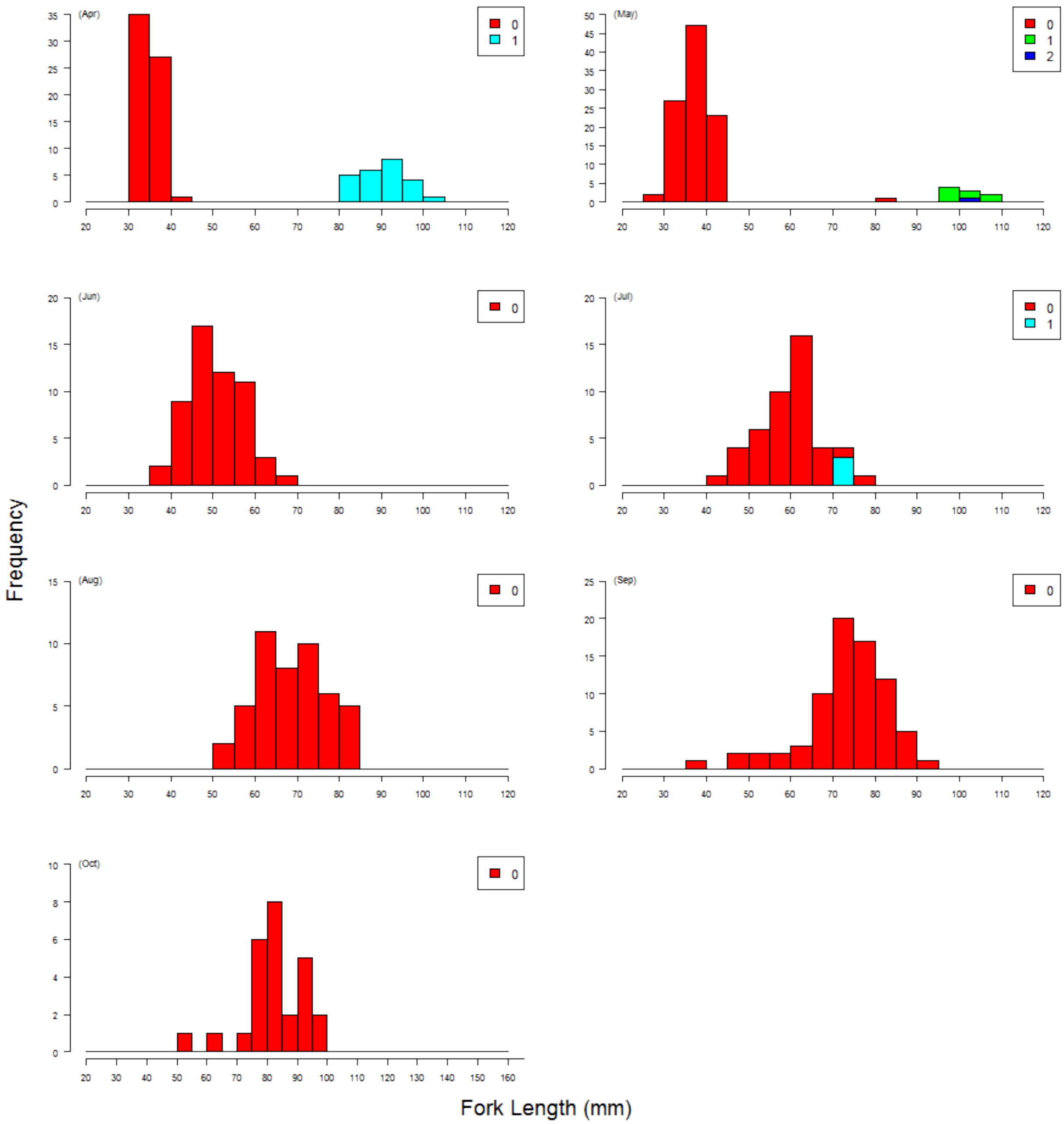


Figure 37. Weight, length relationship for Seton River juvenile Coho salmon sampled in 2015.

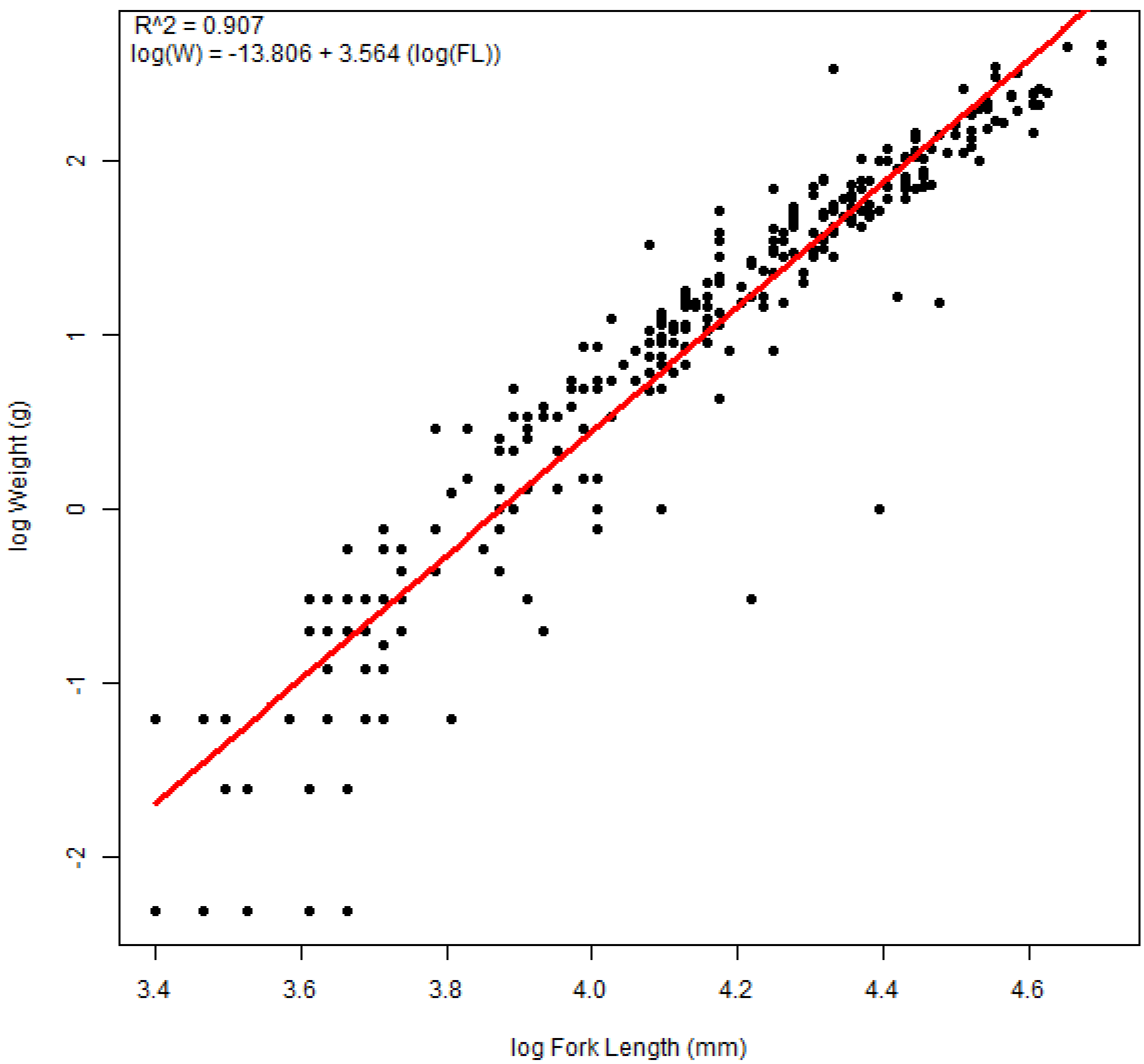


Figure 38. Length boxplot of Seton River age 0 Coho from April -October 2015.

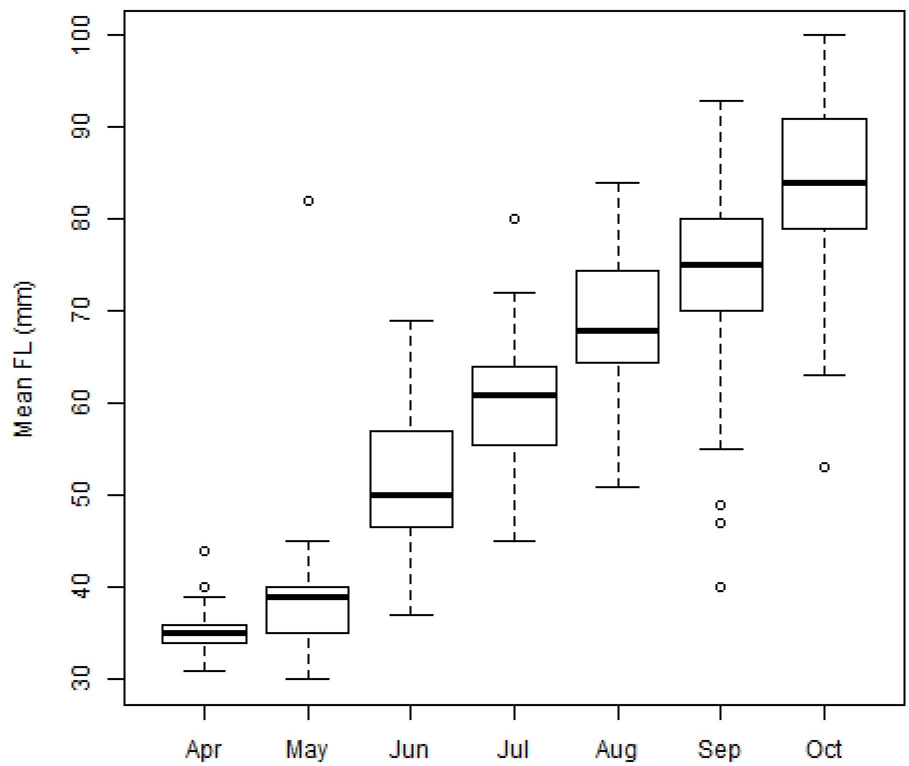


Figure 39. Weight boxplot of Seton River age 0 Coho from April -October 2015.

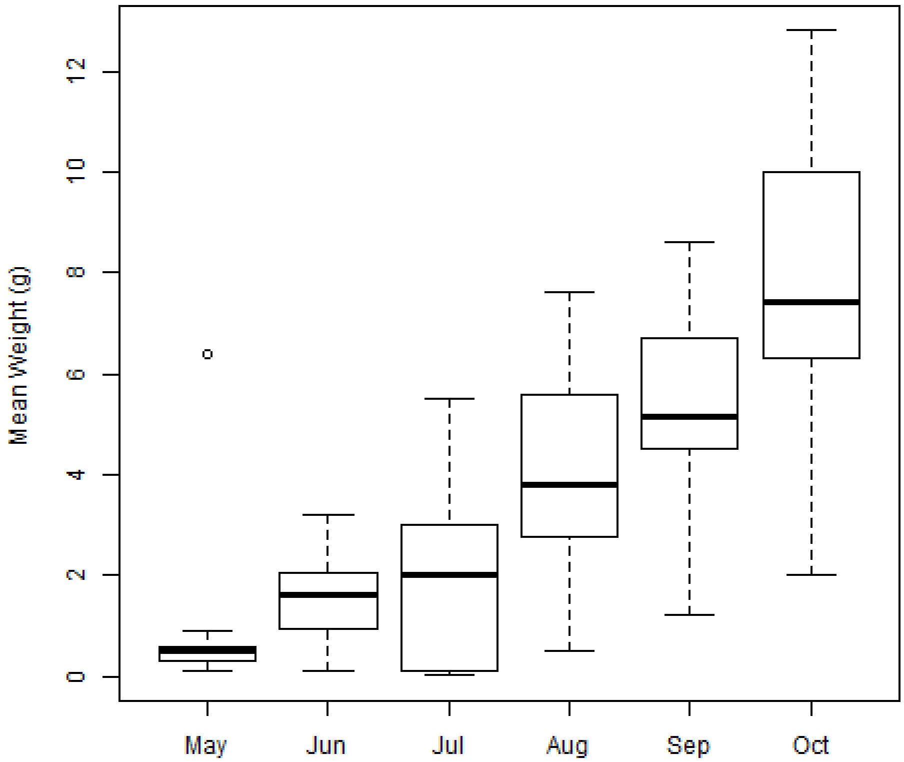


Figure 40. Length and age frequency for Seton juvenile Chinook in 2015.

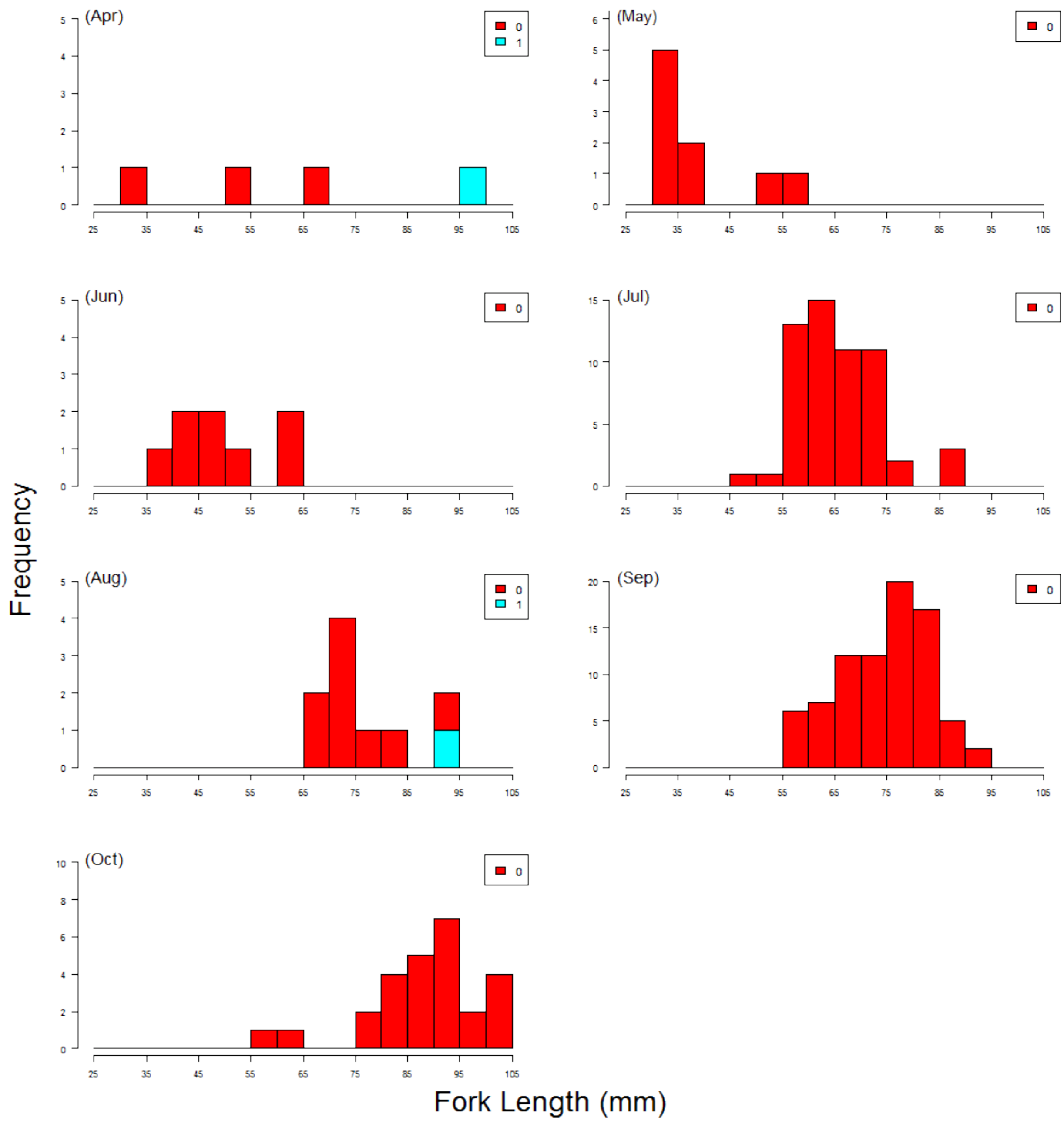


Figure 41. Weight, length relationship for Seton River juvenile Chinook salmon sampled in 2015.

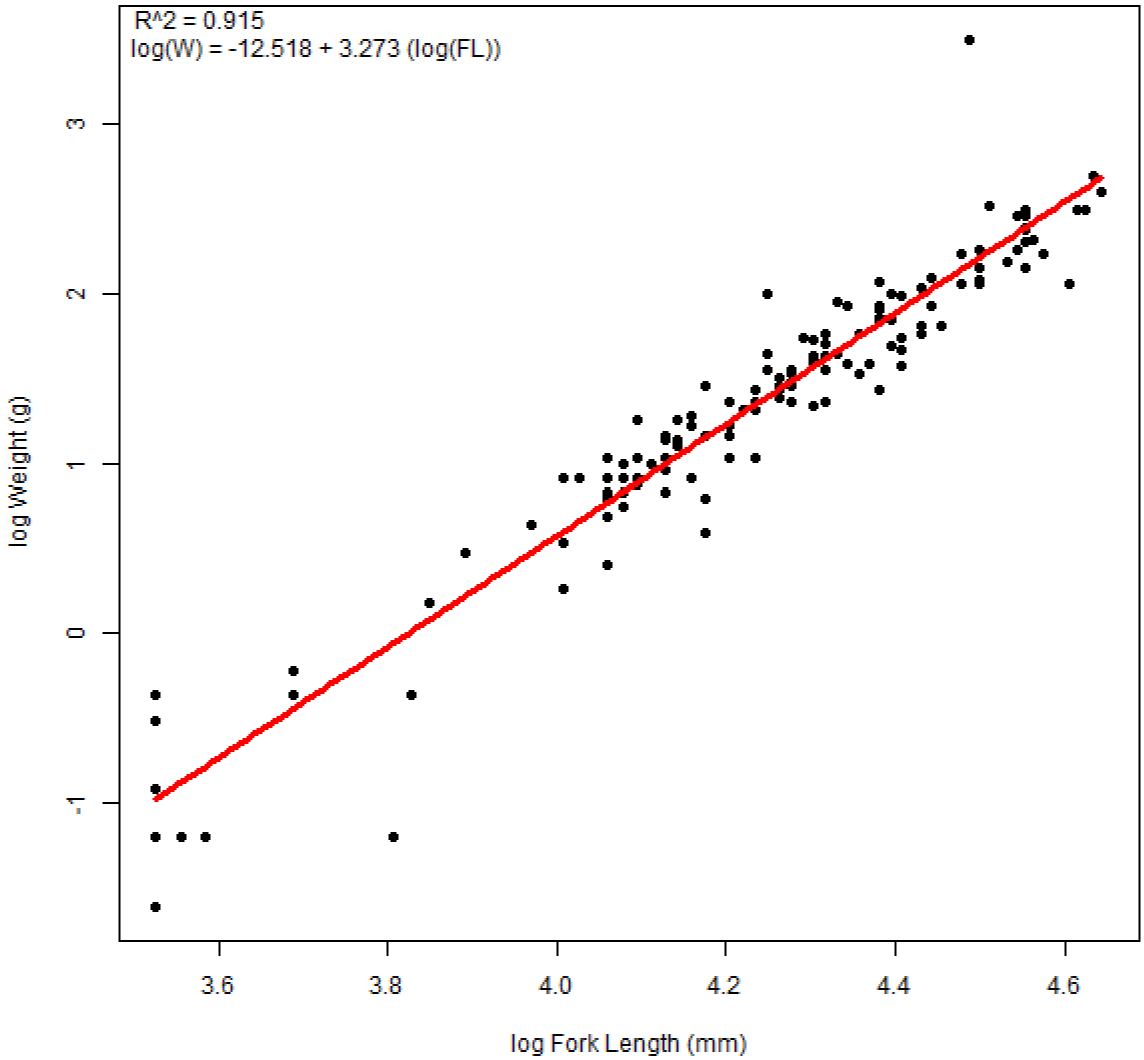


Figure 42. Length boxplot of Seton River age 0 Chinook from April -October 2015.

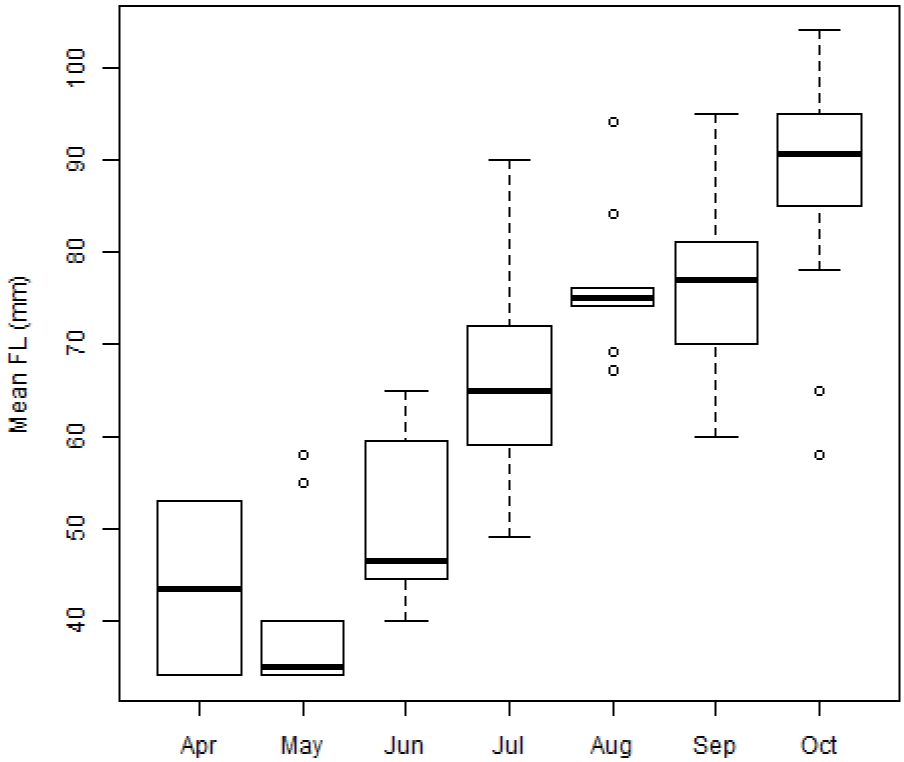


Figure 43. Weight boxplot of Seton River age 0 Chinook from April -October 2015.

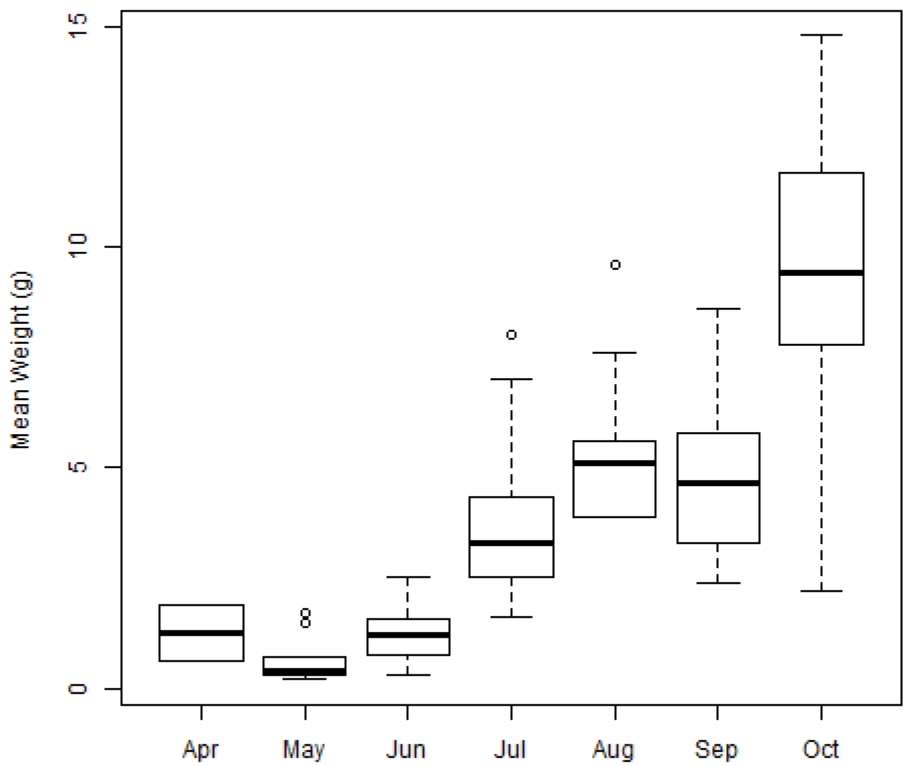


Figure 44. Posterior distributions for capture probability at mark recapture sites, Seton River 2015

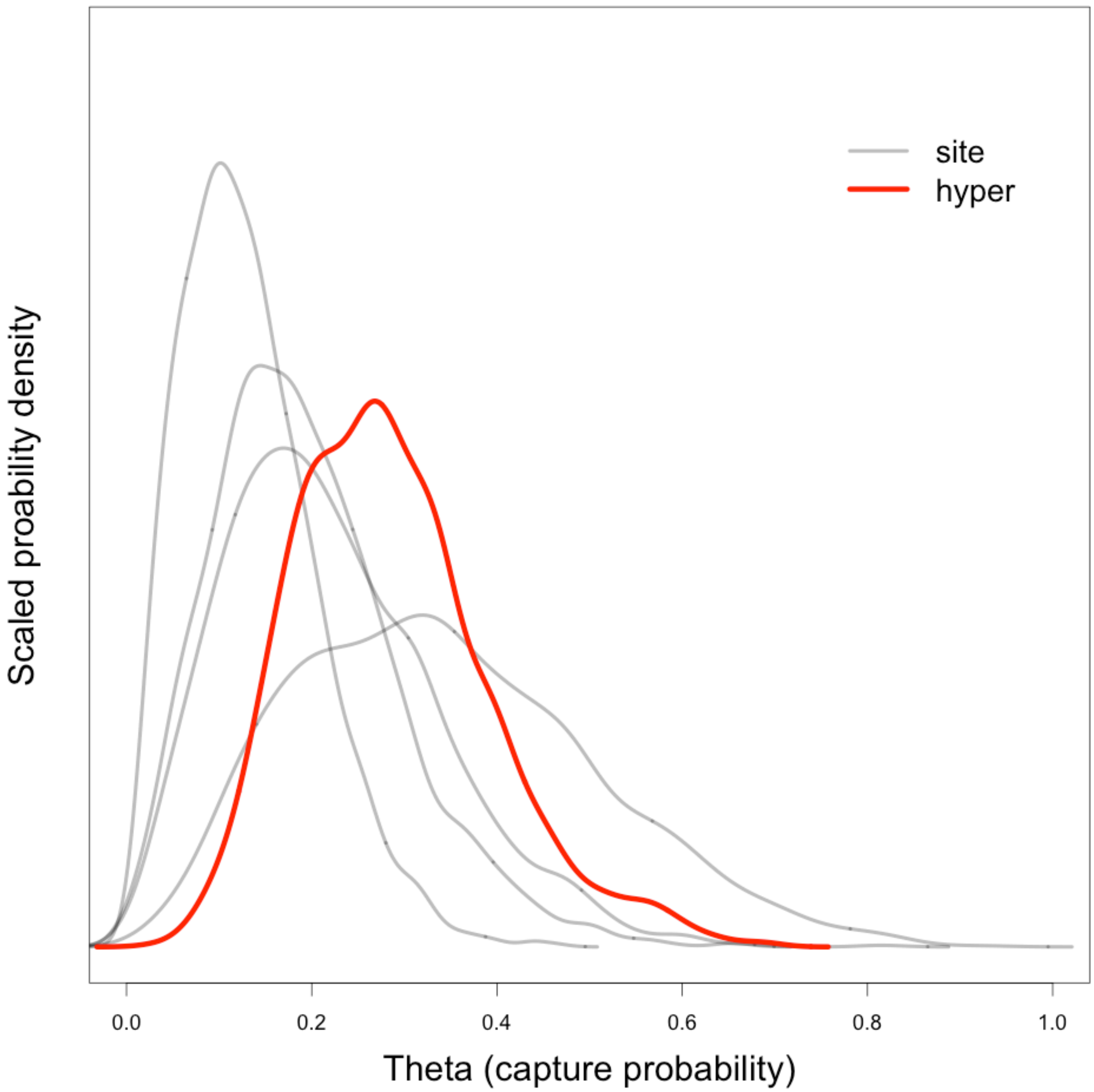


Figure 45. Seton River age 0 Rainbow Trout abundance estimates - Fall 2015. Grey circles represent 2014 densities and black circles represent 2015 densities.

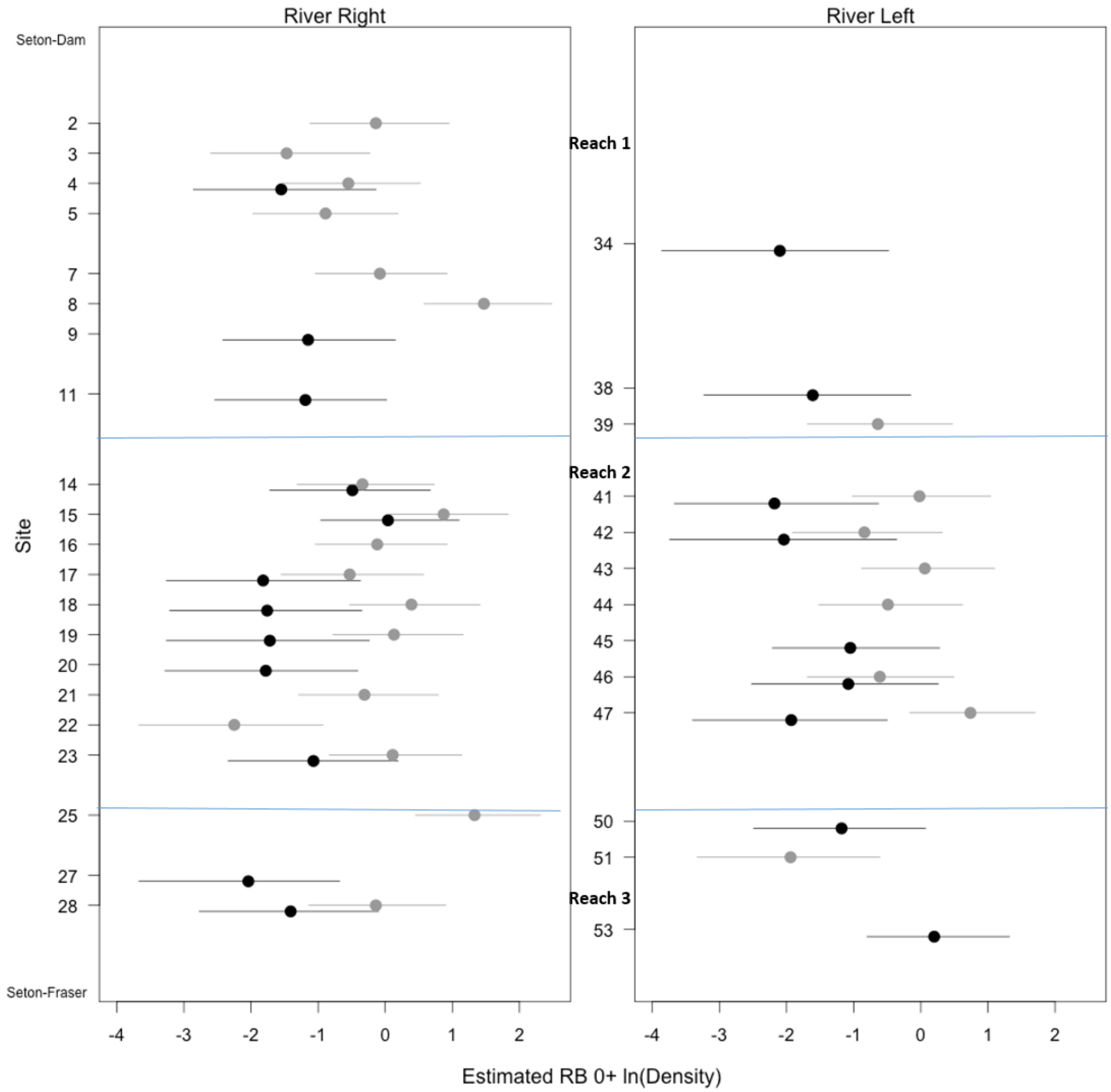

River Right
River Left
Seton-Dam
Seton-Fraser
Reach 1
Reach 2
Reach 3
Site
2
3
4
5
7
8
9
11
14
15
16
17
18
19
20
21
22
23
25
27
28
34
38
39
41
42
43
44
45
46
47
50
51
53
-4
-3
-2
-1
0
1
2
Estimated RB 0+ ln(Density)

Figure 46. Seton River Pink Salmon spawner abundance estimates - 2015.

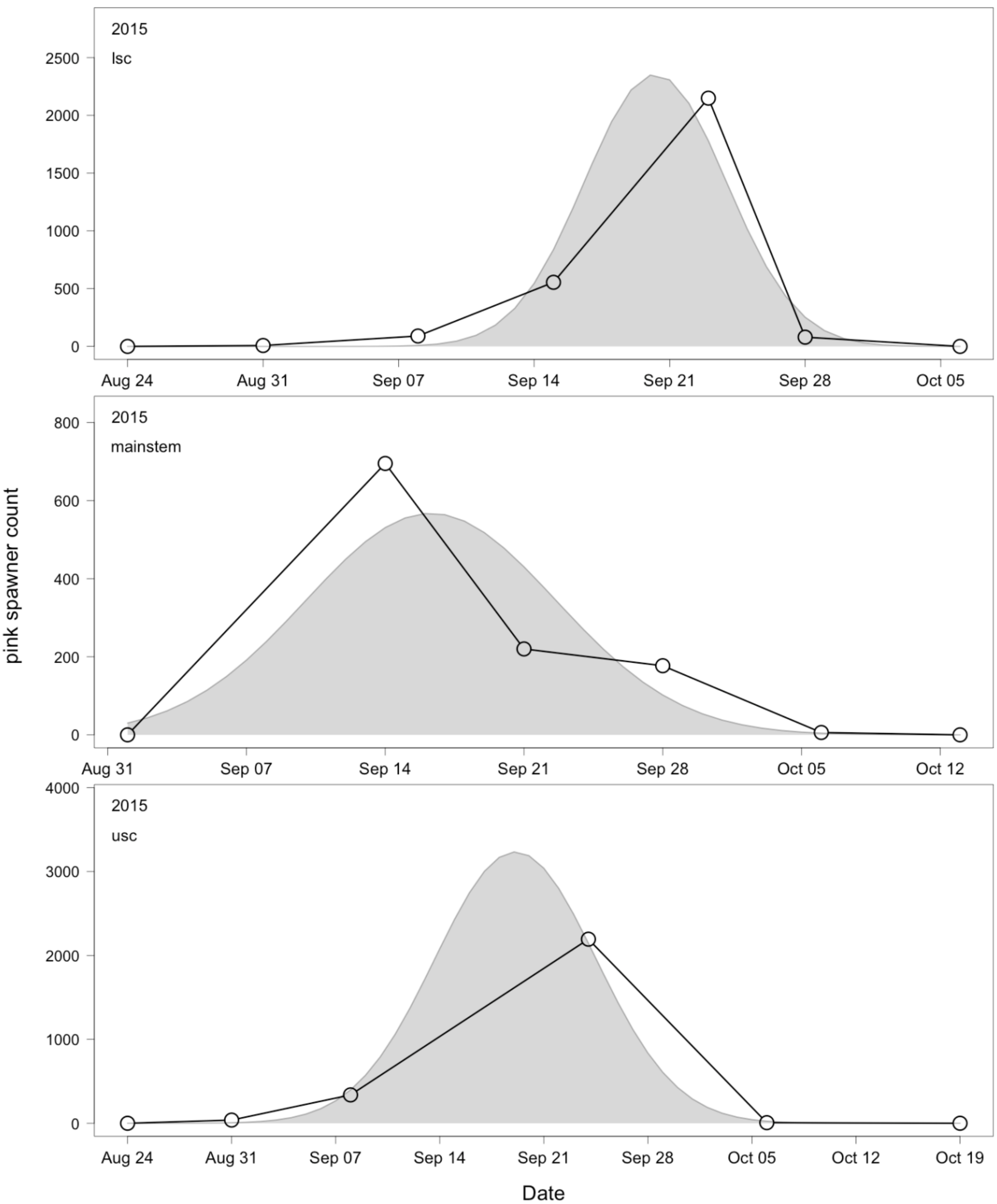


Figure 47. Fraser River discharge at Water survey of Canada Texas Creek gauge (08MF040) – March 23, 2015

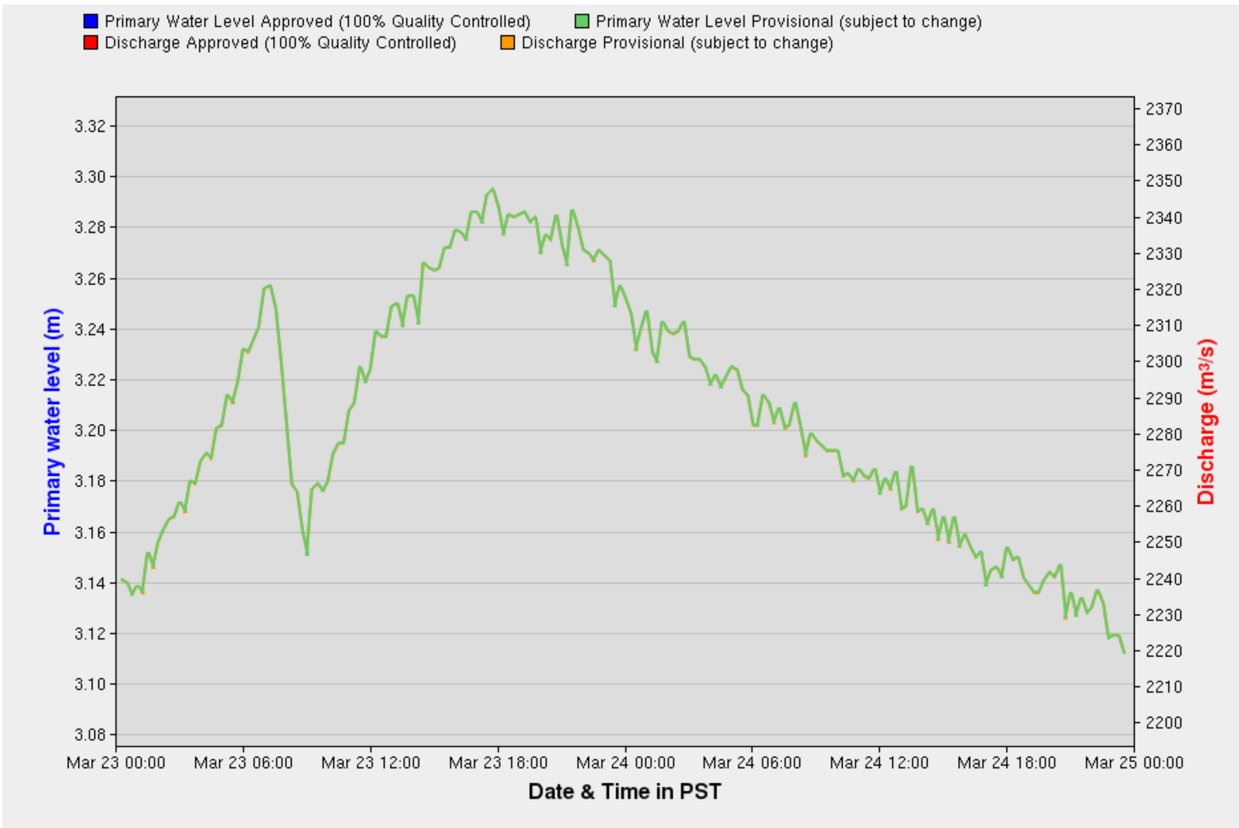


Figure 48. Streambed elevation (m) in the Seton River in 2013 (top panel) and 2015 (bottom panel). Dots represent individual measurement points along 18 transects (T1 to T18).

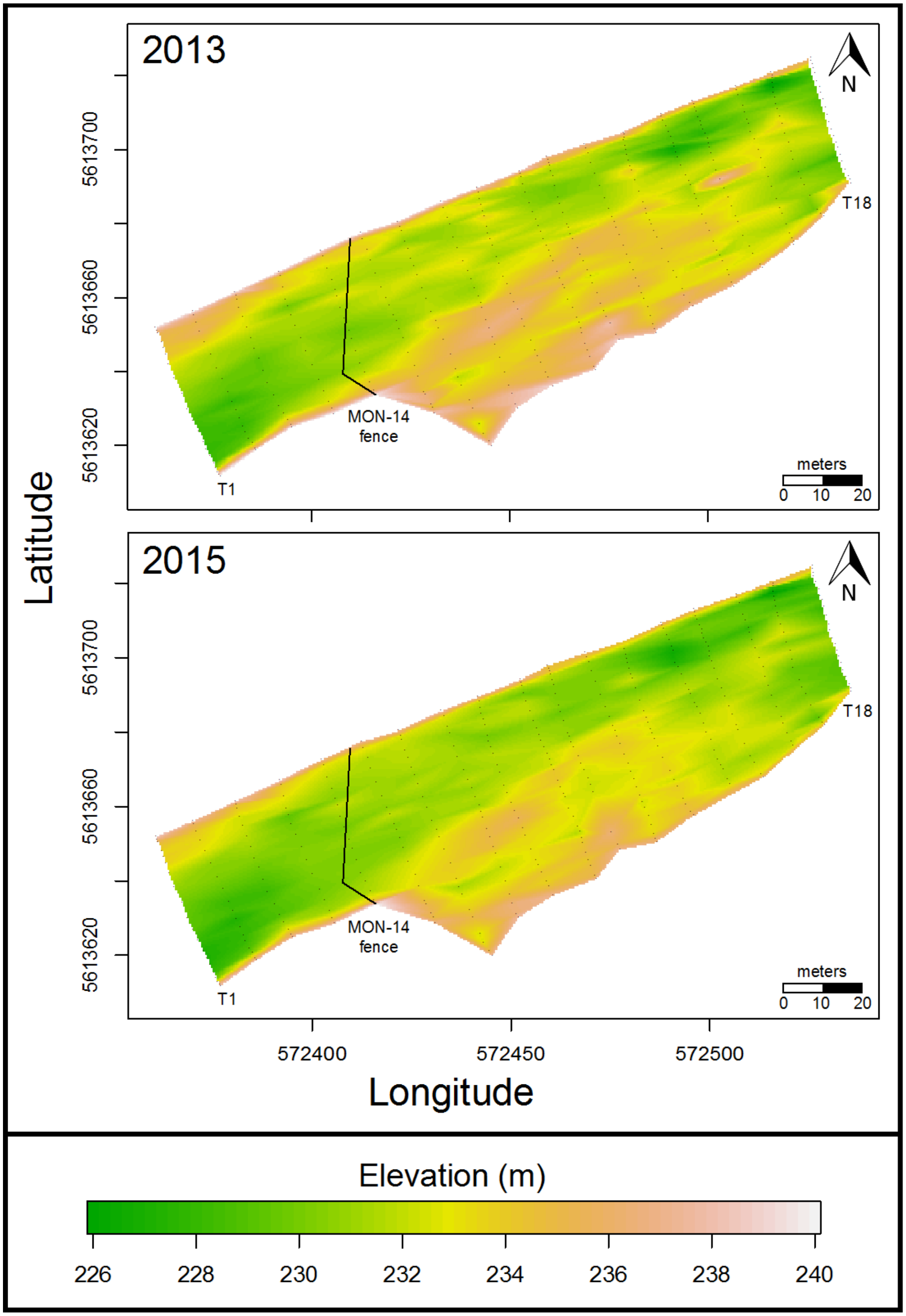
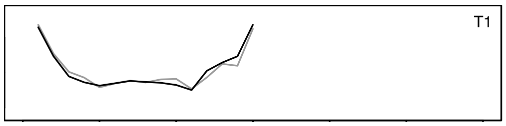
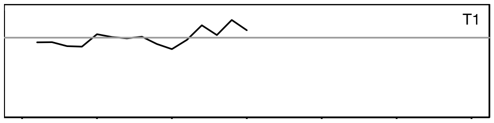


Figure 49. Streambed elevation (m) in the Seton River in 2013 (grey) and 2015 (black). Each panel represents an individual transect (T1 to T18).



8

Figure 50. Change in streambed elevation (m) in the Seton River from 2013 to 2015. Positive and negative changes correspond to deposition and erosion, respectively. Grey lines indicate where streambed elevation has not changed. Each panel represents an individual



8.0 REFERENCES

Bovee, K.D. 1986. Development and evaluation of habitat suitability criteria for use in the Instream Flow Incremental Methodology. Instream Flow Information Paper 21. U.S. Fish and Wilflife Service Biological Report 86(7). 235 pp

Braun, D., Bison, R., Ladell, J., and McCubbing, D.J.F. 2016. Fish Counter Enumeration of Steelhead and Rainbow Trout on the Bonaparte River, 2014. Report prepared for Forests, Lands and Natural Resource Operations, Fish and Wildlife - Kamloops. 19 p

Donahue, B., J. Wentzel, and R. Berg. 2013. Guidelines for RTK/RTN GNSS Surveying in Canada. Natural Resources Canada, Earth Sciences Sector, Surveyor General Branch. Version 1.1.

Hagen, J., S. Decker, J. Korman, and R. G. Bison. 2010. Effectiveness of night snorkeling for estimating steelhead parr abundance in a large river basin. North American Journal of Fisheries Management 30:1303–1314.

Higgins, P.S. 2010 . Assessment of the Impact of the February 25, 2010. Seton Generation Station Shutdown on Fish and Fish Habitat in the Fraser River. Report prepared for BC Hydro, Generation Operations.

Hilborn, R., Bue, B.G., and S. Sharr. 1999. Estimating spawning escapements from periodic counts: acomparison of methods. Can J. Fish. Aquat. Sci. 56: 888-896.

Isermann, D. A. and C. T. Knight. 2005. A computer program for agelength keys incorporating age assignment to individual fish. North American Journal of Fisheries Management 25 : 1153-1160. 1, 2, 3

Johnston, N.T., and P.A. Slaney 1996. Fish Habitat assessment procedures. Province of BC Watershed Restoration Technical Circular No. 8: 97p

Jowett, I.G, 1997. Instream Flow Methods: A comparison of approaches. Regulated Rivers: Research & Management, VOL. 13, 115-127.

Korman, J., Decker, A. S., Mossop, B., & Hagen, J. (2010a). Comparison of Electrofishing and Snorkeling Mark–Recapture Estimation of Detection Probability and Abundance of Juvenile Steelhead in a Medium-Sized River. North American Journal of Fisheries Management, 30(5), 1280–1302. doi:10.1577/M09-159.1

Korman, J., Schick, J., & Clarke, A. (2010b). Cheakamus River Steelhead Juvenile and Adult Abundance Monitoring (pp. 1–224). Cheakamus Project Water Use Plan.

Ladell, J., Korman, J. & McCubbing D.J.F 2010. Cheakamus River Bull Trout Radiotelelmetry and Enumeration Program 2007-2009. Report prepared for Canadian National Railway Company, CN Environment. 124 pp.

Lewis, A., T. Hatfield, B. Chilibeck, and C. Roberts 2004. Assessment Methods for Aquatic Habitat and Instream Flow Characteristics in Support of Applications to Dam, Divert, or Extract Water from Streams in British Columbia. Consultant's report prepared for the British Columbia Ministry of Sustainable Resource Management and the British Columbia Ministry of Water, Land and Air Protection.

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

McCubbing, D.J.F, C.Melville. S. Hall and J.Korman. 2013, BRGMON-3. Lower Bridge River Adaptive Management Program: Adult Salmon and Steelhead Enumeration 2012, Prepared for St'at'imc Eco Resources, Ltd. and BC Hydro (WUP report).

McPhail, J.D. 2007. Freshwater Fishes of British Columbia; University of Alberta Press: Edmonton, Canada. 620p.

Mosley, M.P. 1985. River channel inventory, habitat and instream flow assessment. Progress in Physical Geography, Vol 9: 494.

Ogle, D. 2013. fishR Vignette – Age-Length keys to assign age from lengths. https://fishr.wordpress.com/books/vignettes/

R. Core Team 2014. R: a language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria. http://www.R-project.org/.
Wyatt, R.J. 2002. Estimating riverine fish population size from single- and multiple-pass removal sampling using a hierarchical model. Can. J. Fish. Aquat. Sci 59: 695-706.

Taylor E.B. and m. Yau 2013. Microsatellite DNA analysis of Bulltrout (Salvelinus confluentus), Arctic grayling (Thymallus arcticus), and mountain whitefish (Prosopium williamsoni) in the Peace River and tributaries near the proposed BC Hydro Site C hydroelectric development in northeastern British Columbia: 2006-2011, Site C Cllean Energy Project Fisheries Studies. Report prepared for B.C. Hydro Site C Clean Energy Project. 54 pp.

Troffe, P.M., D. McCubbing and C.Melville. 2010. Cheakamus River Water Use Plan Monitoring Program: 2009Cheakamus River Chum Salmon Escapement Monitoring and Mainstem Spawning Groundwater Survey. Report to BC Hydro. 58p

Ward, B. R., and P. A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River Steelhead trout (Salmo gairdneri) and the relationship to smolt size. Canadian Journal of Fisheries and Aquatic Sciences. 45:1110 1122.

Webb, S., Bison., R., Caverly, A. & Renn, J. 1999. The Reproductive Biology of Steelhead (Oncorhynchus mykiss) in the Bridge and Seton Rivers, As Determined by Radio Telemetry 1996/97 and 1998/99. Report prepared for The Ministry of Environment, Lands & Parks Fisheries Branch. 46 pp.