Bridge River Project Water Use Plan

Seton River Habitat and Fish Monitoring

Implementation Year 7

Reference: BRGMON-09

Study Period: January to December 2019

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Executive Summary

The overall objective of the BRGMON-9 program is to monitor responses of fish habitat and fish populations in the Seton River to the Seton Dam hydrograph. Currently in year seven of ten, this monitoring program was developed to address a series of management questions (MQ) that aim to: 1) better understand the basic biological characteristics of the rearing and spawning fish populations in Seton River, 2) determine how the Seton River hydrograph influences the hydraulic condition of juvenile fish rearing habitats and fish populations, 3) evaluate potential risks of salmon and steelhead redds dewatering due to changes in the Seton River hydrograph, 4) assess how the Seton River hydrograph influences the availability of gravel suitable for spawning, and 5) estimate the effects of discharge from the Seton Generating Station (SGS) on fish habitat in the Fraser River. Monitoring for the latter MQ was revised in 2017 to address stranding concerns in the lower Fraser River as a result of shutdowns at SGS and is addressed in a separate report.

Seton Dam represents a hydraulic bottleneck in the Bridge-Seton Hydroelectric complex; upstream flow conveyance changes can significantly affect the Seton River hydrograph. Seton Dam discharges, generally mimic natural seasonal flows, as per the Water Use Plan (WUP) targets, falling between 12 and 36 m^3/s. In 2014, operations at Seton Dam followed the WUP target flows with only minimal releases above target levels (max discharge 68 m^3/s). Beginning in 2015, the Seton Dam hydrograph was substantially increased with a peak discharge of 100 m^3/s. In 2016 -2018, in response to safety concerns, BC Hydro modified maximum reservoir elevation at the upstream La Joie Dam, resulting in Seton Dam discharges in 2016-2018 that exceeded the WUP target hydrograph, reaching a peak discharge of 114 m^3/s in 2016, 144 m^3/s in 2017 and 93 m^3/s in 2018.

Though modified operations were not expected in 2019, scheduled maintenance at SGS resulted in Seton Dam discharges of 60-87 m^3/s in March, April, and May – exceeding the 11-36 m^3/s target. High discharge in the early spring prevented spring snorkel surveys in March and impacted growth sampling surveys in April and May, but provided an opportunity for a river-wide juvenile salmonid habitat suitability assessment to be completed at 86 m^3/s, adding to measurements already completed at 12, 25, 60, and 100 m^3/s.

Monitoring has revealed important information regarding the basic biological characteristics of fish populations in the Seton River. Monthly bio-sampling surveys conducted annually from April to October

have observed 14 species of fish including seven salmonids, of which age could be determined for Rainbow Trout (age 0-3), Coho, and Chinook Salmon (both age 0-2). Recapture and detection results from PIT-tagged Rainbow Trout from 2014-2019 indicate that Rainbow Trout move between the spawning channels and the mainstem Seton River, suggesting a lack of distinct populations within these habitats. Juvenile salmonids also appear to use spawning channels during specific times of the year (i.e., for overwintering). Coho Salmon juveniles were tagged for the first time in 2019 using a visual indicator elastomer and PIT tags. With only one year of data collection so far, recapture rate was low but all recaptures were caught in the same reach their were originally tagged in, indicating that Coho Salmon juveniles likely show high site fidelity. Notably, juvenile Chinook relative abundance has increased since 2015, yet few adults have been observed until this year. Juvenile Chinook DNA results are pending, but 2016-2018 DNA analysis revealed that 52% of juvenile Chinook captured in the Seton River originated from other Fraser Chinook populations, showing that the Seton River provides rearing habitat for many Chinook Salmon populations.

Juvenile Rainbow Trout abundance has been estimated annual since 2014 using a two-level sampling strategy combining electrofishing and snorkel surveys. To date, a relationship between standing crop and the Seton Dam hydrograph has not been identified. Although the 2014 abundance estimate was substantially higher than in other years (12,183; 95% credible interval of 8,563 – 18,106), there is a high degree of uncertainty in this estimate due to variable densities observed during 2014 shoreline electroshocking. Abundance during modified operations in 2015-2019 has been lower (2,017 – 5,236; 2,606 in 2019); however, with only one year of data during WUP target flows and annual variation in the magnitude and timing of Seton Dam discharge during modified operations years have made it difficult to determine what aspect of the hydrograph has led to reduced abundances. With only one year of abundance data collected under WUP target flows, comparative analyses are limited. Further data collection will enable further exploration of potential relationships between flow condition and Rainbow Trout abundance. Coho and Chinook Salmon are also collected throughout these surveys, but sample sizes are not sufficient to estimate their abundance.

Assessing the basic biological characteristics of adult salmonid populations in the Seton River has been challenging. Enumeration data for Chinook and Coho Salmon and Steelhead Trout, the focus of this monitor, are limited due to low densities and poor visibility during visual surveys. However, observational and telemetry data do confirm that all three species spawn in the Seton River and associated spawning channels. Steelhead Trout spawning has not been visually confirmed for mainstem habitat due to poor visibility. A resistivity counter was operated in the Seton Dam fishway in 2019 through the Steelhead Trout migration period. The counter was successful in enumerating the number of Steelhead Trout, estimating 25 individuals moved past Seton Dam to spawn upstream between April 1 and May 31, 2019. Spawning salmonids were observed in much higher numbers (66 Chinook, and 235 Coho) in 2019 than the previous years, the result of the Big Bar landslide in the Fraser River which created a migration barrier and increased straying rates.

Beginning in 2016, a monitoring strategy was developed specific to modified operations. Focus shifted to surveying side-channel habitats created at discharges >60 m^3/s and bio-sampling increased in the spawning channels and newly wetted side-channels rather than the Seton River mainstem, where many survey sites were made inaccessible. Bio-sampling data collected through the monthly juvenile surveys in 2016-2019 allowed for statistical modeling to compare changes in fish condition between the spawning channel and mainstem habitats across years, assuming year as a proxy for flows. Despite a robust dataset and analytical approach, results have been inconsistent and at this time no conclusions can be drawn regarding the effects of flow to fish condition and growth. Comparative analyses are challenging given only one year of WUP target hydrograph data, and substantial variation across all other years. Continuing bio-sampling will add to this long-term and continuous dataset, that may prove useful in assessing the effects of modified operations to fish if additional years of data can be collected under the WUP target hydrograph.

Habitat suitability surveys were added in the fall of each year beginning in 2018 to assess changes in weighted useable area for juvenile salmonids as a result of modified operations. While surveys in 2018 and 2019 only represent a subsample of the entire river they give an indication of changes in the river since 2014. Preliminary results looking at only those sites that have been surveyed in 2014, 2018, and 2019, indicate that changes to habitat suitability is inconsistent across reaches with increased habitat suitability being observed in Reach 1 but decreased available habitat in the other two reaches. A linear mixed effect model will be developed and used in future years to better assimilate all collected data.

We recommend that counter operations initiated in 2019 continue, given that adult Steelhead were enumerated passing through the counter and further data are needed to estimate the run timing for steelhead migration through the Seton River and Seton Dam. PIT tagging of Coho salmon juveniles, originally performed to support assessment of site fidelity for growth analyses, should be continued in the spawning channels to estimate Coho salmon outmigration timing. Other aspects of the BRGMON-9 will continue to be adaptive, to support data collection across the Seton Dam hydrograph.

Status of BRGMON-9 objectives, management questions and hypotheses after Year 7 (2019)

Management Questions and Hypotheses	Status
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?	- Monthly bio-sampling surveys have been conducted since 2014. Monitoring has identified 14 species of fish, including seven salmonids. Coho and Chinook Salmon juveniles are present, but samples are dominated by Rainbow Trout. Tagging results to date indicate that Rainbow Trout move between the spawning channels and Seton River, indicating that that the spawning channels do not hold distinct populations. Coho Salmon juveniles (young of the year) show high site-fidelity with all recaptures occurring in the same reach the individual was originally tagged in. - High spring discharges at Seton Dam have limited the effectiveness of Steelhead visual surveys but data from the counter show that 25 Steelhead moved through Seton Dam between April 1 and May 31, 2019. Adult Coho Salmon are predominantly observed spawning in the constructed spawning channels. In 2014-2018, only 3 adult Chinook had been observed in Seton River. In 2019, increased numbers of Chinook (n=66) and Coho (n=235) were observed in Seton River, thought to be the result of increased straying due to the Big Bar Landslide. - DNA analyses show that many juvenile Chinook Salmon captured in Seton River originate from other Fraser River stocks (e.g., up to 72% in 2016), suggesting that the Seton River provides important rearing habitat throughout the year. - Abundance of Rainbow Trout ranged from 2,017 (2015) to 12,183 (2014) individuals, with 2019 abundance the lowest since 2015 (2,606 individuals). Coho and Chinook Salmon are not captured in high enough densities to calculate standing crop.
2: How does the proposed Seton hydrograph influence the hydraulic condition of juvenile fish rearing habitats downstream of Seton Dam? H_1: The amount of hydraulic habitat that can be inhabited by juvenile fish is independent of discharge from Seton Dam *H_{1A}: Juvenile standing crop biomass per unit area is inversely related to flow velocity.* *H_{1B}: Juvenile standing crop biomass per unit area is independent of flow depth.* *H_{1C}: Juvenile standing crop biomass per unit area is independent of both flow velocity and depth.*	- Data collected to date suggests that the amount of hydraulic habitat available to juvenile fish varies with Seton Dam discharge (Reject H_1). Habitat suitability has been assessed at 5 Seton Dam discharge from 12 – 145 m^3/s. Flows increases to 60m^3/s, decrease the amount of habitat available to juvenile salmonids. Above 60 m^3/s, side-channels begin to become wetted, buffering some of the juvenile habitat loss occurring in the mainstem, but do not make up for habitat lost between 12 and 60 m3/s. Side channel habitat suitability decreases to zero above 100 m^3/s. - Sub-hypotheses have not been explicitly tested. A robust data set exists for rainbow trout abundance, but no other species given data limitations. Rainbow trout abundance could be qualitatively compared to discharge conditions in a given year, but no analysis currently differentiates between flow velocity and flow depth. Juvenile Rainbow Trout abundance was highest in 2014 under the WUP hydrograph, with 2015 showing a large reduction in abundance with discharge reaching 99.7 m3/s on June 25. 2019 abundance of Rainbow Trout was the lowest since 2015. While no obvious similarities in the discharge curve for 2015 and 2019 exist, small recoveries in the intermediate years indicates there may be a link between juvenile abundance and flows, or at the very least timing of high flow releases from Seton Dam. Analyses are limited by only one year of baseline data (2014). - Examination of fish condition through monthly bio-sampling surveys showed no trends in the data due to year-to-year variability during modified operations 2015-2019. Further sampling will build a long-term biological data set, valuable as a baseline for when Seton River flows return to the WUP target

	hydrograph.
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? H_2: The selected Seton River hydrograph does not result in dewatering of salmon or Steelhead redds	- No redd dewatering events were observed from 2014 – 2019 as the primary spawning area for Pink and Coho Salmon and Steelhead Trout remains wetted throughout the year. Although discharges >60 m3/s, create wetted habitat in several side-channels during Steelhead Trout migration (April – June) that are subsequently dry when flows return to the WUP target hydrograph in July, habitat suitability surveys indicate the substrate in these side-channel habitats is not suitable for spawning Steelhead Trout. - In 2019, discharge from Seton Dam was held at a higher level in August and September than it had been in previous years. Once Seton Dam discharge returned to WUP targets, stranded eggs (likely from Pink Salmon) were observed on stream margins in several places. While these eggs were distributed in larger substrate and unlikely to be true redds, it is recommended that a designated redd stranding survey be completed in future years if Seton Dam discharge is held at 30 m^3/s into September. - While redd stranding risk in Seton river is likely low, H_2 cannot be rejected at this time and redd stranding surveys should be completed to determine the risk for Steelhead redd stranding in side-channel habitats and salmon redd stranding following fall high flows.
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? H_3: The selected Seton River hydrograph does not result in mobilization of gravel or net loss of gravel from the system.	- Riverbed elevation surveys (2013, 2015, 2016, 2017, 2019) of a key spawning area immediately downstream of Seton Dam have shown inconsistent changes in elevation and substrate composition. Some sections of the area have eroded while other sections have shown deposition; there has also been some movement of smaller substrate (gravel and small cobble) downstream. The 2019 survey shows decreases in elevation or erosion of gravel since 2017. However, since 2014, this section of river shows an overall increase in elevation or deposition of gravel suggesting a source of gravel has been depleted since 2017. - The data supports rejecting the first part of H_3, that the Seton River hydrograph does not result in mobilization of gravel, but the deposition results show that it is still undetermined if there is a net loss of gravel. Riverbed elevation surveys are due to be repeated in future years if flows exceed the WUP targets. - Substrate surveys have been added throughout Seton River to determine if gravel is moving downstream as a result of Seton Dam's modified operations.
5: Does discharge from Seton Generating Station impact fish habitat in the Fraser River above and beyond natural variation in Fraser River discharge?	- Five fish were found stranded in the upper Fraser River as a result of three winter Seton Generating Station (SGS) shutdowns (2015-2017). Area dewatered varied based on Fraser River discharge at the time of the shutdown but stranding risk was deemed to be low. Addressing remaining uncertainties on the effects of winter SGS shutdowns on adult redd stranding risk in the lower Fraser River is being assessed under a TOR Addendum (BC Hydro, 2018). These results of this assessment are reported separately.

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List of Abbreviations

AIC – Akike Information Criterion

ALK – Age-Length Key

CPUE – Catch Per Unit Effort

BRG-CC – Bridge-Seton Consultative Committee

EF – Electrofishing

HSI – Habitat Suitability Index

K_f – Fulton's Condition Factor

LSC – Lower Spawning Channel

M-R – mark-recapture

MANOVA – multivariate analysis of variance

MASL – meters above sea level

MOE – Ministry of Environment

MS – mainstem bio-sampling site

OCH – off-channel or side-channel habitat

PIT – passive integrated transponder

SGS – Seton Generating Station

TOR – Terms of Reference

USC – Upper Spawning Channel

WSC – Water Survey of Canada

WUA – weighted useable area

WUP – Water Use Plan

1.0 INTRODUCTION

1.1 Background

The Seton River is a four-km river bound by the Fraser River to the east and Seton Dam to the west (Figure 1-1). Seton Dam was completed in 1956 and was the final dam built as part of the Bridge River hydroelectric development structures. Since construction, Seton Dam has regulated Seton River flows to control the amount of water received by Seton Generating Station (SGS) and manage water levels in Seton Lake.

Adopted in 2011, the Bridge River Water Use Plan (WUP) was developed as part of a consultative process that began in 1999. The WUP aimed to develop an acceptable instream flow regime for the Seton River which balanced environmental, social and economic concerns for competing water uses while recognizing the interdependence of all Bridge River system projects (BC Hydro, 2012). A critical environmental concern identified was the need for a flow regime that considered the high ecological value, in terms of fish and wildlife, that the Seton River provides to local communities. The Bridge-Seton Consultative Committee (BRG CC) therefore set environmental objectives for Seton River that are measured in terms of abundance and diversity of fish populations within the river (BC Hydro, 2012). As a result of the WUP, BRGMON-9 was initiated in 2012 as a ten-year monitoring program, with data collection beginning in 2013.

Figure 1-1. A map of the Bridge-Seton hydroelectric structures operated by BC Hydro (BC Hydro, 2016). This report is focused on the effects of flows from the Seton Dam, the downstream-most structure in the system.

1.2 Changes to the Seton Dam Hydrograph and Subsequent Monitoring

The Seton Dam and generating station are a 'hydraulic bottleneck' in the Bridge-Seton system whereby management changes at the upstream Carpenter and Downton reservoirs and Bridge Powerhouse can have considerable impact on Seton River flows. This hydraulic characteristic has two practical consequences. First, there are periodic discharges above the WUP target hydrograph in the Seton River that are necessitated by water management concerns upstream. For example, in high inflow years, water in the Bridge-Seton system is managed to prevent excessive flow releases from Terzaghi Dam, limiting environmental impacts to the lower Bridge River. Because the quantity of water that can be 'generated' out of the system is limited by the Seton power canal, water releases from Seton Dam that are greater than the target hydrograph for the Seton River may be required. Second, natural variability in flow patterns to the system on seasonal and inter-annual basis can result in highly variable annual hydrographs in Seton River. Maintaining the WUP target hydrograph at Seton Dam is a trade-off between minimizing impacts of instream flow regimes to fish and fish habitat in Seton River and the higher WUP priority of protecting the productive capacity of other upstream waterways (i.e., Lower Bridge River).

Seton River discharges beyond the WUP target hydrograph have occurred since 2015. In response to dam safety risks, BC Hydro modified operations at La Joie Dam in 2016. Specifically, maximum water elevation in Downton Reservoir was decreased from 749 meters above sea level (MASL) to 734 MASL, significantly decreasing the storage capacity. This lower reservoir elevation was maintained through to 2019. As a result of the change in Downton Reservoir storage and WUP prioritization of flows in the Bridge-Seton system, Seton Dam flow releases in 2016-2019 exceeded the WUP target hydrograph (Table 1-1). Reduced storage at Downton Reservoir is expected to continue indefinitely, creating a period of modified operations in the Bridge-Seton system that will increase the likelihood that the WUP target hydrograph for Seton Dam will be exceeded.

Table 1-1. Flow statistics by condition [Water Use Plan (WUP) or modified operations (MOD)] for Seton Dam 2013-2019. *While 2015 was prior to modified operations, flows greatly exceeded the target maximum of 60 m^3/s set forward in the WUP.

Year	Flow Condition	Flow Statistics		
		Mean Annual Discharge (m^3/s)	Minimum Discharge (m^3/s)	Maximum Discharge (m^3/s)
2013	WUP	19	11	36
2014	WUP	24	10	68
2015	WUP*	23	11	100
2016	MOD	36	13	114
2017	MOD	36	11	145
2018	MOD	24	10	93
2019	MOD	35	11	87

In addition to effects to the Seton discharges due to modified operations, scheduled maintenance at SGS resulted in flows above the WUP target for Seton in March and April of 2019. Discharge from Seton Dam returned to WUP targets in late-May, but again exceeded the WUP target maximum of 60 m^3/s during June freshet to balance water concerns upstream. Flows remained high through the remaining spring and summer as they did from 2016 to 2018, having implications for monitoring activities not considered in the Terms of Reference (TOR). However, these changes have presented an opportunity to compare Seton River fish and fish habitat during the WUP target hydrograph to higher discharge hydrographs during periods of modified operations.

During periods of high discharges, water overflows the Seton River mainstem create side-channels. Effects of high discharge to juvenile fish are hypothesized to be buffered because 1) these side-channels may provide favorable habitat for juvenile and sub-adult fish and 2) a possible "dynamic equilibrium" of suitable hydraulic conditions exists [i.e., for different flow levels there is a fixed volume of hydraulic habitat that conforms to tolerances or preferences of small fish, (BC Hydro, 2012)]. However, it is unknown whether this 'dynamic equilibrium'' hypothesis is valid during modified operations given that data previously collected for BRGMON-9 has shown that the 'dynamic equilibrium' hypothesis can be rejected for the WUP target hydrograph (Buchanan et al. 2018).

Additionally, seasonal changes in flow regimes between the spawning period and the emergence of fry could potentially lead to redd dewatering. The potential for dewatering is largely unknown, dependent on where fish deposit eggs and the interaction between channel geometry and observed flows. High discharges under modified operations may also impact 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) high discharges may mobilize spawning gravel. The combination of redd dewatering and gravel mobilization may erode the quantity and effectiveness of spawning habitats in the river.

Changes to study sites as a result of modified operations have required adjustments to BRGMON-9 monitoring activities. In 2016, efforts were focused on identifying side-channel habitats and developing a new monitoring strategy appropriate for periods of high discharges. In 2017, side-channel habitats were surveyed at various instream flows to quantify habitat characteristics and verify fish presence and use. In 2018 and 2019, side-channel habitats were included in the monthly surveying when wetted. Due to modified operations, the September hydrograph exceeded the WUP target for the first time in 2019. To maintain consistent monitoring conditions across years, September sampling was delayed two weeks, once WUP target conditions returned.

1.3 Scope and Objectives

The main objective of the BRGMON-9 program, as outlined in the Terms of Reference, is to monitor the response of fish habitat and fish populations to Seton Dam operations. A second objective is to identify key physical and biological indicators for monitoring the effects of the implemented Seton River hydrograph.

The scope of BRGMON-9 in Year 7 (2019) was to:

1) Document the hydraulic condition in the Seton River;
2) Collect information on juvenile fish habitat use in the Seton river as it relates to the instream flow regime;
3) Monitor anadromous salmon spawning location to assess the potential impacts for redd dewatering;
4) Monitor changes in the quantity, quality, and location of suitable spawning gravel;
5) Complete an annual report that summarizes 2019 monitoring results and incorporates all BRGMON-9 results to date.

The scope of BRGMON-9 included monitoring for any periods exceeding the WUP target maximum of 60 m^3/s.

1.4 Management Questions

The purpose of this monitoring program is to document how the implemented Seton Dam hydrograph (either WUP target or modified operations) influences habitat availability, to inform and refine future performance measures for fish resources in Seton River, and to provide information on the most suitable hydrograph for fish productivity.

This monitor addresses five management questions (MQ):

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 in downstream of Seton Dam?
3. What is the potential risk for salmon and steelhead redds dewatering due to changes in flow between spawning and incubation periods imposed by the Seton hydrograph?
4. How will the Seton hydrograph influence the short term and long-term availability of gravel suitable for use by anadromous and resident species for spawning and egg incubation?

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

Note that MQ5, while still under BRGMON-9, was monitored by another organization beginning in 2018 and as such, no data is presented in this report.

1.5 Management Hypotheses

From the management questions above, three hypotheses and three sub-hypotheses were developed. H_1 and its associated sub-hypotheses are designed to answer MQ1 and MQ2 through the collection of standing-crop biomass and habitat data. H_2 directly addresses MQ3 by assessing spawning and spawning habitat in the Seton River. H_3 addresses MQ4 by evaluating gravel movement in key spawning areas of Seton River. No hypotheses were created for MQ5.

Data from this program will be collected to explicitly test the following null hypotheses (and sub-hypotheses):

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

H_{1A}: Juvenile standing crop biomass per unit area is inversely related to flow velocity.

H_{1B}: Juvenile standing crop biomass per unit area is independent of flow depth.

H_{1C}: Juvenile standing crop biomass per unit area is independent of both flow velocity and depth.

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

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

1.6 Monitoring Approach

The monitoring schedule is designed to collect coincident habitat, abundance, and growth information on Seton River fish populations. These data can be used to better understand the effects of the Seton Dam hydrograph on critical habitat characteristics, and to relate how habitat conditions influence habitat use and relative productivity. Annual surveys are conducted to index population abundance and distribution in relation to habitat conditions, quantify redd dewatering, and determine changes in spawning gravel location and quantity. Standardized data management, analysis, and base mapping continues to be improved to better determine the linkage between fish use and abundance observations and habitat inventories.

2.0 METHODS

2.1 Study Area

The Seton dam is an 18-meter high 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 2-1). Cayoosh Creek enters the Seton River approximately 1.3 km downstream of Seton Dam. High flows from Cayoosh Creek can further increase the flows in the Seton River downstream of the confluence. There are also two constructed restoration channels designed as habitat for spawning salmon that feed from the Seton Canal: The Lower Spawning Channel (LSC) and the Upper Spawning Channel (USC).

Habitat encompassed by this monitoring program includes the Seton River, the spawning channels, and certain side-channel habitats created during modified operations, also referred to as off-channel habitat (OCH).

Using data collected during site selection surveys (Ramos-Espinoza et al. 2014) and visually from Google Maps satellite imagery, the Seton River was divided into three distinct reaches, numbered in ascending order from Seton Dam to the Fraser River confluence (Figure 2-1). As defined in Johnston and Slaney (1996), a reach is a homogeneous section of river. Reach 1 extends from the dam to the confluence of Cayoosh Creek. Reach 2 extends from the Cayoosh Creek confluence to the intake of the Lower Spawning Channel. Reach 3 extends from the lower spawning channel intake to the Fraser River.

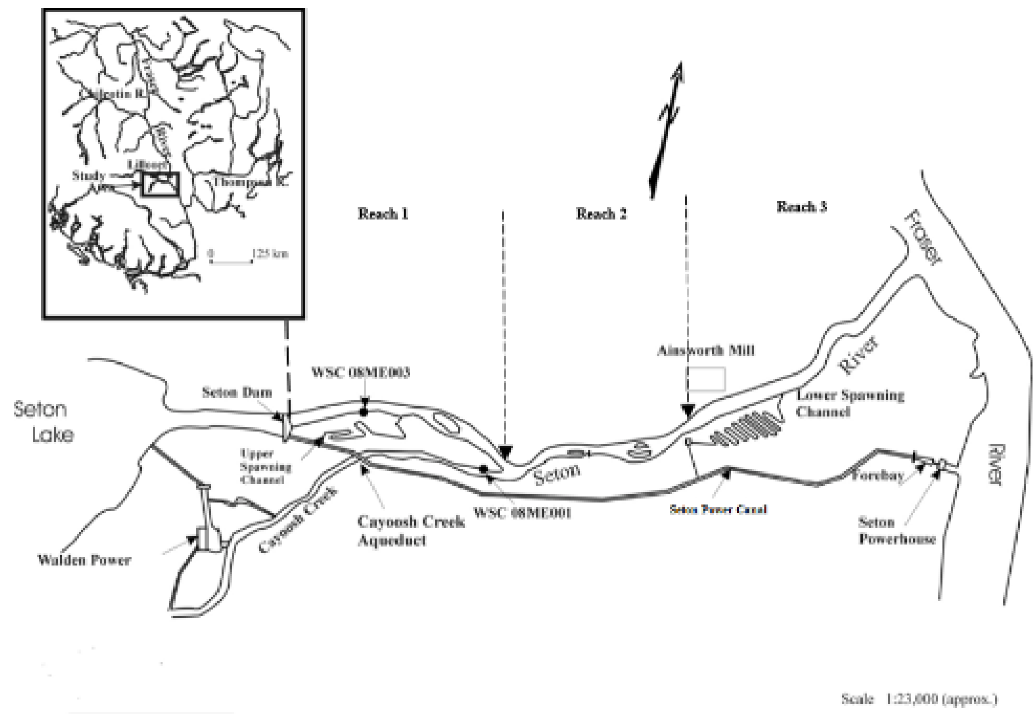


Figure 2-1. Detail of the Seton River study area bound by Seton Lake to the west and the Fraser River to the east. The study area was divided into three distinct reaches. Included on the map, but not included in the study, is Seton Power Canal and Cayoosh Creek.

2.1.1 Site Selection

Tisdale Environmental Consulting surveyed the entire length of Seton River in 2013 and defined distinct hydrological habitat units (riffles, glides, pool; Ramos-Espinoza et al. 2014). Transect sites (n = 125) were identified within each individual habitat unit, with 76 on river right and 49 on river left. River right and river left sites were matched where possible, creating 81 unique transects. These transects have been used for all river-wide habitat suitability assessments.

All other components of BRGMON-9 (i.e., Bio-sampling and Abundance Estimation) draw sites out of this pool of 125. Bio-sampling surveys identified 13 sites out of the 125 which were suitable for electrofishing and routinely produced the necessary sample numbers (see Section 2.4). Juvenile abundance estimation surveys are separated into a fall electrofishing component and a spring snorkeling component. The electrofishing component randomly samples 25 sites (index sites) out of the 125 identified sites each year, and six pre-identified mark-recapture sites. These six sites were originally selected out of the 125 sites but remain the same each year unless fish numbers are insufficient to complete a mark-recapture. The snorkeling component randomly samples 20 sites out of the 125 identified sites each year (see Section 2.5).

The 31 sites (index and mark-recapture) surveyed during the electrofishing component of the abundance estimation have also been assessed for changes in habitat suitability for juvenile Rainbow Trout and Coho and Chinook Salmon annually since 2018.

Due to modified operations, additional sites have been added to the scope of BRGMON-9. In 2016, side-channel habitats were identified and surveyed in a response to high flows. These sites have been surveyed during monthly bio-sampling surveys and during habitat suitability assessments when Seton dam flows exceed 60 m^3/s (Ramos-Espinoza et al. 2016). Sites were also selected for monthly bio-sampling surveys in the LSC and USC, as these habitats are unaffected by flow changes in the Seton River. In 2018, both spawning channels were electrofished extensively to determine areas where high numbers of juvenile salmonids reside, while avoiding spawning salmon and redds. Three sites were chosen in each spawning channel and have since been surveyed during monthly bio-sampling.

2.2 Physical Parameters

2.2.1 Discharge

Discharge data was obtained from the Water Survey of Canada (WSC) gauges at Seton River near Lillooet (08ME003) and at Cayoosh Creek (08ME002). Due to the influence of Cayoosh Creek on the Seton River below the confluence, the discharge data for Reach 1 was taken from the Seton River gauge, located upstream of the confluence (Figure 2-1). For Reach 2 and 3 the discharge data from both gauges were combined to determine the total discharge. The two spawning channels also provide additional inflow, but their combined contribution is constant all year round (~2 m^3/s) and thus was not considered.

2.2.2 Temperature

Water temperature is recorded hourly for the duration of the study using Onset Tidbit Water Temperature Data Loggers (Bourne, Massachusetts, USA). Loggers are attached to solid features either on shore or within the river (e.g. pilings) using aircraft cable and are weighted down using cinder blocks or a lead weight. Loggers are downloaded at minimum monthly to reduce the risk of data loss in the event of high flows blowing out anchor lines.

Water temperatures are monitored in five locations: in the fishway of Seton Dam, the Seton River immediately downstream of the dam (Upper Seton), downstream near the inflow to the LSC (Lower Seton), and within the USC and LSC (Figure 2-2). Splitrock Environmental monitors temperature within the USC and LSC.

To determine if modified operations have affected Seton River water temperatures, annual temperature profiles for Seton Dam, Upper Seton and the Lower Seton were plotted.

Figure 2-2. Location of temperature loggers in Seton River and the Spawning Channels

2.3 Habitat Suitability Assessments

2.3.1 Juvenile Rearing Habitat Suitability

Habitat Suitability Index (HSI) surveys were completed for mainstem Seton River in 2014 to assess suitability for juvenile Rainbow Trout, Coho, and Chinook and determine whether the amount of available habitat changes with Seton Dam flow. To enable comparisons between higher discharges under modified operations and the WUP target hydrograph of 2014, transect surveys were repeated in October of 2018 and 2019 during base flow conditions (12 m^3/s). The sites randomly selected for juvenile abundance surveys each year were used for these HSI surveys (Figure 2-3), providing a sub-sample of available habitat for the entire river. Consistency in flow conditions during surveys allows changes to habitat suitability for these species as a result of modified operations to be detected. The same methodology used in 2014 (as detailed in Ramos-Espinoza et al. 2015) was applied in 2018 and 2019 for field surveys.

Weighted Useable Area (WUA) is calculated using a model developed by the Ministry of Environment (MOE) based on HSI scores (Ptolemy et al. 1994). The MOE provided species and life stage specific HSI scores corresponding to depth, velocity and substrate preferences. The model estimates the amount of suitable habitat available for different species and life stages at any given discharge. Each parameter is weighted by an HSI score ranging from 0 (unsuitable) to 1 (optimal). The amount of suitable habitat is quantified as the product of HSI scores for each habitat value (i.e., water depth, velocity, and substrate) and the wetted width of the transect.

This methodology assumes that the habitat is relatively uniform along the length of each habitat unit, and that each point along the transect represents an area of streambed bound by the halfway point to the neighbouring vertical and the upstream and downstream boundaries (i.e., either the end of the hydrological habitat unit or the neighbouring transect, Mosley 1985).

WUA within each transect was summed to create a total WUA for each habitat unit. Only sites that were surveyed in all three years were compared to show trends in how Seton River is changing as a result of modified operations. While river-wide trends are examined, it should be noted that for evaluations of changes across years, results only represent a random subsample of the total habitat available.

Additionally, a river-wide HSI survey was completed in April 2019 at 86 m^3/s. Combining this data with HSI surveys completed at 12, 25, 60 and 100 m^3/s from 2014 to 2017 enables an assessment of when habitat is maximized for juvenile Rainbow Trout, Coho and Chinook Salmon.

Figure 2-3. Location of Weighted Useable Area transects in Seton River. Lines indicate the location of transects in Reach 1 (A), Reach 2 (B), and Reach 3 (C) completed in each year.

2.4 Bio-sampling of Juveniles

From April through October we conducted monthly open-site electrofishing (Smith-Root LR-24 backpack electrofisher) in the spawning channels and the Seton River between the Seton Dam and the confluence of the Seton and Fraser Rivers. Sampling crews of three experienced technicians performed single-pass electrofishing at established sites (~50 m in length; Figure 2-4). Technicians moved upstream, with one operating the electrofisher and two dip-netting fish. Fork length and weight were measured for all captured fish. To determine age, scales were collected from the area above the lateral line and immediately below the dorsal fin and stored in labelled envelopes. During each sampling period, up to 30 fish of each species and age-class within each reach were sampled.

All captured Rainbow Trout, Bull Trout, Coho Salmon, and Mountain Whitefish >75 mm in length were scanned for passive integrated transponder (PIT) tags, and untagged fish were implanted with a 12 mm PIT tag (Oregon, RFID, Portland, Oregon USA). 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 musculature. Recaptured fish were re-measured to evaluate growth between capture events. In addition, all Coho Salmon juveniles < 75 mm were tagged with a visual indicator elastomer (VIE) that was unique to the capture month and location (see Section 2.6.3).

The original experimental design planned for annual sampling in six of the 13 mainstem sites (MS1 to MS13), in addition to random sampling in the spawning channels, but high discharges due to modified operations from 2016 to 2019 prevented sampling at some of the established sites. Sampling occurred in the pre-established sites when flows permitted, but sampling sites were added in side-channel habitat during periods of modified operations when mainstem sites were inaccessible and side-channels were activated (OCH1 to OCH9; Ramos-Espinoza et al. 2016). Appendix 7-1 provides a summary of the number of sites sampled in each year from 2014 to 2019.

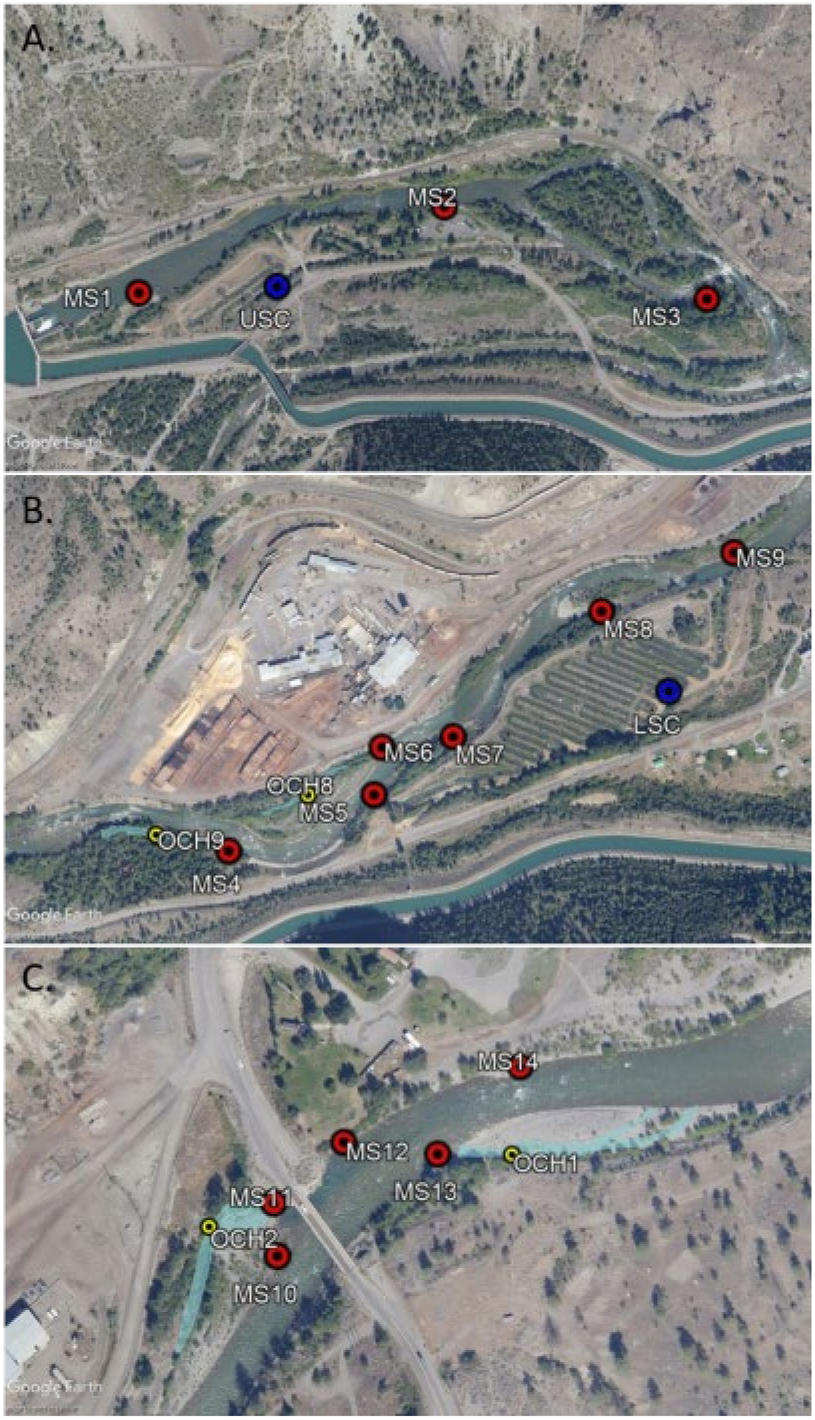


Figure 2-4. Location of juvenile bio-sampling sites in the mainstem Seton River (MS; red circles), Upper (USC) and Lower (LSC) spawning channels (blue circles; sites sampled randomly within the channels), and side-channels (OCH; yellow circles) in 2014-2019 in A) Reach 1, B) Reach 2, C) Reach 3. For reference, Seton Dam can be seen on the far-left side of Panel A, and the Seton – Fraser confluence can be seen on the far-right of Panel C. OCH sites were only surveyed in 2017 and 2018.

2.4.1 Ageing Analysis

Ageing analyses add to our understanding of the basic biological characteristics of fish in the Seton River. Scale samples were stratified by fish length (25-59 mm, 60-124 mm, 125-170 mm, > 170 mm). A maximum of thirty scales per category per month were selected for ageing. Scales were mounted directly onto glass slides, digitally photographed, and each scale was read under magnification by two independent technicians to determine age (Zymonas and McMahon 2009).

Age-length keys (ALKs) were developed for Rainbow Trout, Coho Salmon, and Chinook Salmon. An ALK is a population-specific probability matrix that determines the probability that a fish from a length class is a given age class, and vice versa (Guy and Brown 2007; Ogle 2016). Probabilities are then used to determine proportions of fish from each length class assigned to each age class, from which age can be estimated for unaged fish in a population (Isermann and Knight 2005). Due to the rapid growth rates of juvenile fish, we created two seasonal ALKs for each species: one for March through June and a second for July through October.

2.4.2 Growth and Body Condition

Two distinct growth and body condition metrics were used to explore potential relationships between fish condition and discharge (i.e., the Seton River hydrograph) for Rainbow Trout, Coho Salmon, and Chinook Salmon:

1. Fulton's Condition Factor (K_f): A measure of body condition, referring to the general plumpness or fatness of fish relative to length.
2. Length vs Weight: The predicted weight (or predicted incremental change in weight) given length at a given capture time and location.

The effects of year and capture location were evaluated statistically for their effect on the above evaluation metrics in an Akaike Information Criterion (AIC) multi-model selection approach, With AIC values adjusted for small sample sizes (i.e., AICc; Burnham and Anderson, 2002). While flow conditions have generally been high in all years (2015-2019), the magnitude, timing and duration of peak flows has varied distinctly among study years, allowing year to be used as a proxy for flow condition in analyses.

Body Condition

K_f was calculated according to Anderson and Neumann (1996):

$$K_f = \frac{W * 10^N}{L^3} \qquad \text{Eq 3}$$

where *W* is weight in grams, *L* is fork length in millimeters, and *N* is an integer that scales the condition factor close to a value of one (generally *N*=5 for Seton River salmonids). We performed Multivariate Analysis of Variance (MANOVA) tests (α= 0.05) to determine the effects of year and reach on average K_f values for Rainbow Trout, Coho Salmon, and Chinook Salmon. For Rainbow Trout, age-specific MANOVA testing was performed for age 0 and age 1, while only age 0 were tested for Chinook Salmon and Coho Salmon. Statistical testing was not performed for higher age classes of Chinook and Coho because small sample sizes and missing data resulted in highly imbalanced year-reach comparisons. Five candidate models were tested, and the model with the lowest AICc value was selected as the best-fit model:

1. K_f = 1 (intercept-only model)
2. K_f = year
3. K_f = reach
4. K_f = year + reach
5. K_f = year*reach

When AICc values were within two units of each other (ΔAICc < 2), models were considered to have equal support and the most parsimonious model (with the fewest parameters) was selected. Significant MANOVAs were followed by Tukey's pairwise hypothesis testing to determine statistical differences among groups (completed using the R package FSA at α = 0.5; Ogle 2016).

Length vs Weight

Length and weight are generally highly correlated for fish within a habitat and the relationship can be used to monitor gross changes in fish growth given variable environmental conditions. For example, increases in slope would suggest improved body condition (i.e., more weight per unit of length). Multiple log-linear regression modelling was used to describe the fork length (*L*) vs weight (*W*) relationships for Rainbow Trout, Coho Salmon, and Chinook Salmon pooled for all age classes captured in the Seton River and its spawning channels according to (Ogle 2016):

$$\log(W_i) = \log(\alpha) + \beta \log(L_i) + \epsilon_i \qquad \text{Eq 4}$$

where α and β are intercept and slope parameters and ε is multiplicative model error. A multiple linear regression was performed to evaluate the effects of the categorical covariates of year and capture location (i.e., reach) on the length vs weight relationship. Initially, ten candidate linear models were evaluated that included a length term, and all possible model combinations including year, reach, and year-by-reach interactions. However, with both year and reach each having five distinct categories, candidate models with interaction terms had a large number of parameters. The most complex model had 50 parameters, suggesting that 500-750 samples would be required to properly fit the model. Models with large numbers of parameters may overfit data, leading to misleading results. Although AICc scores do penalize models for each additional parameter, in all cases the most complicated model best described the data. The highly significant results from the initial modelling exercise suggested that overfitting was occurring.

To simplify the modeling approach, reach-specific AIC modelling was conducted. Excluding year by reach interactions is justified given inherent and expected differences in habitat characteristics among reaches that occur regardless of BC Hydro management actions. In contrast, differences in the length-weight relationship among years may indicate an effect of flow management decisions on fish growth. Therefore, being able to statistically detect year-specific differences is more important than reach-specific differences. We performed reach-specific AIC modelling considering three candidate linear models:

1. log(W) = log(L)
2. log(W) = log(L) + year
3. log(W) = log(L)*year

With all modeling, model R-squared values were compared to predicted R-squared values (a measure of how well the model predicts individual observations) and models were assessed for linearity and homogeneity of variances.

2.4.3 Chinook Salmon Stock ID

To better understand the basic biological characteristics of Seton River fish populations, there has been interest in recent years to determine the origin of Chinook Salmon utilizing the Seton River. Although age 0 Chinook have been captured throughout the monitor, few adults have been observed (see Section

2.7). This has led to uncertainties regarding the presence and use of the Seton River by adult Chinook for spawning. Unobserved Chinook may be spawning in the Seton River or, conversely, juvenile Chinook from other populations may be rearing and/or migrating in the Seton River, specifically those from Bridge River. Caudal fin-clip samples have been collected to obtain DNA from a subset of Chinook during bio-sampling and juvenile estimation surveys (Sections 2.4 and 2.5, respectively) since 2016. Samples were analyzed using standardized genetic stock identification protocols at the Pacific Biological Station Molecular Genetics Lab in Nanaimo (Beacham et al. 1996).

2.5 Juvenile Abundance Estimation

2.5.1 Survey Methods

We performed backpack electroshocking in the Seton River annually during September from 2014 to 2019 to estimate juvenile population abundance. Electrofishing has been supplemented with annual night-time snorkel surveys to add population information of larger juveniles that are difficult to survey through electrofishing. Snorkel surveys have been completed in the Seton River during March from 2014 to 2018 and could not be completed in 2019 due to high discharges as a result of scheduled maintenance at SGS. For results of snorkeling surveys from previous years see Appendix 7-2.

To determine site- and river-wide abundance of Seton River fish populations, a two-phase sampling protocol combines mark-recapture and index data [as in Korman et al. (2016) and Hagen et al. (2010)]. In the Seton River, the mark-recapture portion consisted of a two-pass backpack electrofishing program used to estimate river-wide fish detection probability. This detection probability was then applied to counts from separate index sites to obtain abundances for three reaches of the Seton River.

Electrofishing surveys for indexing and mark-recapture were completed in September of each study year at a discharge of 14 m^3/s. Surveys in 2019 were delayed to September 30 due to higher than normal discharge from Seton Dam (34 m^3/s) in the month of September. Electrofishing index sites (n = 25) were randomly selected each year from a pool of 125 sites (see Section 2.1.1), distributed throughout Seton River from Seton Dam to the Seton-Fraser confluence (Figure 2-5). Sites with deep habitats were excluded from juvenile electrofishing abundance surveys as they cannot be efficiently surveyed with an electrofisher. An additional six mark-recapture sites were selected from the 125 sites to represent shallow riffle and glide habitat in each of the three reaches to calculate capture efficiencies to be applied to the index sites. The actual number of mark-recapture sites included in the analysis varied each year due to annual conditions in the river and low to zero catches in some years (Table 2-1).

All open-site electrofishing surveys were performed during daylight hours as described in Section 2.3. Electrofishing sites were 50 m long (shorter where habitat units were not 50 m in length) and were sampled systematically in an upstream direction, attempting to capture all fish observed. In side-channels and narrow sites, the entire width of the river was sampled, while in wider sections the crews sampled as far into the river as was safe to wade. Index sites were surveyed using a single pass, while mark-recapture sites were surveyed with two passes. During the first pass, fish were marked with a fin clip and released in their original capture site. A second pass was performed after 24 hours, and the number of marked fish re-caught recorded. All by-catch salmonid species were also weighed, measured, and sampled for ageing structure.

Our goal was to incorporate index data from both fall open-site electroshocking and spring snorkel surveys in a multi-gear model to estimate juvenile abundance of Coho and Chinook Salmon, Rainbow/Steelhead Trout, Bull Trout, and Mountain Whitefish in the Seton River. A multi-gear sampling design can account for variation in detection probability across different life stages and habitat types (Korman et al. 2016). For example, electroshocking detection probability is generally higher for juveniles relative to adults, whereas the opposite is true during snorkel surveys. The appropriateness of snorkeling and electroshocking also varies with seasonal conditions; snorkeling is not possible during high turbidity periods, while electrofishing is ineffective at high discharges. During both electrofishing and snorkeling, densities were too low to obtain abundance or index estimates for all species apart from Rainbow Trout. For Rainbow Trout, the hierarchical Bayesian model was used to estimate age 0 abundance using electroshocking mark-recapture and index data, while snorkel survey data were used to obtain annual indices of age 1 and age 2 abundance.

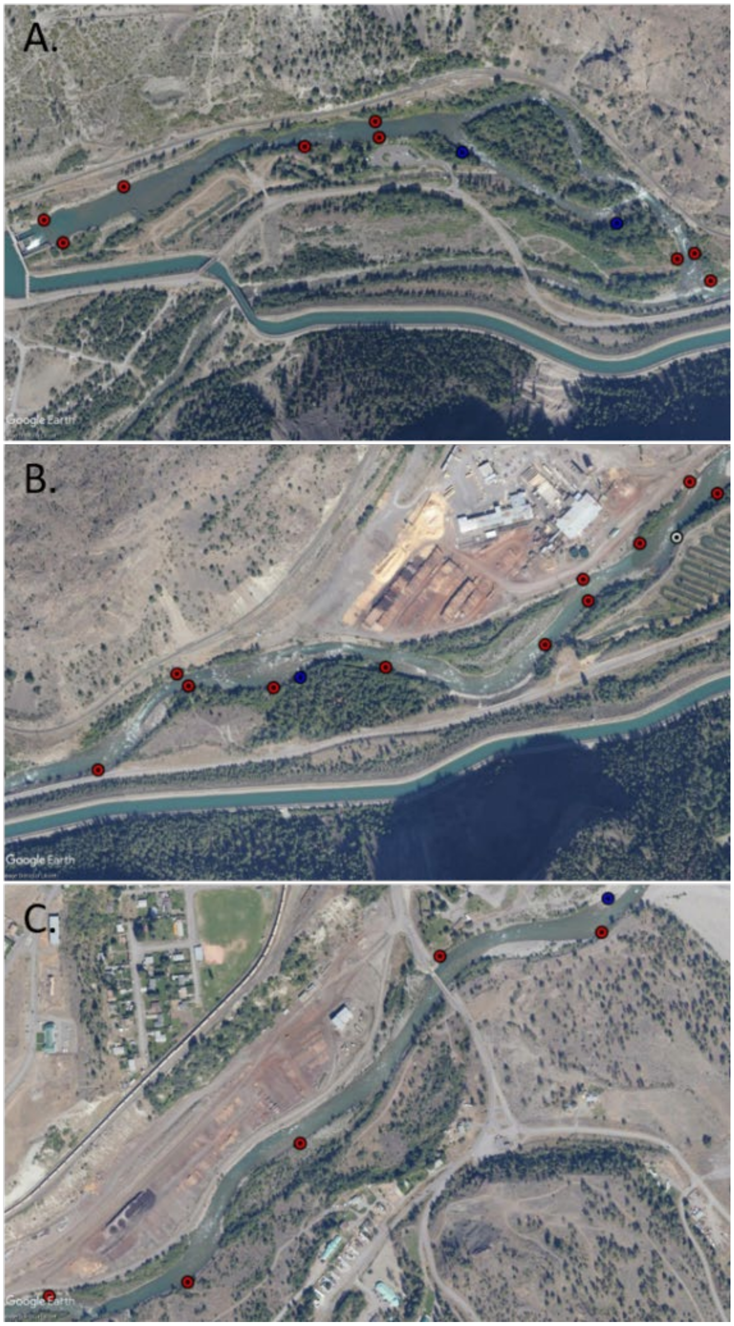


Figure 2-5. Location of juvenile standing crop sites in 2019 within Seton River in Reach 1 (A), Reach 2 (B), and Reach 3 (C). Sites were chosen randomly and cover both river right and river left. Red circles represent index-electrofishing sites, blue circles represent mark-recapture electrofishing sites. Snorkel surveys were not completed in 2019 due to high discharges (a result of scheduled maintenance at Seton Generating Station).

Table 2-1. Summary of sites sampled from 2014-2019 in Seton River for indexing and mark-recapture (M-R) (EF = Electrofishing). *Electrofisher Seconds clock broke in September of 2019. Start time and end time was recorded instead, total time fished is reported (hh:mm).

Year	Site Type	N	Mean	
			Site Length (m)	Time Shocked (s)
2014	EF M-R (Pass 1)	6	59	-
	EF M-R (Pass 2)	6	60	-
	EF Index	25	54	-
	Snorkeling	-	-	NA
2015	EF M-R (Pass 1)	4	48	1448
	EF M-R (Pass 2)	4	47	834
	EF Index	23	50	416
	Snorkeling	10	50	NA
2016	EF M-R (Pass 1)	5	56	1559
	EF M-R (Pass 2)	5	56	1148
	EF Index	23	50	744
	Snorkeling	20	48	NA
2017	EF M-R (Pass 1)	6	52	916
	EF M-R (Pass 2)	6	52	766
	EF Index	24	50	469
	Snorkeling	20	48	NA
2018	EF M-R (Pass 1)	6	52	1075
	EF M-R (Pass 2)	6	52	666
	EF Index	21	43	502
	Snorkeling	20	47	NA
2019	EF M-R (Pass 1)	4	49	00:37*
	EF M-R (Pass 2)	4	49	00:29*
	EF Index	25	46	00:24*
	Snorkeling	-	-	NA

2.5.2 Hierarchical Bayesian Analysis

We used a hierarchical Bayesian mark-recapture model to estimate year-specific abundance and density for age 0 Rainbow Trout in the Seton River. The Bayesian model has been used consistently for all project years, and a detailed description of parameters and model equations can be found in Buchanan et al. (2018) and Korman et al. (2016). The model was implemented through a hierarchical Bayesian framework in R Project Software (R Core Team 2017) and JAGS using the R package jagsUI (Kellner, 2017).

The model consisted of two simultaneous levels: a detection model and a population model. The detection model used mark-recapture data from all sites and years to estimate a representative distribution river-wide detection probabilities (Korman et al. 2016). This method assumes detection characteristics in the Seton River did not change over the entire study period. To maintain consistent detection efficiency, we used experienced field crews and standardized protocols to minimize the effect of sampling crew, and electrofishing took place during similar discharge levels each year (~12 m^3/s).

The population model used the detection probabilities estimated by the detection model to obtain site-specific abundance and density (fish/m) estimates for index sites and unsampled shoreline. The true abundance for each site was determined using the observed number of fish and a detection probability randomly drawn from the distribution created by the detection model. The abundance at each index site was then Poisson distributed with a mean equal the length of the site multiplied by the site-specific density estimated by the process model. All priors used during the hierarchical modeling were uninformative, and modelling was completed in R and JAGS using the package rjags (Plummer 2018).

2.6 Telemetry

2.6.1 Adult Radio Telemetry

Tagging and Bio-sampling

Adult Steelhead Trout have been tagged under BRGMON-3 since 2013 to determine spawning locations. Skilled anglers attempt to capture fish throughout the Seton-Bridge complex, including the Seton-Fraser River confluence (Ramos-Espinoza et al. 2016). Fish captured were gastrically implanted with a TX-PSC-I-1200-M radio tag (44 x 16 x 16 mm; Sigma Eight Inc., Ontario, Canada) using methods described in Burnett et al. (2016). A 32 mm HDX PIT tag was also implanted into the dorsal musculature of each fish. Fork length and sex were recorded during tagging and scale samples were taken from all adults for ageing (see Section 2.4.1). After tagging, fish were held in a submersible holding tube for a minimum of 30 minutes prior to release to ensure full recovery, proper tag placement, and confirm the tag had not been regurgitated.

Tagging effort was distributed throughout the migration period. An effort was made to ensure even distribution of tags between sexes, in consideration of sex-specific migration behaviour and run timing (Korman et al. 2010; Troffe et al. 2010). The tagging schedule was adaptive because suitable capture locations are limited on the Seton River. Tag releases were dependent on capture success, angling conditions, and fish behaviour.

From 2013-2015, attempts were made to radio-tag migrating Coho and Chinook Salmon. Angling was unsuccessful, with only one fish tagged for each species over the 3 years, and was discontinued in 2016.

Tag Tracking

Weekly mobile tracking with a hand-held Lotek W31 radio receiver (Lotek Wireless Inc., Ontario, Canada) was conducted for Steelhead Trout in each year from mid-March (following the first fish tagged) to mid-May throughout the Seton River. Mobile tracking was completed by vehicle or foot and coincided with weekly visual surveys (see Section 2.7) when possible, but in isolation of the technicians conducting the visual surveys to avoid observer bias. Fish location and tag code were recorded, as well as visual sightings of tagged and untagged individuals of all species.

Fixed station logging was conducted from March 8 to June 12, 2019 at one site located on the Seton River, 1.3 km upstream of the Seton - Fraser River confluence (Figure 2-6). The fixed station used a Lotek W31 receiver linked to one Yagi 6-prong directional aerial antenna oriented downstream. Fixed station data were used to corroborate fish locations determined by mobile tracking, identify entry and exit timing into the Seton River, and collect basic data on Steelhead adult migration and spawning in the Seton River.

Figure 2-6. Location of fixed telemetry stations on Seton River. PIT antennas are present near the mouth of the Upper Spawning Channel (USC) and Lower Spawning Channel (LSC) and in the Seton Fishway. A fixed radio antenna is located upstream of the confluence of the Lower Spawning Channel and Seton River.

2.6.2 Passive Integrated Transponder (PIT) Telemetry

As part of the monthly bio-sampling protocol conducted from 2014-2019 (see Section 2.4), all Rainbow Trout >75 mm were implanted with a PIT tag in the ventral cavity. Juvenile Coho Salmon > 75 mm were also PIT tagged beginning in July of 2019. PIT tag data were used to explore movement behaviour relative to changes in discharge from Seton Dam and if the spawning channels sustain populations distinct from the mainstem Seton River, or if a single population is seeded by the spawning channels.

PIT antennas were installed in both spawning channels. Array characteristics varied slightly through the study period. The LSC only had one antenna in 2014, allowing for detection of tagged fish but not directionality of movement or detection efficiency. In 2015, a second antenna was added to create an array (Figure 2-6). A two-antenna PIT array was installed in the USC in May 2015 (Figure 2-6).

Detection efficiency is calculated as the number of fish detected on both antennas divided by the total number of fish detected on the first. In 2018 detection efficiency on the LSC array was very low. Low detection efficiencies indicate that fish were missed on one antenna but observed on the other, and has implications for determining direction of fish movements. Causes for the low detection efficiency in 2018 were examined, and the entire array was moved upstream in 2019 to avoid electrical interference with the LSC resistivity counter operated seasonally by Splitrock Environmental. A solar panel was added to the LSC PIT array to provide power to the system.

2.6.3 Site Fidelity of Juvenile Coho Salmon

To determine the extent of site fidelity among juvenile Coho Salmon, fish < 75 mm were marked with combinations of VIE and fin clips starting in July in 2019. The combination of colour, colour location, and fin clip produced 56 unique tag combinations that distinguished both month and reach of capture (Reach 1, Reach 2, Reach 3, LSC, USC), allowing for recaptures to be identified to their original capture month/location. Coho Salmon > 75 mm were given a 12 mm PIT tag. With recapture data, months since initial tagging and movement between capture locations were examined. Strong site fidelity would indicate that juveniles rarely move between habitats (reaches) and thus the spawning channels could be used as a control for mainstem flow condition to assess whether modified operations affect juvenile growth.

2.7 Spawning Adult Salmonids

2.7.1 Visual Counts

Visual stream counts were performed weekly as conditions allowed throughout the Seton River and spawning channels during the adult salmon migration period. Spawning Steelhead Trout, and Chinook and Coho Salmon were enumerated to provide an index of adult abundance, and any visible redds were noted and georeferenced. Survey methods followed those outlined in BRGMON-3: Lower Bridge River Adult Salmon and Steelhead Enumeration (Burnett et al. 2016), whereby two observers walk along the riverbank in a downstream direction looking for fish and any spawning activity. Fish species, location, and viewing conditions, including cloud cover and lateral water visibility are all recorded. Steelhead Trout surveys were scheduled to be completed from March to June of each year, but have not been completed in the mainstem Seton River since 2016 due to modified operations causing low water visibility. Chinook Salmon surveys commence in August of each year and continue through to October, while Coho Salmon surveys begin in October and are completed by mid-December (Table 2-2). In 2018, August surveys for Chinook Salmon were not completed due to a miscommunication between contractors.

Table 2-2. Timing of Adult Visual Surveys for Steelhead, Chinook and Coho for each year.

	2015	2016	2017	2018	2019
Steelhead	Mar 4 – Jun 15	NA	NA	NA	NA
Chinook	Aug 8 – Oct 6	Aug 16 – Oct 7	Aug 8 – Oct 4	Sep 25 – Oct 15	Aug 1 – Oct 16
Coho	Oct 6 – Dec 15	Oct 7 – Dec 16	Oct 4 – Dec 12	Sep 25 – Nov 26	Oct 7 – Nov 26

2.7.2 Seton Dam Counter for Steelhead Trout

Counter Operations

A resistivity tube counter was used to monitor the Steelhead Trout migration through the Seton Dam fishway from March 1 to May 31, 2019. The resistivity counter, consisting of eight tube sensors and two four-channel Logie 2100C resistivity electronic fish counters (Thurso, Caithness, Scotland), counted upstream and downstream movement of fish through the Seton Dam Fishway (Figure 2-7). Eight video cameras continuously monitored the tubes. Video data were then used to validate data collected by the counter.

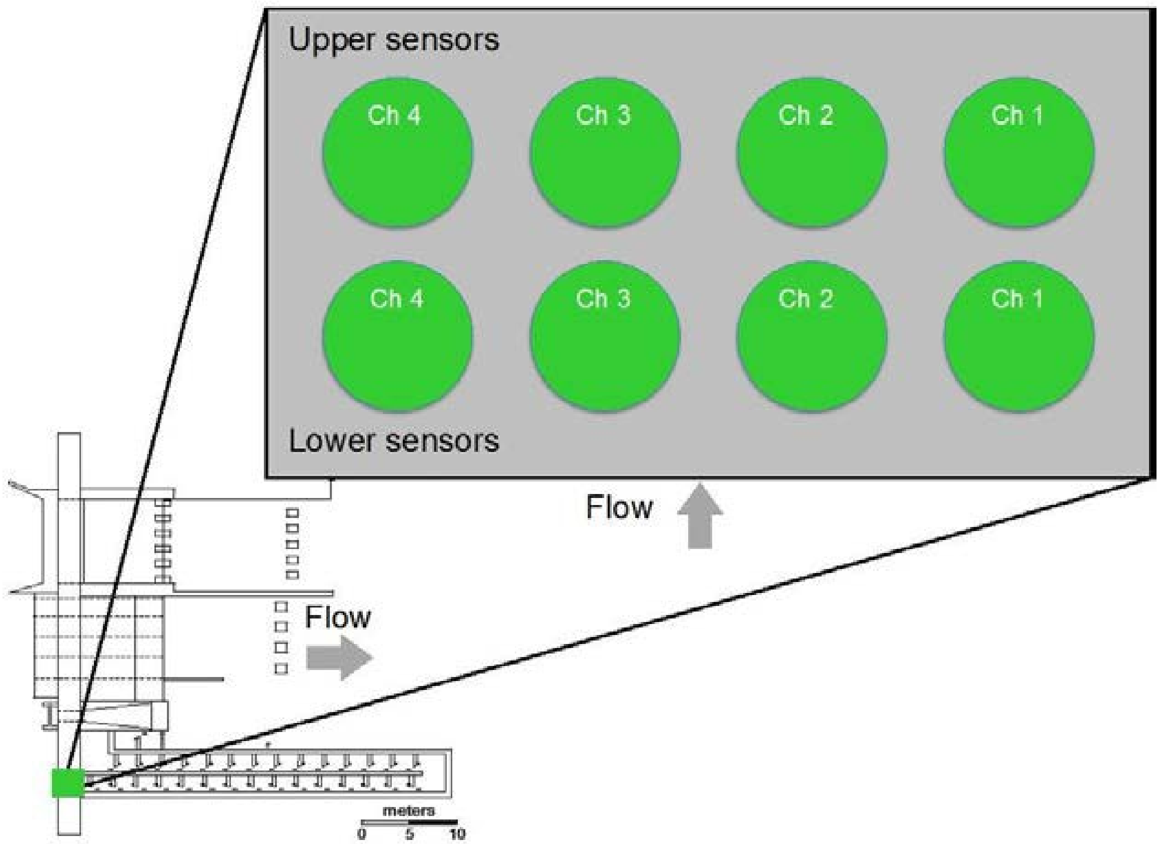


Figure 2-7. Schematic of the fish counter located at the exit of the Seton Dam fishway. The upper and lower sensors were monitored by two, four channel resistivity counters.

A detailed description of the operation of the Seton Dam fish counter can be found in the BRGMON-14: Effectiveness of Cayoosh Flow Dilution, Dam Operation, and Fishway Passage on Delay and Survival of Upstream Migration of Salmon in the Seton-Anderson Watershed (Casselman et al. 2013). Briefly, as a fish swimming through the resistivity sensor tube is more conductive than the water it is displacing, the counter measures a change in electrical resistance. An internal algorithm is then used to determine if a fish passed through the counter, or if a fish entered the sensor unit but failed to pass through. For each detection, the counter records the date and time, water conductivity, channel, direction of movement (upstream or downstream), and peak signal size (PSS) between 0 and 127. The PSS is a function of fish size, position in the sensor tube, electrode sensitivity, river conductivity, and bulk resistance (background resistance caused by flowing water). A minimum PSS threshold of 30 was used at the Seton Dam fish counter to eliminate resistance noise caused by surface air bubbles or debris passing through the sensor tubes (i.e., detection events with PSS < 30 were ignored by the counter).

Video monitoring equipment consisted of digital video cameras attached to the upstream end of each counter tube (one camera per tube). Video data were collected from March 1 to May 31, 2019 and saved to a Digital Video Recorder (DVR) in five-minute increments. Each camera was lit by an underwater LED light to aid in species identification.

Resistivity Counter Validation

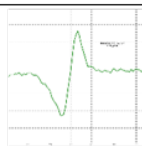
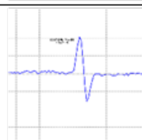
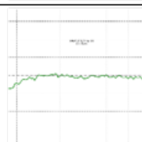
Raw counter data were validated using the video record to determine the number of true positives, false positives, and false negatives (Table 2-3), and to calculate tube-specific counter accuracy. A multi-step validation process that included both targeted validation of counter up and down counts and random validation of additional video data was used (Figure 2-8).

Table 2-3. Definition of error rates used to classify counter records during validation.

Error Category	Resistivity Counter	Video Review
True Positive	Graphical trace (up or down)	Fish observed and movement agrees with up or down classification
False Positive	Graphical trace (up or down)	No fish movement occurred
False Negative	No graphical trace	Fish movement occurred
Unclassified	Graphical trace (up or down)	Video data not available

Raw Counter Measurement

- Counter measures a change in resistance as fish passes over the counter site
- Each trace is examined by a reviewer and classified as an up, down, or event

Up		Fish is moving upstream, passing over all three electrodes
Down		Fish is moving downstream, passing over all three electrodes
Event		Partial or incomplete movement of fish over the counter electrodes (in any direction) caused by a fish nosing up, falling back, or sitting on electrodes. Events may also be caused by air entrainment or debris flow over the electrodes.

Targeted Video Validation

- All up and down records are reviewed on video
- Reviewer watches record plus 1 minute before and after record
- Record is classified as either:
  - **True positive**
  - **False positive**

Random Video Validation

- Subset of randomly-selected video segments is reviewed
- For each 24-hour period, 10 randomly selected 20-minute segments are reviewed
- Fish movement observed on video but without paired graphical trace are classified as **false negative**

Calculate Error Rates and Accuracy

- Determine the total number of true positives (*TP*), false positives (*FP*), and false negatives (*FN*), summarized by:
  - Movement direction (up and down)
  - Species
  - Counter channel
- Calculate accuracy (*A*) for each category

Figure 2-8. Counter validation protocol for Steelhead Trout through Seton Dam.

During targeted validation, each graphical trace (up or down) was verified by watching the corresponding video data and an additional one minute of video before and after. The two-minute time bracket accounted for minor time-stamp discrepancies between the counter and the video records and allowed the analyst to verify movements that were recorded by the counter as multiple records (this occurs when a fish moves slowly through the counter or travels in an erratic manner). Two and a half hours of video footage were reviewed for targeted validation.

A subset of randomly selected video segments was reviewed to determine the number of false negatives (i.e., a fish was observed on the video but the counter recorded no trace). For each full day of video (April 1 – May 15), 10 randomly-selected 20-minute segments of video were reviewed and false negatives were recorded. The amount of video watched was based on estimated population size, number of fish expected to be validated, total number of hours available to be validated, and time constraints (Braun et al. 2016). Over 150 hours of video footage were reviewed for random validation representing approximately 11% of the total video available for analysis. The total number of false negatives was determined by expanding the validated count based on the proportion of video validated (combined validation hours from targeted and random validation = 153) and total hours of video data collected.

The numbers of true positives (*TP*), false positives (*FP*), and false negatives (*FN*) were used to calculate counter accuracy (Equation 4), summarized by direction, species and counter channel:

$$A = \frac{TP}{TP + FP + FN} \qquad \text{Eq 4}$$

Accuracies were used to assess the performance of the counter, and to adjust the counter estimate to obtain final estimates of abundance.

Species Determination

During video validation, each fish observed in the video was identified to species. Tube counters are ideal for species identification as each fish must pass directly by the camera allowing for distinguishing features to be observed. In the unlikely event that the species could not be identified or agreed upon by two independent analysts (e.g., during low visibility conditions), the species was classified as unknown.

Distinguishing characteristics used to determine commonly observed species moving through Seton Dam are listed in Table 2-4 and example photographs can be seen in Appendix 7-3.

Table 2-4. Distinguishing features for commonly seen species moving through Seton Dam

Species	Distinguishing Features
Steelhead Trout (*Oncorhynchus mykiss)*	• Black spots on back, dorsal fin, and caudal fin • Cheeks and sides may be pink • Presence of radio tag antenna (fish tagged under BRGMON-3) • **Length of fish is greater than the electrode spacing (30 cm)** • **PSS ≥ 40**
Rainbow Trout (*Oncorhynchus mykiss)*	• Black spots on back, dorsal fin, and caudal fin • Cheeks and sides may be pink • **Length of fish is less than the electrode spacing (30 cm)** • **PSS < 40**
Bull Trout (*Salvelinus confluentus)*	• White leading edge on pectoral fins and mouth • Light coloured spots against dark coloured body on back
Mountain Whitefish (*Prosopium williamsoni*)	• Small mouth • Pointed nose • Adipose fin
Bridgelip Sucker (*Catastomus columbianus*)	• Ventral sucker mouth • White ventral side • Large anal fin

Abundance Estimate

Abundance of Steelhead Trout through the Seton Dam fishway (E) was calculated using Equation 5:

$$E = \sum_{t=1}^{k} \frac{U_t - D_t}{A} \qquad \text{Eq 5}$$

where, U_t is the total number of upstream detections, D_t is the total number of downstream detections, $U_t - D_t$ is the net up counts (accounting for species ratio is the counter accuracy), A is the counter accuracy, and k is the final day of monitoring for the Steelhead Trout migration period (May 31 in 2019). As no down counts were observed for Steelhead Trout in 2019, Equation 5 can be simplified to:

$$E = \sum_{t=1}^{k} \frac{U_t}{A} \qquad \text{Eq 6}$$

2.8 Gravel Mobilization

Bennett Land Surveying Ltd. (BLS) was contracted in September of 2013, 2015, and 2017 to conduct riverbed topographic surveys of the Seton River at an area 150 m downstream of Seton Dam [Figure 2-9; methods in Ramos-Espinoza et al. (2016)]. This 8,300 m^2 area was identified as the major source of gravel for Seton River, and more importantly is where the majority of spawning occurs. In 2019, another set of topographic surveys were completed at the end of September. Four substrate transects were identified and sampled within the area surveyed by BLS. Each transect consisted of running a measuring tape or marked line across the width of the river, from bankfull pin to bankfull pin, or to a point of safe wading access. At every meter interval along the transect line the proportion of each substrate type was estimated to the nearest 5% within a 1 m^2 section of riverbed along the entire length of the transect or to the furthest point of safe access. Substrate types were classified using the Wentworth scale (Wentworth, 1922), which separates substrate into 7 categories (fines, sand, small gravel, large gravel, small cobble, large cobble, boulder and bedrock). For analysis purposes, a dominant substrate was then assigned for each transect. Substrate classification data were managed, analyzed and visualized in R (Version 3.2.3; R Core Team 2014).

Figure 2-9. Site of riverbed topographic surveys in 2013, 2015, 2017 and 2019.

3.0 RESULTS

3.1 Physical Parameters

3.1.1 Discharge

As in 2016, 2017, and 2018, modified operations in the Bridge-Seton system in 2019 resulted in Seton Dam discharges which significantly exceeded the WUP target hydrograph. Starting on February 28, 2019 flows increased steadily from the WUP target flows of 11 m^3/s to accommodate maintenance at SGS, the earliest occurrence of high flows since this monitor began. Peak annual discharge occurred on April 16 when releases from Seton Dam reached 87 m^3/s (Figure 3-1). Following this peak, flows were reduced below the WUP target maximum of 60 m^3/s, eventually returning to the WUP target hydrograph on May 28. However, due to management concerns upstream, Seton Dam discharge was increased to 60 m^3/s on June 7 where it remained until July 31. The Seton River hydrograph returned to WUP target flows on September 27 and were maintained for the remainder of the year.

Discharge in Reach 2 and 3 of the Seton River is the sum of Cayoosh Creek and Seton Dam discharge. Cayoosh Creek flows typically mimic a natural freshet, with peak flows occurring between May and the end of July. These higher flows from Cayoosh Creek frequently coincide with peak flows from Seton Dam resulting in cumulative high flow impacts in Reach 2 and 3 of Seton River. Flows from Cayoosh in 2019 ranged from 1.1 – 54.4 m^3/s (Figure 3-1).

3.1.2 Water Temperature

Annual low water temperatures occur in March (4°C) and increase gradually throughout the year until September when temperatures peak at approximately 18°C (Figure 3-2). Water temperatures in 2019 followed this pattern, as in 2014-2018. Water temperatures decrease gradually through the fall, stabilizing at approximately 5°C in December or early January. Spawning Channel temperatures follow the same profile as the mainstem Seton River.

Comparison of temperatures during high flow periods to the same period in 2014 yielded inconsistent results. Some periods showed higher mean temperatures during periods of modified operations (i.e., 2015 and 2018, Figure 3-2) while other periods showed lower mean temperatures during periods of modified operations (2017 and 2019, Figure 3-2). At this time no conclusions can be made regarding potential effects of modified operations on Seton River temperatures.

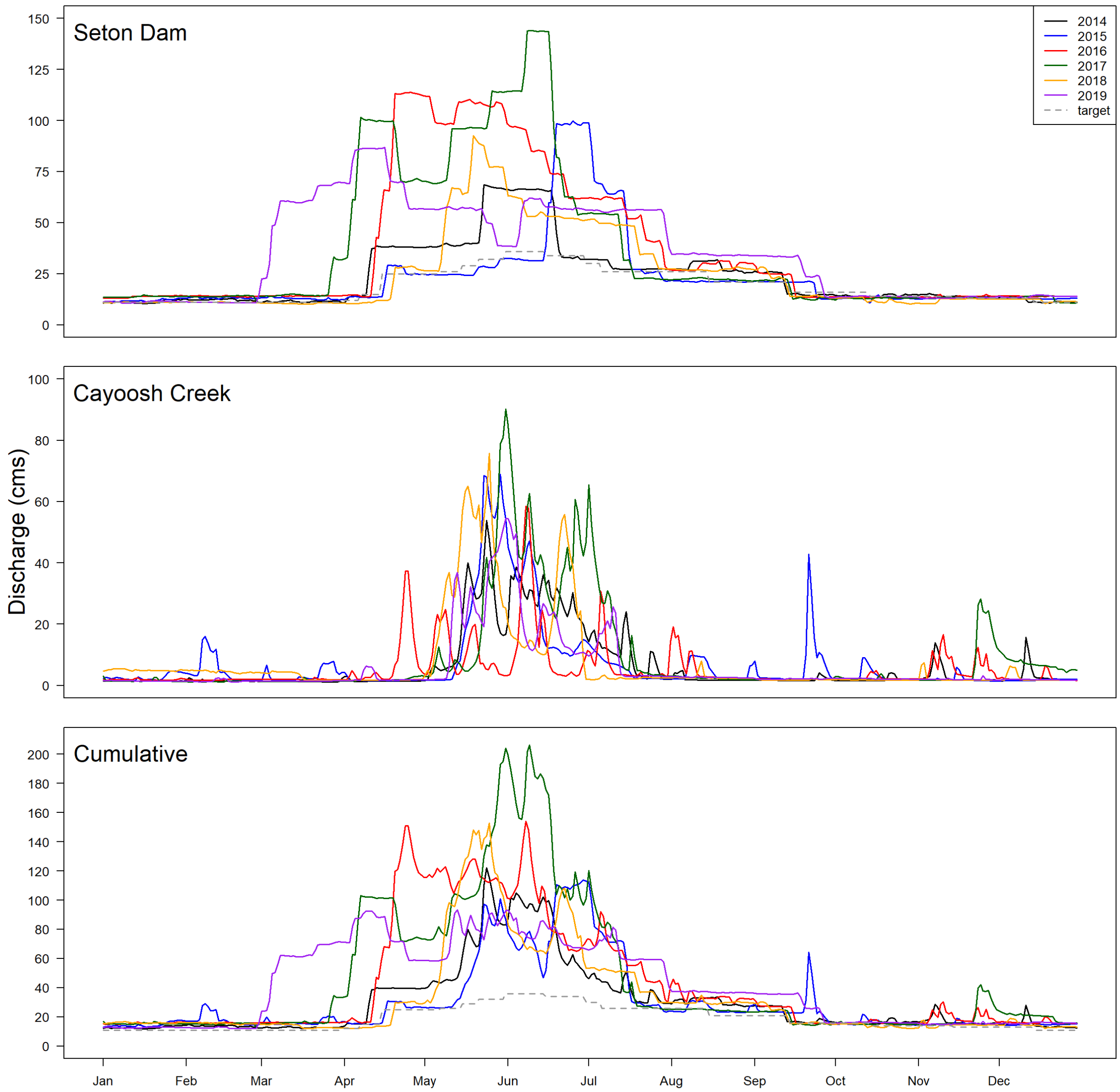


Figure 3-1. Seton Dam and Cayoosh Creek discharge for BRGMON-9 study years and the cumulative flow (Seton River and Cayoosh Creek) in Reach 2 and 3 of Seton River for BRGMON-9 study years.

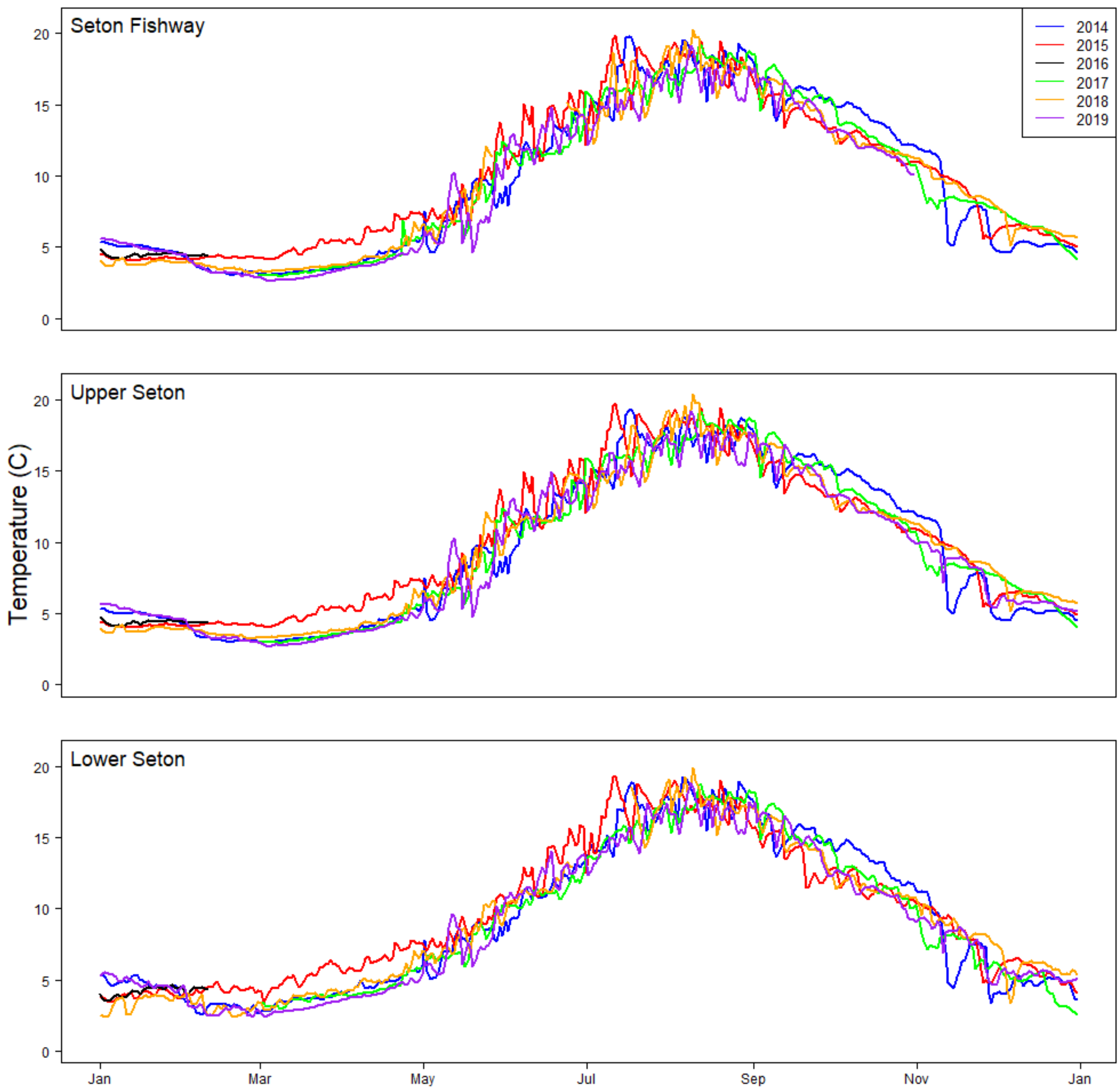


Figure 3-2. Mean daily temperature for the Seton Fishway, Upper Seton, and Lower Seton River from 2013 to 2019. Periods of Modified Operations (Seton Dam discharge > 60 m^3/s) are shaded for each year to easily examine if changes in temperature correspond with higher discharges.

3.2 Habitat Suitability Assessments

To support an ongoing assessment of the discharge-habitat availability relationship in the Seton River for Juvenile Rainbow Trout, Coho, and Chinook Salmon, river-wide HSI surveys were completed from April 5 – 15, 2019 when Seton Dam discharge was 86 m^3/s. At this time, Cayoosh Creek mean discharge was minimal (3.5 m^3/s), having little impact on the overall flow in Reach 2 and 3. The surveys included all mainstem sites (125) and four side-channel habitats wetted at higher discharge.

Additional HSI surveys were completed at each of the juvenile abundance sites during WUP flows to estimate changes in juvenile habitat suitability over time. Surveys were completed from October 10 – 21, 2019 when flows from Seton Dam ranged from 14.0 – 14.2 m^3/s and flow contribution from Cayoosh Creek was minimal. These conditions are comparable to HSI surveys conducted in 2014 and 2018 (Table 3-1). While 2014 surveys were completed for the entire Seton River, only those transects repeated in both 2018 and 2019 were included in comparative assessments, as described below.

Table 3-1. Discharge conditions in 2014, 2018, and 2019 during the habitat suitability surveys used to compare changes in useable area for juvenile Rainbow Trout, Coho, and Chinook.

Year	Survey Dates	Mean Seton Dam Discharge (m^3/s)	Mean Cayoosh Discharge (m^3/s)
2014	Mar 18 – Apr 9	12.3	1.5
2018	Sept 18 – Oct 30	12.6	1.8
2019	Oct 10 – 21	14.1	2.2

3.2.1 River-wide Juvenile Rearing Habitat Suitability

Habitat for all species is greatly reduced as Seton Dam discharge increases from 12 to 60 m^3/s with species experiencing a 72% (Coho salmon juveniles) to 77% (Rainbow Trout Fry) loss in WUA corresponding to habitat losses of 15,787 m^2 (Rainbow Trout Fry) to 28,275 m^2 (Chinook salmon juveniles). At 86 m^3/s, habitat losses in the mainstem river are somewhat buffered by increases in habitat availability in side-channel habitats. For juvenile Coho and Chinook Salmon, this resulted in habitat increases of 3,854 m^2 and 5,385 m^2, respectively when Seton River discharge increased from 60 to 86 m^3/s. Conversely, the amount of habitat available stayed relatively constant from 60 to 86 m^3/s for juvenile Rainbow Trout, with net increases of less than 1,000 m^2 for both life stages (Figure 3-3). Decreases in the amount of habitat available for each species and life stage were observed at 100 m^3/s, with a net decrease ranging from 281 m^2 for Rainbow Trout fry to 7,190 m^2 for Chinook Salmon. However, as the surveys completed at 100 m^3/s represent only a partial river estimate, the available habitat for each species is likely underrepresented.

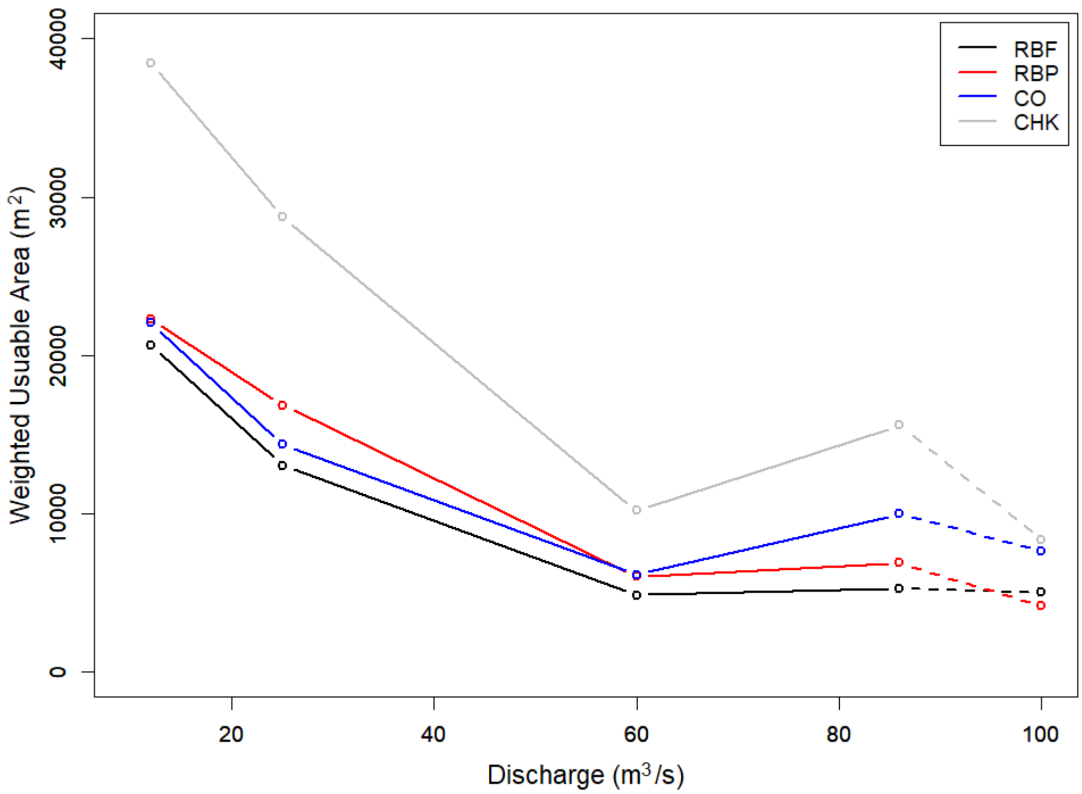


Figure 3-3. Total weighted useable area (WUA; m^2) in Seton River at various discharges from Seton Dam from 2014 – 2019 for Rainbow Trout fry (RBF), Rainbow Trout Parr (RBP), Coho (CO) and Chinook (CHK) Salmon juveniles. WUA at 60 m^3/s represents data from a full surveys of the mainstem river and side-channel habitats. WUA at 100 m^3/s (dashed lines) represent data from a partial mainstem river survey and surveys of side-channel habitats. Side-channel habitats are not wetted below 60 m^3/s.

3.2.2 Changes in Juvenile WUA

Eleven transects at juvenile abundance sites were repeated in 2014, 2018, and 2019 at 12-14 m^3/s. In Reach 1 survey sites, Rainbow Trout fry, parr and Coho Salmon juveniles had a net increase WUA, while Chinook Salmon juveniles had a slight decrease in WUA. All species experienced a net decrease in WUA in Reach 2 and 3 sites, with only Rainbow Trout fry experiencing a slight net increase in WUA in Reach 3 (Figure 3-4). While net changes in WUA were not consistent across reaches, overall net WUA decreased for all species and life stage by 242 m^2 (Rainbow Trout fry) to 1,998 m^2 (Chinook Salmon; Appendix 7-4). Inconsistency of results between reaches may be due to a small number of repeated transects within each reach, ranging from two to six (Figure 3-4), or the influence of Cayoosh Creek flows on Reach 2 and 3 that increase the flows further.

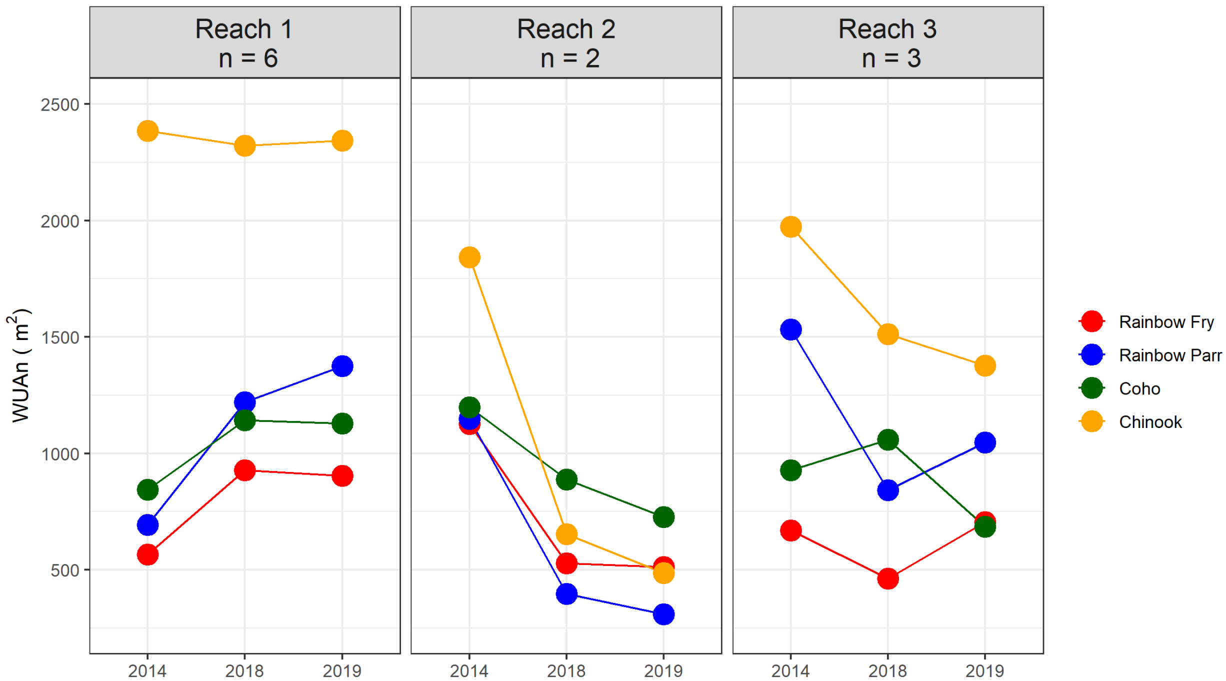


Figure 3-4. Total weighted useable area (WUA) for the 11 sites that were surveyed in 2014, 2018, and 2019 to show trends in changes to Seton River WUA by reach.

3.3 Bio-sampling of Juveniles

Juvenile salmonids were sampled monthly from April to October in 2014-2019. Due to modified operations, some mainstem sites could not be accessed and additional side-channel habitats were sampled when wetted (See Table 2-1 in Section 2.4 for a detailed summary). A wide range of species were captured including six species of salmonids and numerous non-salmonids (Appendix 7-5).

3.3.1 Ageing Analysis

Of salmonids, only Rainbow Trout, Coho, and Chinook Salmon were captured in sufficient numbers (i.e., >500 compared to <50 Sockeye) to show the presence of discrete size classes for an ALK. Fish from all years and capture locations were pooled for ALKs under the assumption that fish move freely between the spawning channels and mainstem (see Section 3.5.2).

Rainbow Trout

Four distinct age classes were identified for Rainbow Trout. The most frequently captured age class was age 0 followed by age 1, while catch rates for age 2 and age 3 Rainbow Trout were lower. In all years, captures of age 1 through age 3 Rainbow Trout were well distributed between the mainstem river habitats and the two spawning channels, while age 0 Rainbow Trout were primarily captured in the mainstem river (Figure 3-5). Fork length distributions for all Rainbow Trout age classes demonstrate clear monthly growth from March to October (Figure 3-6) and suggest that the ALKs adequately estimated age for juvenile Rainbow Trout.

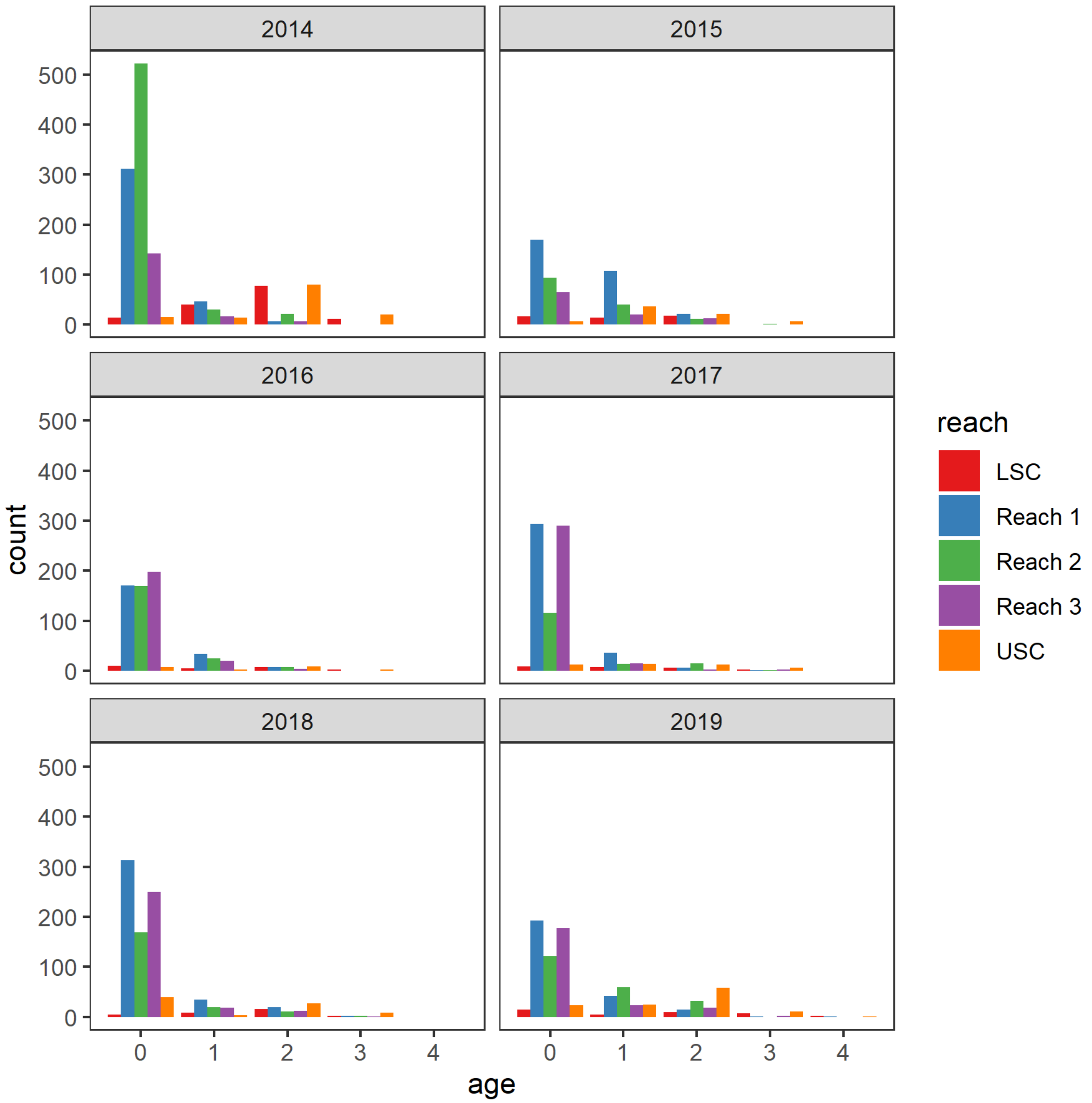


Figure 3-5. Captures of Rainbow Trout in the Seton River mainstem and spawning channels from 2014 to 2019 separated by age and location of capture.

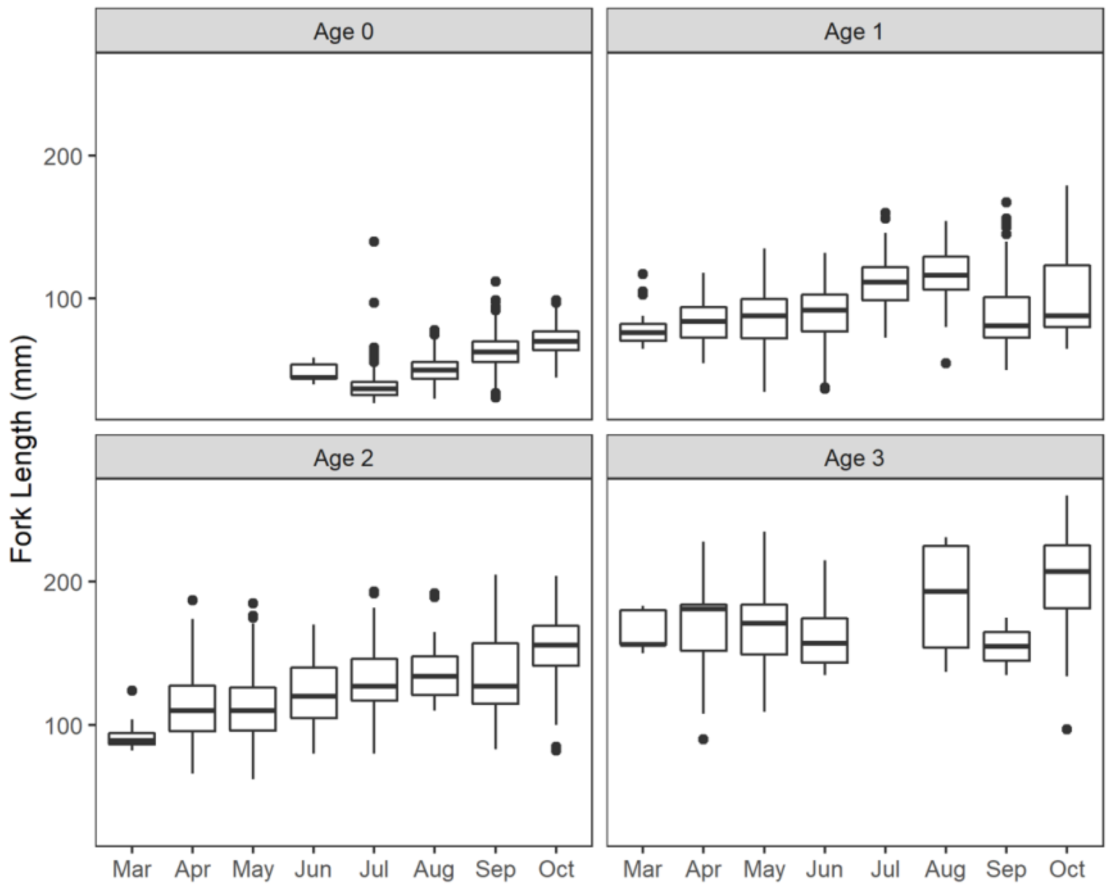


Figure 3-6. Boxplots of fork length for Rainbow Trout aged 0 to 3 captured in the Seton River and the spawning channels from 2014 to 2019.

Coho Salmon

Three distinct age classes were identified for Coho Salmon. Age 0 (n=733) were the most frequently captured followed by age 1 (n=191); only 51 age 2 Coho Salmon have been observed throughout the program. Until 2017, captures of Coho Salmon juveniles were relatively well-distributed among habitats but in 2018 and 2019, large numbers (n=458) have been observed and captured in the LSC relative to other reaches (n=131-288) (Figure 3-7), though this may be the result of increased sampling in the spawning channels in 2018. Fork length distributions for age 0 Coho Salmon demonstrate clear monthly growth from March to October (Figure 3-8), with growth continuing the following spring at age 1. It is assumed larger age 1 Coho Salmon leave the river in June, and a smaller cohort remain in Seton River for a second year, explaining the size reduction observed between June and July for that age class (Figure 3-8). The age 0 and age 1 data suggest that the ALKs adequately estimated age for juvenile Coho

Salmon. Low captures of age 2 Coho made it difficult for the ALK to partition fish with larger fork lengths; however, as all age 2 fish were selected for ageing, the small sample size did not have a noticeable effect on monthly growth trajectories (Figure 3-8).

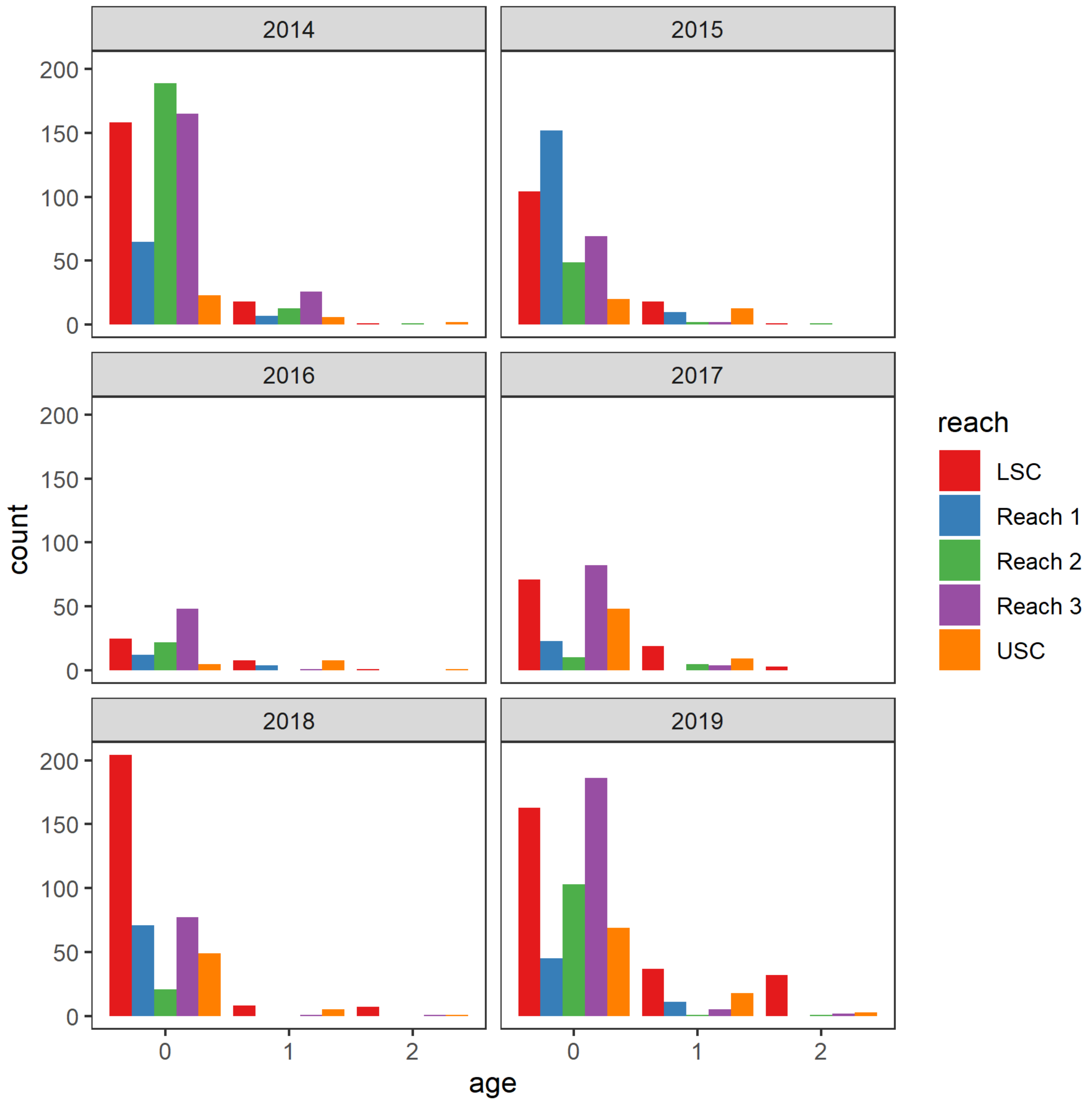


Figure 3-7. Captures of Coho Salmon in the Seton River mainstem and spawning channels from 2014 to 2019 separated by age and location of capture.

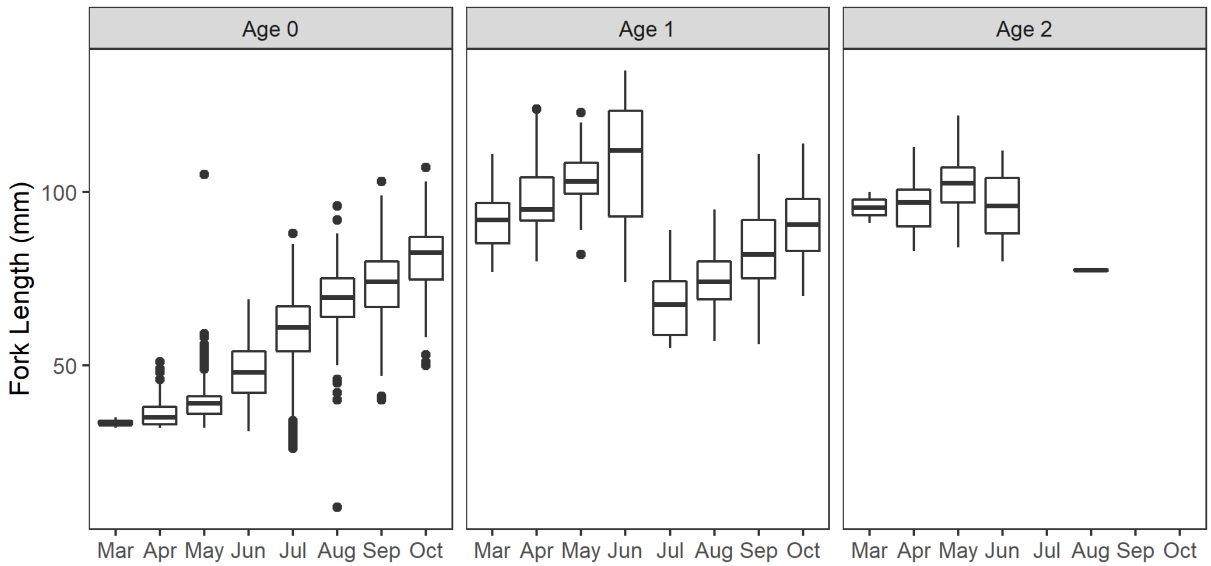


Figure 3-8. Boxplots of fork length for Coho Salmon aged 0 to 2 captured in the Seton River and the spawning channels from 2014 to 2019.

Chinook Salmon

Three distinct age classes were identified for Chinook Salmon. The most frequently captured age class was age 0 (n=323) followed by age 1 (n=58); only 30 age 2 Chinook Salmon were seen throughout the program. Captures of Chinook Salmon were variable between the mainstem river and spawning channels, with no consistent pattern in catch rates by location (Figure 3-9). Fork length distributions for age 0 Chinook Salmon demonstrate clear monthly growth from March to October (Figure 3-10) and suggest that the ALKs adequately estimated age for age 0 juvenile Chinook Salmon. Low captures of age 1 (from July to October) and age 2 Chinook made it difficult for the ALK to partition fish with larger fork lengths; however, as all age 1 and 2 fish were selected for ageing, the small sample size did not have a noticeable effect on monthly growth trajectories (Figure 3-10).

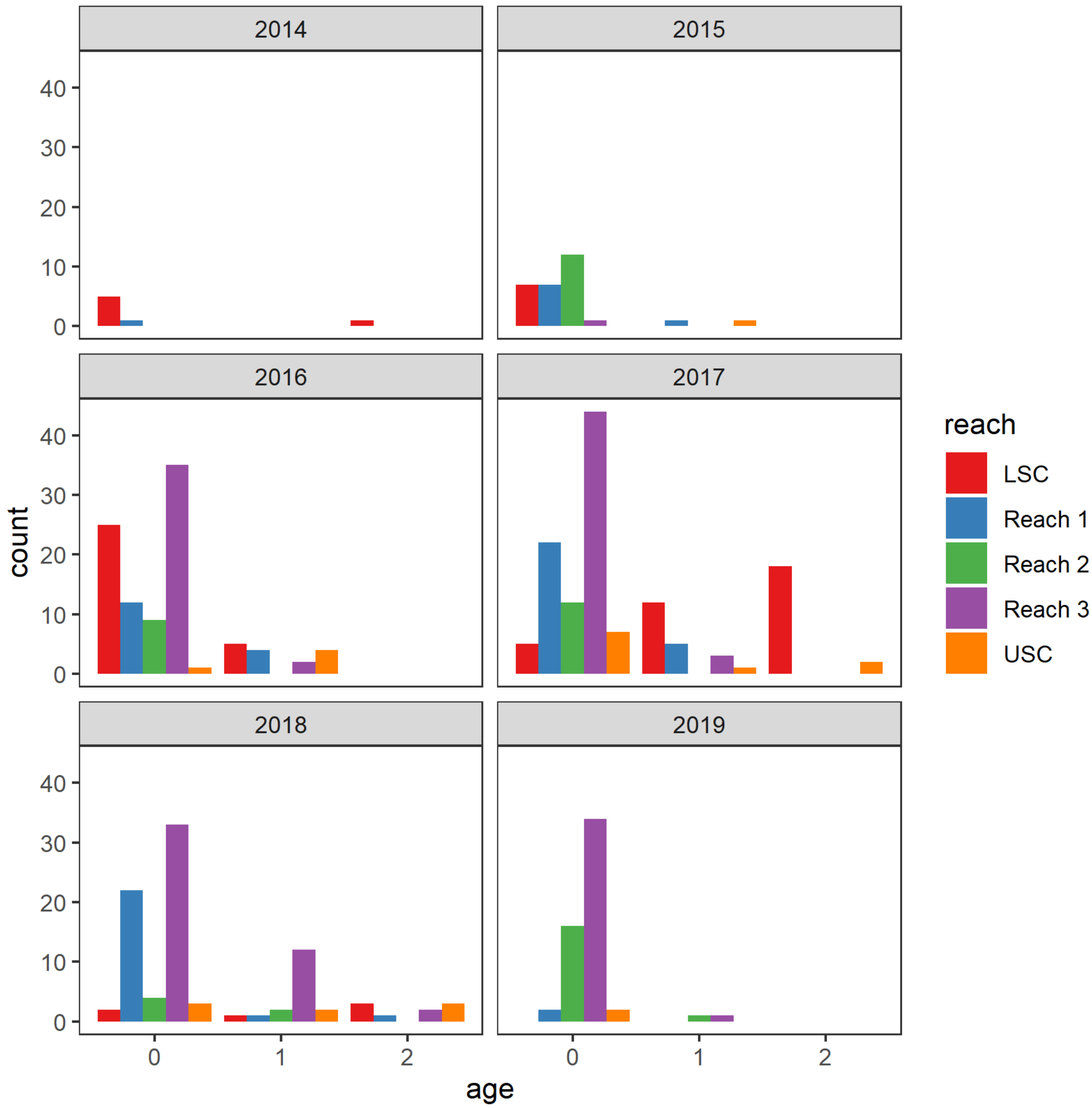


Figure 3-9. Captures of Chinook Salmon in the Seton River mainstem and spawning channels from 2014 to 2019 separated by age and location of capture.

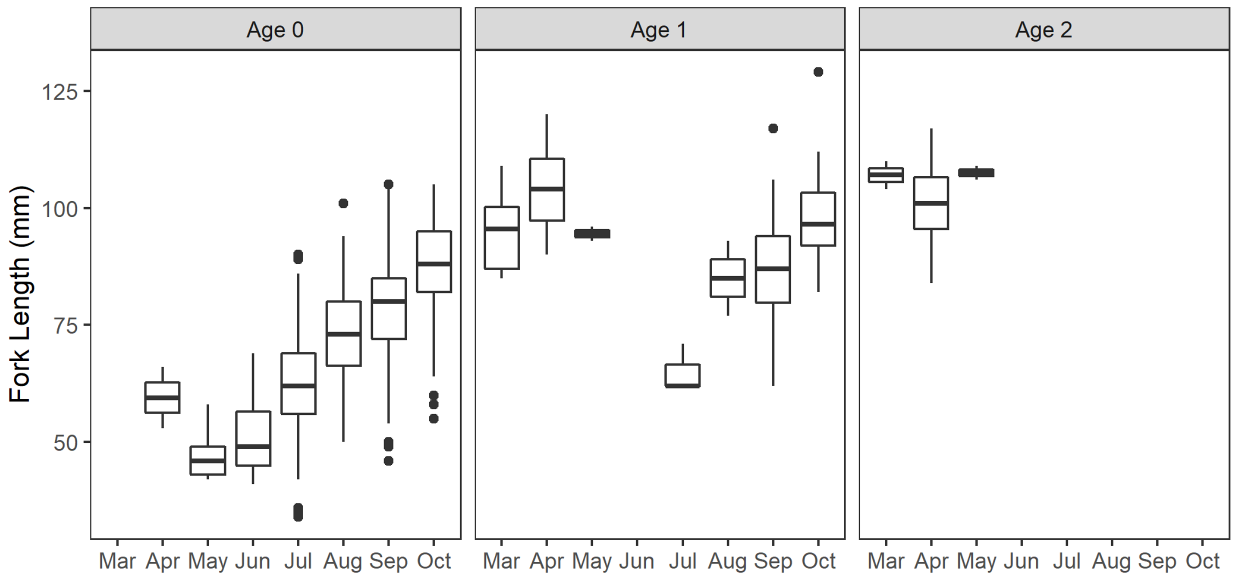


Figure 3-10. Boxplots of fork length for Chinook Salmon aged 0 to 2 captured in the Seton River and the spawning channels from 2014 to 2019.

3.3.2 Growth and Body Condition

Rainbow Trout

Body Condition (K_f)

We determined the age-specific effect of year and reach on mean K_f using MANOVA analyses and AIC model selection. For age 0 Rainbow Trout, the most complex model (year*reach) was selected the top model according to AICc selection (Appendix 7-6).

Tukey's hypothesis testing suggested that for age 0 Rainbow Trout, mean K_f values were statistically similar among LSC and USC, while mean K_f in Reach 1 was higher than in Reach 2 and 3 (ANOVA p-value 8.57e-07; Figure 3-11). Year appeared to have less of an effect of age 0 body condition, but a Tukey's hypothesis test suggest body condition in 2019 was higher relative to all years except 2015 (ANOVA p-value 9.91e-06; Figure 3-11). For age 1 Rainbow Trout, the model with year alone was the best-fit model according to AICc selection; and year had a weakly significant effect on age 1 body condition (ANOVA p-value 0.001). A Tukey's hypothesis test suggested age 1 body condition was higher in 2019 relative to 2014 through 2016 (but similar to 2017 and 2018).

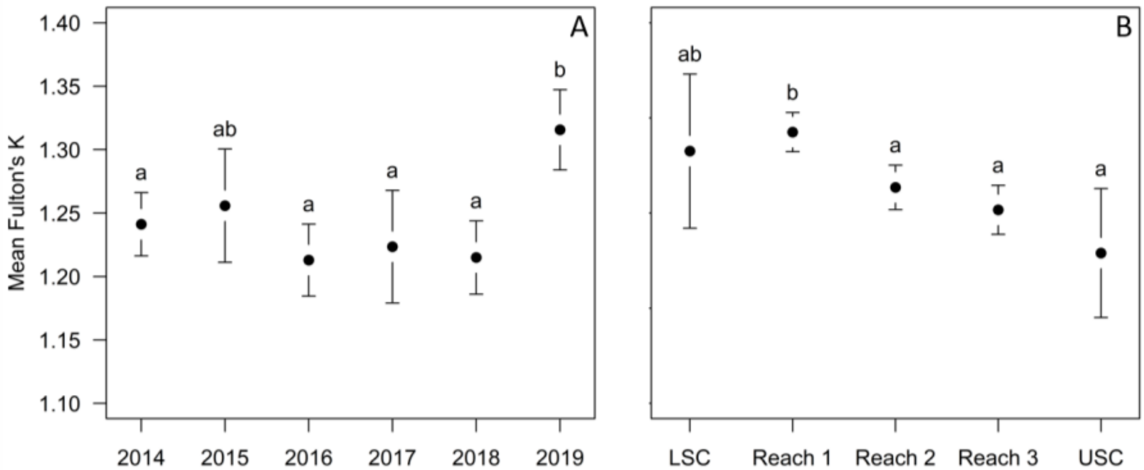


Figure 3-11. Mean condition factor of age 0 Rainbow Trout (A) each year (2014-2019) and (B) in the mainstem Seton River (Reach 1, 2 and 3) and the upper and lower spawning channels (USC and LSC, respectively) for all years. Points that do not share the same letter are statistically different from each other.

Length Vs. Weight Analyses

Effects of year on length and weight relationships were assessed using multiple log-linear regression models with length and weight data pooled for all age classes. We performed separate models for each reach to avoid overfitting. Year was a significant predictor of weight in all reach-specific models except the LSC. In Reach 1 and Reach 2, year had a significant impact on the slope and intercept of the length vs weight model (i.e., both the rate of change between length and weight and the average weight were different between years), while in Reach 3 and in the USC, year had a significant impact on just the intercept (i.e., the average weight was different between years but year had no effect on the rate of change in length given weight). Year appears to be very important, but as with analysis of 2018 data (see Buchanan et al. 2018), the directionality of relationships is inconsistent.

Coho Salmon

Body Condition (K_f)

For age 0 Coho Salmon, the most complex model comparing body condition (year*reach) had the highest AIC support and was selected as the best-fit model (Appendix 7-6). This suggests that year, reach, and their interactions affect mean body condition of Coho Salmon in the Seton River. Tukey's hypothesis testing suggested that mean K_f values were statistically similar among all years except 2017, in which body condition was statistically greater (ANOVA p-value <2.2e-16; Figure 3-9). With all years of data pooled, condition was statistically similar across all reaches (ANOVA p-value 0.005; Figure 3-12).

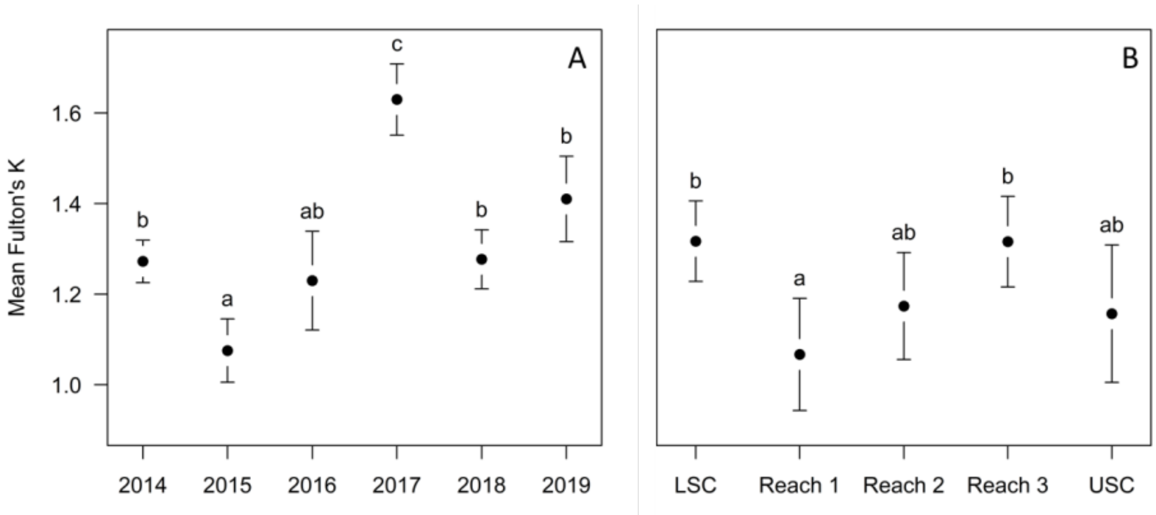


Figure 3-12. Mean condition factor of age 0 Coho Salmon (A) each year (2014-2019) and (B) in the mainstem Seton River (Reach 1, 2 and 3) and the upper and lower spawning channels (USC and LSC, respectively) for all years. Years/Locations that do not share the same letter are statistically different from each other.

Length Vs. Weight Analyses

Best-fit models for reach-specific length vs weight modelling were determined using AIC. Year was found to be a significant predictor of weight in all reach-specific models except for in the USC. In all other habitats, year had a significant impact on the slope and intercept of the length vs weight model (i.e., both the rate of change between length and weight and the average weight were different between years).

Chinook Salmon

Body Condition (K_f)

We determined the age-specific effect of year and reach on mean K_f using MANOVA analyses and AIC model selection. The intercept-only model and the model with year alone had equal AIC support, and we selected the intercept only model as the most parsimonious model (Appendix 7-6). This suggests that neither year, reach, nor any of their interactions affect mean body condition of Chinook in the Seton River, and no further statistical testing was conducted post-hoc (Figure 3-13).

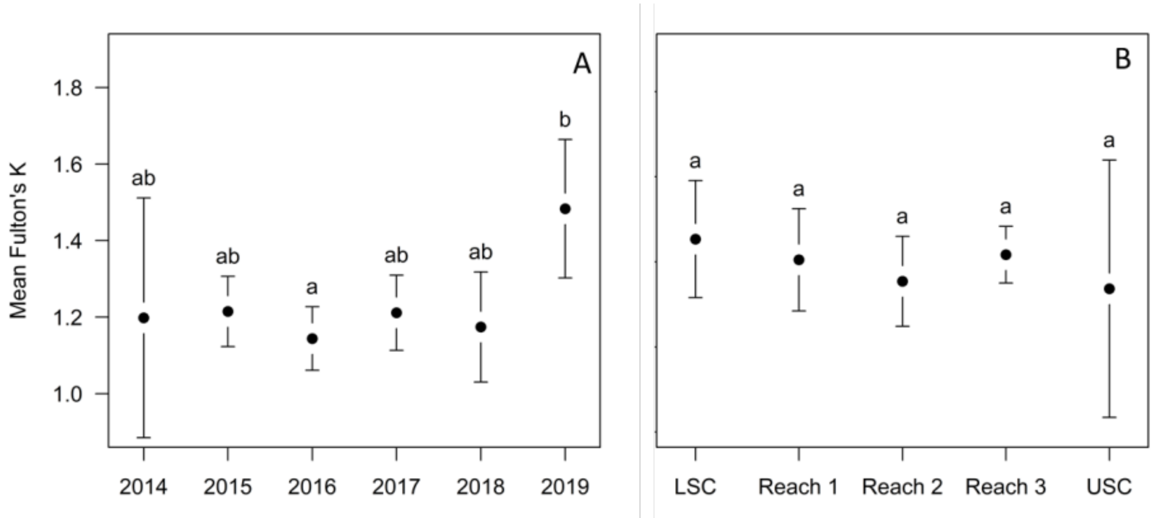


Figure 3-13. Mean condition factor of age 0 Chinook Salmon (A) each year (2014-2019) and (B) in the mainstem Seton River (Reach 1, 2 and 3) and the upper and lower spawning channels (USC and LSC, respectively) for all years. Years/Locations that do not share the same letter are statistically different from each other.

Length Vs. Weight Analyses

Year was not found to be a significant predictor of weight in any reach-specific length vs weight models for Chinook Salmon except for in reach 1, where year had a significant effect on both the slope and intercept of the length vs weight model. Overall, AICc values were more homogenous compared to models for Rainbow Trout and Coho Salmon, suggesting that more complex models with interactive terms tended to overfit the Chinook dataset. Overfitting may be due to a smaller sample size of Chinook over the 6-year sampling period (n total = 628, Reach 1: n = 102, Reach 2: n = 112, Reach 3: n = 287, USC: n = 26, LSC: n = 101).

3.3.3 Chinook Salmon Stock ID

In total, 207 of the 240 samples collected from juvenile Chinook Salmon from 2016 to 2018 sent for analysis were identified to stock origin (Appendix 7-7). The most numerous stock groupings present within Seton River are Seton River/Portage Creek (n = 99; current molecular methods cannot distinguish Portage Creek from Seton River), Stuart (n = 30), Quesnel (n = 25), Nechako (n = 16) and Chilko (n = 14). An additional 23 Chinook Salmon were detected from other watersheds (Appendix 7-8). Although across all years, juvenile Chinook Salmon originating from other watersheds were captured throughout the Seton River, most (57%) were captured in Reach 3, closest to the Fraser River confluence (Table 3-2). No Bridge River Chinook were captured in Seton River.

Table 3-2. Proportion of Seton River (Portage Creek) Chinook Salmon relative to all other populations captured in each sampling location of Seton River by year (LSC/USC = Lower and Upper Spawning Channels, respectively). Current molecular methods cannot distinguish Portage Creek from Seton River Chinook Salmon. Sample sizes presented in parenthesis.

Reach	2016	2017	2018	All years combined
1	0.57 (14)	0.67 (9)	0.95 (21)	0.77 (44)
2	0.36 (28)	0.79 (14)	0.50 (2)	0.50 (44)
3	0.15 (40)	0.70 (30)	0.31 (29)	0.36 (99)
LSC	0.08 (12)	0.50 (2)	1.0 (1)	0.20 (15)
USC	1.0 (1)	0.25 (4)	1.0 (1)	0.50 (6)

Stock proportions varied throughout the year. There was a trend for more Chinook Salmon of other stock origins to be present in late summer and early fall months (August - October), while the opposite is true for spring and early summer months (May – July; Figure 3-14).

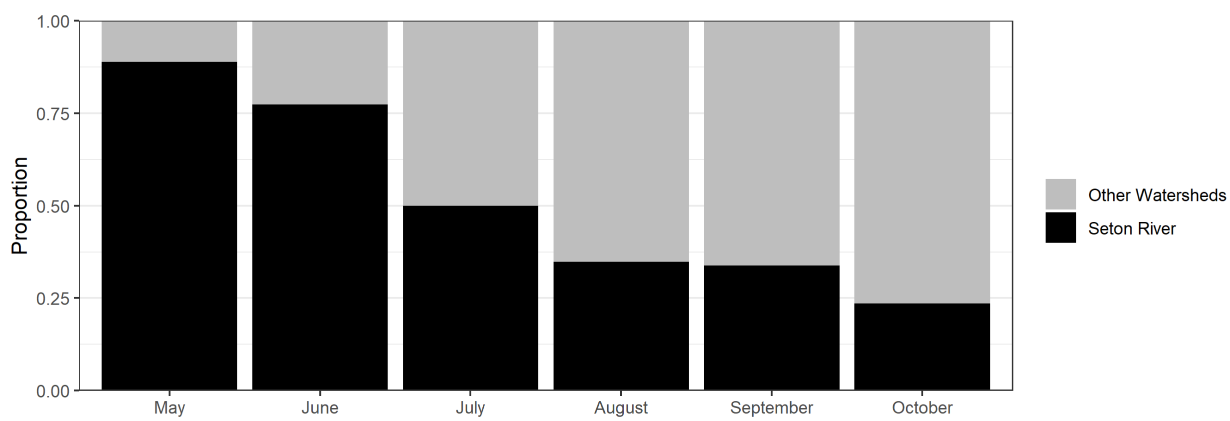


Figure 3-14. Proportion of juvenile Chinook Salmon other Seton River/Portage Creek origin relative to those of all other origins caught each month from 2016-2018.

3.4 Juvenile Abundance Estimation

During October 2019, electroshocking covered approximately 29% of the total shoreline of Seton River, consistent with previous years (Table 3-3). Although all species encountered were enumerated, weighed, and measured, only age 0 Rainbow Trout were captured in sufficient densities to be used in the Bayesian hierarchical modeling. Average recapture percentages calculated using mark-recapture data from 2014 through 2019 (i.e., recaptures/marks * 100) ranged from 10% in 2015 to 35% in 2019 (Table 3-4). The mean of the beta hyperparameter for detection probability estimated by the Bayesian hierarchical model for 2014 through 2019 was 0.25 (i.e., 25% detection probability; Figure 3-15) with an SD of 0.02.

Table 3-3. Percentage of shoreline sampled during electrofishing at shoreline index sites in the Seton River from 2014 to 2019.

Reach	Percent Sampled					
	2014	2015	2016	2017	2018	2019
1	44	32	35	33	24	35
2	68	49	53	42	18	26
3	20	28	22	28	33	25
Total	**39**	**34**	**34**	**33**	**27**	**29**

Table 3-4. Recapture probabilities (recaptures/marks) calculated for mark-recapture sites in the Seton River during shoreline electroshocking from 2014 to 2019.

Year	Avg Recapture % (SD)	N
2014	29 (8)	6
2015	10 (11)	4
2016	27 (15)	5
2017	28 (5)	6
2018	21 (9)	6
2019	35 (5)	4

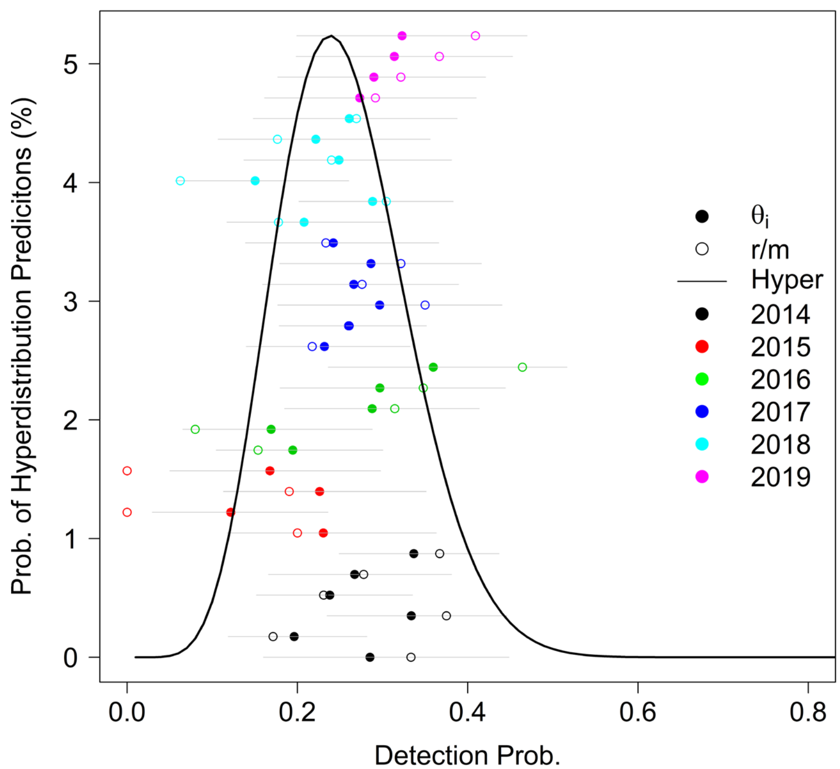


Figure 3-15. Parameter estimates from the hierarchical Bayesian model that estimate age 0 juvenile Rainbow Trout abundance. Shows the median hyperdistribution for detection probability, the median estimates of site-specific detection probability at mark-recapture sites and 95% credible interval (θ_i), and expected values (r/m).

The total river-wide abundance of age 0 Rainbow Trout in the Seton River in 2019 was 2,606 fish with a 95% credible interval of 537 – 3,807 fish (Table 3-5). Abundance in 2019 was the second lowest since the study began, ahead of only 2015 (Table 3-5). Although the 2014 abundance estimate was substantially higher than in other years, there is a high degree of uncertainty in this estimate due to variable densities observed during 2014 shoreline electroshocking (Figure 3-16, Figure 3-17). The hyperdistribution of fish density for the Seton River in 2019 (mean density 0.31 fish/m) is shown along with site-specific density estimates in Figure 3-18. The mean of the hyperdistribution of fish density in 2019 was the second lowest amongst all sample years, ahead of only 2015 (0.24 fish/m).

Table 3-5. Mean posterior estimate of abundance and 95% credible interval (in parentheses) for Seton River Reach 1, 2 and 3 from 2014 to 2019.

Reach	2014	2015	2016	2017	2018	2019
1	3,974	652	1,291	1,629	1,459	845
	(2,757, 5,886)	(452, 919)	(698, 2,603)	(993, 2,796)	(875, 2,482)	(177, 1,238)
2	3,555	615	1,277	1,657	1,512	780
	(2,512, 5,211)	(439, 844)	(791, 2,288)	(1,060, 2,720)	(934, 2,525)	(166, 1,144)
3	4,653	750	1,514	1,950	1,677	981
	(3,233, 6,915)	(529, 1,046)	(841, 3,011)	(1,232, 3,260)	(1,069, 2,713)	(196, 1,424)
Total	12,183	2,017	4,082	5,236	4,648	2,606
	(8,563, 18,106)	(1,432, 2,807)	(2,337, 7,942)	(3,298, 8,811)	(2,885, 7,720)	(537, 3,807)

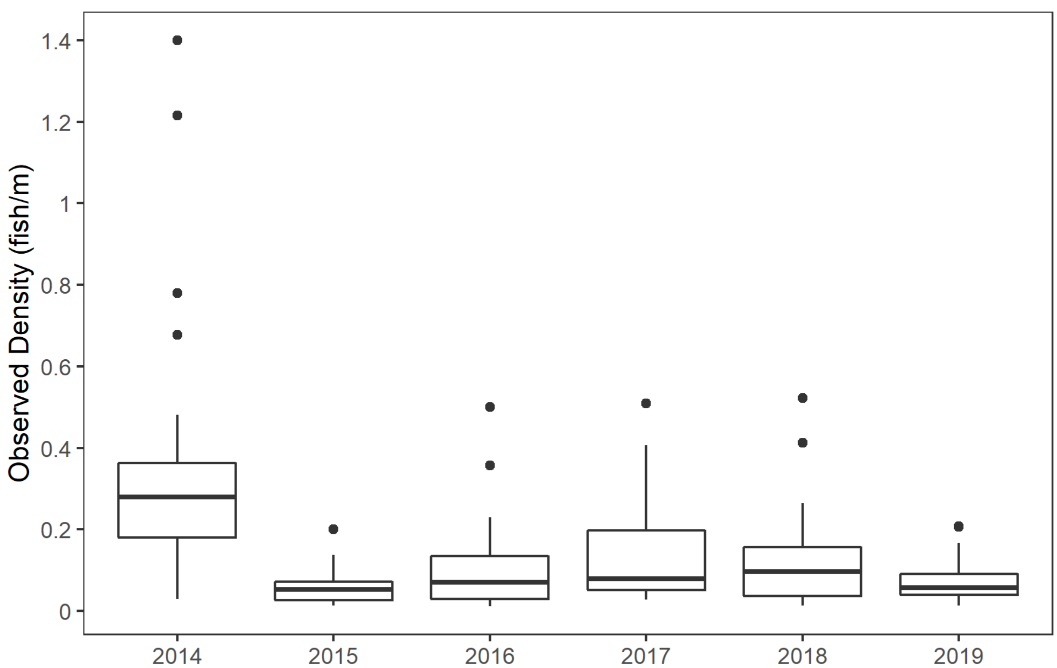


Figure 3-16. Density of age 0 Rainbow Trout (fish/m) directly calculated from shoreline electrofishing index sites (observed data) in the Seton River from 2014 to 2019.

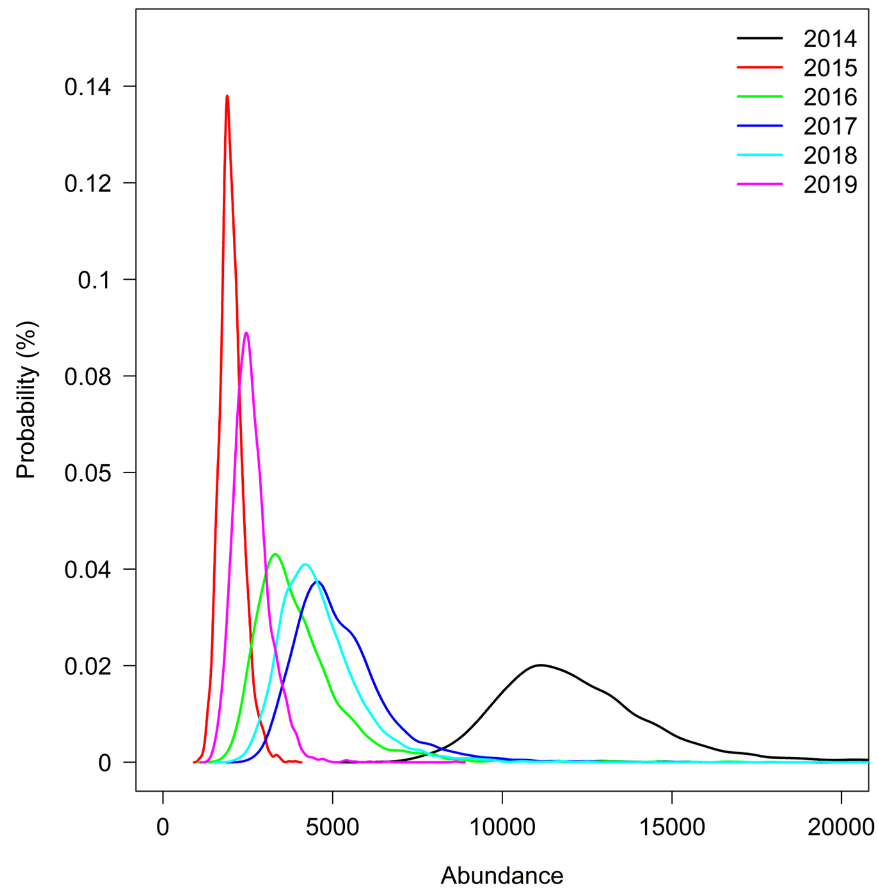


Figure 3-17. Posterior probability distributions for total abundance of age 0 Rainbow Trout in Seton River from 2014 to 2019.

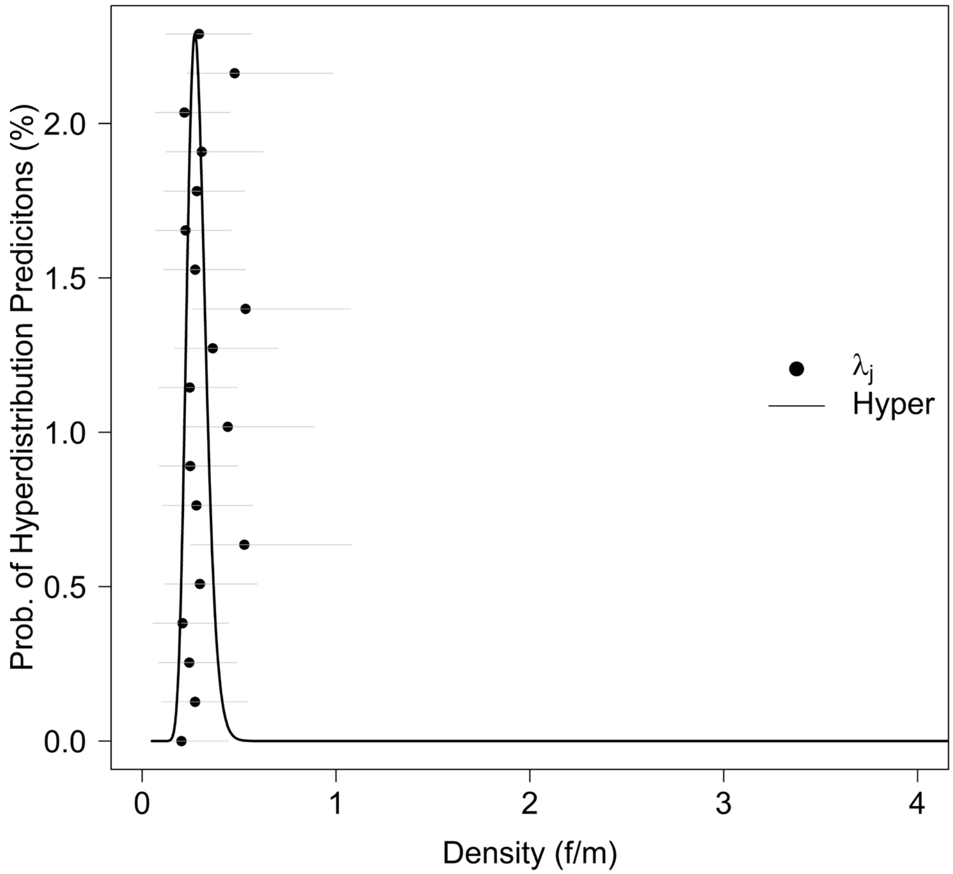


Figure 3-18. Estimates of fish density (fish/m) for age 0 Rainbow Trout in the Seton River in 2019. Filled points are the mean and 95% CI of individual index sites and the black line is the hyperdistribution based on the means of the hyperparameters estimated during the hierarchical Bayesian modeling. The vertical order of the site-specific estimates shows their position in the river from downstream to upstream and is unrelated to the numerical y-axis.

3.5 Telemetry

3.5.1 Adult Radio Telemetry

Radio tags were detected by fixed telemetry stations and through mobile tracking on the Seton River. Eight of the 25 Steelhead Trout tagged at the Seton – Fraser confluence (via BRGMON-3) in 2019 were detected on the radio receiver located at the LSC confluence (1.42 km upstream of Seton-Fraser confluence). Four Steelhead Trout were detected through mobile radio tracking and PIT antennas at Seton Dam, passing Seton Dam between May 5 and May 13. The timing of these fish past Seton Dam is consistent with what has been observed in previous years (Table 3-6). No tagged Steelhead were detected through mobile tracking in Seton Lake.

Of the other 17 Steelhead Trout tagged at the Seton – Fraser confluence in 2019, eight moved into the Lower Bridge River and were monitored under BRGMON-3, the other nine may have continued upstream in the Fraser River to spawn elsewhere (e.g. Chilcotin River).

Table 3-6. Timing of radio-tagged Steelhead observed in Seton River from 2014-2019

Year	Steelhead Tagged	Steelhead Detected in Seton River	First Tag Deployed	First Detection	Last Detection
2014	15	3	March 14	April 21	May 21
2015	18	5	February 27	April 14	April 30
2016	6	3	March 7	April 4	April 13
2017	21	3	February 21	May 2	May 31
2018	20	2	Mach 12	April 20	April 24
2019	25	8	March 7	May 5	May 13

3.5.2 Passive Integrated Transponder (PIT) Telemetry

From April 4, 2013 to October 30, 2019, a total of 1589 Rainbow Trout were PIT tagged in the USC (n = 312) and LSC (n = 235) and mainstem Seton River (n = 1042).

With the LSC array only having one antenna in 2014, detection efficiency could not be calculated in that year. For other years, detection efficiency for the downstream antenna ranged from 14% in 2016 to 84% in 2017 and from 0% in 2018 to 89% in 2019 for the upstream antenna (see Appendix 7-9). The LSC PIT array was moved on May 30, 2019. Prior to the move, detection efficiency was 75% and 40% for the upstream and downstream antennas, respectively, which increased to 89% and 67%, respectively, after the move. From 2014-2019, 71 Rainbow Trout were detected on the LSC PIT array. As determination of fish direction is directly related to the efficiency of each individual PIT antenna, direction can only be confidently confirmed for 38 fish (Figure 3-19). The remaining 33 were either detected in 2014 when directionality could not be assigned, were not detected on both antennas, or moved between antennas numerous times, confusing the assignment of direction. Two juvenile Coho Salmon were detected on the upstream antenna of the LSC PIT array in 2019. Direction of movement cannot be assigned for either individual.

In the spring of 2016, movement into the LSC for juvenile and adult fish was blocked by a temporary fish fence designed to capture out-migrating smolts. In the spring of 2017, the fence was re-installed but altered to allow adult fish passage through a tube. The ability for juvenile fish to pass through the tube is unknown, and high flows present a likely barrier. Starting in 2018, a modified Incline Plane Trap has been used to sample out-migrating juveniles, allowing for free passage of adults and juveniles in and out of the spawning channel.

The USC array had two antennas for the entire monitoring period. Detection efficiency for the downstream antenna ranged from 40% in 2015 to 100% in 2017 and 2018 and from 73% in 2018 to 100% in 2015 for the upstream antenna (Appendix 7-10). From 2015-2019, 108 Rainbow Trout were detected on the USC PIT array, of which direction can be confidently identified for 98 individuals (Figure 3-20). The remaining 20 detections could not be assigned a direction. Three juvenile Coho Salmon were detected on the USC PIT array in 2019, of which direction can be confidently identified for 2 individuals.

Analysis of movement data indicate that Rainbow Trout move in and out of spawning channels from mid-March to December. Movements do not appear to be associated with flow changes in the mainstem Seton River and there appears to have been a directed movement into spawning channels in the fall since 2015 (Figure 3-19, Figure 3-20). This may indicate that juveniles overwinter in the spawning channels and suggests that fish from the Seton River mainstem and spawning channels are from one population. Corroborating this suggestion are eleven fish that were detected on both the USC and LSC PIT arrays occurring from 2015-2019 and for both rearing and spawning purposes (detailed life history of each fish in Appendix 7-11). Generally, fish moving into the spawning channels were age 2 or older.

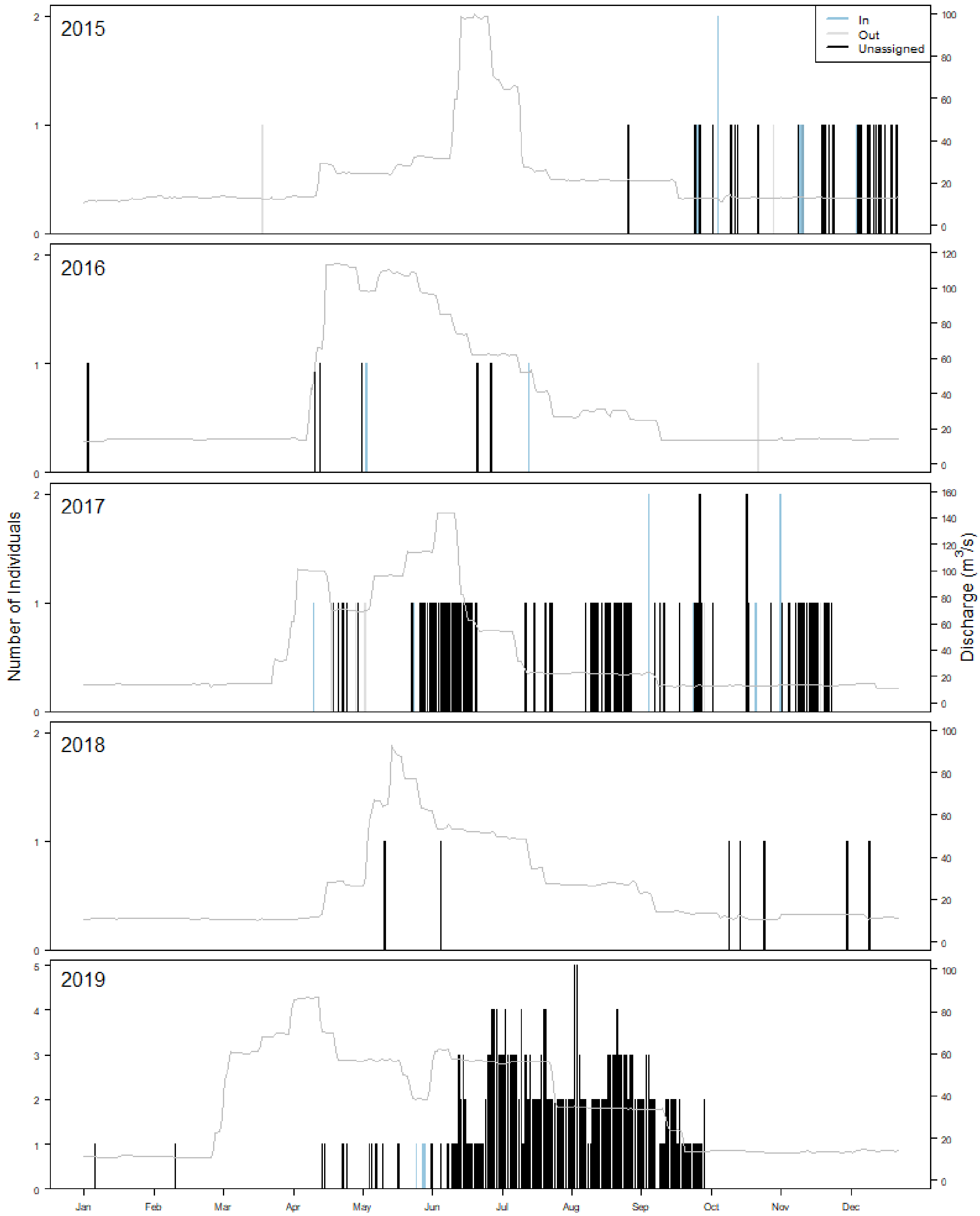


Figure 3-19. Rainbow Trout detections on the Lower Spawning Channel PIT array in 2015, 2016, 2017, 2018, and 2019 in relation to discharge. Movements could not be assigned in 2018 due to low detection efficiencies.

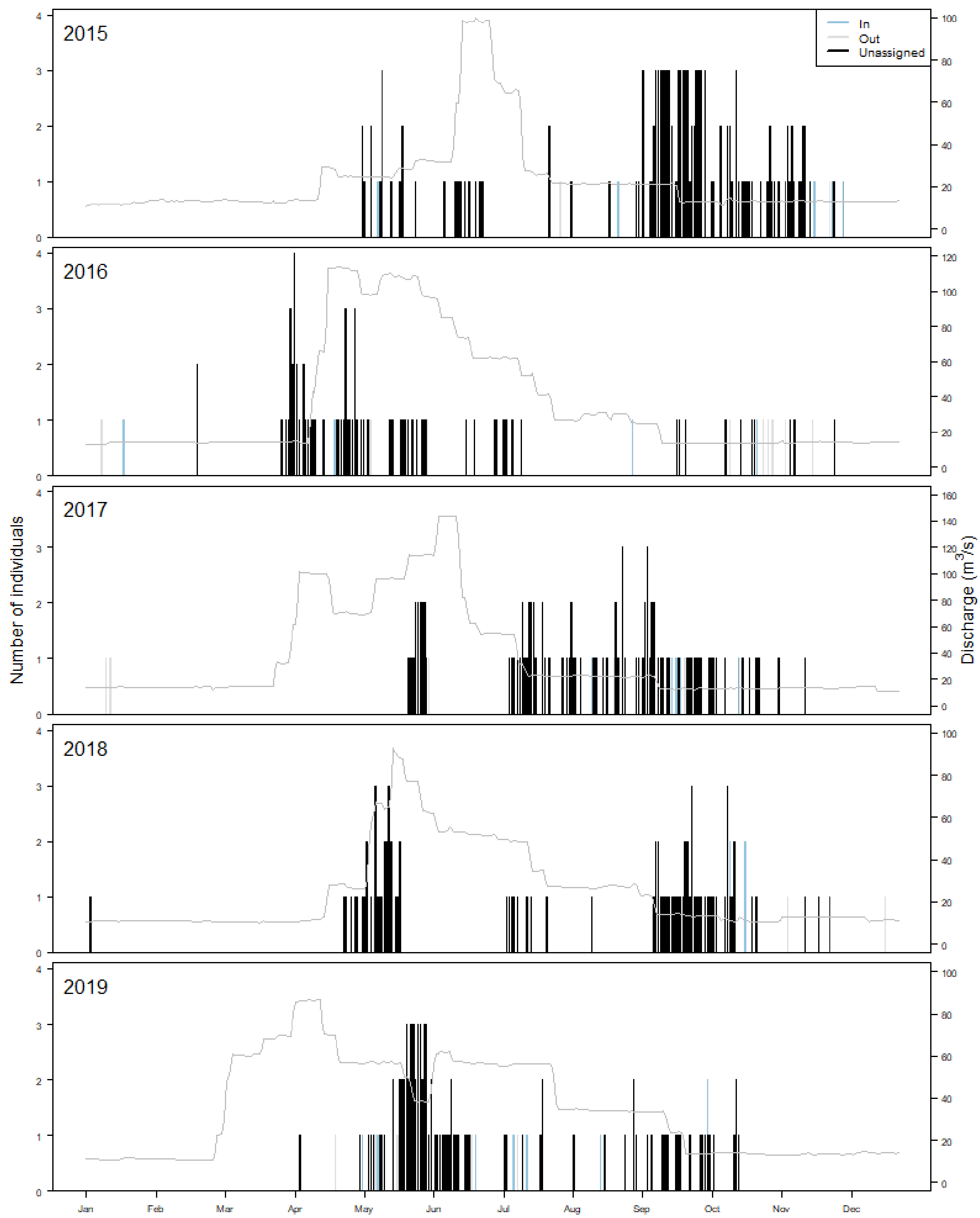


Figure 3-20. Daily Rainbow Trout detections on the Upper Spawning Channel PIT array in 2015, 2016, 2017, 2018, and 2019 in relation to discharge.

3.5.3 Site Fidelity of Juvenile Coho Salmon

Coho Salmon were captured and marked with VIE monthly from July to October in every reach. As Coho Salmon grew through the season, the use of VIE (for fish <75 mm) decreased and PIT tags were used instead. Overall, only four out of 97 VIE-marked Coho Salmon were recaptured, all in the same reach they were tagged in (Table 3-8; two each in LSC and Reach 1). Three recaptured fish were marked during the previous month, and one, in the LSC, after three months.

From July 17 to October 30, 2019, a total of 99 juvenile Coho Salmon were PIT tagged in the USC (n=21) and LSC (n=44) and mainstem Seton River (n=34). Three PIT-tagged Coho were recaptured through growth sampling and stock assessment surveys (Table 3-7). All three fish were recaptured in the same electrofishing site they were initially tagged in within the LSC. The one fish recaptured in September was initially tagged in July and both those recaptured in October were initially tagged in September.

The USC PIT array captured the movement of three Coho Salmon, two of which were originally tagged in the USC in the site closest to the PIT array. Neither fish showed directed movements and likely stayed in the USC. The other Coho Salmon was originally tagged in Reach 1 of Seton River on October 1, 2019 and moved into the USC on October 20, 2019 (Table 3-8). The LSC PIT array captured the movement of two Coho Salmon. Both were originally tagged in the LSC and direction of movement cannot be assigned (Table 3-8).

Table 3-7. The number of Coho Salmon tagged in each month of sampling (tags) and the number of recaptures. Data includes both PIT tags and Visual Indicator Elastomer (VIE).

	July	August		September		October	
Reach	**Tags**	**Tags**	**Recaptures**	**Tags**	**Recaptures**	**Tags**	**Recaptures**
1	4	6	1	12	1	2	0
2	5	0	0	3	0	1	0
3	12	5	0	16	0	1	0
LSC	36	13	1	15	1	23	3
USC	16	11	0	10	0	5	0
Total	**73**	**35**	**2**	**56**	**2**	**32**	**3**

Table 3-8. Juvenile Coho Salmon tagged with PIT and detected on antennas in the Lower and Upper Spawning Channels (LSC and USC, respectively) in 2019.

PIT Code	Tag Date	Tag Location	Detection Date	Detection Location
00462683	Oct 1, 2019	Reach 1	Oct 20, 2019	USC
01027321	Oct 4, 2019	USC	Oct 10, 2019	USC
01027365	Aug 21, 2019	USC	Aug 31, 2019	USC
00462521	July 17, 2019	LSC	Aug 9, 2019	LSC
00462541	Aug 21, 2019	LSC	Sept 9, 2019	LSC
			Sept 10, 2019	
			Sept 11, 2019	

3.6 Spawning Adult Salmonids

3.6.1 Visual Counts

Observations of adult spawning salmonids have generally been low and variable among years and locations (Appendix 7-12). Adult Chinook Salmon were observed in the Seton River mainstem from August 1 to September 19 in 2019 in all reaches. This is the first observation of adult Chinook Salmon using Seton River since 2016 (Figure 3-21). Coho Salmon have been observed in the Seton River mainstem from the beginning of October through to the beginning of November in each study year (2015-2019) but only in Reach1 (Figure 3-22). Coho Salmon are primarily observed using the Lower Spawning Channel (Appendix 7-12). Like Chinook Salmon, observed Coho numbers were much higher in 2019 relative to previous years. For example, 66 Chinook Salmon and 235 Coho Salmon were observed in 2019 relative to 3 and 190, respectively, for all previous years combined. Pink Salmon were present in the Seton River in 2015, 2017, and 2019 from the end of August through to mid-October (Figure 3-23). Though Pink Salmon are predominantly observed in the spawning channels (Appendix 7-12), they have been observed in each reach of the Seton River mainstem.

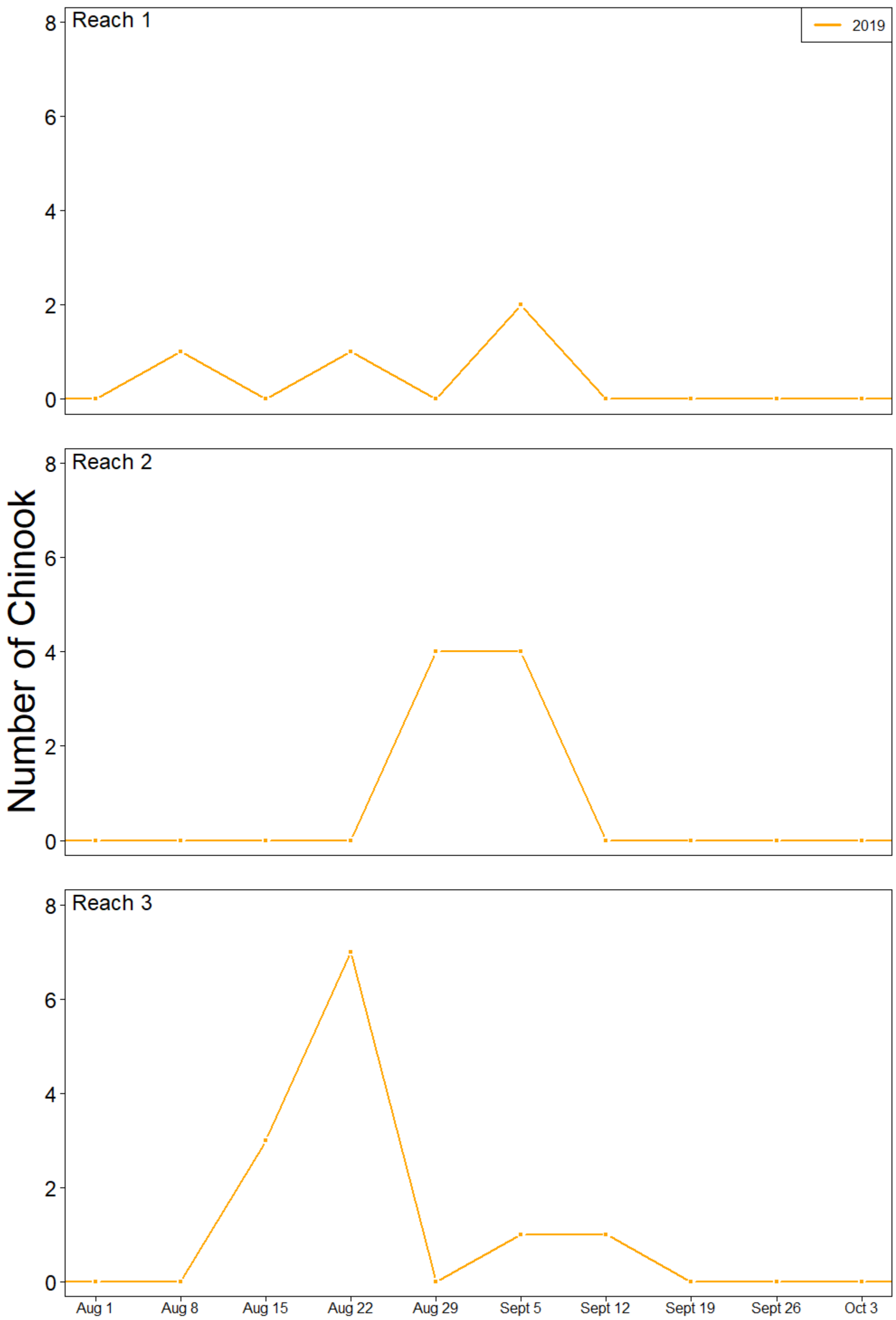


Figure 3-21. Chinook salmon observed during weekly streamwalks within each reach of Seton River in 2019. No Chinook salmon have been observed in previous years.

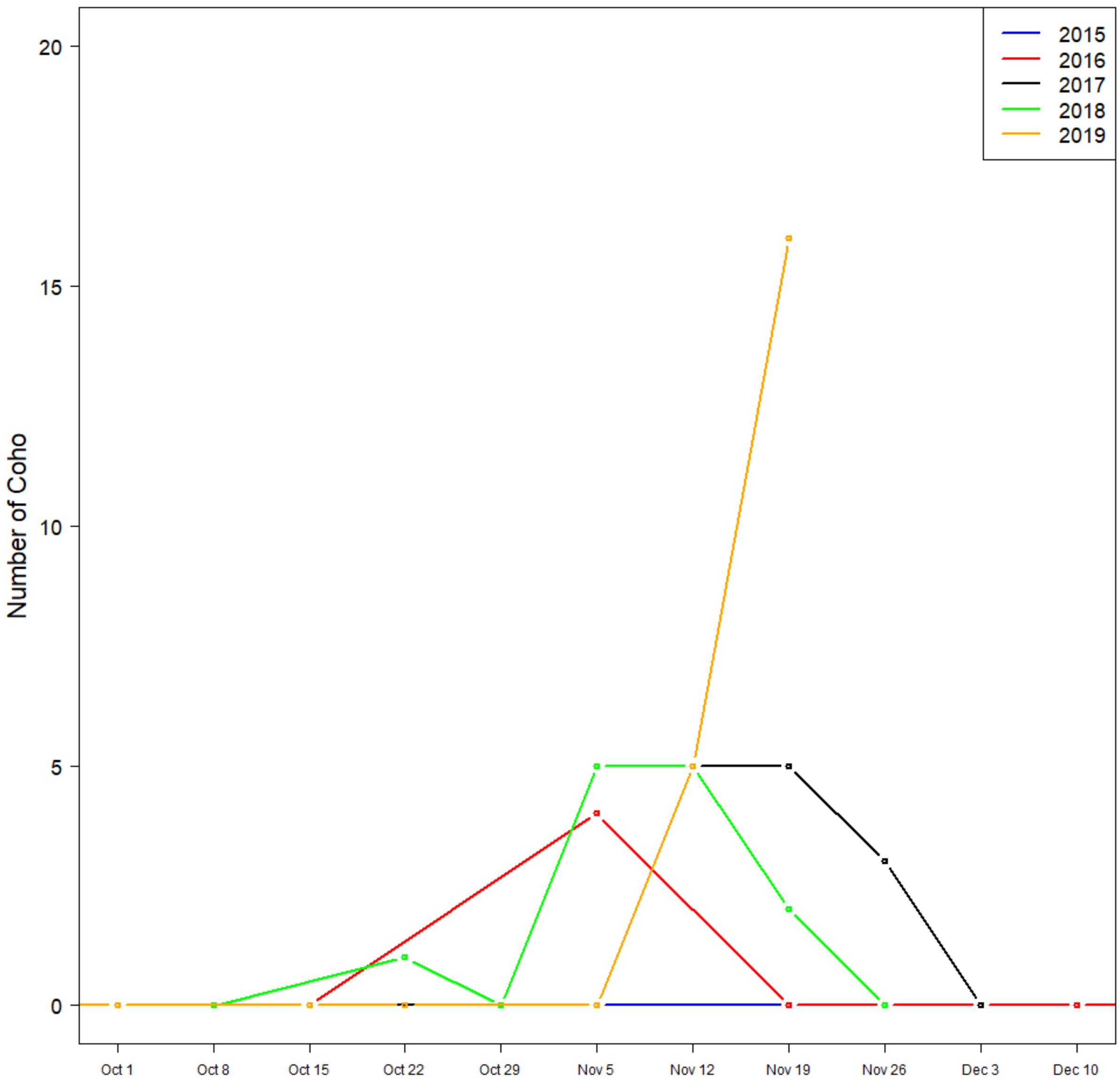


Figure 3-22. Coho salmon observed during weekly streamwalks within Reach 1 of Seton River. Coho salmon have not been observed in Reach 2 or 3 of Seton River.

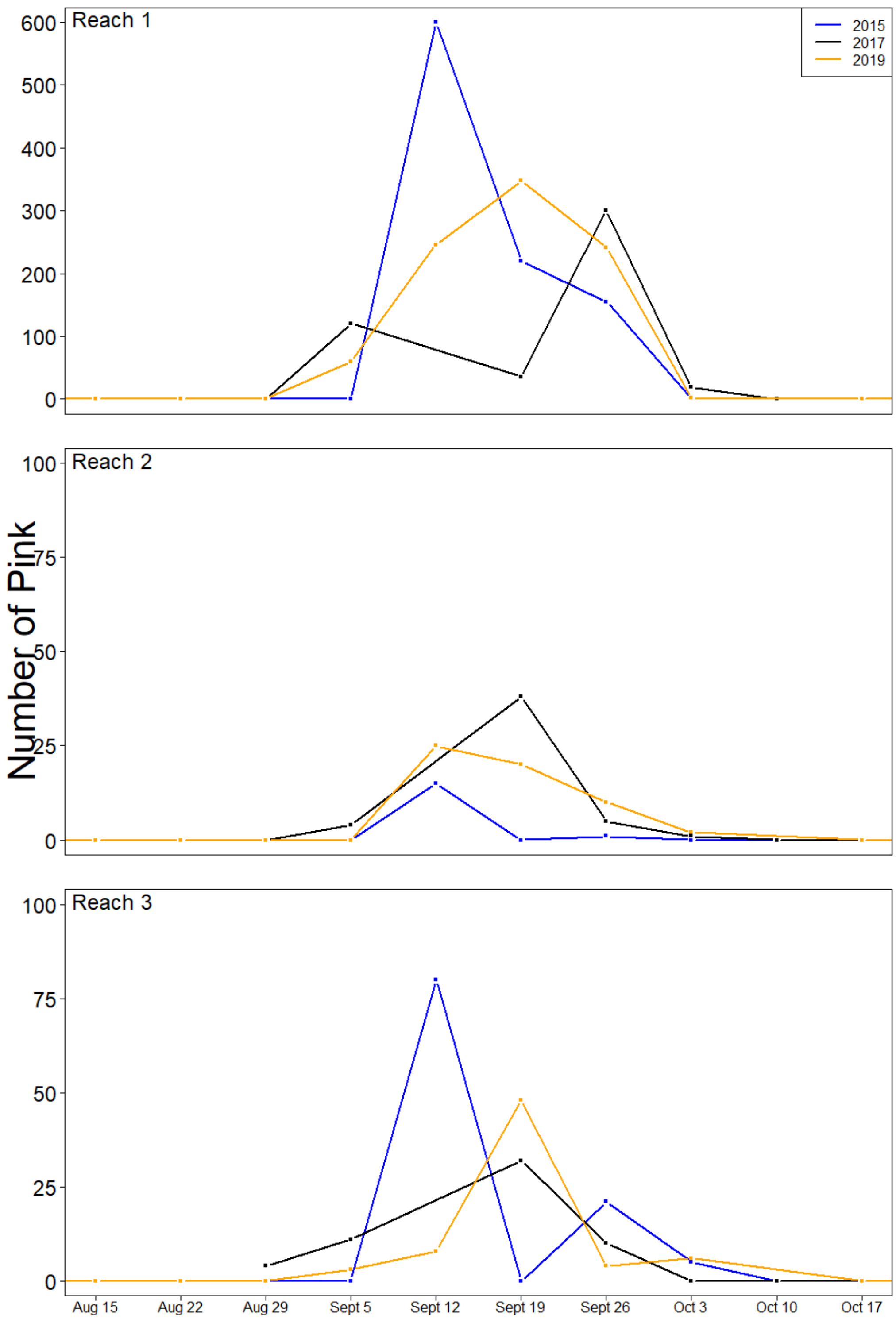


Figure 3-23. Pink salmon observed during weekly streamwalks within each reach of Seton River. Pink salmon spawn in Seton River in odd number years only.

3.6.2 Seton Dam Counter for Steelhead Trout

Counter Accuracy

The counter under-estimated the number of Steelhead Trout moving upstream through the upper and lower counter tubes with an average accuracies of 67% and 73%, respectively (Table 3-9). The lower set of tubes were most actively used, and no Steelhead Trout were observed moving downstream through the counter tubes.

Table 3-9. Summary of counter accuracy data for Steelhead Trout migrating upstream through each counter channel (tube) in the Seton Dam fishway 2019.

Counter	Channel 1 (n)	Channel 2 (n)	Channel 3 (n)	Channel 4 (n)	Average (SD)
Upper	0% (1)	100% (4)	100% (2)	NA (0)	67% (57%)
Lower	100% (3)	75% (3)	100% (4)	18% (3)	73% (38%)

Migration Timing and Abundance Estimate

The Seton Dam resistivity counter recorded 17 Steelhead Trout moving upstream (species identified through video validation, Appendix 7-3). After correcting for counter accuracy, 25 Steelhead Trout are estimated to have passed Seton Dam between April 1 and May 31, 2019 (Figure 3-24). The first was detected on the counter on April 30 at 15:00 and the last on May 28 at 13:48. After correcting observed counts for counter accuracy, peak migration occurred on May 27 with seven Steelhead Trout moving past the counter. While the majority (n = 16) moved when Seton Dam discharge was held at 57 m^3/s, a secondary pulse (n = 9) moved through Seton Dam after discharge was reduced below 50 m^3/s on May 24, 2019 (Figure 3-24).

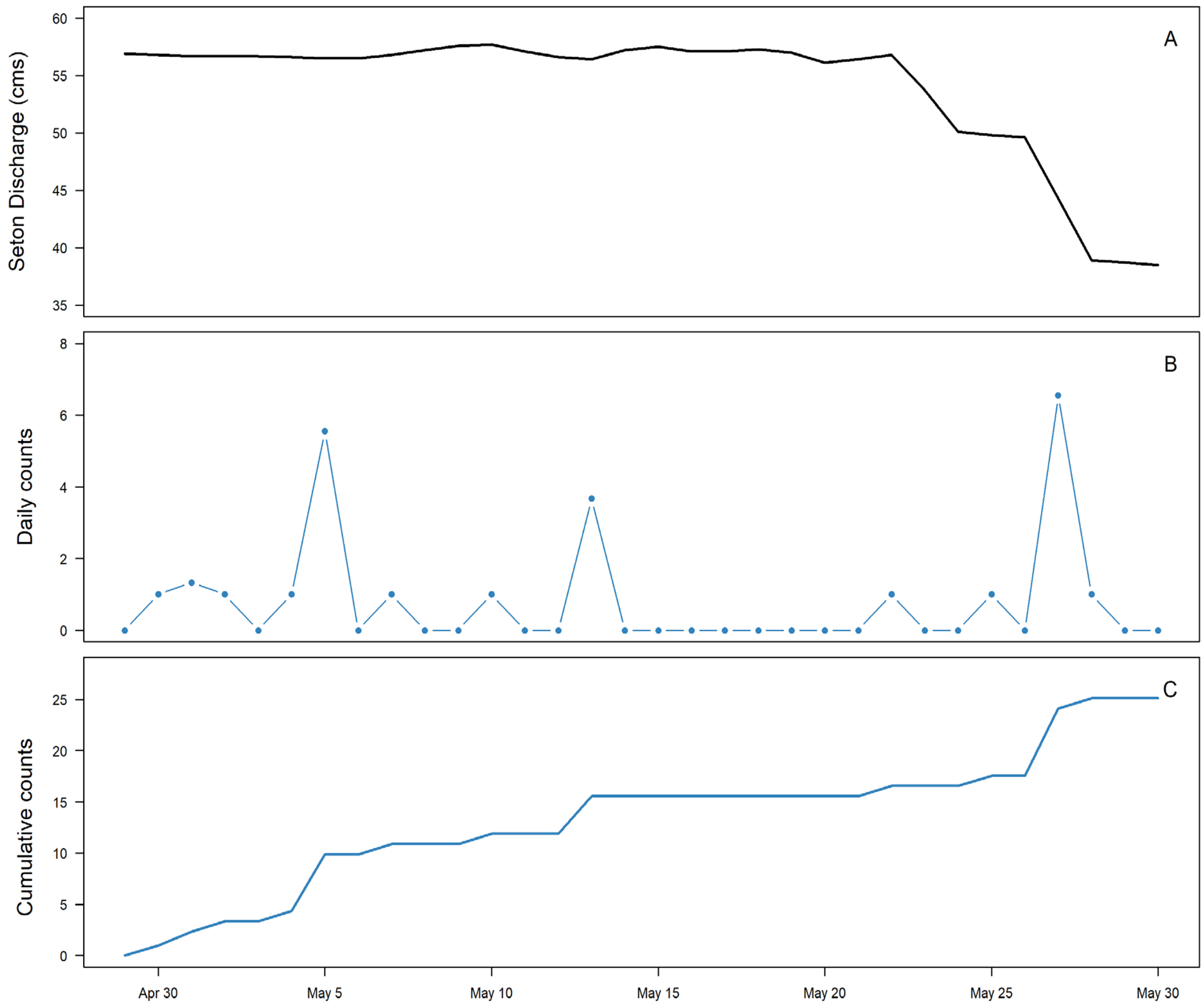


Figure 3-24. (A) Discharge from Seton Dam, (B) Steelhead Trout daily up counts, and (C) cumulative counts from April 1 – May 30, 2019. No Steelhead Trout were observed on the counter prior to April 30, 2019.

3.7 Gravel Mobilization

Analysis of the elevation data showed that elevation change was variable within and between transects (Ramos-Espinoza et al. 2016), but overall the area surveyed appears to be higher in elevation in 2019 than it was in 2013, suggesting an overall deposition of substrate (Figure 3-25). However, 2019 shows areas have deepened since 2017 suggesting that some erosion has occurred since the last survey. Further analysis of substrate composition also showed variable substrate changes in the area. Both Pebble count data and dominant visual substrate estimates indicate that the uppermost transect (G1B) saw an increase in substrate size. The pebble count data for the second transect (G1D) shows that a net increase in substrate size has occurred while the dominant visual substrate estimates indicate that the substrate size has decreased since 2014. For the third transect (G1F), both the pebble count and visual substrate estimate support that no net change in substrate has occurred since 2014. The lowest transect (G1G) saw a decrease in dominant substrate size using a visual estimate but no change was observed in the pebble count (Table 3-10, Table 3-11).

The trend of larger substrate being observed upstream and smaller substrate observed downstream suggests that smaller substrate is being eroded and being deposited downstream.

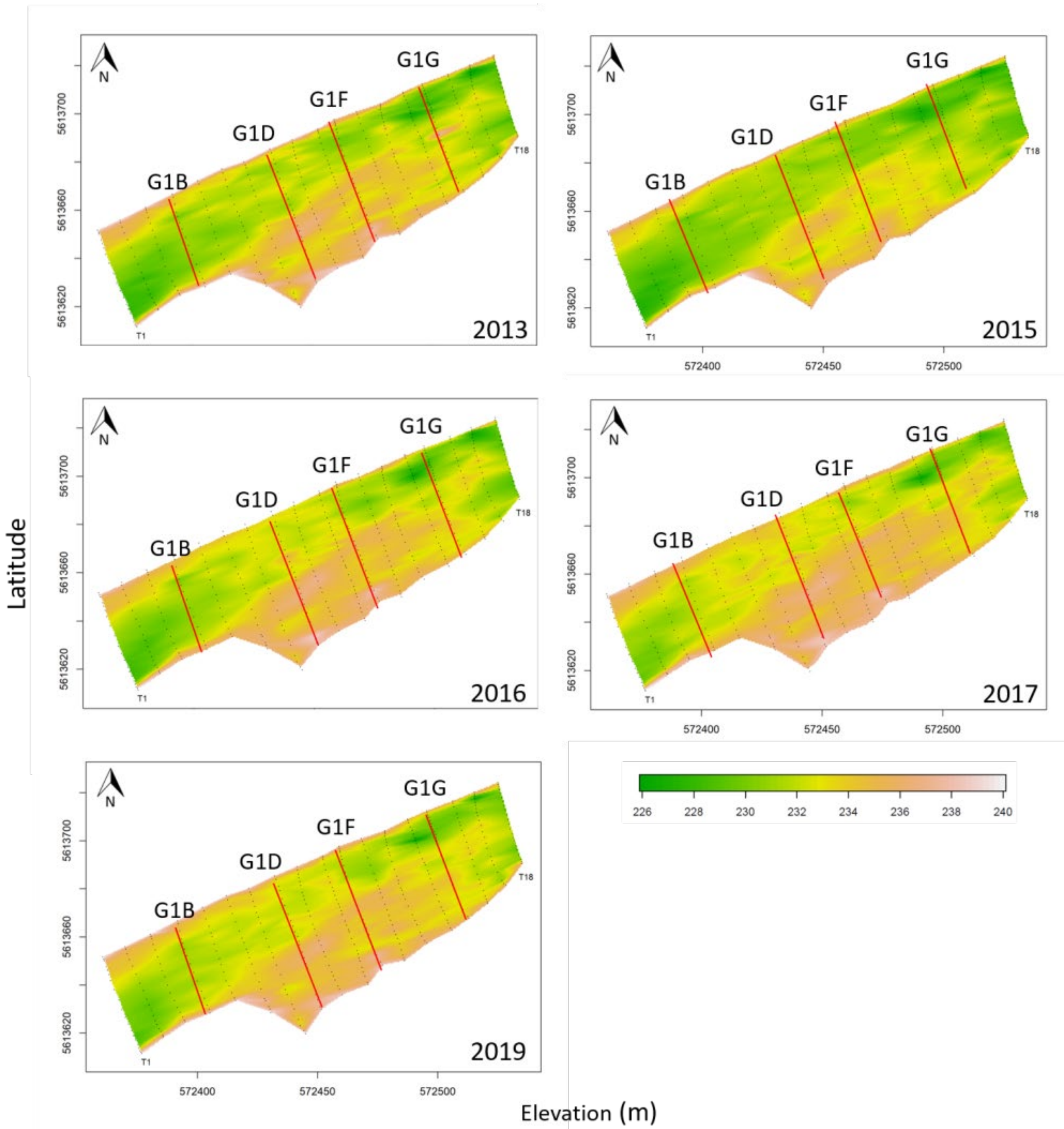


Figure 3-25. Streambed elevation (m) in the Seton River from 2013 – 2019. Dots represent individual measurement points along 18 transects (T1 to T18) and red lines represent substrate transects.

Table 3-10. Geometric mean and Standard Deviation (SD) of substrate size (mm) at four transects in the Seton River between 2014 and 2019. LG = Large gravel (16-64 mm), SC = Small cobble (64-128 mm), LC = Large cobble (128-256 mm), B = Boulder (256-400 mm).

Transect	Method	2014	2015	2016	2017	2019	Net change
G1B	Pebble Count	NA	11 ± 15.7 mm (SG)	33 mm ± 18.9 (LG)	41 ± 20.3 mm (LG)	56 mm (LG)	Larger
G1D	Pebble Count	NA	27 ± 35.7 mm (LG)	23 mm ± 12.6 (LG)	45 ± 69.1 mm (LG)	75 mm (SC)	Larger
G1F	Pebble Count	NA	25 ± 24.0 mm (LG)	NA	55 ± 98.7 mm (LG)	58 mm (LG)	No Change
G1G	Pebble Count	NA	36 ± 47.0 mm (LG)	28 ± 14.1 mm (LG)	42 ± 70.7 mm (LG)	62 mm (LG)	No Change

Table 3-11. Visual estimates of dominant substrate size class at four transects in the Seton River between 2014 and 2019. LG = Large gravel (16-64 mm), SC = Small cobble (64-128 mm), LC = Large cobble (128-256 mm), B = Boulder (256-400 mm).

Transect	Method	2014	2015	2016	2017	2019	Net change
G1B	Visual	LG	B	NA	B	SC	Larger
G1D	Visual	LC	LC	NA	LC	SC	Smaller
G1F	Visual	LC	LC	NA	LC	LC	No Change
G1G	Visual	B	SC	NA	LC	LC	Smaller

4.0 DISCUSSION

Objectives of this program are to monitor responses of fish and fish habitat to Seton Dam operations, and to identify potential indicators of the effects of the implemented Seton River hydrograph. The program was originally designed to monitor fish and fish habitat under WUP target flows. However, due to the modified operations at La Joie Dam, the Seton River hydrograph increased outside of these target flows, impacting monitoring activities at designated study sites. To ensure that management questions could still be addressed during periods when discharge from Seton Dam exceeded WUP targets, new '*Modified Operations*' monitoring methods were adopted in 2016 and have continued through to 2019. For example, bio-sampling during periods of modified operations focused on side-channel habitats and spawning channels rather than the mainstem, where many sites were inaccessible for sampling above 60 m^3/s. Conversely, sampling efforts to evaluate juvenile standing stock biomass were not affected by the increased Seton River hydrograph because the surveys are completed when flows return to WUP targets.

As the seventh year of a 10-year program, data collected in 2019 continues to build upon knowledge gained in previous years. Although preliminary synthesis analyses have identified some trends, continued monitoring is required to fully address each MQ. Herein, findings to date are discussed in the context of MQs. Many methods are not specific to a given MQ, and collected data therefore often informs multiple MQs. The first two MQs were addressed by conducting bio-sampling, visual count surveys, habitat surveys, and tagging. Under MQ1, data collection aims to understand basic biological characteristics of the rearing and spawning populations in Seton River. The intention of MQ2 is to determine how the Seton River hydrograph influences the hydraulic condition of juvenile fish rearing habitats. Streamwalks and redd surveys were conducted to address MQ3, which aims to evaluate potential risks of salmon and steelhead redds dewatering due to changes in the Seton River hydrograph. Riverbed topographic surveys were conducted to address MQ4, which asked how the Seton River hydrograph influences availably of gravel suitable for spawning. To determine potential effects of shutdowns at the SGS on fish habitat in the Fraser River (MQ5), stranding surveys were conducted in the Fraser River.

Additionally, results under several management questions were impacted in 2019 as a result of the Big Bar Landslide. Thought to have occurred in late 2018, the Big Bar Landslide created a waterfall in the

Fraser River Canyon approximately 75 river km upstream of the Fraser-Seton confluence, impeding the passage of migrating Salmon and Steelhead to further upstream tributaries. It is presumed that a higher level of straying to tributaries downstream of the slide (i.e., Bridge River and Seton River) occurred as a result. Impacts of the Big Bar Landslide are discussed within each management question herein.

MQ1: What are the basic biological characteristics of the rearing and spawning populations in Seton River in terms of relative abundance, distribution, and life history?

As no hypothesis fall under MQ1, there is no direct testing or conclusions to be drawn. Most data collected under BRGMON-9 contributes to the understanding of fish populations in the Seton River and will continue to do so each year.

Biological Characteristics of Rearing Populations in Seton River

Monthly juvenile bio-sampling surveys have identified 14 fish species in the Seton River, including seven salmonids (Coho, Chinook, Pink and Sockeye Salmon, Rainbow Trout, Bull Trout, and Mountain Whitefish). Rainbow Trout are the most prevalent during sampling, followed by Coho and Chinook Salmon, thus these three species are the focus of monitoring. Four age classes of Rainbow Trout (0-3) and three age classes of both Coho and Chinook Salmon (0-2) have been identified. DNA has been collected from juvenile Chinook Salmon to determine stock origin since 2016. Results exemplify that the Seton River provides important rearing habitat for these fish, as individuals are present from both Portage Creek/Seton River origin, in addition to upstream tributaries of the Fraser River (e.g., Chilcotin, Quesnel). Therefore, management actions that may influence rearing conditions in the Seton River would influence not only the local population but those from throughout the Fraser River. Interestingly, no Bridge River origin Chinook have been observed using Seton River.

Beginning in July 2019, all juvenile Coho Salmon captured through monthly bio-sampling surveys were given either a VIE mark or a PIT-tag, allowing movements and distribution to be tracked either through recapture or detection on PIT antennas in the LSC, USC and Seton Dam. Three PIT-tagged Coho and four VIE marked fish were recaptured during bio-sampling surveys with an additional five PIT tagged Coho detected on the spawning channel PIT arrays in 2019. Though total recaptures and detections are low in 2019, preliminary results show that site fidelity is high and that juveniles in spawning channels may not be experiencing high flow conditions. Further years of data collection will confirm but if high site fidelity is continually observed then Coho Salmon juveniles in the spawning channels could be used as a control for those in the mainstem and impacts to growth and body condition as a result of high flow could be examined. Increased detections are expected in the spring of 2020 as Coho Salmon smolts out-migrate. Continuation of this component will confirm 2019 results and will inform future data analysis.

Rainbow Trout have been tagged since 2014, and detection data indicate that Rainbow Trout, regardless of capture location, do move between the spawning channels and the mainstem. Though detection data is limited to 11 individuals that moved between the two channels, it suggests that distinct populations of Rainbow Trout do not exist within each spawning channel. The timing of movements in and out of the spawning channels do not correlate with discharge events from Seton Dam, and are more likely seasonal (e.g, over-wintering or spawning).

Biological Characteristics of Spawning Populations in River

Currently, information regarding adult abundances is limited to inconsistent count data, precluding any analyses. Estimating adult salmonid abundance for the Seton River mainstem has been difficult because few adult salmonids, with the exception of Pink salmon, have been observed until 2019, and during modified operation years, high discharge from Seton Dam reduces visibility in the spring.

The most frequently observed species are Coho Salmon and in odd number years (i.e., 2015, 2017, 2019), Pink Salmon. Both species are predominately observed in spawning channels and, therefore, their numbers relative to other species are likely biased as it is easier to observe fish in these areas than in the mainstem Seton River. Coho Salmon numbers are still low and variable, ranging from 13 individuals in 2017 to 235 in 2019. Coho have been observed in the Seton mainstem from the start of October through to the end of November. When present, Pink salmon spawn in much higher numbers than other salmon species. Pink Salmon have been observed from the end of August through to mid-October. In the mainstem, Coho and Pink Salmon are observed predominantly downstream of Seton Dam in reach 1. Visual tagging of Pink Salmon was attempted in 2015 and 2017 to assess observer efficiency and create AUC estimates. However, insufficient numbers were captured to release tags into the river, and thus all estimates should be considered an index of relative abundance.

Historically, Seton River was not assessed to have a distinct population of Chinook salmon and any observed were assumed to be migrating through Seton River on their way to spawning grounds in Portage Creek, or strays from other Fraser River tributaries (John Candy, DFO, pers. Comm.). While DNA has not been assessed for adult Chinook Salmon, results from juveniles suggest that some Portage Creek fish are spawning in the Seton system as age 0 fish are caught annually in April. Only three adult Chinook salmon were observed across all years visual surveys were attempted prior to 2019, while 36 were observed in 2019. In 2019, Chinook were observed between Aug 1 and September 19.

Increased adult counts for all salmon species in 2019 are the result of higher stranding rates due to Fraser River passage being impeded by the Big Bar Landslide. Although most adult salmonids will home rather than stray, mature fish with advanced senescence may select the nearest available spawning location instead of migrating to their natal site (Keefer and Caudil 2014). Therefore, we may expect returning adults from Upper Fraser River populations to have strayed to the Seton River once their condition had deteriorated such that a lengthy migration was not possible. Increased straying is further supported by DNA analysis completed for Bridge River Chinook salmon for the purposes of brood stock collection: all Chinook salmon sampled for DNA in 2019 were identified to natal streams upstream of the Big Bar Landslide (Coldstream Ecology, personal communication).

BRGMON9 has attempted to visually survey spawning Steelhead annually since 2014 but high turbidity and increased discharge have made it difficult to observe fish. In 2019, the Seton Dam Counter was operated and proved an effective way to enumerate Steelhead passing Seton Dam in the spring. After correcting for counter accuracies, 25 Steelhead Trout were estimated to have passed Seton Dam between April 30 and May 28, 2019. However, several uncertainties remain around the Steelhead estimate which are difficult to quantify:

1. *Impacts of the Fraser River – Big Bar Landslide*
   As the Seton Dam counter has not been operated in previous years it is impossible to know whether an estimate of 25 Steelhead Trout should be considered normal or anomalous given the likely higher rate of straying caused by the Big Bar landslide. As passage is restored through the landslide area, future years of monitoring would provide an indication of size Seton population of Steelhead migrating past Seton Dam.
2. *Entrainment*
   Evidence from the Steelhead telemetry study under BRGMON3 indicates that entrainment is occurring in the Seton system (White et al. 2019). A Steelhead Trout tagged in 2019 moved through Seton Dam twice, approximately 8 days apart (derived from PIT and radio telemetry data). As no down movement was recorded on the counter or PIT antennas, this fish must have been entrained through Seton Dam or the Powerhouse. While entrainment can be monitored

for tagged fish it is difficult to quantify the rate of entrainment for non-tagged fish. If entrainment is occurring and fish are passing Seton Dam multiple times, the estimate of 25 Steelhead may be inflated.

3. *Steelhead use of Seton River as Spawning Habitat*
   While the counter gives a good indication of fish moving through Seton Dam to spawn upstream, discharge and turbidity have made it difficult to quantify the total number of Steelhead Trout that may be using the Seton River mainstem as spawning habitat. No tagged Steelhead were observed by PIT antennas in the spawning channels in 2019, but they have been observed in previous years (2 fish in 2015) and they were assumed to have spawned exhibiting a residence time of 10 days.

Telemetry data from BRGMON3 consistently shows that Steelhead Trout move into the Seton River. Continued used of the Seton Counter in conjunction with the BRGMON3 tagging program will increase the understanding of Seton River Steelhead Trout, and potentially the impacts of Seton Dam operations on this species. Additionally, increasing the telemetry infrastructure in the Seton River, in known spawning areas, will effectively leverage shared information between the two monitors and thus more efficiently address uncertainties regarding the basic biological characteristics of Steelhead Trout, a focus of both programs. Increased discharges in the spring during the Steelhead spawn timing create poor visibility conditions preventing the observations of spawning fish. The fixed radio telemetry station will allow us to confirm that a fish was present and how long it resided for. BRGMON3 tagging activities will continue to allow entrainment to be observed and identified through PIT data and counter estimates to be adjusted accordingly.

MQ2: How does the proposed Seton hydrograph influence the hydraulic condition of juvenile fish rearing habitats downstream of Seton Dam?

The primary monitoring activity to address MQ2 was HSI surveys of juvenile rearing habitats, providing estimates of both habitat quality and quantity. However, monitoring activities also evaluated effects of flow to juvenile fish populations. Analyses of various metrics of juvenile fish growth were assessed as indicators of the in-season effects of high discharge, and trends in estimates of standing crop biomass over various years may also elucidate effects of flow. Across all sampling methods, fish captures have been dominated by Rainbow Trout, followed by Coho and Chinook Salmon, which are thus the focus when evaluating effects of flow. To understand the effects of flow to rearing habitats, habitat surveys have been completed throughout the monitor at various discharges. To understand effects of flow on fish growth, or fish population size, year can be used as a proxy for flow conditions.

Effects of Flow to Juvenile Fish Rearing Habitats

Habitat suitability surveys for juvenile salmonids have been completed for the mainstem river and side-channel habitats at discharges ranging between 12 and 143 m^3/s. Mainstem surveys completed from 2014 to 2016 show habitat availability decreases for all species as dam discharge increases from 12 to 60 m^3/s. However, high discharges as a result of modified operations wetted side-channel habitats, making them available to juvenile fish. Though these additional habitats do buffer habitat changes in the mainstem from 60 – 86 m^3/s, any habitat gained from the wetting of new habitat is lost again at 100 m^3/s. Results indicate that the amount of available habitat suitable for juvenile Rainbow Trout, Coho and Chinook Salmon varies with Seton Dam discharge and therefore we can reject H_1: the amount of hydraulic habitat that can be inhabited by juvenile fish is independent of discharge from Seton Dam. Additional surveys are needed for Seton Dam releases below 40 m^3/s to determine where habitat is maximized for juvenile fish in the mainstem.

To assess impacts of four years of high discharge conditions to juvenile rearing habitat as a result of modified operations, habitat suitability surveys were completed in the fall at 12-14 m^3/s in 2018 and 2019. Surveys were completed at a subset of locations initially surveyed in 2014 at 12 m^3/s prior to modified operations. Eleven sites were repeated in all three surveys years and show that there has been an overall net decrease in habitat suitability for all species since 2014. When compared to 2014 conditions, 2019 had a net loss in overall WUA for Rainbow Trout Fry and Parr, and juvenile Coho and Chinook Salmon. However, the changes were inconsistent across reaches, with Reach 1 exhibiting a net increase for all species except for Chinook, and Reach 2, a net decrease. These inconsistencies are likely a factor of the varying discharge conditions in each reach; conditions in Reach 1 are solely impacted by flow releases from Seton Dam and Reach 2 and 3 are also influenced by Cayoosh River which, while regulated, can be seasonally variable, increasing discharge in Seton River by an additional 1-90 m^3/s. While surveys only represent a subsample of the entire river, they represent long-term changes that may be occurring within each reach as a result of the modified operations of Seton Dam. A more robust modelling approach will be taken in future years (i.e., linear mixed effects modelling) which will accommodate any inconsistencies in the data, such as transects surveyed in 2014 but not 2018 or 2019.

Effects of flow to juvenile fish populations

Standing crop surveys have been conducted annually since 2014 at base flow conditions, making it the most consistent dataset collected under BRGMON9. Sufficient data is only available to provide estimates for age 0 Rainbow Trout, which has ranged from 2,017 (2015) to 12,183 (2014) individuals. Abundance in 2019 was 2,606 which is the second lowest since the study began. To date, a relationship between standing crop and discharge for Rainbow Trout has not been identified. However, the dataset is limited by having only one year of sampling during the WUP target hydrograph, preventing comparative analyses of WUP and modified operations. Until more data are collected during years with the WUP target hydrograph, it is impossible to know whether 2014 was anomalous or indicative of Rainbow Trout abundance under the target flow regime.

During years of modified operation (2015-2019) there are lower abundances of Rainbow Trout than were observed in 2014 (the only modified year of WUP operations), suggesting there may be a link between higher discharge and lower abundances. Further data collection during consecutive years of WUP conditions will enable further exploration of the potential relationship between flow condition and Rainbow Trout abundance. The lowest maximum discharge and the highest overall abundance of Rainbow Trout occurred in 2014. Conversely, maximum discharges from 2015 to 2019 exceeded WUP targets and Rainbow Trout abundances were considerably lower. Reduced Rainbow Trout numbers in subsequent years may be due to the timing of high flows (i.e., during emergence). Monthly bio-sampling data suggest that Rainbow Trout fry emerge from their redds in late June or early July. If discharge from Seton Dam is greater than 60 m^3/s during this time, fry may be flushed into the Fraser or displaced from suitable habitat. A further explanation for low Rainbow Trout abundances is that Seton River discharge from 2015 to 2019 may have crossed a threshold value above which habitat is too limited to support a greater population of juvenile Rainbow Trout, specifically fry. If it exists, the threshold value would be between 68.6 m^3/s (2014 max Seton Dam Discharge) and 86.7 m^3/s (2019 max Seton Dam discharge). The HSI surveys indicate habitat availability for Rainbow Trout fry decreases considerably above 60 m^3/s. Therefore, emergent fry may be rearing in less suitable habitat, potentially impacting survival.

To further investigate if flows have an effect on juvenile populations, sampling effort was increased in the spawning channels in 2018 with the idea that if two distinct populations (mainstem vs spawning channel) of Rainbow Trout existed, the fish sampled in spawning channels would be unimpacted by modified operations and thus serve as a control for body condition and growth. However, location as a model factor yielded inconsistent results and PIT data also indicates that Rainbow Trout move between the spawning channels and the mainstem. Therefore, location is likely not representative of the flow conditions experienced by this species. However, location may provide a good proxy for flow condition for juvenile Coho Salmon. Though only 3 PIT-tagged and 4 VIE marked juvenile Coho Salmon were recaptured in 2019, all were recaptured in the same reach they were initially tagged in. Further years of tagging is recommended to fully determine if Coho Salmon exhibit high site fidelity for some Seton River habitats as juveniles.

Condition of fish is examined through monthly bio-sampling surveys. With lower densities of fish observed since 2015, it could be expected that body condition may have increased as fewer fish lead to less competition for resources. Seeing an increase in body condition would indicate that there is a density dependent factor driving the size of Rainbow Trout in Seton River. Alternatively, poor rearing conditions, as a result of limited habitat, could mean that those fish remaining in Seton River have limited resources available. Bio-sampling has produced a robust dataset to which extensive statistical testing has been applied. The main finding is that year is an important factor driving differences in growth parameters. However, results are nonetheless inconclusive, with specific differences between individual years being inconsistent across the two years these analyses have been conducted. This may be due to variability of flow within the modified operations from year to year, or to the potential for substantial time lags to occur between changes to river flows, and responses to these changes being detected in fish populations.

Additional monitoring during years with the WUP target hydrograph will be needed to properly assess the effects of the WUP and modified operation hydrographs on juvenile fish populations and effectively answer MQ2. In the interim, each year of modified operations data collection should be considered baseline data that contributes to a long-term biological data set. These data will be able to provide valuable comparisons and aid in management decisions regarding the best hydrograph for juvenile salmonids and inform the effects of potential future discharges above the WUP target hydrograph.

MQ3: 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?

Spawning habitat for all species is limited in the Seton mainstem and can be attributed to the relatively restricted nature of the river that has been extensively dyked or armored throughout. This creates higher velocities in the river and few areas for substrate to be deposited. Visual surveys of spawning Steelhead Trout and salmon have identified two areas in the mainstem Seton River where spawning occurs; immediately below Seton Dam and at the outflow of the LSC. To date, no redd dewatering has been observed as a result of changes in flow imposed by the Seton hydrograph as both identified spawning areas remain wetted at all flows.

During periods of modified operations, side-channels become wetted during the Steelhead Trout migration and spawning period. If redds were present in the side-channels, they would be at risk of becoming dewatered if the Seton Dam hydrograph returned to WUP targets prior to emergence. However, habitat surveys in 2017 indicate that the substrate in the side-channels is unsuitable for spawning Steelhead Trout and therefore the potential risk of redd dewatering in side-channel habitats is deemed low.

In 2019, discharge from Seton Dam was held at a higher level in August and September than it had been in previous years. Once Seton Dam discharge returned to WUP targets, stranded eggs (likely from Sockeye or Pink salmon) were observed on stream margins in several places. While these eggs were distributed in larger substrate and unlikely to be true redds, it is recommended that a designated redd survey be conducted in August before flows return to WUP, with a secondary survey conducted in September following the rampdown to assess if stranding is a concern. While redd stranding risk in Seton river is likely low, H_2: the selected Seton River hydrograph does not result in dewatering of salmon or Steelhead redds, cannot be rejected until a surveys is completed to determine the risk of salmon redd stranding following fall high flows.

MQ4: 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?

Periods of high discharge as a result of modified operations have the potential to impact substrate availability in Seton River as higher velocity flows are known to mobilize gravel. Riverbed topographic surveys are generally completed every other year to monitor changes in streambed elevation and substrate downstream of Seton Dam. A detailed topographic survey was completed in 2019 and indicates that changes in elevation have occurred since 2013, though results are variable. This may be due to the variable high discharges being released from Seton Dam. Studies have shown that a discharge threshold needs to be reached before substrate is mobilized. For example, research in the Bridge River has found that discharges between 20 and 50 m^3/s are required to keep spawning gravel in the system, but that this may vary with channel characteristics and substrate composition (Ellis et al. 2018). In the Seton River, scouring was observed prior to modified operations (2013-2015) and deposition observed in 2016 and 2017 following high discharge events as a result of modified operations. In 2019, results indicate that scouring has occurred since the last survey. It is likely a source of gravel was mobilized Therefore, downstream movement of smaller substrate from upstream areas of Seton River may be occurring (reject H_3). Overall gravel size for the upstream transects is larger in 2019 than it was in 2013 with smaller gravel sizes being observed in the lowest transect. The variable change in gravel size among transects indicates that smaller gravel is being mobilized and being deposited downstream. The next detailed topographic survey is due to be completed in 2021 and will continue to inform these inferences regarding the influence of the Seton hydrograph on spawning gravel.

MQ5: Does discharge from Seton Generating Station impact fish habitat in the Fraser River above and beyond natural variation in Fraser River Discharge.

Stranding risk was assessed at two sites in the Fraser River approximately 2 km and 11 km downstream from the SGS from 2015-2017. A total of three shutdowns were monitored. The area dewatered on each shutdown was largely dependent on Fraser River discharge at the time of shutdown and although ramping rates exceeded the 5 cm/h recommended by DFO, only 5 individuals were observed stranded. As such, stranding risk was assessed to be low for these sites and monitoring discontinued. An addendum to the BRGMON-9 program was put forth in 2018 to address stranding concerns further downstream. This monitoring is conducted by a different organization and reported separately (BC Hydro, 2018).

5.0 RECOMMENDATIONS

The following recommendations are suggested to inform the management questions and address data gaps:

1. Weighted Useable Area has been calculated for Seton River at 12, 25, 60, and 86 m^3/s. An additional partial estimate is available at 100 m^3/s. To determine at which flows habitat is maximized for juvenile salmonids, an additional survey of mainstem habitat should be done between 25 and 60 m^3/s. For river-wide estimates to occur, flows from Seton Dam must be held at target flows for approximately 2 weeks.

2. While there is no good way to enumerate Steelhead Trout using Seton River as spawning habitat, continued used of the Seton Dam Counter in conjunction with the BRGMON3 tagging program would increase the understanding of Steelhead use of Seton River and inform potential impacts of operations at Seton Dam on this species. Additional fixed telemetry stations in combination with mobile tracking surveys downstream of Seton Dam would inform potential spawning locations.
3. The VIE and PIT tagging protocol for Coho salmon juveniles initiated in 2019 provided preliminary data regarding site-fidelity. The tagging program should be continued to increase the understanding of Coho salmon juvenile movement throughout the year and will provide data on returning adults using the spawning channels and passing through Seton Dam.
4. To properly assess the risk of redd stranding following the fall rampdown, a redd survey should be conducted prior to the rampdown. All redds found along the margin of the river should be marked and visited following the rampdown.

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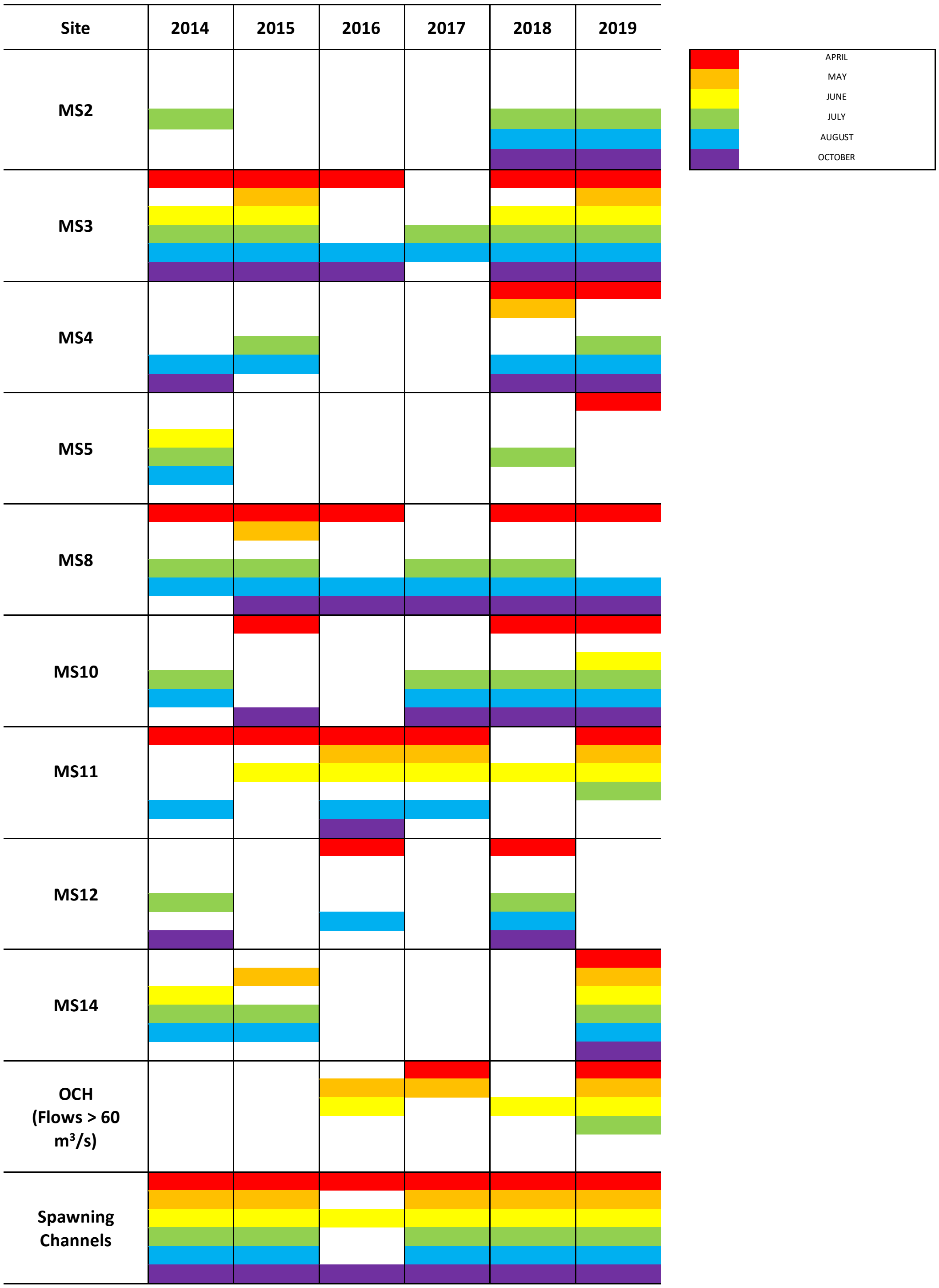
7.0 APPENDIX

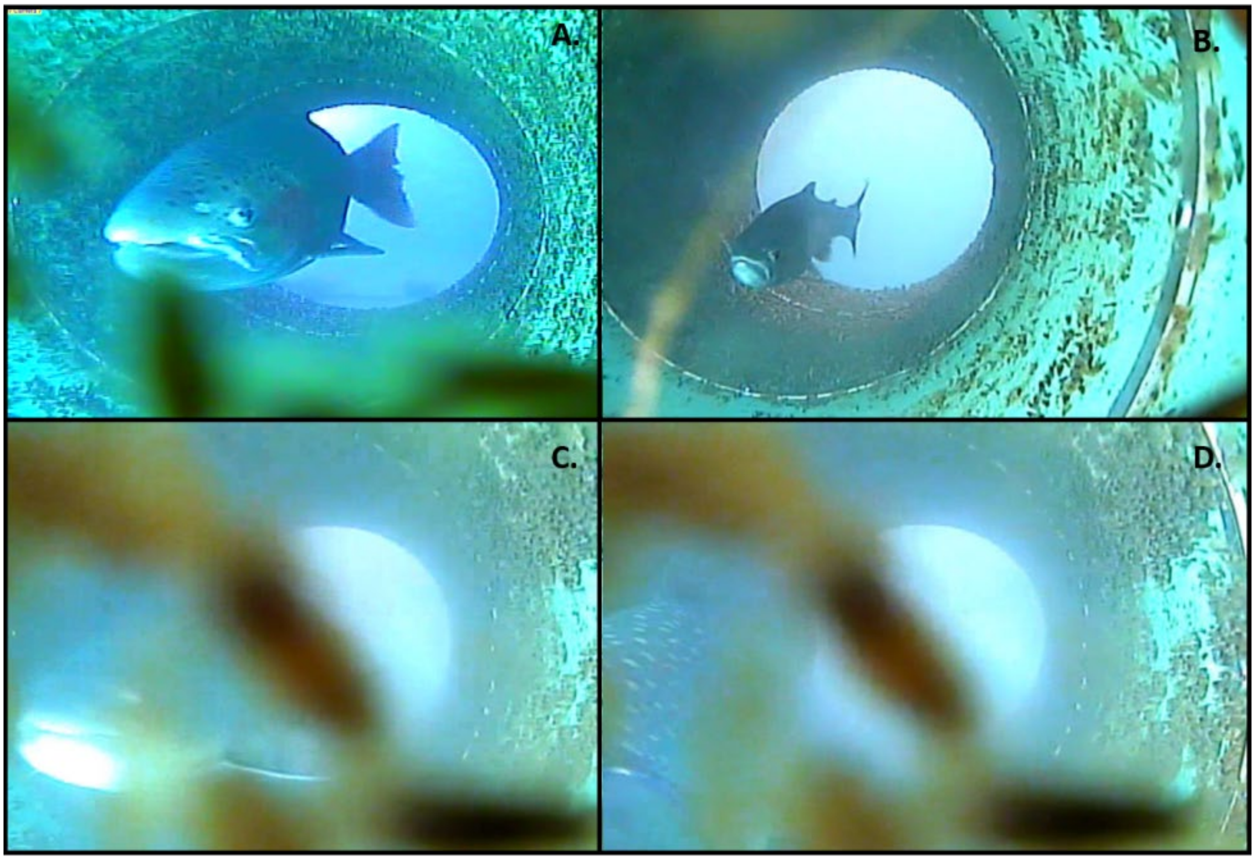
Appendix 7-1. Juvenile bio-sampling sites in the mainstem Seton River (MS) and the spawning channels (USC and LSC combined) and the years and months in which they were sampled from 2014 – 2019. Sampling generally occurs in the third week of each month.



Appendix 7-2. Mean and standard deviation (SD) of fork lengths (FL; mm) and sample sizes (n) of fish species observed during snorkel surveys from 2015 to 2018. No surveys were completed in 2019 due to high discharge from Seton Dam as a result of schedule maintenance at Seton Generating Station.

	2015			2016			2017			2018		
Species	**n**	**FL**		**n**	**FL**		**n**	**FL**		**n**	**FL**	
		Mean	**SD**		**Mean**	**SD**		**Mean**	**SD**		**Mean**	**SD**
Bridgelip Sucker	-	-	-	1	130	-	-	-	-	-	-	-
Bull Trout	1	180	-	1	175	-	-	-	-	-	-	-
Chinook	-	-	-	-	-	-	48	84.2	11.8	22	100.5	5.8
Coho	27	-	-	42	90.1	14.8	26	85	15.8	34	89.1	16.8
Pink										7	30	0
Sculpin	-	-	-	4	127.5	84.2	7	72.9	12.5	2	75	35.4
Lamprey	-	-	-	1	110					-	-	-
Mountain Whitefish	1	-	-	16	243.1	75.3	13	169.2	73.3	1	110	-
Rainbow Trout	102	88.7	27.1	129	121.5	42.7	90	102.7	39.7	73	118.1	42.6
Redsided shiner	8	85	0	-	-	-	-	-	-	1	150	-
Steelhead	-	-	-	1	600		-	-	-	-	-	-

Appendix 7-3. Examples of A.) Steelhead Trout, B.) Rainbow Trout, C.) Bull Trout – showing white leading edge on fins and D.) Bull Trout showing white spots on dark back observed migrating through the Seton Dam in 2019.



Appendix 7-4. Summary of juvenile salmonid weighted useable area (WUA; m^2) estimated in 2014, 2018, and 2019 at 12 m^3/s. WUA estimates are provided for each species/life stage in each reach in addition to the percent net change in WUA. Additional sites were surveyed in each year but only those done in all years are shown below for ease of comparison.

		WUA (m^2)											
		RB Fry			RB Parr			Coho			Chinook		
Reach	**Site**	**2014**	**2018**	**2019**	**2014**	**2018**	**2019**	**2014**	**2018**	**2019**	**2014**	**2018**	**2019**
1	G1B	32	91	81	109	322	520	82	214	104	861	636	871
	G1D	116	138	200	82	162	353	123	190	215	634	422	598
	G2C	73	118	161	276	209	187	100	172	196	494	400	323
	P3BR5A	89	144	82	155	140	179	302	245	247	271	234	299
	R3B	175	334	296	43	372	130	157	212	282	69	578	238
	SC2B	81	102	83	29	15	7	82	109	84	57	52	14
	total	**566**	**927**	**903**	**694**	**1220**	**1376**	**846**	**1142**	**1128**	**2386**	**2322**	**2343**
2	G5B	926	449	430	804	335	214	796	509	402	1259	537	301
	LG3B	200	79	81	345	60	95	401	288	324	584	116	185
	total	**1126**	**528**	**511**	**1149**	**395**	**309**	**1197**	**797**	**726**	**1843**	**653**	**486**
3	G9BR10A	454	195	270	324	66	179	477	526	221	587	208	304
	G10BR11A	105	191	311	769	522	723	222	213	255	666	701	763
	LG7B	110	75	124	439	254	144	228	319	207	721	603	309
	total	**669**	**461**	**705**	**1532**	**842**	**1046**	**927**	**1058**	**683**	**1974**	**1512**	**1376**
RIVER TOTAL		**2361**	**1916**	**2119**	**3375**	**2457**	**2731**	**2970**	**2997**	**2537**	**6203**	**7487**	**4205**

Appendix 7-5. Total number of fish species caught during juvenile bio-sampling surveys in all years of BRGMON-9 monitoring. Effort increased in the spawning channels in 2017 through 2019 which may account for the increased abundance of some species.

Species	Count					
	2014	2015	2016	2017	2018	2019
Bridgelip Sucker	30	47	12	38	162	100
Bull Trout	4	1	1	5	4	11
Sculpin *Spp.*	182	302	119	395	431	255
Chinook Salmon	22	197	211	298	121	67
Coho Salmon	674	447	143	279	456	629
Longnose Dace	400	484	111	565	801	374
Lamprey	0	0	2	1	0	0
Mountain Whitefish	14	7	6	1	0	5
Northern Pikeminnow	0	0	16	0	0	0
Peamouth Chub	0	1	6	0	0	2
Pink Salmon	36	0	0	0	5	0
Rainbow Trout	1377	664	684	864	966	500
Red-sided Shiner	59	14	19	41	72	45
Sockeye Salmon	6	24	4	2	0	40

Appendix 7-6. AIC model selection results for body condition modelling in the Seton River for Rainbow Trout, Coho Salmon, and Chinook Salmon. Bold values represent the best fit model (lowest AIC and fewest model parameters).

	RB Age 0		RB Age 1		CO Age 0		CHK Age 0	
Model	**AIC**	**ΔAIC**	**AIC**	**ΔAIC**	**AIC**	**ΔAIC**	**AIC**	**ΔAIC**
K ~ 1	1427.25	54.39	1116.86	9.95	2507.49	144.57	778.51	1.25
K ~ year	1406.35	33.51	**1106.91**	**0.00**	2405.51	42.58	**777.26**	**0.00**
K ~ reach	1401.52	28.67	1117.75	10.84	2500.65	137.73	784.96	7.69
K ~ year + reach	1378.62	5.78	1109.35	2.44	2399.14	36.22	782.82	5.55
K ~ year*reach	**1372.85**	**0.00**	1132.98	26.07	**2362.92**	**0.00**	805.48	28.22

Appendix 7-7. Bio-file for Chinook Salmon juveniles sampled for DNA from 2016-2019. Results from 2019 DNA analysis are still pending - stock origin cannot be provided.

Year	DNA_ID	Date Collected	Reach Collected	Length	Age	Stock Origin
2016	1	22-Jun-16	2	55	0	portage
2016	2	22-Jun-16	2	58	0	portage
2016	7	22-Jun-16	2	55	0	portage
2016	8	22-Jun-16	2	45	0	portage
2016	10	22-Jun-16	2	60	0	portage
2016	13	22-Jun-16	3	57	0	other
2016	14	22-Jun-16	3	69	0	other
2016	15	22-Jun-16	3	60	0	other
2016	16	22-Jun-16	3	58	0	other
2016	17	22-Jun-16	3	46	0	portage
2016	18	22-Jun-16	3	56	0	other
2016	19	22-Jun-16	3	59	0	other
2016	21	22-Jun-16	3	49	0	portage
2016	22	23-Jun-16	3	57	0	portage
2016	23	23-Jun-16	3	66	0	other
2016	24	23-Jun-16	3	56	0	portage
2016	25	23-Jun-16	3	60	0	portage
2016	26	23-Jun-16	3	45	0	portage
2016	29	09-Aug-16	1	80	0	portage
2016	30	09-Aug-16	1	85	0	other
2016	31	09-Aug-16	1	82	0	portage
2016	32	09-Aug-16	2	77	0	portage
2016	33	09-Aug-16	2	90	0	other
2016	34	09-Aug-16	2	78	0	portage
2016	35	09-Aug-16	2	83	0	other
2016	36	09-Aug-16	2	82	0	other
2016	37	09-Aug-16	2	80	0	other
2016	38	09-Aug-16	2	91	0	other
2016	39	09-Aug-16	2	85	0	other
2016	40	09-Aug-16	2	80	0	other
2016	41	09-Aug-16	lsc	79	0	other
2016	43	11-Aug-16	3	75	0	other
2016	44	11-Aug-16	3	64	0	other
2016	45	11-Aug-16	3	65	0	other
2016	46	11-Aug-16	3	73	0	other
2016	47	11-Aug-16	3	65	0	other
2016	48	11-Aug-16	3	72	0	other
2016	49	11-Aug-16	3	70	0	other
2016	52	20-Sep-16	1	90	0	portage

2016	53	20-Sep-16	1	87		portage
2016	54	20-Sep-16	1	97	1	other
2016	55	20-Sep-16	1	86	0	portage
2016	56	20-Sep-16	1	98	0	other
2016	57	20-Sep-16	1	106	1	other
2016	58	20-Sep-16	1	100	1	other
2016	59	20-Sep-16	1	100		other
2016	60	21-Sep-16	1	92	0	portage
2016	62	21-Sep-16	1	89		portage
2016	63	21-Sep-16	1	92	0	portage
2016	65	22-Sep-16	3	88	0	other
2016	66	22-Sep-16	3	71		other
2016	69	22-Sep-16	3	80		other
2016	70	22-Sep-16	3	78		other
2016	71	22-Sep-16	3	72		other
2016	74	22-Sep-16	2	70	0	other
2016	75	22-Sep-16	2	56	0	other
2016	76	22-Sep-16	2	76		other
2016	78	23-Sep-16	3	83	0	other
2016	81	23-Sep-16	2	87		other
2016	82	23-Sep-16	2	63	0	other
2016	84	23-Sep-16	3	68		other
2016	85	23-Sep-16	3	73		other
2016	86	23-Sep-16	3	79		other
2016	87	23-Sep-16	3	68		other
2016	88	23-Sep-16	3	72		other
2016	89	23-Sep-16	3	82		other
2016	90	23-Sep-16	3	82		other
2016	91	23-Sep-16	3	70		other
2016	92	23-Sep-16	3	85	0	other
2016	93	23-Sep-16	3	87	0	other
2016	94	23-Sep-16	3	62		other
2016	96	23-Sep-16	3	70		other
2016	97	26-Sep-16	2	85		portage
2016	98	27-Sep-16	2	99	0	other
2016	99	26-Sep-16	2	104	0	other
2016	100	27-Sep-16	2	96	0	other
2016	101	24-Oct-16	2	88	0	other
2016	102	24-Oct-16	2	92	0	other
2016	103	24-Oct-16	2	101	1	other
2016	106	24-Oct-16	lsc	101	0	other
2016	107	24-Oct-16	lsc	94	0	other

2016	108	24-Oct-16	lsc	104	0	other
2016	109	24-Oct-16	lsc	92	0	other
2016	110	24-Oct-16	lsc	99	0	other
2016	111	24-Oct-16	lsc	88	0	other
2016	112	24-Oct-16	lsc	102		other
2016	113	25-Oct-16	lsc	112	1	other
2016	114	25-Oct-16	lsc	129	1	other
2016	115	25-Oct-16	lsc	101	1	other
2016	116	25-Oct-16	lsc	93	0	portage
2016	117	25-Oct-16	2	86	0	portage
2016	118	25-Oct-16	2	80	0	portage
2016	119	25-Oct-16	usc	89	0	portage
2017	1021	16-May-17	usc	109	2	other
2017	1022	16-May-17	usc	106	2	other
2017	1023	17-May-17	usc	43	0	portage
2017	1024	17-May-17	2	40	0	portage
2017	1025	17-May-17	3	41	0	other
2017	1026	17-May-17	3	45	0	portage
2017	1027	17-May-17	3	42	0	portage
2017	1028	17-May-17	3	44	0	portage
2017	1029	17-May-17	3	48	0	portage
2017	1030	17-May-17	3	41	0	portage
2017	1031	17-May-17	3	40	0	portage
2017	1032	17-May-17	3	38	0	portage
2017	1033	17-May-17	3	53	0	portage
2017	1034	17-May-17	3	46	0	portage
2017	1035	17-May-17	3	42	0	portage
2017	1036	17-May-17	3	45	0	portage
2017	1037	17-May-17	3	41	0	portage
2017	1038	17-May-17	lsc	49	0	portage
2017	1039	17-May-17	3	48	0	portage
2017	1040	17-May-17	3	50	0	portage
2017	1041	17-May-17	3	44	0	portage
2017	1042	17-May-17	3	46	0	portage
2017	1043	17-May-17	3	46	0	portage
2017	1044	17-May-17	2	49	0	portage
2017	1045	17-May-17	2	52	0	portage
2017	1046	17-May-17	2	43	0	portage
2017	1047	17-May-17	2	50	0	portage
2017	1048					portage
2017	1049	17-Aug-17	1	70	0	portage
2017	1050	19-Sep-17	1	89	0	other

2017	1052	17-Aug-17	1	74	0	portage
2017	1053	17-Aug-17	2	74	0	other
2017	1054	16-Aug-17	3	50	0	portage
2017	1056	16-Aug-17	3	70	0	portage
2017	1057	17-Aug-17	1	68	0	portage
2017	1058	17-Aug-17	1	79	0	other
2017	1059	16-Aug-17	3	87		other
2017	1060	17-Aug-17	1	89	0	portage
2017	1061	16-Aug-17	3	68	0	other
2017	1062	17-Aug-17	1	91	0	other
2017	1063	19-Sep-17	1	82	0	portage
2017	1064	16-Aug-17	3	65	0	other
2017	1065	17-Aug-17	2	80	0	portage
2017	1066	17-Aug-17	2	82	0	other
2017	1067	16-Aug-17	3	66	0	other
2017	1068	17-Aug-17	2	80	0	portage
2017	1069	16-Aug-17	3	72	0	other
2017	1070	16-Aug-17	lsc	73	0	other
2017	1071	19-Jul-17	3	62	0	portage
2017	1072	19-Jul-17	3	76	0	other
2017	1073	19-Jul-17	3	62	0	portage
2017	1078	19-Jul-17	3	56	0	other
2017	1079	20-Jul-17	1	71		portage
2017	1083	19-Jul-17	3	58	0	other
2017	1086	17-Aug-17	2	76	0	portage
2017	1088	19-Jul-17	2	60	0	other
2017	1094	17-Aug-17	2	81	0	portage
2017	1095	16-Aug-17	usc	85		other
2017	1096	17-Aug-17	2	75	0	portage
2017	1097	19-Jul-17	2	78	0	portage
2018	2000	19-Jun-18	lsc	52	0	portage
2018	2011	19-Jun-18	3	52	0	portage
2018	2001	19-Jun-18	2	42	0	portage
2018	2002	19-Jun-18	1	46	0	portage
2018	2003	19-Jun-18	1	40	0	portage
2018	2004	19-Jun-18	1	39	0	portage
2018	2005	19-Jun-18	1	48	0	portage
2018	2007	19-Jun-18	1	41	0	portage
2018	2009	19-Jun-18	1	41	0	portage
2018	2010	19-Jun-18	1	42	0	portage
2018	2012	19-Jun-18	3	48	0	portage
2018	2013	19-Jun-18	3	24	0	portage

2018	2014	19-Jun-18	3	36	0	portage
2018	2106	21-Aug-18	3	70	0	other
2018	2107	21-Aug-18	3	63	0	portage
2018	2108	21-Aug-18	3	73	0	other
2018	2109	21-Aug-18	3	79	0	other
2018	2111	17-Sep-18	1	81	0	portage
2018	2112	17-Sep-18	1	71	0	portage
2018	2113	17-Sep-18	1	95	0	other
2018	2114	17-Sep-18	1	75		portage
2018	2116	18-Sep-18	1	93	0	portage
2018	2117	18-Sep-18	1	82	0	portage
2018	2118	18-Sep-18	1	82	0	portage
2018	2119	18-Sep-18	1	90	0	portage
2018	2122	18-Sep-18	1	79	0	portage
2018	2123	18-Sep-18	1	81	0	portage
2018	2124	18-Sep-18	1	78	0	portage
2018	2125	18-Sep-18	1	82	0	portage
2018	2126	18-Sep-18	1	85	0	portage
2018	2127	19-Sep-18	1	78	0	portage
2018	2129	19-Sep-18	2	98	1	other
2018	2131	20-Sep-18	3	82	0	other
2018	2132	20-Sep-18	3	79	1	other
2018	2133	20-Sep-18	3	89	0	portage
2018	2134	20-Sep-18	3	88	0	other
2018	2135	20-Sep-18	3	87	1	other
2018	2136	20-Sep-18	3	85	0	other
2018	2137	20-Sep-18	3	76	0	portage
2018	2140	24-Sep-18	3	86	0	other
2018	2141	24-Sep-18	3	90	1	other
2018	2142	24-Sep-18	3	78	0	other
2018	2143	24-Sep-18	3	89	1	other
2018	2144	24-Sep-18	3	84	0	other
2018	2145	24-Sep-18	3	83	0	other
2018	2146	24-Sep-18	3	94	1	other
2018	2147	24-Sep-18	3	90	0	other
2018	2148	24-Sep-18	3	83	0	other
2018	2149	25-Sep-18	3	105	1	other
2018	2150	25-Sep-18	3	83	0	portage
2018	2151	25-Sep-18	3	79	0	portage
2018	2152	25-Sep-18	3	92	1	other
2018	2153	25-Sep-18	3	86	0	other
2018	2154	25-Sep-18	usc	97	0	portage

2019	1	2019-07-16	2	51	0
2019	2	2019-07-16	2	46	0
2019	3	2019-07-16	2	42	0
2019	4	2019-07-16	2	44	0
2019	5	2019-07-16	2	56	0
2019	6	2019-07-16	2	62	1
2019	7	2019-07-16	2	46	0
2019	8	2019-07-16	2	36	0
2019	9	2019-07-16	2	34	0
2019	10	2019-07-16	2	46	0
2019	11	2019-07-16	3	51	0
2019	12	2019-07-16	3	51	0
2019	13	2019-07-16	3	51	0
2019	14	2019-07-16	3	66	0
2019	15	2019-07-16	3	59	0
2019	16	2019-07-16	3	53	0
2019	17	2019-07-16	3	50	0
2019	18	2019-07-16	3	52	0
2019	19	2019-07-16	3	71	1
2019	20	2019-07-16	3	46	0
2019	21	2019-07-16	3	55	0
2019	22	2019-07-16	3	46	0
2019	23	2019-07-16	3	58	0
2019	24	2019-07-16	3	61	0
2019	25	2019-08-20	1	70	0
2019	26	2019-08-20	2	66	0
2019	27	2019-08-20	3	64	0
2019	28	2019-08-20	3	64	0
2019	29	2019-08-20	3	59	0
2019	30	2019-08-20	3	60	0
2019	31	2019-08-20	3	61	0
2019	32	2019-08-20	3	60	0
2019	33	2019-08-20	3	70	0
2019	34	2019-08-20	3	65	0
2019	35	2019-08-20	3	75	0
2019	36	2019-08-20	3	72	0
2019	37	2019-08-20	2	69	0
2019	38	2019-08-20	2	66	0
2019	39	2019-08-21	usc	101	0
2019	40	2019-08-21	usc	91	0
2019	44	2019-10-30	3	60	0
2019	45	2019-10-30	3	103	0

2019	46	2019-10-30	3	84	0

Appendix 7-8. DNA results for Chinook Salmon juveniles caught in Seton River in 2016, 2017, 2018. Results from 2019 are still pending and will be presented in future reports.

Stock Origin	2016	2017	2018
Chilko River	10	2	2
Cottonwood River	2	0	0
Deadman Creek	0	1	0
Fontoniko Creek	4	0	0
Indianpoint Creek	0	0	1
Cariboo River	0	1	0
Chilcotin River	2	0	0
Nechako River	13	3	0
Portage (Seton)	26	41	32
Quesnel River	14	0	11
Salmon River	2	0	2
Slim Creek	6	1	0
Stuart River	13	11	6
Willow River	1	0	0

Appendix 7-9. Detection efficiency calculated using PITR package for each of the Lower Spawning Channel PIT antennas (downstream = antenna 1, upstream = antenna 2), summarized by year.

Year	Antenna	Detection efficiency	Shared detections	Detections on array	Detections not on array	Missed detections
2015	1	0.82	9	11	11	2
2015	2	0.82	9	11	11	2
2016	1	0.14	1	3	7	6
2016	2	0.67	2	7	3	1
2017	1	0.84	11	18	13	7
2017	2	0.61	11	13	18	2
2018	1	0.33	1	4	3	2
2018	2	0	0	3	4	4
2019 (before change)	1	0.40	2	4	5	3
2019 (before change)	2	0.75	3	5	4	1
2019 (after change)	1	0.67	8	9	12	4
2019 (after change)	2	0.89	8	12	9	1

Appendix 7-10. Detection efficiency calculated using PITR package for each of the Upper Spawning Channel PIT antennas (downstream = antenna 1, upstream = antenna 2), summarized by year.

Year	Antenna	Detection efficiency	Shared detections	Detections on array	Detections not on array	Missed detections
2015	1	0.40	12	13	30	18
2015	2	1.00	13	30	13	1
2016	1	0.88	15	19	17	2
2016	2	0.79	15	17	19	4
2017	1	1.00	14	17	14	0
2017	2	0.82	14	14	17	3
2018	1	1.00	18	22	18	2
2018	2	0.73	16	18	22	6
2019	1	0.74	25	27	34	9
2019	2	0.93	25	34	27	2

Appendix 7-11. Detections for the 11 Rainbow Trout that moved between the two Spawning Channels in which the direction of movement can be confidently assigned.

Date of Detection	PIT code	Tag Date	Age at Tag	FL	Age at Detection	Antenna	Direction	Purpose
03-Oct-15	586038	Jun 2014	2	118	3	LSC	in	rearing
09-Oct-15	586038	Jun 2014	2	118	3	USC	in	rearing
01-Dec-15	657744	Jul 2015	1	160	2	USC	out	rearing
02-Dec-15	657744	Jul 2015	1	160	2	LSC	out	rearing
22-Apr-16	586036	Apr 2014	2	103	4	USC	in	spawning
07-May-16	586036	Apr 2014	2	103	4	LSC	in	spawning
18-May-16	586036	Apr 2014	2	103	4	USC	out	spawning
17-Oct-16	657061	Sep 2015	1	78	2	USC	out	rearing
30-Oct-16	657061	Sep 2015	1	78	2	LSC	out	rearing
27-Aug-17	656873	Mar 2017	NA	88	NA	USC	In	rearing
08-Sep-17	656806	Mar 2017	2	101	2	USC	in	rearing
11-Sep-17	656806	Mar 2017	2	101	2	LSC	in	rearing
27-Sep-17	657877	Sep 2016	0	76	1	USC	in	rearing
25-Oct-17	656873	Mar 2017	NA	88	NA	LSC	In	rearing
21-Oct-17	734906	Oct 2016	0	87	1	USC	out	rearing
09-Nov-17	734906	Oct 2016	0	87	1	LSC	in	rearing
09-Nov-17	657877	Sep 2016	0	76	1	LSC	in	rearing
27-Nov-17	734906	Oct 2016	0	87	1	LSC	out	rearing
17-Oct-18	656876	Mar 2017	NA	72	NA	USC	In	rearing
26-Dec-18	656876	Mar 2017	NA	72	NA	USC	In	rearing
04-Oct-19	301615	Apr 2019	NA	85	NA	USC	Out	rearing

Appendix 7-12. Streamwalk counts of Steelhead Trout and Chinook, Coho and Pink Salmon annually since 2015. A dash indicate that no survey was completed.

	2015			2016			2017			2018			2019		
Location	**Seton**	**USC**	**LSC**	**Seton**	**USC**	**LSC**	**Seton**	**USC**	**LSC**	**Seton**	**USC**	**LSC**	**Seton**	**USC**	**LSC**
Steelhead	1	0	1	-	-	-	-	-	-	-	-	-	-	-	-
Chinook	0	0	0	2	0	1	0	0	0	-	-	-	24	6	36
Coho	0	4	18	4	25	64	13	0	0	13	22	27	21	34	180
Pink	1098	2577	2887	-	-	-	579	495	727	-	-	-	1026	1528	1789