Bridge River Project Water Use Plan

Lower Bridge River Adult Salmon and Steelhead Enumeration

Implementation Year 7

Reference: BRGMON-3

Study Period: March 1, 2018 to December 6, 2018

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Bridge-Seton Water Use Plan

Implementation Year 7 (2018):

Lower Bridge River Adult Salmon and Steelhead Enumeration

Reference: BRGMON-03

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Lower Bridge River Adult Salmon and Steelhead Enumeration, 2018

Multibeam sonar and resistivity counters in the Lower Bridge River

Executive Summary

The Lower Bridge River Adult Salmon and Steelhead Enumeration program (BRGMON-3) enumerates adult salmonid returns, data that supports evaluation of the effects of different flow releases from Terzaghi Dam [40 river kilometers (rkm) from Fraser River] on salmon productivity in the Lower Bridge River (LBR). BRGMON-3 aims to develop new, and refine historic, approaches for estimating adult abundance, and assess the quantity, quality and distribution of salmon spawning habitat. Adult escapement data from BRGMON-3 will be used with juvenile salmonid abundance estimates from the Lower Bridge River Aquatic monitor (BRGMON-1) to develop stock recruitment models. These models will evaluate effects of dam flow releases on juvenile salmonids independently from other factors such as marine survival and adult exploitation. In 2016, operations of the Bridge River hydroelectric complex were modified due to dam safety risks at La Joie Dam and repairs at the Bridge River Generating Stations in Shalalth. High flow releases from Terzaghi Dam have occurred in 2016-2018 to manage the excess water stored in Carpenter Reservoir. As a result, management questions for BRGMON-1, and thus objectives of BRGMON-3, have been refined to also address the effects of this high flow regime.

In 2018, a combination of multibeam sonar and resistivity counter was used to enumerate Steelhead Trout, Chinook and Coho Salmon migrating above the counter site (25.5 rkm from Fraser River). The first five weeks (March 23 to May 9) of the estimated 9-week-long Steelhead Trout spawning period (Late March to Early June) were assessed, during which an estimated 14 Steelhead Trout spawned upstream of the counter. The counters were removed early due to increasing Terzaghi Dam releases, and therefore this estimate should be considered a minimum number. Flows ramped up from 3 m^3s^{-1} during March 2018, reaching a peak hydrograph of 102 $m^3 s^{-1}$ between June 26 to July 3, and returned to the WUP target hydrograph of 15.0 $m^3 s^{-1}$ by August 1. A hydrograph of 5 m^3s^{-1} was achieved by August 17, prior to the historic run timing of Chinook and Coho Salmon (August to December). Therefore, both counters could be used to estimate Chinook Salmon abundance during the spawning period (August 15 to October 1), with an estimated 30 Chinook Salmon spawning upstream of the counter site. However, this number should also be considered a minimum estimate because construction of a full channel spanning fish fence impeded upriver migration of adult salmon after August 29. Only the sonar counter was used to estimate Coho Salmon abundance during the spawning period (October 1 to December 7), as the final ramp down to 1.5 $m^3 s^{-1}$ prevented passage over the resistivity counter pads. During this period, an estimated 545 Coho Salmon spawned upstream of the counter site.

Data from visual streamwalk surveys in 2018 were used to generate area-under-the-curve (AUC) abundance estimates of Chinook and Coho Salmon in reaches 3 and 4 of the LBR. Observer efficiency and residence time estimates were generated using radio telemetry mark-recapture (3 Chinook Salmon and 25 Coho Salmon). Historic visual count data were also compiled, and AUC estimates were calculated for Chinook and Coho Salmon in the area upstream of the counter site. AUC estimates from 1993 to 2018 ranged from 21 (2009) to 3,106 (2004) Chinook Salmon, and from 79 (1999) to 3,539 (2011) Coho Salmon from 1997 to 2016. Using AUC methods, a total spawner abundance estimate of 25 Chinook and 1,245 Coho Salmon were derived for the area upstream of the counter site. Chinook returns severely declined after 2004 and have since remained at these depressed levels. This pattern of declining abundance has been observed throughout the Fraser Watershed for Chinook Salmon. Coho returns were high between 2011 and 2013 (ranged from 1,700 to 3,500) but declined after 2013. The 2018 Coho estimate is the highest calculated since 2014. Twenty-one Steelhead Trout were tagged, but no visual counts were conducted due to the limited visibility in the river during their spawning period. No historical visual count data were available for Steelhead Trout prior to 2014, but radio and PIT telemetry data suggest that Steelhead spawn above the counter site and also in Reach 2 in 2018. Continued collection of resistivity and sonar counter data will be compared to AUC abundance estimates during the final BRGMON-3 synthesis.

During Chinook Salmon redd sampling in 2018, three redds were identified and surveyed to characterize preferred spawning habitat characteristics (water depth, velocity and substrate characteristics) and to determine the distribution of redds between the counter site and Terzaghi Dam (25.5 to 40 rkm from the Fraser River). Chinook Salmon spawned in the lowest average water depths and velocities observed since 2016. Consistent with the findings from both 2016 and 2017, the geometric mean (D_{50}) of the substrate sampled in the tail spill of the redds was higher relative to pre-high discharge years. However, only three redds were sampled in 2018 and values were still within the preferred spawning substrate size range of Chinook Salmon. This increase is likely associated with the downstream mobilization of smaller sized substrate during high flow releases from Terzaghi Dam. Chinook salmon continued to stage and spawn in Fraser Lake in 2018 (first observed in 2017 redd surveys) and are beginning to utilize habitat in Reach 4, closer to Terzaghi Dam (within 2km and first observed in 2017 redd surveys). Coho salmon staged and spawned in areas similar to Chinook Salmon, including Michel Moon, Russel Springs, Fraser Lake, Eagle and Longskinny. 2018 was the first year of successful Coho redd sampling, and continued monitoring and analysis will be included in future reports. Preliminary data suggest that Coho

Salmon utilize the same spawning habitat as Chinook Salmon, however, there is a greater preference for Reach 4.

Adult salmon spawning habitat assessments, a key objective of BRGMON-3, were expanded on in response to the modified high flow regime in the LBR. Habitat assessments were conducted in locations known to be important for spawning and used to construct Habitat Suitability Index (HSI) models to determine the amount of available spawning habitat for each species in the areas assessed. Surveys were completed in spring and fall 2018 to characterize the instream conditions after the 2017 and 2018 high flow events, respectively. Previous spawning information (redd surveys and telemetry) informed the locations for habitat transects in Reach 3 and 4, and 66 transects were established in 15 habitat units, covering 6.1% of the river above the Yalakom confluence. The total area of suitable spawning habitat decreased from 3727 m^2 to 3595 m^2, a difference that is not statistically significant. Habitat surveys will continue each fall to monitor habitat availability in the LBR.

Scale samples were analyzed from 46 Steelhead Trout (2014-2018), 50 Chinook Salmon (2013-2018) and 153 Coho Salmon (2011-2018) that were captured and tagged during this monitoring program. Steelhead Trout displayed a complex life history consisting of six distinct age classes. We found that the two major age classes present in 2017 and 2018 samples were dominated by the 2012 and 2013 brood. Scales collected from Chinook Salmon indicated that most returning adults were 1.3+ (age 4), indicating that fish out-migrated as yearlings (stream-type) having spent one winter in freshwater and returned to spawn after spending three winters in the ocean. Age data for Coho Salmon identified three dominant age classes in the LBR, with age 1.1+ being dominant and 2.1+ being subdominant. Both age classes displayed similar juvenile life histories, whereby juveniles spent 1-2 years (winters) in freshwater before out-migrating as smolts.

Observations made during this monitor will provide information to aide BRGMON-1, in which effects of flow on juvenile standing crop abundance and biomass will be assessed. The objectives of BRGMON-3 are to 1) provide data to BRGMON-1 to evaluate whether spawner abundance is a limiting factor in the production of juvenile salmonids, and 2) quantify the quantity and quality of habitat in the LBR. We recommend the continued use of radio telemetry for all species, to develop accurate observer efficiencies and survey length for AUC estimates, and also continued redd surveys for Chinook and Coho Salmon to monitor the distribution of spawners in Reach 3 and 4 of the LBR in relation to managed flow releases. The combination of counter technologies was successfully used in 2018 to enumerate Steelhead Trout, but we note that flows in the LBR need to remain at or below 20 $m^3 s^{-1}$ until mid to late

May in order to generate a complete and accurate estimate of Steelhead Trout abundance. HSI curves and redd surveys will address questions regarding the quantity and quality of available spawning habitat in the LBR.

Moving forward, we will continue to develop a relationship between streamwalk data and counter-derived estimates of abundance and use this relationship to refine the accuracy of future abundance estimates. If the fish fence is deployed in 2019, we recommend that it be moved at least 250m upstream from the counter infrastructure to reduce recycling behavior through the counters, thus improving accuracy of models and reducing post-processing time. The fish fence affected every component of BRGMON-3 during the Chinook Salmon migration period and if continued, at the current location, it will decrease our ability to provide meaningful information to BRGMON-1.

BRGMON-3 Status of Objectives, Management Questions and Hypotheses after Year 7

Study Objectives	Management Questions	Management Hypotheses	Year 7 (Fiscal Year 2018) Status
Evaluate effects of Terzaghi Dam operations on the spawning habitat and distribution of Steelhead Trout, and Chinook and Coho Salmon, and to generate spawner abundances under the alternative test flow regimes.	What is the annual abundance, timing, and distribution of adult salmon and steelhead spawning in the Lower Bridge River and are these aspects of spawning affected by the instream flow regime?	$H_{1.1}$: There is no relationship between the instream flow regime and the abundance, timing or distribution of spawning salmon and steelhead in the Lower Bridge River.	Three complete years (2014, 2015, 2018) of adult salmon and Steelhead enumeration have been collected. High flow releases from Terzaghi Dam in 2016 damaged the resistivity counter and subsequent abundance estimates will be generated using a combination of counter technologies (resistivity and multibeam sonar) and will provide accurate and consistent estimates. Telemetry and streamwalk data will be important in evaluating the distribution and timing of spawning. Continued monitoring is required to adequately evaluate Question 1.
	What is the quality and quantity of spawning habitat in the Lower Bridge River and how is spawning habitat affected by the instream flow regime?	The instream flow regime does not affect spawning habitat quality or quantity in the Lower Bridge River.	Data on spawning habitat used by Chinook Salmon has been collected for five years. 2018 was the first year of successful redd surveys for Coho Salmon (but not for steelhead due to conditions during their spawning period). Spawner distribution for all species has been identified through telemetry, and continued effort will reveal whether managed flows in the LBR impact spawner distribution. Question 2 will be addressed upon completion of data collection and analysis.

BRGMON-3 Modified Operations Management Questions and Hypotheses after Year 7

Study Objectives	Management Questions	Management Hypotheses	Year 7 (Fiscal Year 2018) Status
Evaluate effects of the modified flow regime on the spawning habitat and distribution of Steelhead Trout, and Chinook and Coho Salmon, and to generate spawner abundances under the alternative test flow regimes.	Have flow releases from Terzaghi Dam under the modified flow regime affected the quality and quantity of spawning habitat available in the Lower Bridge River? If so, what are the potential effects on fish and what mitigation options are available?	Quality and Quantity of spawning habitat in the Lower Bridge River has not been changed as a result of the modified flow regime.	Collection of habitat suitability data for adult spawners began in Spring 2018 to quantify habitat quality (depth, velocity and substrate) after the high flow events of 2017 and were completed again in Fall 2018 to evaluate the 2018 high flow regime. There was no significant difference between the amount of suitable spawning habitat pre- and post-2018 high flow event. However, continued monitoring is still required to adequately evaluate Hypothesis 1.
	Have flow releases from Terzaghi Dam under the modified flow regime affected the distribution of adult spawning in the Lower Bridge River? If so, what are the potential effects	Distribution of adult spawning in the Lower Bridge River has not been changed as a result of the modified flow regime.	Low escapement of Chinook Salmon since the new high flow regime was implemented (2016) has limited our ability to draw meaningful conclusions. Steelhead continue to spawn across Reach 3 and 4, while other salmon are beginning to utilize Reach 4. Continued monitoring is required to adequately evaluate Hypothesis 2.

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Glossary of Terms

AUC	Area-Under-The-Curve
ATU	Accumulated Thermal Units
BRGS	Bridge River Generating Stations
BRS CC	Bridge-Seton Consultative Committee
BRS FTC	Bridge-Seton Fisheries Technical Committee
DFO	Department of Fisheries and Oceans Canada
HSI	Habitat Suitability Index
IFO	Interim Flow Order
IFR	InStream Fisheries Research
LBR	Lower Bridge River
ML	Maximum Likelihood
OE	Observer Efficiency
PIT	Passive Integrated Transponder
PSS	Peak Signal Size
SER	St'át'imc Eco-Resources Ltd.
SL	Survey Life
WUP	Water Use Plan

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St'át'imc Eco-Resources Ltd. (SER) fisheries technicians provided essential field service throughout the duration of this monitoring program. SER administrators Bonnie Adolph, Gilda Davis and Jude Manahan provided logistical and administrative support for this project. Richard Bailey from the Department of Fisheries and Oceans (DFO) Canada provided historical abundance data.

1.0 Introduction

1.1 Background

The Bridge River hydroelectric complex is a power producing tributary of the middle Fraser River. It provides important habitat for Pacific salmon and Steelhead Trout (*Oncorhynchus* spp.) and has historic and current significance for the St'át'imc Nation. River discharge is affected by BC Hydro through the operation of Carpenter Reservoir and Bridge River Generating Stations 1 and 2 (BRGS). The Bridge River was originally impounded in 1948 through the construction of the Mission Dam approximately 40 km upstream of the confluence with the Fraser River. In 1960, Mission Dam was raised to its present configuration (~ 60 m high, ~ 366 m long earth fill structure) and renamed Terzaghi Dam in 1965. From 1960 to 2000, apart from periodic spill releases during high inflow years, flows were exclusively diverted through the BRGS to the adjacent Seton River catchment for power production at the Seton Generating Station (SGS; **Error! Reference source not found.**). A 4-km section of the Bridge River channel immediately downstream of Terzaghi Dam remained continuously dewatered; groundwater and small tributaries contributed flow in the dewatered reach (~ 1 m^3s^{-1} averaged across the year; Longe and Higgins 2002).

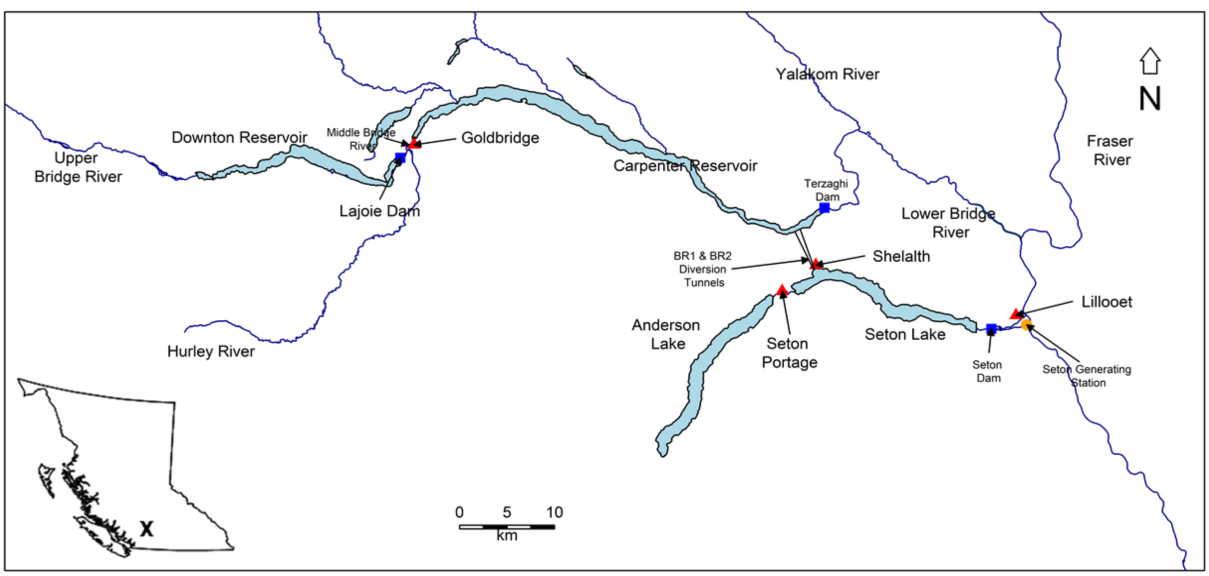

Figure 1: Bridge and Seton Watersheds showing Terzaghi Dam and the diversion tunnels to Bridge River Generating Stations 1 and 2.

Lack of a continuous flow release from Terzaghi Dam was a long-standing concern for the St’át’imc Nation, federal and provincial regulatory agencies, and the general public. During the late 1980s, BC Hydro, Fisheries and Oceans Canada (DFO), and the BC Provincial Ministry of Environment engaged in discussions over appropriate flow releases from the dam. In 1998, an agreement was reached for a continuous flow release from Carpenter Reservoir via a low-level flow control structure to provide fish habitat downstream of the dam. The agreement included the provision of a 3.0 m^3s^{-1} interim annual water budget for instream flow releases based on a semi-naturalized hydrograph ranging from 2 to 5 m^3s^{-1}. The Deputy Comptroller of Water Rights for British Columbia issued an Order under Section 39 of the Water Act to allow initiation of the interim flow releases from Carpenter Reservoir into the Lower Bridge River (LBR), and the continual release of water into the LBR began on August 1, 2000.

A condition of the Interim Flow Order (IFO) was the continuation of environmental monitoring studies in response to concerns regarding environmental impacts of the introduction of water from Carpenter Reservoir, and to improve understanding of the influence of reservoir releases on the recovery of the LBR aquatic ecosystem. The Aquatic Ecosystem Monitoring Program was implemented (continuing as BRGMON-1, Bridge-Seton WUP Monitoring Terms of Reference 2012), which collected baseline data of juvenile salmonid standing crop, primary production and stream temperature before the continuous release began and monitored ecosystem responses to the flow trials (Sneep and Hall 2011).

The IFO continued until the Water Use Plan (WUP) for the Bridge River hydroelectric complex was approved by the St’át’imc Nation and regulatory agencies and authorized by the Comptroller of Water Rights for the Province of British Columbia. The Bridge-Seton Consultative Committee (BRS CC) submitted a draft WUP to the Comptroller in September 2003. Subsequent recommendations by the St’át’imc Nation were adopted in 2009 and 2010, and a final WUP was submitted to the Comptroller of Water Rights on March 17, 2011.

A 12-year test flow release program was proposed under the draft WUP in 1998 that tested three alternative flow release regimes (referred to as: 1 m^3s^{-1}/y, 3 m^3s^{-1}/y, 6 m^3s^{-1}/y) that differed in the total magnitude of the annual water budgets, but not the shape of the hydrograph. The flow treatment was subsequently revised and was set to 3 m^3s^{-1}/y from August 2000 to April 2011, and 6 m^3s^{-1}/y from May 1, 2011 to April 15, 2015. The intention of the flow trial was to establish a long-term flow release strategy for the LBR. The BRS CC recommended detailed monitoring of ecosystem responses to instream flow. In response, the BRS Fisheries Technical Committee (BRS FTC) developed a monitoring program aimed at evaluating the physical habitat, aquatic productivity, and fish responses to instream flows.

The BRS FTC expressed uncertainty about the availability and importance of spawning habitat for anadromous species, and how this may affect interpretation of the juvenile salmonid response monitored under BRGMON-1. Coincident with the juvenile standing crop estimates from BRGMON-1 that aim to determine the effects of flow, time series data of adult salmon abundance during the flow trials could determine the influence of spawner density on juvenile recruitment. Accordingly, the BRS CC recommended a monitoring program to evaluate the effects of the flow regime on spawning habitat and distribution to enumerate spawning abundances under the alternative test flow regimes (Adult Salmon and Steelhead Enumeration Program BRGMON-3, Bridge-Seton WUP Monitoring Terms of Reference 2012). BRGMON-3 monitors abundance and distribution of spawning salmonids in the LBR, with a focus on stream-rearing species (Steelhead Trout, and Chinook and Coho Salmon). Abundance and distribution of spawning salmonids has been assessed previously by DFO in the LBR. BRGMON-3 will also build on these previous studies by developing survey methods and analytical techniques that produce rigorous, quantitative estimates of LBR salmon and steelhead abundance and distribution to assist in evaluating the usefulness of historical archived data. A combination of fish counting technologies, radio telemetry, population estimates derived from visual estimates, spawning habitat assessments and biological measures are used to evaluate escapement, migration behaviour and habitat availability in the LBR.

In October 2013, the construction of a crump weir and electronic resistivity fish counter above the Yalakom-Bridge confluence (25.5 rkm) was completed. The counter enumerates Steelhead Trout (*Oncorhynchus mykiss*), and Chinook (*O. tshawytscha*) and Coho Salmon (*O. kisutch*) abundances upstream of the counter site. Resistivity counters can provide estimates of spawner abundance within 10% of the true abundance (e.g., Deadman River; McCubbing and Bison 2009).

In late 2015, an assessment of flow management options identified the need for further modifications of planned operations, including the LBR hydrograph, to be able to pass higher flows down the LBR due to: (1) the loss of storage capacity at Downton Reservoir, and (2) additional capacity limitations associated with de-rated generator units in 2015 at the BRGS in Shalalth. Modified operations have involved several flow variances in the LBR during the monitoring period. In 2016, BC Hydro modified La Joie Dam operations to address dam safety risks when reservoir levels exceed El. 734 m. Specifically, the modification involved lowering the maximum normal reservoir level to El. 734 m as an interim measure to mitigate potential seismic risk associated with the integrity of the upstream shotcrete dam face.

High flow years resulted in peak hydrographs of 97 m^3s^{-1} in 2016, 127 m^3s^{-1} in 2017 and 102 m^3s^{-1} in 2018 (**Figure 2**). We highlight that the fish counter was designed to withstand a peak flow of 20 m^3s^{-1}, and thus damage was expected. High flow releases in 2016 caused extensive damage to previously deployed fish counter equipment, including the resistivity counter sensors (on river left), video validation equipment and PIT telemetry gear. Due to the high-water levels and extent of damage, the resistivity counter could not be used at all in 2016. Instead, alternative methods of enumeration were tested in 2016, including a combination of sonar and resistivity counter technologies which was determined to be an effective method for high flow years (Burnett et al 2017).

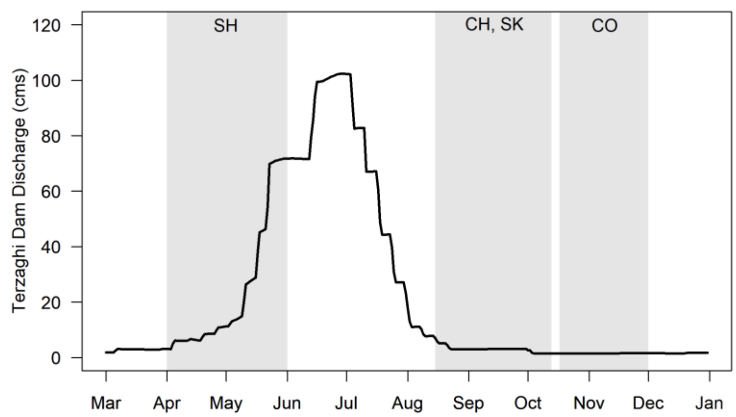

Figure 2: Discharge from Terzaghi Dam into the Lower Bridge River in 2018. Migration timing of anadromous salmonids are represented by shaded rectangles. SH = Steelhead Trout, CH = Chinook Salmon, SK = Sockeye Salmon, and CO = Coho Salmon.

Following the pilot study conducted in 2016 (Burnett et al. 2017), we used an ARIS multibeam sonar unit for adult enumeration. The ARIS unit was fixed to a custom-built aluminium mount located on river-left where the counter pads were damaged by the high flows in 2016. ARIS sonar technology is used by agencies in North America and is industry standard (e.g. Lagasse et al. 2017).

High flow releases will continue until 2028 when modifications to address La Joie Dam safety risks and repairs at the BRGS in Shalalth are expected to be complete. High flow events may cause the downstream mobilization of smaller sized substrate which may affect egg-fry survival through the removal of fine sediments, however, remaining substrate may be less suitable for redd construction (Chapman 1988). A comprehensive assessment of critical spawning habitat was implemented to quantify substrate, depth and velocity profiles of the critical spawning habitat in Reach 2, 3 and 4 of the LBR. Habitat Suitability Index (HSI) surveys were calculated from these measures of habitat to construct species-specific suitability curves to quantify the amount of available spawning habitat within identified habitat units (Raleigh et al. 1986).

1.2 Management Questions

Specific management questions were not listed in the terms of reference (TOR) for this monitor. Instead, this monitoring program would aide interpretations of results of the Aquatic Ecosystems Monitoring Program (BRGMON-1). Specifically, the objectives of the monitor are to provide information to aid in addressing the question:

1) What is the annual abundance, timing, and distribution of adult salmon and steelhead spawning in the Lower Bridge River and are these aspects of spawning affected by the instream flow regime?

2) What is the quality and quantity of spawning habitat in the Lower Bridge River and how is spawning habitat affected by the instream flow regime?

BRGMON-3 addresses this management question via two hypotheses:

H_1: There is no relationship between the instream flow regime and the abundance, timing or distribution of spawning salmon and steelhead in the Lower Bridge River.

H_2: The instream flow regime does not affect spawning habitat quality and quantity in the Lower Bridge River.

H_2 attempts to fill data gaps identified during WUP development. The BRS WUP process identified significant uncertainty regarding the quality and quantity of spawning habitat in the LBR. Implementation of this monitoring program is intended to improve the utility of the juvenile standing crop data by examining relationships with juvenile recruitment and the amount of spawning habitat available.

As an amendment to original BRGMON-3 WUP management question, the modified flow regime created two additional management questions:

3) Have flow releases from Terzaghi Dam under the modified flow regime affected the quality and quantity of spawning habitat available in the Lower Bridge River? If so, what are the potential effects on fish and what mitigation options are available?

4) Have flow releases from Terzaghi Dam under the modified flow regime affected the distribution of adult spawning in the Lower Bridge River? If so, what are the potential effects on spawning success and what mitigation options are available?

BRGMON-3 addresses this new management questions via two hypotheses:

H_3: Quality and quantity of spawning habitat in the Lower Bridge River has not been changed as a result of the modified flow regime.

H_4: Distribution of adult spawning in the Lower Bridge River has not been changed as a result of the modified flow regime.

H_3 aims to collect the data needed to support evaluations of whether adult spawner habitat suitability has been altered by the modified flow regime.

H_4 aims to collect the data needed to support evaluations of whether adult spawner habitat selection has been altered by the modified flow regime.

1.3 Key Water Use Decisions Affected

Results from BRGMON-3 will inform the development of the long-term flow regime for the LBR. BRGMON-3 provides the data needed to build spawner recruit relationships, support BRGMON-1 in the interpretation of responses of the aquatic ecosystem to varied flow treatments (0 m^3s^{-1}/y, 3 m^3s^{-1}/y, and 6 m^3s^{-1}/y), and improve our understanding of the influence of instream flow on salmon spawning and rearing habitat quantity and quality in the LBR. In 2017 and 2018, we monitored spawner abundance and distribution in relation to a new high flow treatment (19 m^3s^{-1}/y). We note that there is potential for these high flow conditions to occur annually for approximately 10 years until La Joie Dam and the BRGS are repaired. The high flow treatment may be having effects on juvenile abundance (Sneep et al. 2018) that could be reflected in adult abundance even after the repairs are completed and the flow treatment is returned to the prescribed 6 cms hydrograph. Results presented herein pertain to the high flow treatment and not to the original WUP flow treatments outlined above but will still support the development of a long-term flow regime for the LBR.

2.0 Methods

2.1 Site Description

The confluence of the LBR with the Fraser River is located ~7 km north of the Lillooet town center and extends 40 rkm west to Terzaghi Dam and Carpenter Reservoir. The reservoir extends from to the Middle Bridge River in Gold Bridge, which is regulated by the Lajoie Dam, 45 km west of Terzaghi Dam. Water from Carpenter Reservoir is diverted through two tunnels at the east end of the reservoir to Bridge 1 and Bridge 2 generating stations in Shalath. Carpenter Reservoir begins filling in the Spring during freshet and “full pool” is reached in late Summer with a maximum water depth of 55 m (Perrin and Macdonald 1997). Historically, water was only released down the LBR when reservoir levels exceeded 55m, however, BC Hydro and BRG FTC agreed upon continuous flow releases beginning in 2000 and the implementation of the Bridge River Water Use Plan (BRG WUP).

The LBR is separated into four study reaches, where boundaries are defined by the end of the current reach and beginning of the subsequent: Reach 1 extends from the Bridge-Fraser confluence to Camoo FSR Bridge (0-18 rkm); Reach 2 continues to the Yalakom-Bridge confluence (18-25.5 rkm); Reach 3 continues to 37.3 rkm (25.5-37.3 rkm); Reach 4 continues to Terzaghi Dam (37.3-40 rkm;

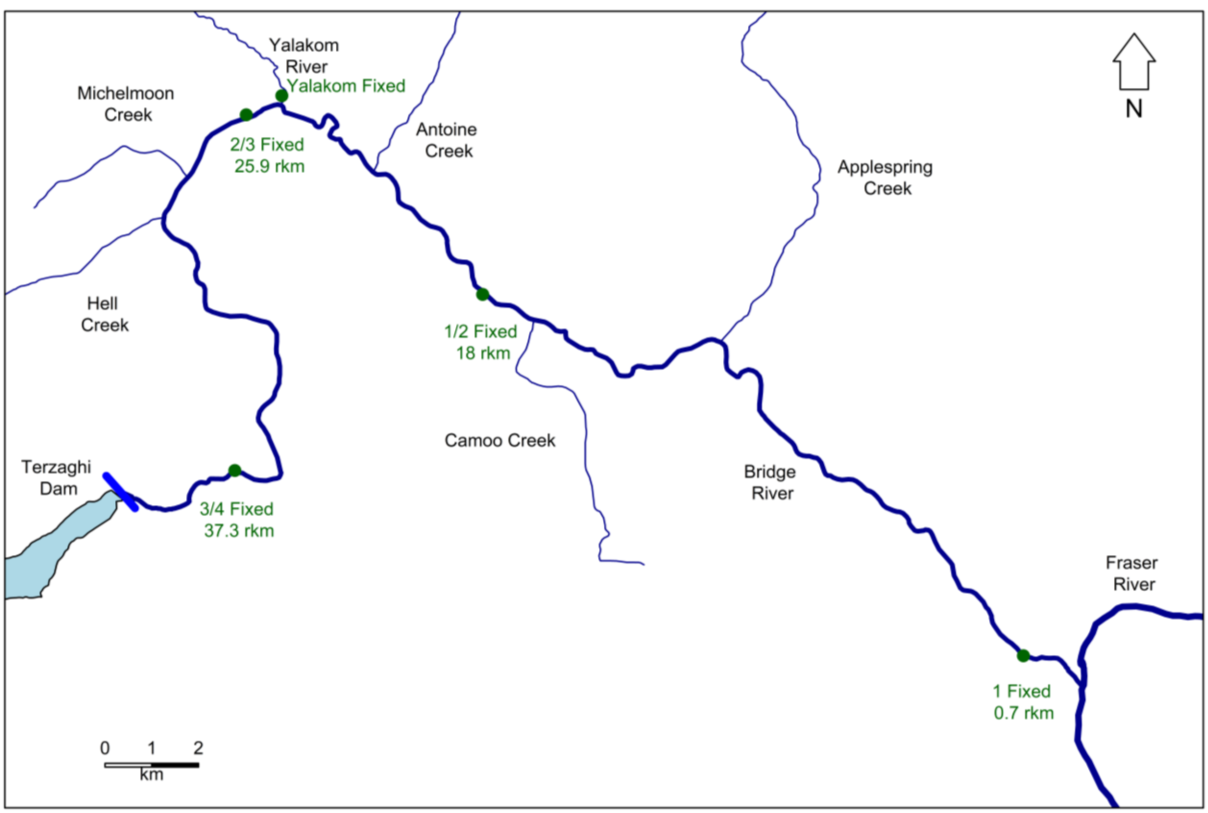

Figure 3). The counter infrastructure is located ~300 m upstream of the Yalakom River (Reach 2/3 boundary). All reach boundaries have fixed-radio receivers to assess entry and exit into corresponding reaches, and an additional receiver is located on the Yalakom to assess whether fish use this river for spawning or holding (~150 m upstream of the confluence with the LBR). Reach 3 and 4 are subdivided further into eight streamwalk sections from Terzaghi Dam to the Yalakom River (1-8), with boundaries located at Longskinny (1; 39.6 rkm), Eagle (2; 38.8 rkm), Bluenose (3; 38.2 rkm), Cobra (4; 34.4 rkm), Fraser Lake (5; 33.2 rkm), Russel Springs (6; 30.7 rkm), Hell Creek (7; 28.8 rkm), and Yalakom (8; 25.5 rkm; **Figure 4**).

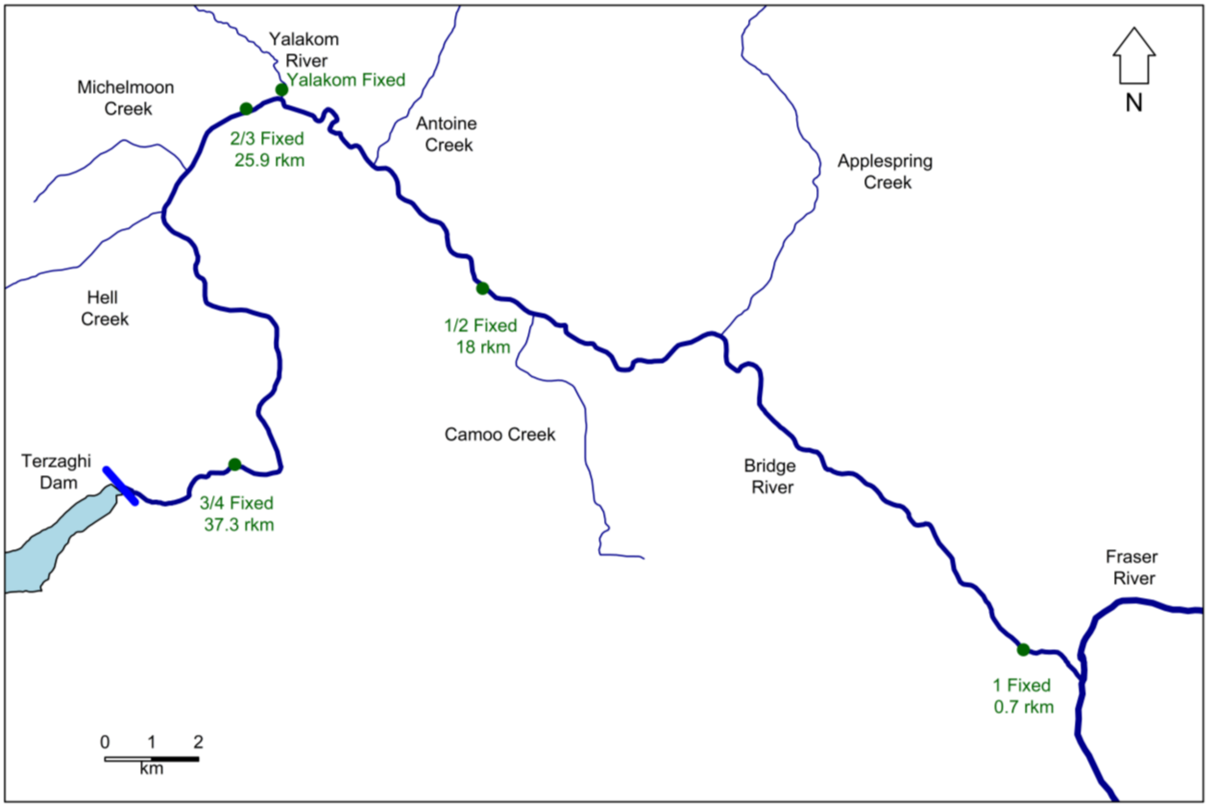

Figure 3: Fixed telemetry stations (green circles) that also act as boundaries between reaches (1-4) in the Lower Bridge River study area (including corresponding river kilometers; rkm) from Terzaghi Dam to the Fraser River.

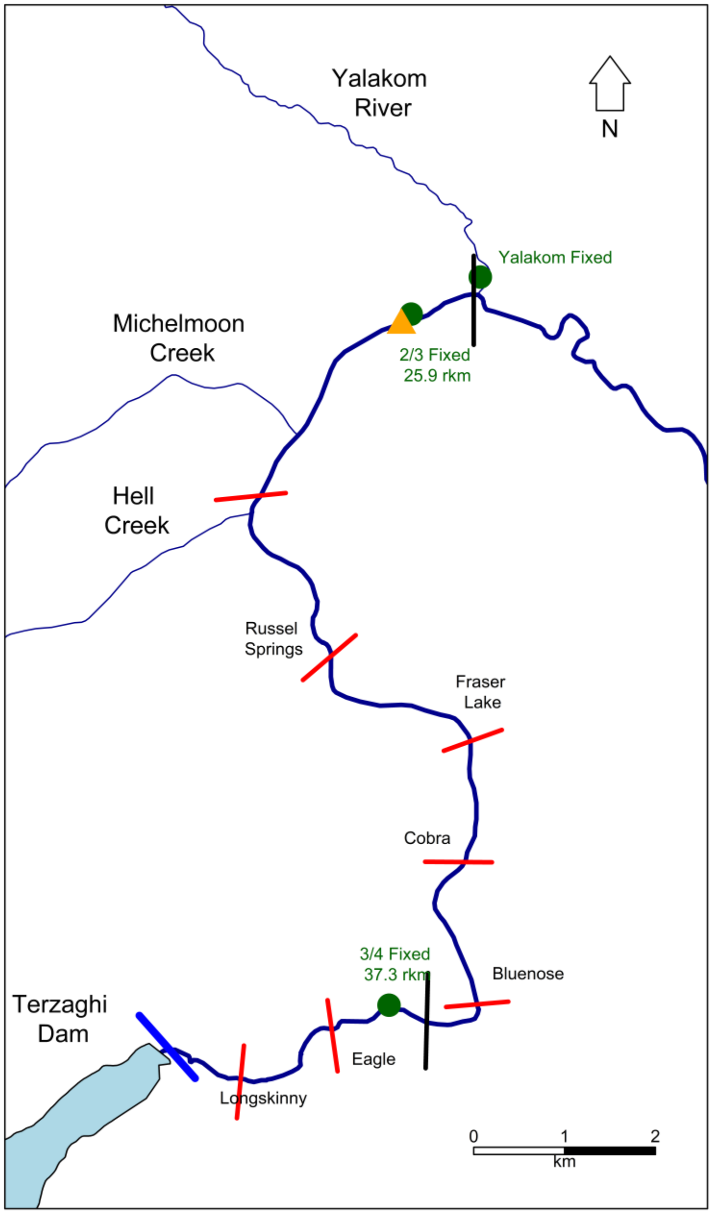

Figure 4: Streamwalk section boundaries (red lines), reach boundaries (black lines), fixed receiver locations (green), including common name of important Chinook spawning sections in Reach 3 and 4 of the Lower Bridge River study area from Terzaghi Dam to the Yalakom (~15rkm).

BRGMON-3 previously focused stream walks and telemetry efforts in Reach 3 and 4, however, under the modified flow regime increased monitoring occurred in Reach 1 and 2. Spot checks for Chinook Salmon occurred throughout September at Camoo FSR Bridge and behind the Bridge River Band office. Reach 2 visual surveys began in October 2018, where the entire section was walked from the upstream end of Horseshoe Bend to Camoo FSR Bridge (24.5-18 rkm). Habitat surveys of Reach 1 and 2 that began in 2018 will be reported in the 2019 annual report.

2.2 Objectives and Scope

The objective of the test flow program is to examine relationships between the magnitude of flow releases from Terzaghi Dam and the relative productivity of the LBR aquatic and riparian ecosystem by observing changes in juvenile salmonid productivity in response to test flows. Objectives specific to BRGMON-3 include documenting the abundance of adult salmonids to:

1. Determine if assessments of changes in juvenile standing crop with flow are confounded by variation in spawner abundance
2. Understand the effects of flow releases on quality and quantity of salmon and Steelhead Trout spawning habitat.

BRGMON-3 monitors abundance and distribution of spawning salmonids in the LBR, with a focus on stream-rearing species (Steelhead Trout, and Chinook and Coho Salmon). A combination of fish counting technologies, radio telemetry, population estimates derived from visual estimates, spawning habitat assessments and biological measures are used to evaluate escapement, migration behaviour and habitat availability in the LBR. BRGMON-3 is used to inform juvenile stock recruitment models of BRGMON-1, which aims to understand the impacts of changes in Terzaghi Dam discharge by measuring juvenile population responses (i.e., egg-to-fry survival, smolts produced per spawner, fry-parr standing crop). Estimating egg-to-fry survival and smolts produced per spawner requires accurate estimates of spawner abundance; this is the focus of BRGMON-3. Adult salmonid abundance is not a direct indicator of habitat condition, and changes in spawner abundance will not be used as a response to flow impacts.

In response to the modified flow regime that will persist in the LBR until 2028, a change in the scope of services of BRGMON-3 includes the assessment of high flows on density and distribution of adult spawners and the quantity and quality of spawning habitat. Objectives of the modified BRGMON-3 include:

1. Determine how adult spawner distribution has been changed as a result of the modified flow regime.
2. Determine how quantity and quality of spawning habitat has been changed as a result of the modified flow regime.

The modified BRGMON-3 monitors abundance and distribution of spawning salmonids (Steelhead Trout, and Chinook and Coho Salmon) in the LBR, using telemetry, streamwalks and redd surveys to assess changes in location and distribution of spawning. Habitat surveys to generate HSI models of habitat availability aim to understand the impacts of changes in Terzaghi Dam operations.

2.3 Steelhead and Salmon Enumeration

BRGMON-3 focuses on the stock assessment of adult Steelhead Trout, Chinook Salmon and Coho Salmon, as these are the only anadromous salmonids that rear for an extended period in the LBR. Following the BRGMON-3 TOR, supplemental surveys are conducted when possible to estimate the spawning abundance of Sockeye (*O. nerka*) and Pink Salmon (*O. gorbuscha*) when present (BC Hydro 2012).

In October 2013, the construction of a fish counter near the downstream end of Reach 3 was completed. A five-channel (Channel 1 on river left and Channel 5 on river right) Logie 2100C electronic resistivity counter (Aquantic, Scotland, UK) enumerated Steelhead Trout, and Chinook and Coho Salmon abundance upstream of the counter site. Resistivity counters can provide estimates of spawner abundance within 10% of the true abundance (e.g., Deadman River; McCubbing and Bison 2009). Used in conjunction with graphics and video data that can confirm fish passage and direction, error rates can be applied to abundance results to estimate counter accuracies (Ramos-Espinoza et al. 2018).

Given damage in 2016 due to high flows, Burnett et al. (2017), tested alternative enumeration methods which combined the use of the resistivity counter with an ARIS sonar unit. The resulting counting infrastructure divides the river into two sections: river right is covered by a resistivity crump weir counter, and river left enumerates fish using an ARIS sonar (Figure 6; described in Section 2.3.3). These methods are combined to calculate a species-specific abundance estimate. We modified the remaining section of the resistivity crump weir sensor on river right in February 2017, from a one-channel to a two-channel sensor to increase counter accuracy (**Figure 5**). Water levels during the Steelhead Trout migration period are high enough to permit passage over the crump weir sensor. However, during the Chinook Salmon migration period, flows in the LBR are decreasing and water levels over the crump weir sensor are low (~ 2 cm depth). We suspect that Pink Salmon can use the crump weir sensor to move upstream, but given body size, water levels may be too low for Chinook Salmon. The crump weir sensor was operated to enumerate any Chinook Salmon and verify this. The resistivity counter validation process is described in detail in Section 2.3.2.

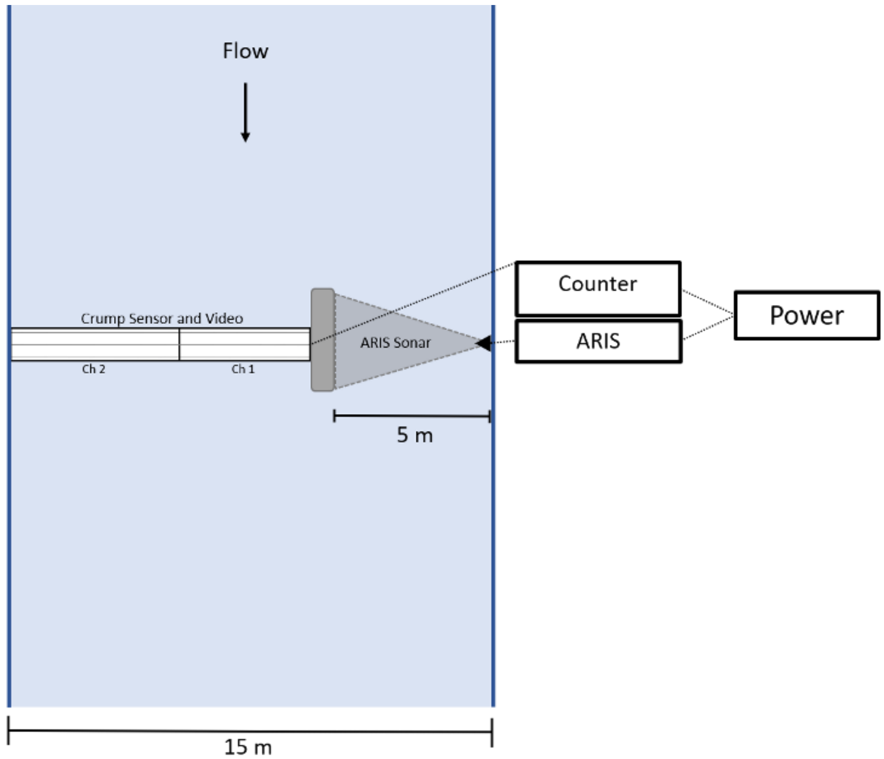

Figure 5: Configuration of the resistivity counter crump sensor, video validation system, multibeam sonar, and power system in the LBR, 2018.

On August 29, 2018, a fish fence was installed immediately upstream of the counter infrastructure to collect Chinook Brood stock for a potential enhancement hatchery. Chinook were unable to enter Reach 3 and 4 after this date, so data pertaining to abundance estimates, radio telemetry and spawning locations were limited to the individuals that migrated past the counter site before this date.

2.3.1 Resistivity Counter Abundance Estimates

The resistivity counter operates in conjunction with up to four electrode sensors (e.g., crump weir sensors) that span the channel width to detect the upstream and downstream movement of fish over the sensors. The counter measures the resistance between two pairs of electrodes: one pair consists of the downstream and center electrodes, and the other pair consists of the upstream and center electrodes. The resistance measured is a function of water conductivity. There is a change in resistance when a fish swims over the electrodes because the fish is more conductive than the water it displaces. The change is recorded by the counter and interpreted by an algorithm to determine if it is consistent with that of a fish. Direction is recorded along with a date and time stamp. The counter algorithm can classify each record as: (1) up, (2) down, or (3) event. If the change in resistance is determined to not follow a typical fish trace (by algorithm) but the values reach a pre-defined threshold value, the record is classified as an event instead of an up or down count. Events can be due to a fish interacting with the electrodes but not completely passing over all three electrodes, other objects or animals that cause a change in resistance, or from electrical noise. For each record (ups, downs or events), the counter also records the peak signal size (PSS) that corresponds to the peak of a sinusoidal curve that is created when a fish passes over the sensor pad (Figure 6). PSS is related to mass and can thus be used as a proxy for fish size (McCubbing et al. 2000) or species, if clear size differences among species that spawn at similar times. The resistivity counter crump weir is only passable during the Steelhead migration, as low flows during the Summer and Fall prevent the upwards migration of large salmon.

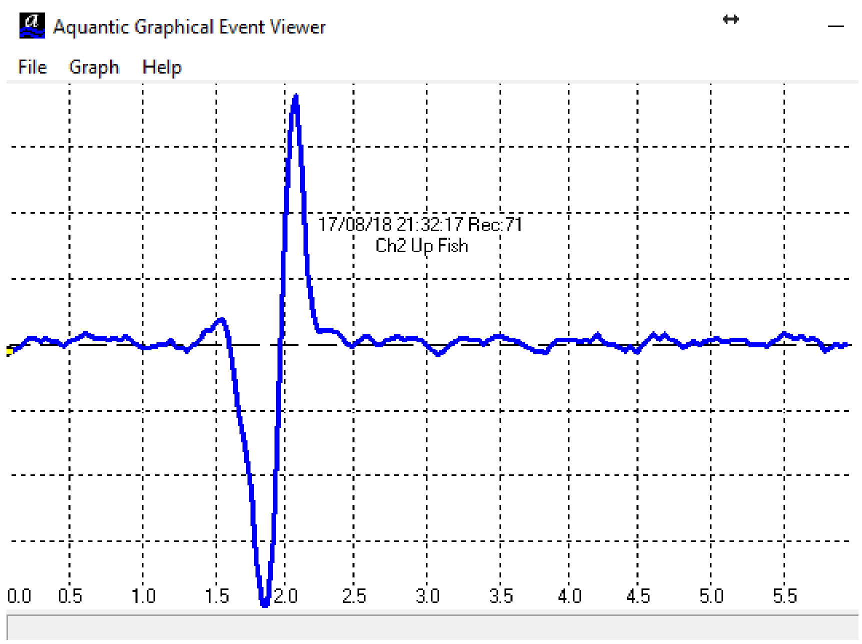

***Figure 6:** Example graphical trace (sinusoidal curve) showing a true up movement with two equal but opposite peaks, indicating the size and direction of the fish movement. The counter algorithm applies specific criteria to each record, which allow for some flexibility in the ratio of the peaks.*

Differentiating Between Large Steelhead and Smaller Resident Species

Steelhead are longer and heavier than Rainbow Trout or smaller resident species, allowing for species-specific counts that are based on fish size. We identified a size cutoff that aims to minimize misclassification of counts into the two life history forms for up and down counts independently. To differentiate counts based on the size of fish we created plots of the distribution of PSS and identified troughs, which indicate the descending end of the Rainbow Trout size distribution and ascending end of the Steelhead size distribution. PSS is a measure of the maximum change in resistance measured by the counter as a fish passes through the counter (relative to only water passing through the sensor) and is proportional to the mass of the fish. The point where the least overlap between distributions of PSS occurs is used as the PSS cutoff to distinguish between Steelhead and Rainbow Trout. Therefore, the PSS cutoff for Steelhead and Rainbow Trout is inferred from the PSS value that corresponds to the fewest detections, if it exists, or alternatively from the PSS that corresponds to the minimum 7- or 9-point rolling averages of detection frequencies across all PSS values up to 127. Each approach should produce very similar estimates under normal circumstances, and which is applied is ultimately up to the discretion of the analyst.

2.3.2 Validation

Video data were collected using four Swann infrared cameras connected to a battery-powered Swann digital video recorder DVR4575 (Swann ®), strung on cables above the counter pads. Additionally, two white LED lights (3-watt, 300 Lumen) were installed to improve the quality of the video footage at night.

Counter data were validated to determine true positives, true negatives and error rates, including false positives and false negatives, and calculate the counter accuracy. Validation includes a combination of the counter algorithm (change in resistance), graphics (e.g., Figure 7) and video footage. True positives were defined as any up or down counts that corresponded to a fish passing over the sensor in the recorded direction; these can be verified from graphical traces and/or video footage. False positives were defined as any up or down count where no fish was observed on the video footage. False negatives were defined as any time a fish passed upstream or downstream over the counter sensor, as determined by video, but the counter did not record anything.

The four-stage validation approach included: (1) review of graphical traces for each counter record to determine false positives and false negatives created by the counter algorithm, (2) targeted video validation to identify false positives produced by the counter, (3) random video validation to identify false negatives by the counter, and (4) calculation of counter accuracy using the number of true positives, false positives and false negatives. Each individual stage is described below.

The resistivity counter can be programmed to record and display the individual graphical traces or changes in resistance observed (Figure 7). Review of the graphical traces is a form of pseudo-validation of the counter algorithm, which determines if the change in resistance detected by the sensor pad is due to a fish moving upstream, downstream or actively moving near or on the sensor pad but not resulting in a passage event. After review of all the counter output, records that were misclassified by the counter algorithm were corrected. If completed by an experienced analyst, this is a cost-effective approach to correct many of the algorithm's false positive and false negative counts (Braun et al. 2016B).

During targeted validation, all corrected records from graphics were matched with the video to verify the presence of fish. The corresponding video records were viewed one minute before to one minute after the counter record. This targeted validation procedure focuses on fish that have been detected by the counter and determines the counter's false positive and false negative error rates, but it does not provide a random assessment of false negative errors. To do this, we also reviewed a subset of randomly selected video segments and recorded all false negatives, which we term 'random validation'. We reviewed 22 randomly selected 10-minute segments of video data per day (i.e., 15% of total migration period) to validate the Steelhead Trout and Chinook Salmon migrations, between April 14 and May 8 and between August 14 and September 31, respectively. We selected these date ranges based on peak migration timing of the two species from in 2014 (Melville et al. 2015) and 2015 (Burnett et al. 2016).

Due to operator error, no graphics and video data was collected from the resistivity counter for 4.8 days during the Steelhead Trout migration. For these five days, the algorithm accuracy and PSS cut-offs estimated during the video validation process were used. During the Chinook Salmon migration there was one day where there was no graphics data collected. For this time period, all the counter records were viewed and verified on the video and a separate counter accuracy was calculated for this period.

After validation was complete, counter accuracy was calculated as follows:

(5)
$$A = \frac{TP}{TP + FP + FN}$$

where A is the accuracy, TP is the number of true positives, FP is the number of false positives, and FN is the number of false negatives.

Abundance Estimates

All Steelhead Trout up and down counts were verified during video analysis. Species-specific net up counts are calculated as follows:

(6)
$$E = \sum_{t=1}^{n} \left(\frac{U_t}{A_{up}} - \frac{D_t}{A_{down}} \right)$$

where E is the estimated abundance, U_t is the daily number of upstream fish detections for day t, D_t is the daily number of downstream detections for day t, A_{up} is the counter accuracy for detecting upstream migrating fish, and A_{down} is the counter accuracy for detecting downstream migrating fish. n is the end date of the species' upstream migration. We estimate n using video validation and known species run timing. Overlaps in species migration timing make it difficult to determine the start and end date for each species. Species-specific migration start and end dates were determined by collating information from other data sources, which included radio telemetry, streamwalks, video observations and a previous telemetry study (Webb et al. 2002).

2.3.3 Multibeam Sonar Abundance Estimates

Following the pilot study conducted in 2016 (Burnett et al. 2017), we used an ARIS Explorer 1800 (Sound Metrics Corporation, Bellevue, Washington, USA) for adult enumeration. We fixed the ARIS unit to a custom-built aluminium mount, positioned it at half of the water depth and oriented it horizontally (0° tilt angle) across the channel. Multibeam sonar users typically manually count each fish observed crossing the sonar beam to enumerate a population (Holmes et al. 2006). However, due to the large time investment required to review the sonar video collected, Echoview software (Version 8; Echoview Software Pty Ltd., Hobart, Australia) was used as a post-processing tool to reduce the time associated with detecting fish (previous versions reviewed in Braun et al. 2016A). Due to a few instances of software corruption and temporary power loss, a combined total of 4.9 days of data was not collected during the Steelhead migration, and 1.1 days of data was not collected during the Coho migration.

ARIS sonar files were imported into Echoview and the raw data were displayed as a virtual echogram; objects were plotted in relation to the angle of the beams and distance to the sonar head. To increase the efficiency of Echoview's internal fish detection algorithm, a data manipulation template was created in Echoview to remove background noise and thus increase the clarity of the video data. We then applied this template to each sonar file using Echoview's automating scripts. Background noise was removed at a rate of 1.1 GB per hour. Echoview automatically processed the Steelhead data in 43 days, Chinook data in 29 days, and Coho data in 25 days, all with minimal human supervision. During this step, Echoview highlighted sections of sonar data that contained fish-like movements that were then verified by an experienced analyst. Echoview's verification process ensured the validity of the fish detected after the automation process. During this process, the analyst manually examined each fish-like movement detected by the software. After the verification process, the time stamps, length, and positioning data from each individual fish was exported for further analysis in R (R core team, 2018).

Due to the nature of the site and flow dynamics (acoustically noisy), the Echoview software did not provide accurate length data for the fish. The exported length data was precise but was biased low for Steelhead and high for Chinook and Coho. For a subset of fish (~10 %), lengths were measured using the sonar's proprietary software (ARISFish, Sound Metrics Corporation, Bellevue, Washington, USA). Visual examinations of manually measured fish compared to calculated lengths, found that larger individuals were being overestimated by the algorithm. Upon further assessment of sonar images, "shadow-like" traces were cast on to the individual, causing the algorithm to over estimate actual lengths. To accommodate for this error, all fish with calculated lengths above 800 mm were extracted and manually measured using ARISFish. These individuals were excluded from the length prediction models and combined with model output post-analysis. This method improved model prediction of up fish, however, there was still a high degree of variability in down length estimates.

ARISFish measurements were deemed accurate through measurements of a test fish of known size. To predict the length of all other fish (not measured), we used a linear model that related ARISFish lengths to the Echoview estimated lengths separate models for up and down length measurements. Distance from the sonar head (in meters) and time in beam were included as a covariates, to assess whether location or duration in the beam affected length calculations. AIC model selection was used to determine the most parsimonious model predict lengths for up and down migrating fish separately. Considering other salmon and trout are also present in the LBR during the Chinook and Coho Salmon migration period, a species-specific size cut-off was applied to the predicted lengths to determine the number of Chinook and Coho Salmon crossing the sonar beam. Tagging data from BRGMON-9 (n = 70 in 2017), BRGMON-3 (n= 104 fish tagged from 2012-2018) and BRGMON-14 (n= 1363 in 2013, 2017 and 2018) was used to inform the size cut-off decision for species specific migration times. Note that length cut-offs were calculated based on length-frequency distributions to most accurately encompass the desired species and that other species size classes may have some level of misclassification.

For the 4.9 days of data not collected during the Steelhead migration (March 31 to April 2, April 6 to 8, and April 11 to 12), a normal probability density function was used to predict daily net up counts when there was missing sonar data (Braun et al. 2016B). Visual observations of daily up and down counts during the Coho Salmon migration period, identified a distinct increase in down counts towards the end of the migration period. This behavior is indicative of kelting. Down counts are typically subtracted from up counts to calculate a daily net up count. However, after the onset of kelting down counts are not subtracted because fish are assumed to have spawned. We estimate the date kelting began using the run timing of down counts during the observed kelting period (late November). We estimated the parameters for the normal distribution of kelts by fitting a normal probability density function to daily down counts during the kelt migration period, from November 15 to December 6. These dates were determined by the analysis and cover the beginning and end of kelting. Specifically, we estimate the mean, standard deviation and a scale parameter, which transforms the probabilities into daily counts. We use a least squares fitting method that minimizes the sum of squares between the observed and predicted counts. These parameters (mean, standard deviation, and scale) are then used to predict the daily number of kelts migrating downstream throughout the full migration period between October 1 to December 6. The mean and standard deviation define the kelt migration timing and the sum of the scale parameter provides an estimate of the total number of kelts. We define the onset of the kelt out-migration date as the date when 5% of the kelts were estimated to have migrated based on the predicted normal distribution of kelt migration timing.

2.3.4 Effects of Fish Fence Installation

Specific only to the Chinook Salmon migration period, a separate assessment using resistivity counter and sonar technology was conducted to evaluate the behavioral effects and data processing complexities that the fish fence (installed August 29) had on the migration of salmon. Briefly, a full channel spanning fish fence and swim-through trap box were installed immediately upstream (approximately 10m) of the counter infrastructure to collect Chinook Salmon brood stock for conservation and enhancement purposes. The installation occurred to target the historic peak of the Chinook migration period and impeded both Chinook and Sockeye Salmon migration after August 29. The fish fence affected many components of the BRGMON-3 scope of services (e.g. telemetry, AUC estimate and redd surveys), however, this assessment will focus on behavior changes observed before and after fence installation using fish counter technologies.

Specifically, this assessment will observe changes in behavior via up and down events and processing time. Counter and sonar daily enumeration will be combined for comparison between August 25 and 26 (pre-fence) and September 1 and 2 (post-fence).

2.4 Radio Telemetry

2.4.1 Fish Capture, Tagging and Sampling

Fish capture by angling was completed by teams of two to three SER fisheries technicians. Tag application and effort was distributed throughout each species migration periods: February to April for Steelhead Trout, August to September for Chinook Salmon, and October to November for Coho Salmon

(Figure 2). Effort was also made to evenly distribute tags between males and females as migration behaviour and run timing can differ by sex (Korman et al. 2010, Troffe et al. 2010). SER fisheries technicians were unable to angle for Steelhead Trout at the Bridge-Fraser confluence as in previous study years as gravel infilling due to changes in the instream river conditions created poor angling conditions. Steelhead angling occurred at the Seton-Fraser confluence (~8km downstream of the Bridge-Fraser confluence), with a high proportion (76%, 16/21 steelhead) of fish entering the LBR in 2017 (Ramos-Espinoza et al. 2018). Angling locations above the Yalakom-Bridge confluence where Chinook and Coho were previously captured were also infilled by gravel and unsuitable for angling. In 2018, effort was made to capture Chinook and Coho Salmon in Reach 1 and 2 of the LBR.

Captured study fish were gastrically implanted with a TX-PSC-I-1200-M radio tag (45 × 16 × 16 mm; Sigma Eight Inc., Ontario, Canada). Tag burst rate varied depending on whether the fish is active (i.e., presumed alive; 5 s burst rate) or inactive (i.e., presumed dead; 13 s burst rate), thus informing estimates of residence time in Reach 3 and 4. External visual identification tags (i.e., Peterson disc) were also applied to Chinook and Coho Salmon in 2018 to generate an estimate of observer efficiency during visual surveys. This method was not used for Steelhead due to high flows causing poor visibility in the LBR. Estimates of residence time and observer efficiency are needed for use in estimating abundance through area-under-the-curve (AUC) methods (see Section 2.5.2). Fork length (mm) and sex were recorded during tagging, and scale samples were obtained for ageing purposes (see Section 2.8). Following capture, fish were held in a submersible holding tube for a minimum of 30 minutes prior to release to ensure survival and tag retention.

2.4.2 Fixed and Mobile Receivers

Fixed radio telemetry stations were installed at five locations along the LBR (Figure 3). Stations consisted of SRX_400 receivers (Lotek Wireless Inc., Ontario, Canada) connected to a single 6-element Yagi antenna oriented perpendicular to flow. Fixed stations were installed prior to tagging and operated during migratory periods for target species (i.e., March to June for Steelhead, August to October for Chinook, and October to December for Coho). Data from fixed stations were used to corroborate fish location identified during mobile tracking, determine entry and exit timing of tagged fish into each reach, and to collect information on migration and spawning behaviour in the LBR.

Mobile tracking was conducted weekly using a hand-held SRX_400 receiver and twice a week during peak spawning to increase the temporal and spatial resolution of telemetry data. Tracking was carried out from March 4 to June 13 for Steelhead Trout, August 9 to October 5 for Chinook Salmon and

October 5 to December 3 for Coho Salmon. Reach 3 and 4 were surveyed in their entirety, while Reach 1 and 2 only consisted of spot checks at the LBR-Fraser confluence (Reach 1), Antoine Creek and Horseshoe Bend (Reach 2), due to limited accessibility. Radio tracking was conducted by vehicle and on foot independently of the technicians who conducted the visual count to avoid observer bias (i.e., searching for tags known to be in the area). We present the migration rates (in km day^{-1}) of radio-tagged fish and residency time above Reach 2 and 3 boundaries.

2.5 Visual Counts and AUC Population Estimates

2.5.1 Visual Counts

Chinook and Coho Salmon estimates have occurred since 1993 and 1997, respectively, using various methods to generate escapement to spawning grounds. A fish fence located in Fraser Lake (33.2 rkm) was used between 1993 to 1996 to enumerate Chinook Salmon and is assumed to be an absolute count of escapement. Visual helicopter surveys were used to enumerate both Chinook and Coho Salmon from 1997 to 2004 (missing 2000, 2002 and 2003 for Chinook Salmon, 2000 and 2002 for Coho Salmon). Visual stream side counts have been used since 2005 to enumerate both Chinook and Coho Salmon in Reach 3 and 4 (missing 2007 for Coho Salmon). Count data obtained from DFO was used to reconstruct AUC estimates for Chinook Salmon from the Yalakom confluence to Terzaghi Dam (Reach 3 and 4) since 1993.

Abundance estimates for all counts except those from the fence are calculated through AUC estimation (Hilborn et al. 1999, Millar et al. 2012) using observer efficiencies (OE) and residence times (also termed 'survey life'; SL) determined by radio telemetry, PIT data and visual surveys conducted since 2011. For part of the year, the LBR has low visibility due to the release of glacial silt from Terzaghi Dam, so standard visual enumeration metrics may not be suitable for the study watershed. PIT arrays were installed in the LBR at the counter site and at the Reach 3-4 boundary in October 2015 to measure OE and SL in 2016. High flow releases in 2016 caused extensive damage to the PIT antennas and consequently, radio telemetry was reinstated to assess spawner distribution and migration behaviour. OE was calculated based on the percentage of 'marked' individuals observed during visual estimates compared to the number of tagged fish known to be in the study area inferred from telemetry. SL was determined as the time between when a tagged fish moved past the counter site into Reach 3 until assumed mortality (i.e., the radio tag switched to 13 second burst rate). LBR-specific OE and counter derived estimates will be used to back-calculate historic estimates of abundance from visual count data (Troffe et al. 2008).

The 2018 visual streamwalk surveys followed methods used in previous years of this monitor, where two observers walked in a downstream direction on the riverbank, counted fish and recorded species and location. Viewing conditions, cloud cover, and lateral water visibility were also recorded (Sneep and Hall 2011). Visual counts occurred weekly for Chinook, Sockeye and Coho Salmon along the entire length of Reach 3 and 4 (Figure 4), spot counts occurred at the Camoo FSR Bridge in Reach 2 and behind the Bridge River Band office in Reach 1. Surveys started on August 9 and continued until December 13, when spawning ceased based on previously collected streamwalk and telemetry data. Beginning October 2018, as a change to the scope of services (BC Hydro 2012), stream walk surveys of Reach 2 for spawner and redd abundance took place weekly for the end of Chinook and entire Coho migrations (October 4 to November 28) to assess whether adult salmon spawn within this section of river. Visual surveys followed the same protocols as for Reach 3 and 4 and covered the river from Horseshoe Bend to the Camoo FSR bridge (Figure 5). Surveys for Steelhead Trout were deemed ineffective in Year 1 (2011) of BRGMON-3 due to high turbidity and flows in the LBR; thus, visual surveys have not been completed for Steelhead Trout since.

2.5.2 Area Under the Curve Estimates of Spawner Abundance

In 2018, as in previous years, an AUC analysis (Hilborn et al. 1999, Millar et al. 2012) was used to estimate abundance for Chinook and Coho Salmon using visual count data combined with OE and SL estimates obtained from radio telemetry.

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

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

where a is the maximum height of the spawner curve, m_s is the time of peak spawners, and τ_s^2 is the standard deviation of the arrival timing curve.

Because the normal density function integrates to unity, the exponent term in Equation 1 becomes $\sqrt{2\pi\tau_s}$ and Equation 1 can be simplified to

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

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

(9)
$$\hat{E} = \frac{\hat{F}_G}{l * v}$$

$\hat{E}$ in Equation 3 is estimated using maximum likelihood (ML), where $\hat{a}$ and $\hat{\tau}$ are the ML estimates of *a* and τ_s in Equation 2 ($\hat{C}_t = \hat{a}\sqrt{2\pi\hat{\tau}_s}$).

The AUC estimation in Equation 1 can be re-expressed as a linear model, allowing the estimation to be performed as a simple log-linear equation with an over-dispersion correction factor. Correction for over-dispersion accounts for instances where the variance of the observations exceeds the expected value. The log-linear model is computationally simple and can be completed using standard generalized linear modelling.

The estimated number of fish-days ($\hat{F}_G$) can be estimated following

(10)
$$\hat{F}_G = \sqrt{\frac{\pi}{-\hat{\beta}_2}}exp\left(\beta_0 - \frac{\hat{\beta}_1^2}{4\hat{\beta}_2}\right)$$

where β_0, β_1, β_2 are the regression coefficients of the log-linear model. Uncertainty in observer efficiency and survey life are incorporated into the estimated spawner abundance using the covariance matrix of the modeled parameters (β_0, β_1, β_2) via the delta method (described in Millar et al. 2012).

Chinook Salmon

In 2012 and 2013, OE for Chinook Salmon was calculated as the number of externally-tagged fish observed in each visual survey divided by the total number of tagged fish present as indicated by radio telemetry. Deceased fish were not included in calculations of OE as only live counts are used in AUC estimates. Chinook Salmon were not visually tagged in 2014 or 2015 and thus OE could not be estimated; OE (0.50) and SL (10.5 days) were used (Ramos-Espinoza et al. 2018). In 2018, these same model parameters were applied because few fish were tagged (n = 3) and no tags were observed during streamwalk surveys.

Aside from 1993 to 1996 when counting fence numbers are available, historical Chinook Salmon visual count data from Reach 3 and 4 were used to reconstruct AUC estimates of spawner abundance until 2010. Visual count data prior to 2000 were recorded from paper copies of spawner survey datasheets and post-2000, data were retrieved from the DFO Stock Assessment database. Prior to 1993, the data did not have enough detail to calculate estimates, and three years (2000, 2002, 2003) were missing from the dataset; therefore, no estimate is available for these years. Historical count data were often missing zero counts at the beginning and end of surveys, which can result in inaccurate estimates or no estimate. Zeroes were added to the count dataset to improve the accuracy and temporal coverage of estimates. A zero count was added on August 8 for all years that did not start with a zero count. A zero count was added on October 2 for all years that did not end with a zero count. We chose these dates based on other years of count data that had zero count surveys at the beginning and end of the survey.

Generating accurate and precise historic AUC estimates is challenging due to inconsistencies in historic methods, a lack of OE data, and only a short time series of AUC-derived abundance estimates for resistivity counter comparisons. No historical data exist for OE or SL. Mean and standard error of OE and SL from 2012-2014 and 2016-2018 were used in the historical AUC modelling of both helicopter and streamwalk counts (Table 1). Historical estimates will continue to be updated as more OE and SL data is collected.

Table 1: Chinook Salmon AUC abundance estimates with standard error (SE) and upper and lower confidence intervals (CI) for the Lower Bridge River from 1993-2018. Abundance results are calculated considering estimates of observer efficiency (OE) and residences times (survey life; SL).

Year	OE	OE SE	SL	SL SE	Abundance	Abundance SE	Method of Estimation	Lower 95 CI	Upper 95 CI
1993	NA	NA	NA	NA	151	0	Fence count	151	151
1994	NA	NA	NA	NA	550	0	Fence count	550	550
1995	NA	NA	NA	NA	851	0	Fence count	851	851
1996	NA	NA	NA	NA	1100	0	Fence count	1100	1100
1997	0.50	0.14	10.5	0.65	2005	1581	Visual helicopter	427	9406
1998	0.50	0.14	10.5	0.65	873	254	Visual helicopter	494	1543
1999	0.50	0.14	10.5	0.65	2576	847	Visual helicopter	1352	4906
2001	0.50	0.14	10.5	0.65	1784	981	Visual helicopter	607	5244
2004	0.50	0.14	10.5	0.65	3106	1139	Visual helicopter	1514	6374
2005	0.50	0.14	10.5	0.65	591	232	Visual streamwalk	274	1274
2006	0.50	0.14	10.5	0.65	399	124	Visual streamwalk	217	733
2007	0.50	0.14	10.5	0.65	309	108	Visual streamwalk	156	613
2008	0.50	0.14	10.5	0.65	164	94	Visual streamwalk	53	507
2009	0.50	0.14	10.5	0.65	21	7	Visual streamwalk	10	41
2010	0.50	0.14	10.5	0.65	208	67	Visual streamwalk	110	392
2011	0.50	0.14	10.5	0.65	82	33	Visual streamwalk	38	179
2012	0.58	0.14	10.0	0.65	364	114	Visual streamwalk	196	674
2013	0.28	0.14	11.0	0.65	168	90	Visual streamwalk	59	479
2014	0.28	0.14	12.0	0.65	591	314	Visual streamwalk	209	1673
2015	0.50	0.14	10.5	0.65	158	68	Visual streamwalk	68	370
2016	0.50	0.14	10.5	0.65	265	85	Visual streamwalk	141	497
2017	0.28	0.14	10.5	0.65	215	116	Visual streamwalk	74	621
2018	0.50	0.14	10.5	0.65	25	7	Visual streamwalk	14	44

OE = observer efficiency, SE = standard error, CI = confidence interval.

Coho Salmon

In 2012 and 2013, estimates of OE and SL for Coho Salmon were calculated using the same methods outlined above for Chinook Salmon. In 2018, we used average OE (0.22) and SL (20 days) calculated from fish tagged in 2012, 2013, and 2016-2018 for AUC estimation (Table 2). Historical AUC estimates of Coho Salmon abundance from 1997 to 2010 were calculated using the same methods described for Chinook Salmon. Prior to 1997, count data was of insufficient detail to produce estimates and the years 2000, 2002 and 2007 were missing from historical records. Mean and standard error of OE and SL from 2012, 2013, 2016 and 2017 were used in the historical AUC modelling of Coho Salmon abundance (Table 2).

Table 2: Coho Salmon AUC abundance estimates with standard error (SE) and upper and lower confidence intervals (CI) for the Lower Bridge River from 1993-2018. Abundance results are calculated considering estimates of observer efficiency (OE) and residences times (survey life; SL).

Year	OE	OE SE	Residence time	Residence time SE	Abundance	Abundance SE	Method of estimation	Lower 95 CI	Upper 95 CI
1997	0.22	0.02	19.6	1.29	619	1419	Visual helicopter	7	55245
1998	0.22	0.02	19.6	1.29	1079	400	Visual helicopter	522	2232
1999	0.22	0.02	19.6	1.29	81	NA	Visual helicopter	NA	NA
2001	0.22	0.02	19.6	1.29	1033	134	Visual helicopter	801	1331
2003	0.22	0.02	19.6	1.29	1217	134	Visual helicopter	981	1510
2004	0.22	0.02	19.6	1.29	233	50	Visual helicopter	153	356
2005	0.22	0.02	19.6	1.29	739	123	Visual streamwalk	533	1025
2006	0.22	0.02	19.6	1.29	674	110	Visual streamwalk	489	929
2008	0.22	0.02	19.6	1.29	102	16	Visual streamwalk	75	139
2009	0.22	0.02	19.6	1.29	1601	242	Visual streamwalk	1191	2152
2010	0.22	0.02	19.6	1.29	463	81	Visual streamwalk	329	653
2011	0.22	0.02	19.6	1.29	3678	636	Visual streamwalk	2621	5161
2012	0.25	0.02	16.0	1.29	1662	386	Visual streamwalk	1055	2619
2013	0.27	0.02	19.0	1.29	2974	355	Visual streamwalk	2353	3759
2014	0.22	0.02	19.6	1.29	424	74	Visual streamwalk	301	596
2015	0.22	0.02	19.6	1.29	174	23	Visual streamwalk	135	224
2016	0.22	0.02	19.6	1.29	488	69	Visual streamwalk	370	642
2017	0.19	0.02	23.0	1.29	451	65	Visual streamwalk	339	599
2018	0.22	0.02	19.6	1.29	1245	169	Visual streamwalk	954	1624

2.6 Chinook and Coho Salmon Redd Evaluation

2.6.1 Redd Surveys

Chinook Salmon spawner habitat quantity and quality has been assessed from 2014 to 2018, with increased efforts to survey Coho Salmon spawner habitat in 2018. Redd habitat surveys characterize preferred spawning habitats and monitor any changes to habitat characteristics (water depth, velocity, spawning substrate) that might occur due to managed flow releases. Chinook and Coho Salmon redds were assessed in Reach 3 and 4 of the LBR and beginning in October 2018 Reach 2 was included as well. Water depth, velocity, dominant substrate characteristics and redd dimensions were measured at each redd. Specifically, water depth and velocity were measured at the tail spill, adjacent to and leading edge of each redd (Reibe et al. 2014).

Measurements adjacent to the redd were assumed to be representative of habitat prior to the digging of redds, and thus can be interpreted as the preferable spawning habitat for salmon. Water velocity was taken at 60% of the total depth (mean column velocity-V60) where depth was less than one meter. A Swoffer (Model 2100) current velocity meter was used to measure velocities and the top set wading rod of the Swoffer was used to measure depth to the nearest centimeter. We calculated the geometric mean (D50) of 20 pieces of substrate located in the tail spill of each salmon redd to characterize the substrate sought out during redd digging. Note that the geometric mean is commonly used to reduce the influence of extreme substrate sizes on the mean (e.g., sand and large boulders).

Seventeen temperature loggers (3 for Chinook and HOBO Water Temperature Pro v2; Onset Computer Corporation, Massachusetts, USA) were attached to 5’ lengths of rebar at 60% of the total depth at a number of sampled redds in Reach 3 and 4 to monitor accumulated thermal units (ATU) over the incubation period. Loggers were not buried 30cm into the substrate adjacent to redds as in previous years, because groundwater was found to have negligible influence on subsurface stream temperatures (Ramos-Espinoza et al. 2018). Loggers were deployed on September 26, 2018 for Chinook Salmon and will be removed in late March and temperature data will be included in the 2019 BRGMON-3 report.

2.6.2 Redd Analysis

Prior to all analyses, residuals were visually examined and tested for normality using the Anderson-Darling test, as well as for homoscedasticity using the Levene’s Test, to evaluate whether variables met test assumptions (R Core Team 2018; nortest, car and randtest packages). Habitat variables (depth, velocity and substrate) measured at each redd over the study period (2014-2018; no 2014 substrate data collected), were compared separately using a fixed factor one-way analysis of variance (ANOVA), evaluating spawning preference between years (model: habitat variable = year). A Tukey multiple comparison of means post-hoc test was applied to significant model results (95% family-wise confidence level) to determine years where significant differences occurred.

2.7 Monitoring of Spawning Habitat

2.7.1 Habitat Surveys

Historical radio telemetry, visual survey and redd evaluation data were used to identify important spawning locations where reach-wide, cross-sectional habitat assessments were completed. Spawning locations were divided into habitat units as defined in Johnston and Slaney (1996) and transect sites were identified within each individual unit (63 total sites). Water depth, and velocity and substrate measurements were used to inform HSI models (Bovee 1986), where species specific spawning habitat requirements would be quantified in the LBR. HSI models provide objective criteria regarding habitat requirements for species during specific life history periods (Raleigh et al. 1986). These methods quantify the amount of available spawning habitat, which can evaluate flow regime impacts and inform management decisions.

The number of transects established within each habitat unit was dependent on the heterogeneity of the unit (visual estimates of depth, velocity and substrate), with more similar habitat requiring fewer transects to accurately describe the habitat conditions. Each transect was located equidistant from the upstream and downstream end of the unit and represents an area of stream bed half way to the neighboring vertical points and to the up and downstream boundaries of the transect (Mosley 1985). Water depth and velocity were taken every meter, at 60% of the depth (mean column velocity-V60) where depth was less than one meter. A Swoffer (Model 2100) current velocity meter was used to measure velocities and the top set wading rod of the Swoffer was used to measure depth to the nearest centimeter. A visual assessment of substrate classes (fines, small gravel, large gravel, small cobble, large cobble, boulder and bedrock) was assessed at each depth-velocity transect and used for HSI curves. The geometric mean (D50) of 100 pieces of substrate located in each transect area was measured as a secondary characterization of substrate. All transect sites were geo-referenced using a hand-held GPS receiver (accurate to ±10 m) and marked with a 5/8” diameter rebar pin, placed above bankfull width.

Surveys were conducted for Reach 3 and 4 in the spring of 2018 (March 8 to 23) to observe the effects from high flows in 2017 and again in the fall of 2018 (September 5 to 25) to observe the effects from the high flows of 2018. Fall 2018 HSI calculations were compared to Spring 2018 to evaluate the high flow events observed in June 2018. Reach 1 and 2 surveys were implemented in the fall 2018 sampling program to quantify spawning habitat in the lower section of the LBR and will be reported on in 2019. HSI surveys will continue each fall in all reaches of the LBR to quantify the effects of the new high flow regime.

2.7.2 Habitat Suitability Index (HSI)

Habitat data was analyzed using a model developed by Ptolmey et al (1994), which is based on HSI scores. The Ministry of Environment provided species and life stage-specific HSI scores corresponding to depth, velocity, and substrate preferences. This model estimates the amount of suitable habitat for different species and life stages at a given discharge. Each parameter is weighted by an HSI score ranging from 0 (unsuitable) to 1 (optimal habitat suitability). The amount of suitable habitat is quantified as the product of HSI scores for each habitat value (e.g. water depth, velocity and substrate) plus the wetted width of the transect. Using these data, two metrics were calculated: 1) % Weighted Useable Width (WUW) and 2) Weighted Useable Width in metres (with respect to the bankfull width). The WUW values can then be expanded by the length of the unit to create a % Weighted Useable Area (WUA) and total WUA.

In circumstances where whole channel cross-sections could not be completed, transects were evaluated from each shoreline until wading became unsafe. This is not a concern when using the HSI model to determine the distribution of spawning salmon in the LBR, as areas where velocities are too fast or too deep for safe data collection are also unsuitable spawning habitat according to HSI curves (velocities and depths too great). In sections where a transect was completed on only one shoreline and the river channel was observed to be uniform, the measurement/data from one shoreline was mirrored rather than measured on the opposing shoreline for analysis.

2.7.3 Habitat Analysis

HSI data were compared pre- and post-2018 high flows using a fixed factor one-way ANOVA, evaluating changes to the abundance of available spawning habitat (model: HSI = treatment). Assumptions were tested as per methods used in redd analyses (Section 2.6.2) and if not met, data was $\log_{10}$ transformed and residuals re-tested.

2.8 Ageing of Adult Salmon and Steelhead

During tagging and sampling, scale samples were obtained from Steelhead Trout, and Chinook and Coho Salmon for ageing. It has been difficult to collect quality scale samples from Chinook Salmon, as scales are resorbed at the time of capture and additional handling in the high air and water temperatures causes physiological stress. Few (n = 50) non-resorbed samples have been collected to date. Scale samples were placed in coin envelopes marked with identification data (e.g., radio and PIT code) for future cross-reference. After a period of air-drying, scales were removed from the envelopes, cleaned and placed directly on glass slides and read under a microscope. Digital photographs were taken and archived for future reference. Age was determined using the methods outlined in Ward and Slaney (1988), in which two people independently determined age without knowledge of the size, time and location of capture of the sampled fish. Samples were discarded when a consensus between both persons could not be reached.

Age was assigned according to the European age designation system (Koo 1962), which expresses age or age classes as two numbers separated by a decimal. The first number represents the number of years or winters the fish spent in freshwater and the second number represents the number of years or winters spent in the ocean. Collectively the two numbers can be added together to provide a total age or age class at maturity. For example, a 1.2 represents a 3-year-old fish that spent 1 year (or 1 winter) in the freshwater environment and 2 years (or 2 winters) in the ocean and spawned in their fourth year of life. Whereas using the Gilbert-Rich age notation, this same fish would be considered a 4_2, representing a 4-year-old fish that spent 2 winters in freshwater (including year in gravel). Reading scales that have been resorbed can be very challenging. Resorbed scales were aged using DFO's resorbtion scale criteria (MacLellan and Gillespie 2015), allowing readers to decide on whether any number of annual zones are missing.

We present age data from all fish captured and tagged during this monitoring program (2011-2018), including 46 Steelhead Trout (2014-2018), 50 Chinook Salmon (2013-2018) and 153 Coho Salmon (2011-2018). Considering that some radio- and PIT-tagged individuals migrate further up the Fraser River post-release, we only include age data of individuals that spawned in the LBR. Data were summarized as length-at-age (i.e., fork length vs. age) and the distribution of age classes across study years.

3.0 Results

3.1 Counter Abundance Estimates

3.1.1 Steelhead Trout (Resistivity and Multibeam Sonar)

Resistivity Counter

The resistivity counter equipment was installed on March 23. The counter was operational between April 8 until May 9 when it was removed due to forecasted high flows greater than 20 m^3s^{-1} that could cause damage to the equipment in the water. During this time 744 hours of video were recorded, of which, 119.5 hours were validated (4 hours of targeted validation and 115.5 hours of random validation) from April 8 to May 6.

Species were identified through the video validation where possible. We classified observed fish into two groups during video validation: Steelhead Trout (n = 4) and resident fish species (n = 32), either Rainbow (*Oncorhynchus mykiss)* or Bull Trout (*Salvelinus confluentis)*. Fish lengths estimated from video footage and were used to differentiate groupings. According to tagging data, Steelhead Trout were assumed to have fork lengths ≥ 600 mm and resident fish species < 600 mm.

The relationship between the standard length measured from the video and the PSS measured by the counter was also examined. We found a positive relationship between standard length and PSS (Figure 8). We determined a PSS cut-off of 100 distinguished Steelhead Trout from resident fish species and minimized the overlap between the two groups' PSS size distributions (Figure 7).

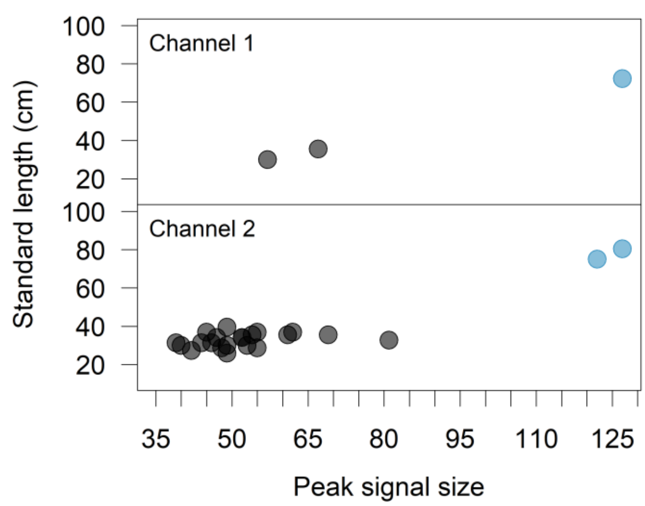

Figure 7: Relationship between standard length and peak signal size (PSS) generated by resistivity counter in the Lower Bridge River. Based on this relationship, PSS ≥ 100 are assumed to be Steelhead Trout (blue points), PSS < 100 are assumed to be resident fish (black points).

Within counter data corrected for algorithm errors (26 days), counter accuracy was 89% for upstream movement. The counter had four false positive detections in the upstream direction, resulting in an overestimate for the number of Steelhead Trout moving upstream. Downstream movements for Steelhead Trout had a counter accuracy of 100% (Table 3). It should be noted the accuracies were produced with a small sample size. There were 33 true positive upstream movements and two true positive downstream movements.

Table 3: Accuracy of resistivity counter during Steelhead migration in Lower Bridge River, where graphics and video data were available. Counter accuracy was determined through targeted and random video validation.

Direction	True Positive	False Positive	Video Negative	False Negative	Accuracy	Estimate
Up	33	4	0	0	89%	Over
Down	2	0	0	0	100%	Correct

For the five days when no video or graphics data was collected, we used the counter algorithm accuracies generated during step 1 of the validation process (section 2.3.1). The counter algorithm recorded a higher number of false positives for upstream movements, resulting in an overestimate of counts and higher number of false negatives for downstream movements resulting in an underestimate of counts. The counter algorithm had an upstream movement accuracy of 82% and downstream counter accuracy of 50% (Table 4).

Table 4: Counter algorithm accuracies that were applied to the 5-day period when no graphics or video data were available during the Steelhead migration in Lower Bridge River.

Direction	True Positive	False Positive	Video Negative	False Negative	Accuracy	Estimate
Up	31	4	0	3	82%	Over
Down	3	1	0	2	50%	Under

The first Steelhead Trout detected by the counter moving upstream was on April 8 at 23:50, and the first downstream movement was on April 21 at 16:20. Steelhead Trout were still actively migrating (up and down movements observed in counter) in the last few days before May 9 (Figure 2). Therefore, a portion of the upstream migration and downstream kelt migration in 2018 was missed due gear removal. The LBR resistivity counter recorded 220 upstream movements and 208 downstream movements. After accounting for counter accuracy, and species composition (PSS cut-off) we estimated a total of 11 Steelhead Trout upstream migrants upstream of the counter between April 8 and May 9 (maximum of 12 on May 3, 2018).

Multibeam Sonar

Lengths estimated by Echoview were positively related to the ARISFish lengths but were biased low (Figure 8A). The linear model used to predict fish lengths only included the Echoview lengths, which explained a large portion of the variance in the ARISFish lengths (Table 5 and 6). Distance from the sonar beam (Figure 8B) was not used to predict length as it has been in previous years. Further exploration of the models for a direction (up and down) term indicated a difference between the two directions, and thus two models were used to predict lengths for up and down movements of fish (Up: $R^2 = 0.91$, $P < 0.001$, Down: $R^2 = 0.87$, $P < 0.001$; Figure 8C).

Table 5: Model output for predicted lengths of fish moving upstream during the Steelhead Trout migration period, models were ranked and selected based on AICc to calculate species abundance estimates.

Intercept	Log (target length mean)	Target range mean	Time in beam	R^2	df	Delta AICc	weight
0.76	0.81			0.91	3	0.00	0.57
0.77	0.81		-0.01	0.91	4	2.23	0.19
0.74	0.81	0.00		0.91	4	2.30	0.18
0.74	0.81	0.01	-0.02	0.91	5	4.48	0.06

Table 6: Model output for predicted lengths of fish moving downstream during the Steelhead Trout migration period, models were ranked and selected based on AICc to calculate species abundance estimates.

Intercept	Log (target length mean)	target range mean	time in beam	R^2	df	Delta AICc	weight
0.22	0.96			0.86	3	0.00	0.48
0.36	0.95	-0.03		0.87	4	1.23	0.26
0.17	0.96		0.04	0.87	4	2.18	0.16
0.30	0.96	-0.03	0.06	0.87	5	2.98	0.11

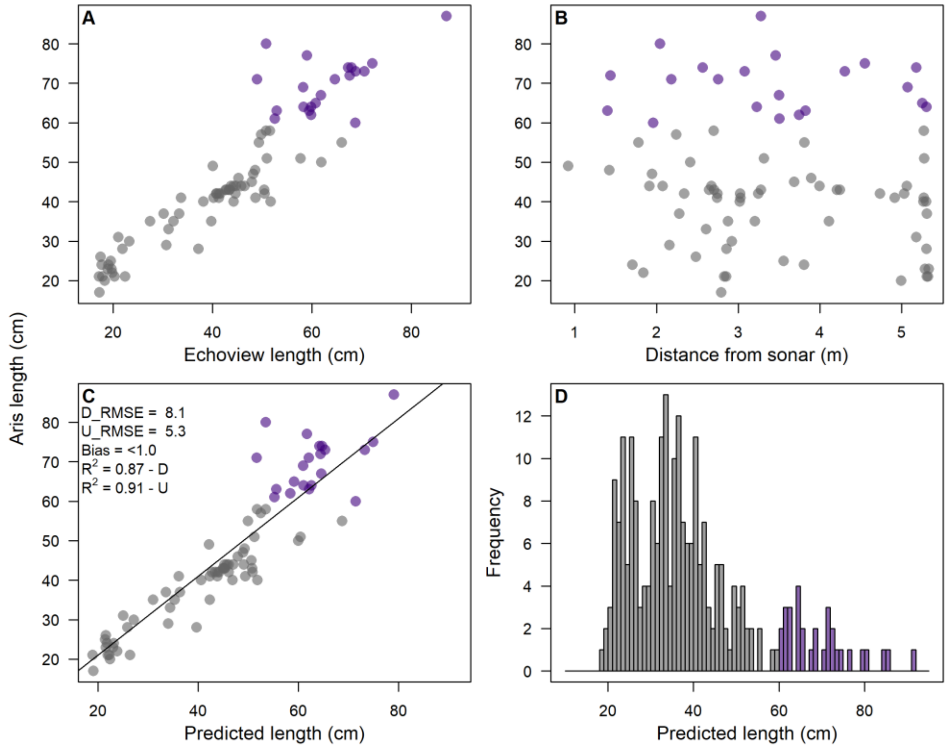

*Figure 8: **Manually measured fish length in ARISFish software in relation to (A) Echoview generated length and (B) distance from sonar. (C) Observed ARISfish lengths in relation to predicted lengths from a linear model that included Echoview length. Black line indicates unity (1:1). (D) Histogram of the predicted lengths of fish counted by Echoview. Points are fish observed using Echoview. Purple and grey correspond to Steelhead Trout and resident fish species, respectively. According to tagging data, Steelhead Trout were assumed to have fork lengths ≥ 600 mm and resident fish species < 600 mm.***

The sonar operated from March 22 to May 9, and Steelhead Trout were detected passing through the sonar beam throughout the entire recording period. Sixteen individuals passed upstream, and fifteen individuals passed downstream of the multibeam sonar, yielding an estimate of one Steelhead Trout that migrated upstream past the counter site (Figure 9A).

Combining the resistivity counter and multibeam sonar estimates yields a minimum abundance estimate of 14 individuals spawning upstream of the counter site on May 3, 2018 (Figure 9B).

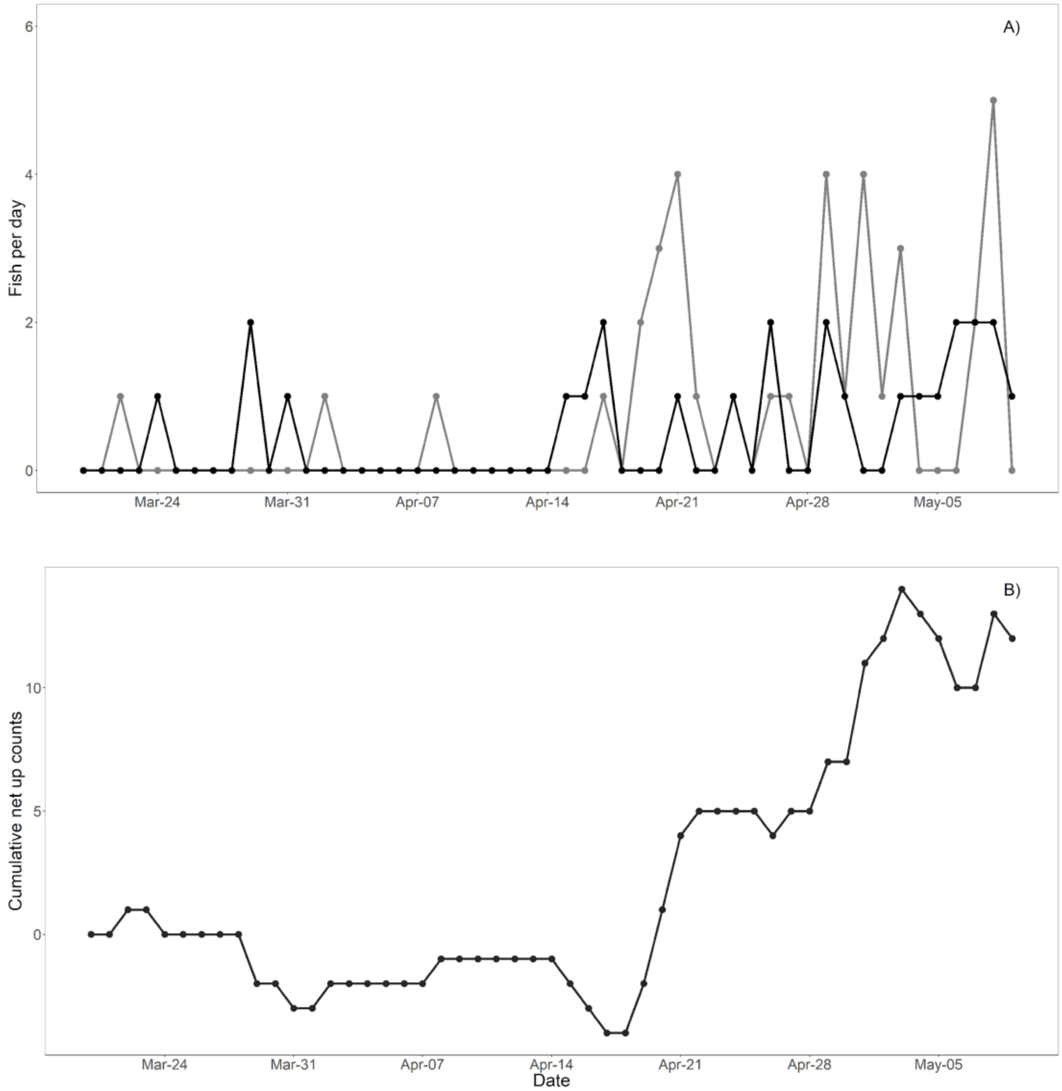

Figure 9:* *(A) combined multibeam sonar and resistivity counter derived daily up (grey) and down (black). Cumulative net up (B) counts for Steelhead Trout in the Lower Bridge River in 2018.

3.1.2 Chinook Salmon (Resistivity and Multibeam Sonar)

Resistivity Counter

The resistivity counter equipment was installed on August 16, 2018 and operated until September 30, 2018. During the Chinook spawning period a total of 903 hours of video were recorded, of which 135.3 hours were validated (6.3 hours of targeted validation and 129 hours of random validation). It was previously assumed that Chinook Salmon did not use the resistivity channel section to migrate and the movement of fish occurred solely on river left (monitored by the ARIS multibeam sonar). However, with the installation of the fish fence upstream of the counter site on August 29, 2018, Chinook Salmon were visually confirmed, for the first time, to have moved both up and downstream over the counter pads (n

= 1 and 14, respectively). Chinook Salmon were only observed passing over the counter pads after August 29th and therefore did not affect the abundance estimate presented.

Multibeam Sonar

Lengths estimated by Echoview were positively related to the ARISFish lengths but were biased low (Figure 10A). Previously, estimates for both ups and downs were biased high, however, in 2018 there was image distortion of larger fish causing lengths to be over estimated. This issue was addressed by manually measuring all fish above an estimated length of 800mm, which improved the model fit of smaller fish (<800mm). The linear model used to predict up fish lengths included both the Echoview length and distance from the sonar, while the down fish lengths required Echoview lengths, distance from the sonar and time in beam (Figure 10B). Two models were thus used to predict lengths for up and down movements of fish (Figure 10C; Table 7 and 8). The Echoview lengths were better predicted when fish swam closer and spent more time in front of the sonar unit.

Table 7: Model output for predicted lengths of fish moving upstream during the Chinook Salmon migration period, models were ranked and selected based on AICc to calculate species abundance estimates.

Intercept	Log (target length mean)	target range mean	time in beam	R^2	df	Delta AICc	weight
0.86	0.83	-0.03		0.67	4	0.00	0.70
0.85	0.83	-0.03	0.01	0.67	5	1.66	0.30
0.94	0.79			0.65	3	11.90	0.00
0.93	0.79		0.01	0.65	4	13.61	0.00

Table 8: Model output for predicted lengths of fish moving downstream during the Chinook Salmon migration period, models were ranked and selected based on AICc to calculate species abundance estimates.

Intercept	Log (target length mean)	target range mean	time in beam	R^2	df	Delta AICc	weight
0.90	0.82	-0.05	0.09	0.57	5	0.00	0.62
0.90	0.83	-0.05		0.56	4	1.00	0.38
0.98	0.77		0.08	0.54	4	11.05	0.00
0.98	0.78			0.53	3	11.76	0.00

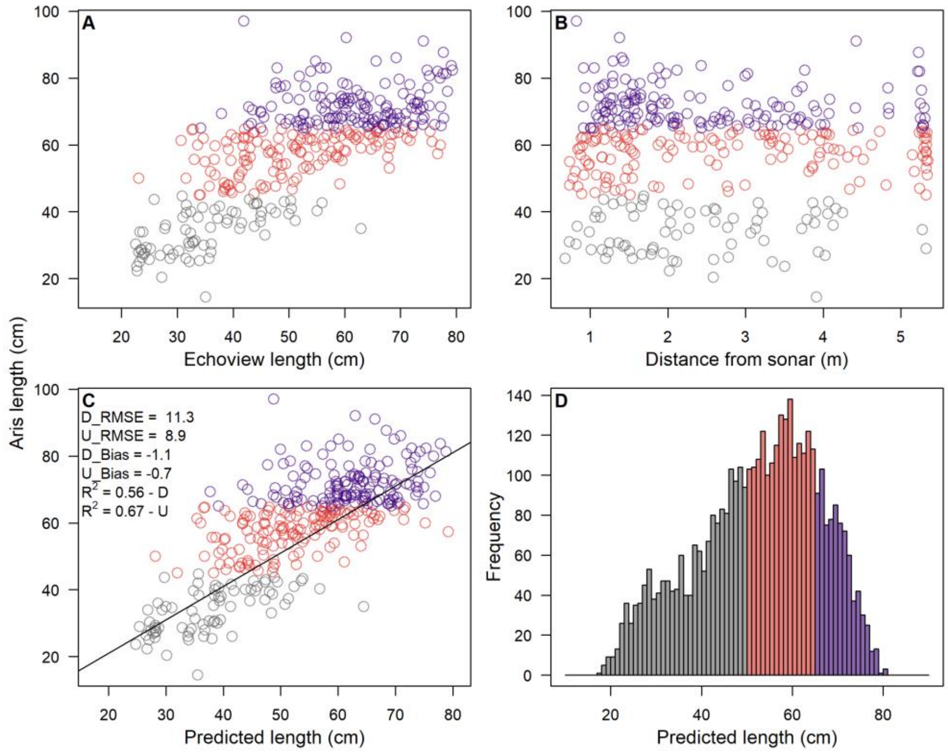

***Figure 10:** Manually measured fish length in ARISFish software in relation to (A) Echoview generated length and (B) distance from sonar. (C) Observed ARISfish lengths in relation to predicted lengths from a linear model that included Echoview length. Black line indicates unity (1:1). (D) Histogram of the predicted lengths of fish counted by Echoview. Points are fish observed using Echoview. Purple, orange and grey correspond to Chinook, Sockeye and resident fish species, respectively.*

The sonar operated from August 14 to September 30, and Chinook Salmon were detected passing through the sonar beam throughout the entire recording period. Ten percent of the total fish tracks and all target mean lengths above 800 mm generated by Echoview were measured. Using fork length data from Bridge River collected from 2014 to 2018, we determined that, as in previous years, a size cut-off of 650 mm fork length would minimize the amount of overlap between Chinook Salmon and other fish species (Figure 10D). There were no Chinook Salmon observed on the resistivity counter and the multibeam sonar estimate yields a minimum abundance estimate of 30 individuals spawning upstream of the counter site before August 29 (Figure 11).

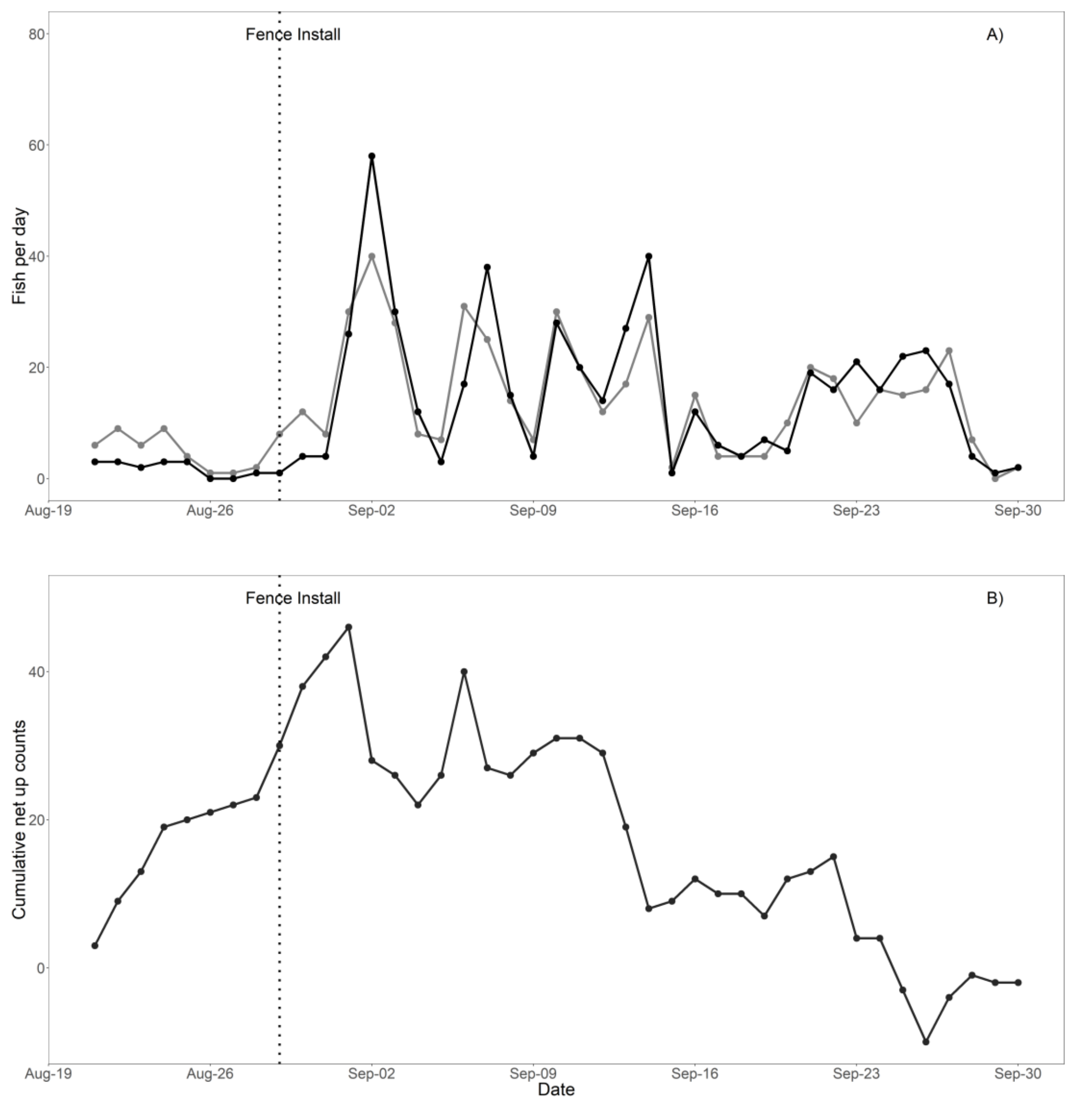

***Figure 11:* (A) combined multibeam sonar and resistivity counter derived daily up (grey) and down (black). Cumulative net up (B) counts for Chinook Salmon in the Lower Bridge River in 2018. The vertical dotted line indicates when the fish fence was installed, representing the final date that was used to generate a spawner abundance.**

Effects of Fish Fence Installation

After the installation of the fish fence on August 29, the number of detected fish increased dramatically as up and down counts (Figure 11A) mirrored each other for the remainder of the run. Between August 25 and 26 (pre-fence) and September 1 and 2 (post-fence) there were 134 and 1074 sonar fish tracks recorded, respectively. Up and down counts were very similar over this period and the number of fish that recycled within the sonar beam was comparatively high. Recycled fish are removed from population estimates; however, this requires validation and removal by an experienced analyst. The time allocated to validating a single fish track applied to the total number of tracks is 10-fold higher before and after fence installation (**Table 9**).

Table 9: daily up and down counts, recycled fish and estimated validating time for sonar fish tracks processed by Echoview.

Date	Up Counts	Down Counts	Recycled	Total tracks	Validating time (hours)
2018-08-25	27	8	34	69	1.7
2018-08-26	21	3	41	65	1.6
2018-09-01	109	104	216	429	10.7
2018-09-02	163	160	322	645	16.1

Between August 29 and September 30, the sonar and counter recorded an abundance of -32 (484 ups and 516 downs). During the operation of the fish fence twenty-one Chinook Salmon (2 females and 19 males) were captured by the fence. No population estimate can be generated post fence installation.

3.1.3 Coho Salmon (Multibeam Sonar)

Resistivity Counter

Resistivity counter is not operated during Coho Salmon migration period due to low flows over the counter pads (1.5 $m^3 s^{-1}$) that would not permit fish passage.

Multibeam Sonar

Lengths estimated by Echoview were positively related to the ARISFish lengths but were biased low (Figure 12A). This issue was addressed by manually measuring all fish above an estimated length of 800 mm, which improved the model fit of smaller fish (< 800 mm). The linear model used to predict up and down fish lengths included target length mean, distance from sonar and time in beam (Figure 12B). Exploration of the models for a direction (up and down) term indicated a difference between the two directions, and thus two models were used to predict lengths for up and down movements of fish (Figure 12C; Table 10 and 11). Length estimates were improved when fish were closer to and spent more time in the sonar swath.

Table 10: Model output for predicted lengths of fish moving upstream during the Coho Salmon migration period, models were ranked and selected based on AICc to calculate species abundance estimates.

Intercept	Log (target length mean)	target range mean	time in beam	R^2	df	delta AICc	weight
0.68	0.81	-0.04	0.09	0.70	5	0.00	0.99
0.57	0.85	-0.03		0.69	4	8.36	0.02
0.42	0.85		0.04	0.68	4	19.83	0.00
0.41	0.86			0.68	3	19.95	0.00

Table 11: Model output for predicted lengths of fish moving downstream during the Coho Salmon migration period, models were ranked and selected based on AICc to calculate species abundance estimates.

Intercept	Log (target length mean)	target range mean	time in beam	R^2	df	delta AICc	weight
1.08	0.72	-0.05	0.11	0.50	5	0.00	0.98
1.09	0.74	-0.05		0.49	4	7.55	0.02
0.99	0.71		0.08	0.48	4	16.19	0.00
1.00	0.72			0.47	3	20.04	0.00

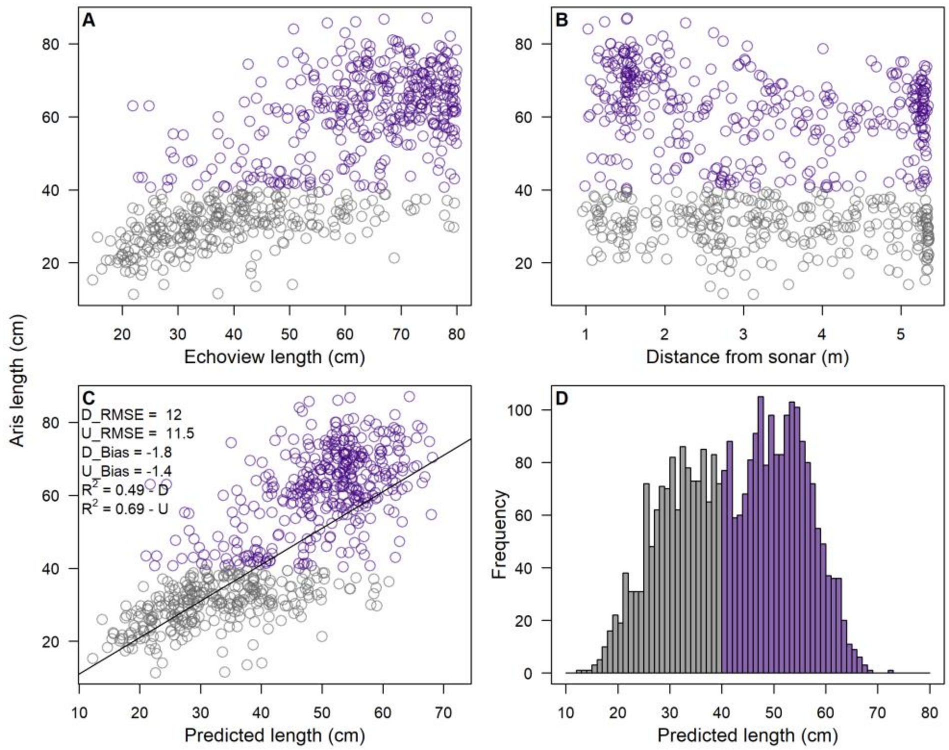

Figure 12: Manually measured fish length in ARISFish software in relation to (A) Echoview generated length and (B) distance from sonar. (C) Observed ARISfish lengths in relation to predicted lengths from a linear model that included Echoview length. Black line indicates unity (1:1). (D) Histogram of the predicted lengths of fish counted by Echoview. Purple and grey correspond to Coho Salmon and resident fish species, respectively. Dots are fish observed using Echoview.

The same methods of Chinook Salmon post-processing of ARIS sonar data was applied to Coho Salmon. We determined that a size cut-off of 400 mm fork length (same cut-off used in previous years) would minimize the amount of overlap between Coho Salmon and other fish species (Figure 12D). The sonar operated from October 1 to December 6, and Coho Salmon were detected passing through the sonar beam throughout the entire recording period. The normal model estimated the onset of the kelt out-migration date to be November 25, so all down counts were removed after this date. A sonar abundance estimate of 545 (1422 ups and 877 downs) Coho Salmon migrated past the counter site between October 1 and December 6 (Figure 13).

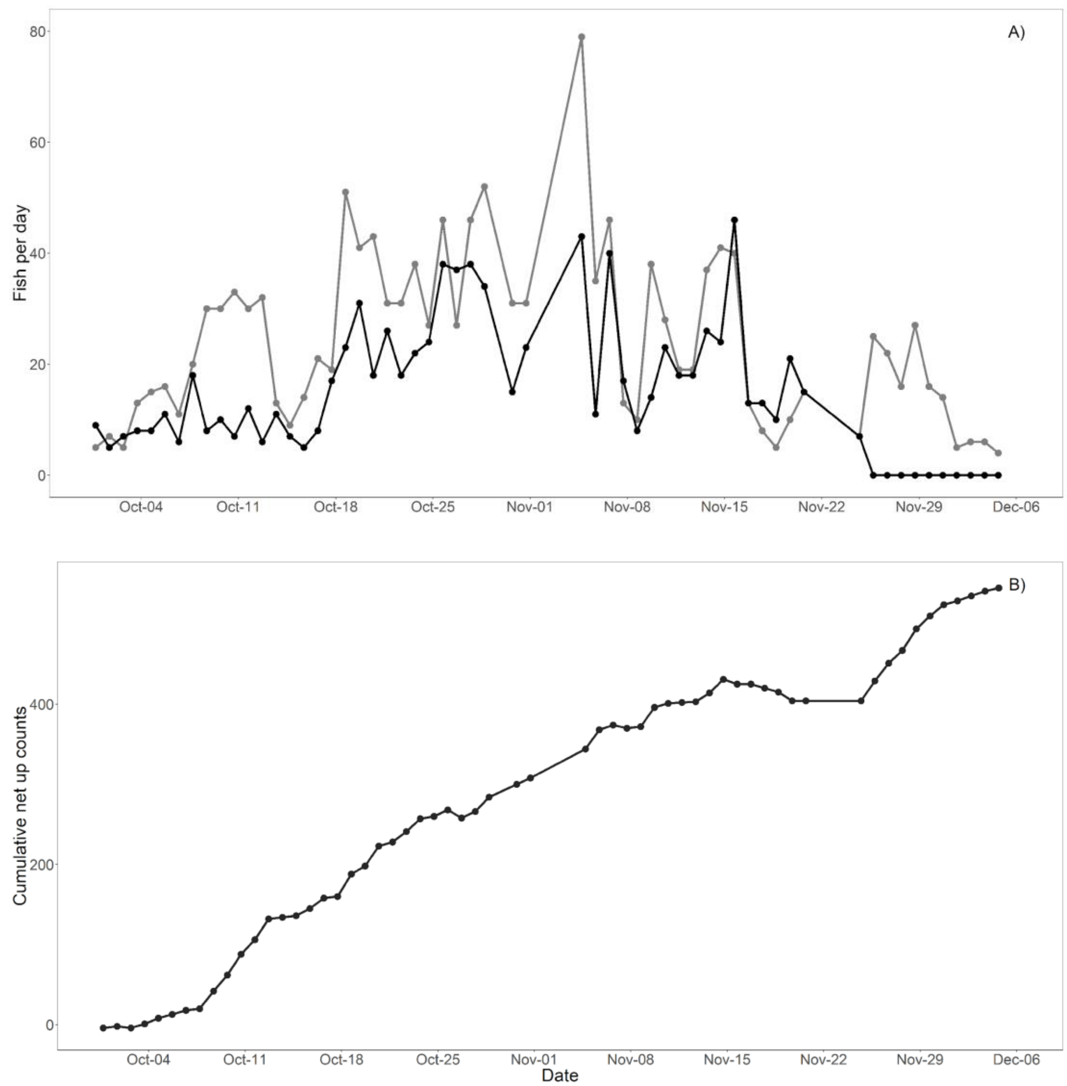

Figure 13: ***(A) sonar derived daily up (grey) and down (black). Cumulative net up (B) counts for Coho Salmon in the Lower Bridge River in 2018.***

3.2 Radio Telemetry

3.2.1 Detection efficiencies

Steelhead, Chinook and Coho were radio tagged in 2018. Detection efficiencies at fixed receiver stations were high (e.g., ≥ 80%) for Steelhead in all reaches, and were variable for Coho (Table 12). Detection efficiency of fixed stations 1 and 2 was low (45% and 46%, respectively). However, there was a known malfunction of Receiver 2 between October 15 and November 6 and when tags believed to have passed by the receiver during the outage are removed, detection efficiency increases to 100%. Detection efficiency at receivers 3 and 4 were high (Table 12).

Efficiencies could not be calculated for Chinook Salmon due to the impaired migration past the fish fence. For all species, efficiencies were not calculated for Reach 4 as there is no upstream receiver to verify entry from Reach 3.

Table 12: Detection efficiency of fixed radio receivers during Steelhead and Coho migrations in the Lower Bridge River in 2018. Reach 4 efficiencies were not calculated as there is was only one receiver. Note, efficiencies could not be calculated for Chinook Salmon due to the impaired migration past the fish fence.

Species	Location of Receiver	Detection Efficiency
Steelhead Trout	Station 1	92% (12/13)
	Station 2	100% (6/6)
	Station 3	80% (4/5)
Coho Salmon	Station 1	45% (5/11)
	Station 2	46% (6/13)
	Station 3	92% (11/12)

Numbers in parentheses represent the number of individuals detected out of the total known to have passed by fixed radio telemetry stations.

3.2.1 Steelhead Trout

Fish Capture, Tagging and Sampling

Twenty Steelhead Trout (5 males and 15 females) were angled and radio tagged from March 12 to April 20 at the Seton-Fraser confluence (Appendix 1). Mean fork lengths for males and females were 780 mm (range: 660 to 871 mm) and 758 mm (range: 630 to 855 mm), respectively. SER technicians captured two additional female Steelhead Trout on October 12 and 16 during angling for Coho Salmon at the Bridge-Fraser confluence that were not radio tagged, as per discussions with FLNRORD (R. McCleary, personal communication, 2018).

Movement and spawning locations

Sixteen of the 20 radio-tagged Steelhead Trout were detected on fixed stations and/or mobile tracking in the LBR. All radio-tagged Steelhead Trout moved into the LBR by May 21, with an average entry date of April 27 ± 15 days (range April 4 – May 21), which is within the range of previous telemetry data (2015-2018; April 21 ± 16 days). The average time between tagging at the Seton-Fraser confluence and entry into the LBR was 32 days ± 15 days. The last fish tagged on April 20 entered the LBR the following day, while the longest duration prior to entry into the LBR was 64 days. Fish with assumed spawning locations spawned throughout Reach 4 (n = 5), 3 (n = 3) and 2 (n = 4) throughout April and May (Figure 14; Appendix 2).

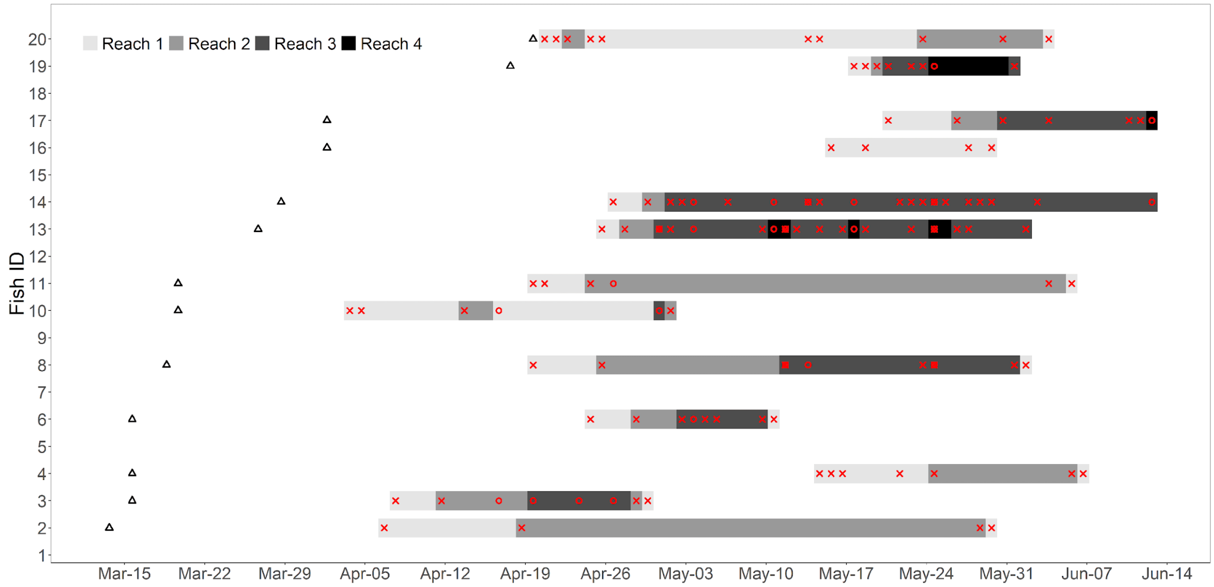

***Figure 14**: Time series of radio-tagged Steelhead Trout in the Lower Bridge River in 2018. Triangles denote tagging date, o denotes mobile tracking detections, × denotes fixed receiver detections and ■ denotes dates of both mobile and fixed detections.*

Specifically, radio-tagged Steelhead Trout were estimated to have spawned in the following streamwalk sections in Reach 3 and 4 (n = 8), and in Reach 2 (n=4; Figure 16):

- Between Longskinny and Terzaghi Dam (39.6 to 40 rkm, Section 8; n=1)
- Between Bluenose and Eagle (38.2 to 38.8, Section 6, n=1)
- Between Cobra and Bluenose (34.4 to 38.2 rkm, Section 5, n=3)
- Between Russel Springs and Fish Fence (30.7 to 33.2 rkm, Section 3, n=1)
- Between the Yalakom confluence and Hell Creek (25.5 to 28.8 rkm, Section 1, n=2)
- In Reach 2 (18.0 to 26 rkm, n=4) but there was not enough data to determine exact locations

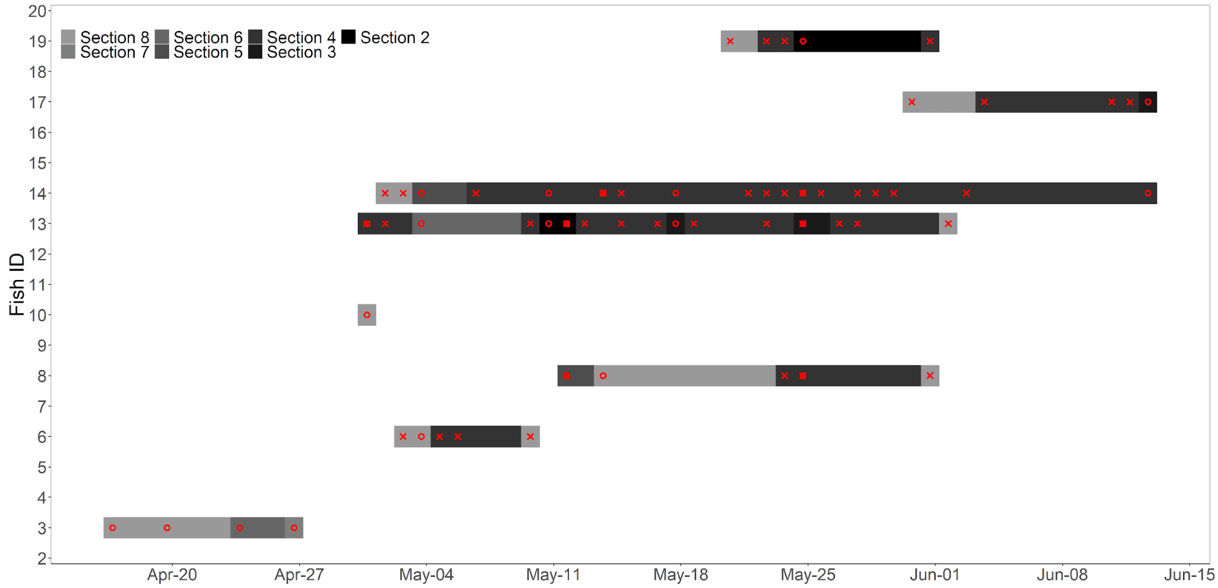

***Figure 15:** Time series of radio-tagged Steelhead Trout in streamwalk sections of Reach 3 and 4 of the Lower Bridge River in 2018. Start of bars indicate when individuals entered Reach 3, o denotes mobile tracking detections, × denotes fixed receiver detections and ■ denotes dates of both mobile and fixed detections.*

Of the eight individuals that spawned in Reach 3 and 4, five moved upstream past the counter site before May 9 (when counting equipment was removed). Of the 12 known spawners, seven exhibited kelting behaviour and exited the system between April 30 and June 7, two of which passed the counter site before May 9. Radio-tagged Steelhead Trout had a mean residence time of 24 days (range: 8 – 41 days, n = 5) above Reach 2 and 21 days (range 8-43 days, n = 7) above Reach 3 of the LBR (**Table 13**). Steelhead Trout that showed directed upstream migrations in the LBR exhibited a mean migration rate of 4.1 km day^{-1} (range: 0.8 to 8.4 km day^{-1}, n = 12) from the Bridge-Fraser confluence to the assumed spawning reach (**Table 13**).

Table 13: Tagging information and spawning distribution of radio-tagged Steelhead Trout in the Lower Bridge River in 2018, including calculated migration rates and residence time in specific reaches. All fish were tagged at the Seton-Fraser confluence.

Tag NO.	Sex	Tagging Date	Entry Date to LBR	End Date	Assumed Spawning Reach	Assumed Spawning Section	Migration Rate (km day-1)	Reach 2 Residence Time (days)	Reach 3 Residence Time (days)
2	F	2018-03-14	2018-04-07	2018-05-30	2	NA	1.4	41	NA
3	F	2018-03-16	2018-04-08	2018-04-30	3	Fish Fence to Russel	3.4	NA	11
4	F	2018-03-16	2018-05-15	2018-06-07	2	NA	5.5	13.1	NA
6	F	2018-03-16	2018-04-25	2018-05-11	3	Yalakom to Hell Creek	3.6	NA	8
8	F	2018-03-19	2018-04-20	2018-06-02	3	Cobra to Bluenose	1.7	NA	29.5
10	F	2018-03-20	2018-04-04	2018-05-02	3	Yalakom to Hell Creek	1.9	18.2	NA
11	F	2018-03-20	2018-04-20	2018-06-06	2	NA	4.3	40.3	NA
13	M	2018-03-27	2018-04-26	2018-06-02	4	Longskinny to Terzaghi	8.2	NA	32.8
14	M	2018-03-29	2018-04-27	2018-06-13	4	Cobra to Bluenose	5.8	NA	42.5
17	F	2018-04-02	2018-05-21	2018-06-13	4	Cobra to Bluenose	2.6	NA	14
19	F	2018-04-18	2018-05-18	2018-06-01	4	Bluenose to Eagle	8.1	NA	11.9
20	F	2018-04-20	2018-04-21	2018-06-04	2	NA	1.9	7.9	NA
						Mean	4	24.1	21.4
						Minimum	1.4	7.9	8
						Maximum	8.2	41	42.5

Note: Yalakom River to Hell Creek (25.5 to 28.8 rkm), Hell Creek to Russel Springs (28.8 to 30.7 rkm), Russel Springs to Fish Fence (30.7 to 33.2 rkm), Fish Fence to Cobra (33.2 to 34.4 rkm), Cobra to Bluenose (34.4 to 38.2 rkm), Bluenose to Eagle (38.2 to 38.8 rkm), Longskinny to Plunge Pool (39.3 to 40.0 rkm)

Of the four Steelhead for which spawning information is unknown, three were only detected at the lower receiver near the Fraser River Confluence and one had < 3 detections. Of the four individuals that did not enter the LBR, two were detected via radio and PIT telemetry in the Seton River and two had unknown fates and may have moved to other Fraser tributaries upstream.

As no streamwalks or redd surveys are conducted for Steelhead Trout in the LBR due to poor visibility and high flow regime not permitting safe visual or measured evaluation of spawning habitat, spawning locations were not confirmed. Spawning location were estimated by visually assessing fish tracks generated from both fixed and mobile telemetry to identify plateaus in individual upstream migration, indicating individuals were relatively stationary for several days. 2018 was the first year in which spawning was assumed to have occurred in Reach 2 of the LBR, and was evenly distributed in Reach 2, 3 and 4 (Figure 16). In 2016, there were only 3 individuals that were assumed to have spawned in the LBR, with 100% of that occurring in Reach 3. Most of the spawning is concentrated around the Reach 3/4 boundary, near Terzaghi Dam.

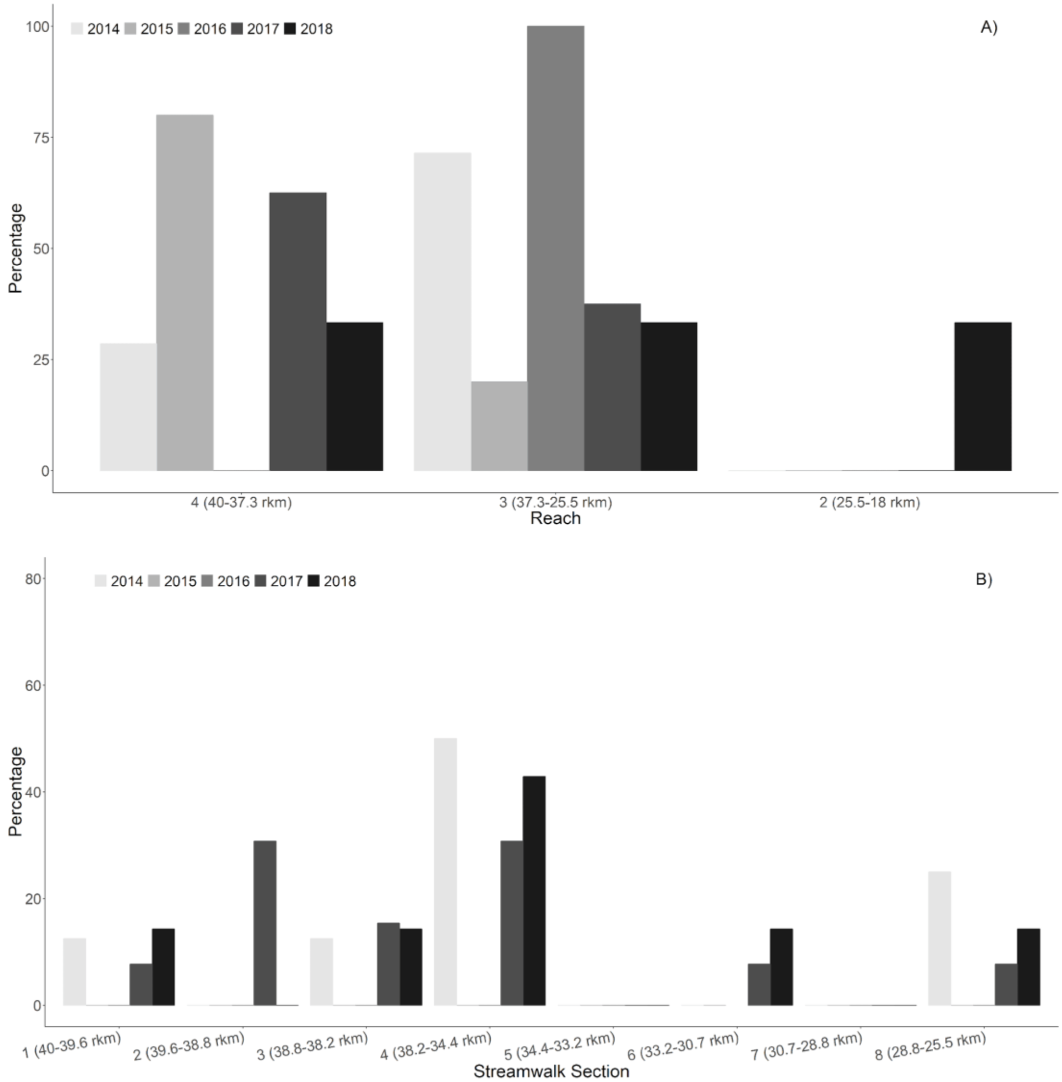

Figure 16: Relative proportion of estimated spawning locations for Steelhead Trout from radio telemetry, distributed by reach (top), and streamwalk section (bottom) from Terzaghi Dam to the Yalakom confluence.

3.2.2 Chinook Salmon

Fish Capture, Tagging and Sampling

Despite applying the same angling effort as in past monitoring years, we were only able to capture three female Chinook Salmon at the Bridge-Fraser confluence in Reach 1 (n = 1), and below the Yalakom confluence in Reach 2 (n = 2; Appendix 1). Fork length of radio-tagged fish were 950, 680 and 600 mm.

Movement and spawning locations

The individual tagged at the Bridge-Fraser confluence was never detected at a receiver in the LBR and was likely a fish from a more northern tributary of the Fraser. The two individuals that were tagged below the Yalakom-Bridge confluence were observed at either fixed or mobile receivers in the LBR above there original tagging location (**Figure 17**; Appendix 2). Telemetry data from the two tagged fish in the LBR quantified recycling behaviour (up and down movement) after the installation of the fish fence on August 29. This was characterized by intermittent detections at the mid-telemetry station (counter site), just below the fish fence (Figure 18). If we assume that the fish fence did not impair spawning success, both individuals may have spawned between the counter site and the Yalakom-Bridge confluence (Table 14). Residence time, migration rates or fixed receiver detection efficiencies were not calculated for Chinook.

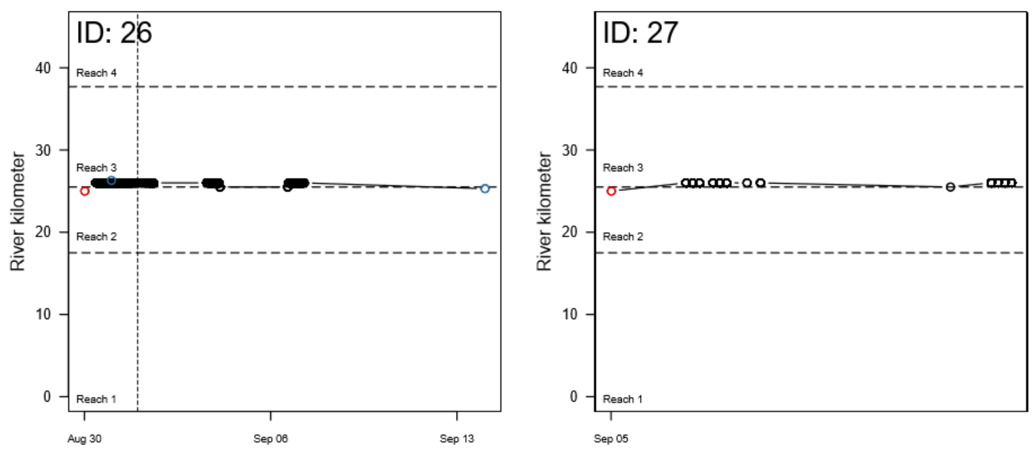

Figure 17: Detection histories of radio-tagged Chinook Salmon in the Lower Bridge River in 2018. Black lines connect the release information (red) with data collected from fixed (black) and mobile (blue) telemetry. Horizontal dashed lines indicate boundaries between different reaches and the vertical dashed line occurs on August 29, when the fish fence was installed upstream of the fish counter and telemetry station.

Table 14: Tagging information of radio-tagged Chinook Salmon in the Lower Bridge River in 2018 and inferred spawning location. Fish were tagged at the Yalakom Confluence (rkm 25.5)

Tag no.	Sex	Tagging Date	End Date	Assumed spawning location	
				Reach	Section
26	F	August 30	September 14	3	Yalakom to Counter
27	F	September 5	September 7	3	Yalakom to Counter

Note: Yalakom River to the counter site (25.5 to 28.8 rkm).

3.2.3 Coho Salmon

Fish Capture, Tagging and Sampling

Twenty-five Coho Salmon (15 males and 10 females) were captured and radio tagged from September 27 to November 12 at the Bridge River confluence (n = 21), Camoo FSR Bridge (n = 3) or below the Yalakom-Bridge confluence (n = 1; Appendix 1). Mean fork length of radio-tagged males and females was 595 mm (range: 515 to 690 mm) and 592 mm (range: 543 to 680 mm), respectively.

Movement and spawning locations

Nineteen of the 25 radio-tagged Coho Salmon were detected on fixed stations and/or by mobile tracking in the LBR. Fish with assumed spawning locations spawned in all reaches; Reach 4 (n = 8), 3 (n = 4), 2 (n = 2) and 1 (n = 5), between October and December (Figure 18; Appendix 2). Of the six that were not detected by either fixed or mobile telemetry, five were tagged at the Bridge-Fraser confluence and one below the Yalakom confluence.

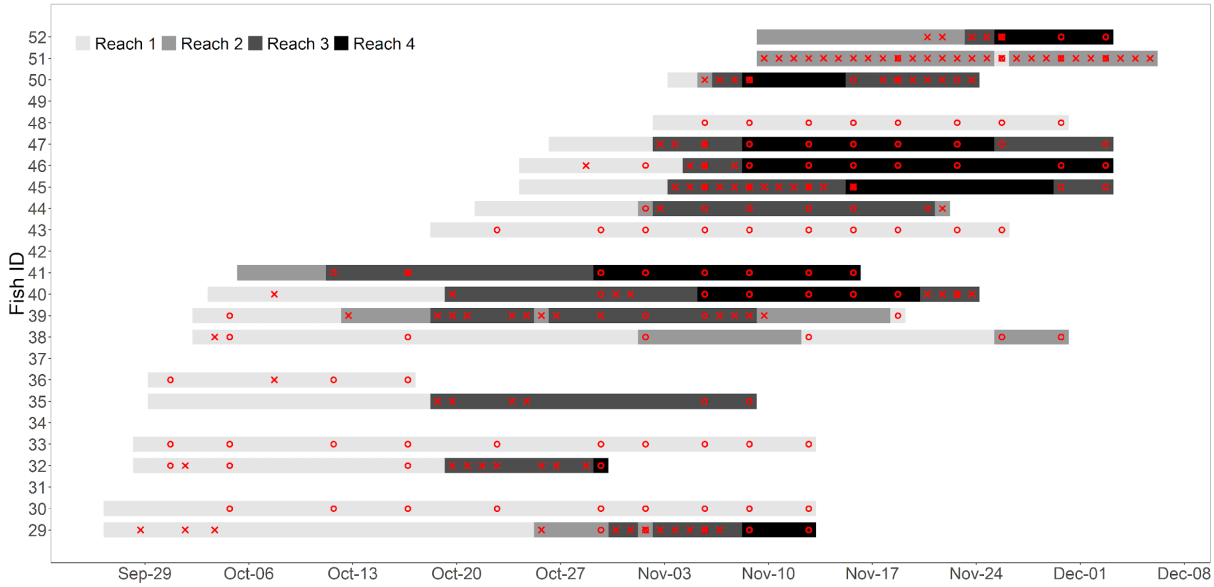

Figure 18: Time series of radio-tagged Coho Salmon in the Lower Bridge River in 2018. Start of bars indicate tagging date, o denotes mobile tracking detections, × denotes fixed receiver detections and ■ denotes dates of both mobile and fixed detections.

Specifically, the 19 radio-tagged Coho Salmon spawned across the following streamwalk sections in Reach 3 and 4, along with Reaches 1 and 2 (Figure 19):

- Between Longskinny and Terzaghi Dam (39.6 to 40 rkm Section 8, n=3)
- Between Bluenose and Eagle (38.2 to 38.8 rkm Section 6, n=1)
- Between Cobra and Bluenose (34.4 to 38.2 rkm, Section 5, n=4)
- Between Russel Springs and Fish Fence (30.7 to 33.2 rkm, Section 4, n=1)
- Between the Yalakom confluence and Hell Creek (25.5 to 28.8 rkm, Section 1, n=2)
- At the Camoo receiver at the Reach 2/3 boundary (18 rkm, n=1)
- In Reach 2 (18 to 26 rkm, n=1), but there was not enough data to determine location.
- In Reach 1 (0 to 18 rkm, n=5) fish either spawned, died or spit tags at the Bridge-Fraser confluence following tagging

- Four fish were detected fewer than three times with mobile tracking near the Fraser River Confluence
- Two fish were detected fewer than three times with mobile tracking between Reach 2 and 3

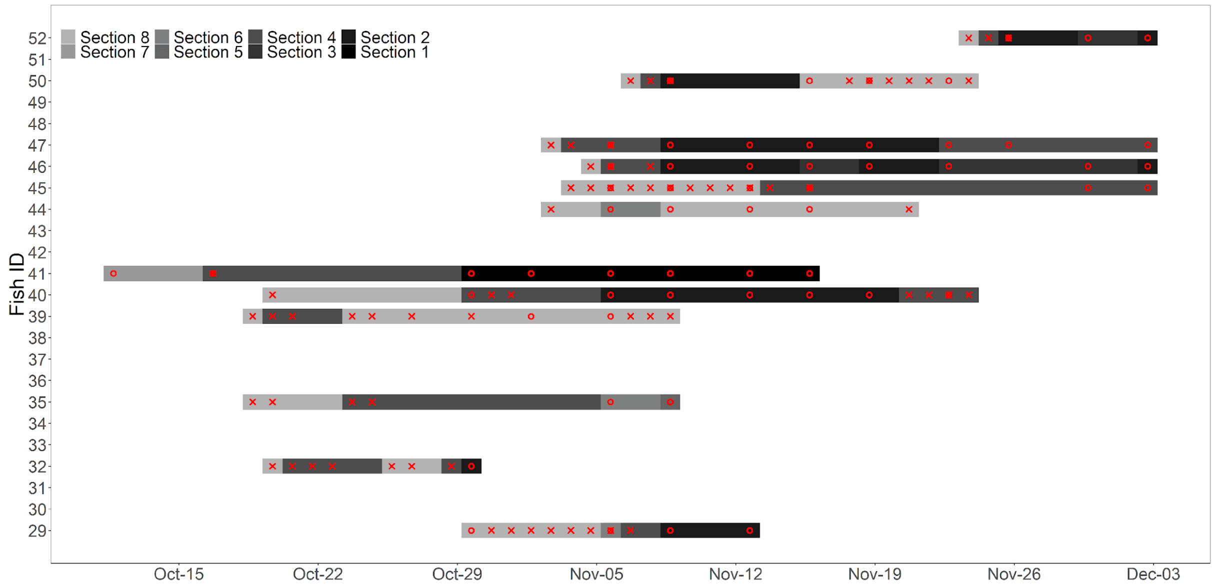

***Figure 19:** Time series of radio-tagged Coho Salmon in streamwalk sections of reaches 3 and 4 of the Lower Bridge River in 2018. Start of bars indicate when individuals entered reach 3, o denotes mobile tracking detections, × denotes fixed receiver detections and ■ denotes dates of both mobile and fixed detections.*

Radio-tagged Coho Salmon had a mean residence time of 23 days (range: 12 – 38 days, n = 6) above Reach 2 and 21 days (range 9-30 days) above Reach 3 of the LBR (Table 15). Coho Salmon that showed directed upstream migrations in the LBR exhibited a mean migration rate of 3.3 km day^{-1} (range: 0.8 to 8.7 km day-1, n = 13) from the Bridge-Fraser confluence to the assumed spawning reach (Table 15).

Table 15: Tagging information of radio-tagged Coho Salmon in the Lower Bridge River, with inferred spawning location and calculated migration rates and residence time. Tagging location was either at the Bridge River Bridge at rkm 0.5 (Bridge) or at that Camoo FSR Bridge at rkm 18 (Camoo).

Tag no.	Sex	Tagging location	Tagging Date	End Date	Assumed spawning location Reach	section	Migration rate (km day^{-1})	Residence time (days)
29	F	Bridge	2018-09-27	2018-11-13	4	Longskinny to Terzaghi	1.1	14
30	M	Bridge	2018-09-27	2018-11-13	1	NA	NA	NA
32	M	Bridge	2018-09-29	2018-10-30	3	Cobra to Fish Fence	2.3	9.7
33	M	Bridge	2018-09-29	2018-11-13	1	NA	NA	NA
35	M	Bridge	2018-09-30	2018-11-09	3	Fish Fence to Russell	1.6	20.5
36	M	Bridge	2018-09-30	2018-10-17	1	NA	NA	NA
38	M	Bridge	2018-10-03	2018-11-30	2	NA	NA	NA
39	M	Bridge	2018-10-03	2018-11-19	3	Hell to Counter	2.6	21.7
40	F	Bridge	2018-10-04	2018-11-24	4	Longskinny to Terzaghi	1.5	30.3
41	M	Camoo	2018-10-06	2018-11-16	4	Longskinny to Terzaghi	1.7	NA
43	F	Bridge	2018-10-19	2018-11-26	1	NA	NA	NA
44	F	Bridge	2018-10-22	2018-11-22	3	Hell to Counter	2.3	18.8
45	F	Bridge	2018-10-25	2018-12-03	3	Cobra to Bluenose	2.5	28.5
46	F	Bridge	2018-10-25	2018-12-03	4	Bluenose to Eagle	8.5	27.7
47	M	Bridge	2018-10-27	2018-12-03	4	Cobra to Bluenose	4.5	29.9
48	M	Bridge	2018-11-03	2018-11-30	1	NA	NA	NA
50	M	Bridge	2018-11-04	2018-11-24	3	Hell to Counter	8.7	17.7
51	M	Camoo	2018-11-10	2018-12-06	2	Camoo FSR Bridge	NA	NA
52	F	Camoo	2018-11-10	2018-12-03	4	Cobra to Bluenose	4.7	9.3
					Mean	NA	3.3	20.7
					Minimum	NA	1.1	9.3
					Maximum	NA	8.7	30.3

Note: Yalakom River to Hell Creek (25.5 to 28.8 rkm), Hell Creek to Russel Springs (28.8 to 30.7 rkm), Russel Springs to Fish Fence (30.7 to 33.2 rkm), Fish Fence to Cobra (33.2 to 34.4 rkm), Cobra to Bluenose (34.4 to 38.2 rkm), Bluenose to Eagle (38.2 to 38.8 rkm), Longskinny to Plunge Pool (39.3 to 40.0 rkm)

3.3 Visual Surveys

3.3.1 Steelhead Trout

As in previous years, streamwalks were not conducted for Steelhead Trout in 2018 due to poor visibility in the LBR during the spring spawning period.

3.3.2 Chinook Salmon

Visual counts of Chinook Salmon were conducted from August 9 to October 12, at which point spawning was assessed to be complete and no fish were observed. The fish fence was installed on August 29, the first fish observed on September 7, and a peak live count of 8 fish occurred on September 21 (Appendix 3). Fish observed during visual assessments are individuals that migrated past the counter site and fish fence prior to August 29. Relative abundance of spawners was highest from Fish Fence to Cobra (Section 4; 33.2 to 34.4 rkm), where counts represented on average 50% of total abundance. Chinook Salmon were most commonly observed from Longskinny to Eagle (Section 1-2) in Reach 4 and from Fraser Lake to Russell Springs (Section 5-6) in Reach 3 (Figure 20). As in previous monitoring years, water visibility was variable and low throughout the Chinook Salmon migration period, ranging from 0.5 to 0.9 m for the entire study period (Appendix 3). There were no Chinook Salmon observed during Reach 2 streamwalks or spot checks in Reach 1.

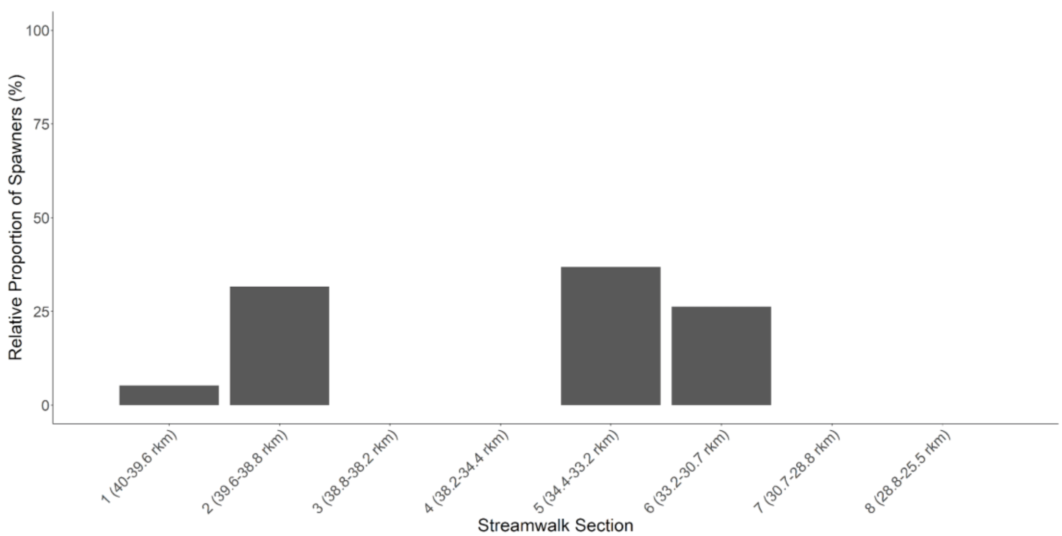

Figure 20:** **Cumulative proportion of Chinook spawners observed in the various streamwalk sections of Reach 3 and 4 in the LBR in 2018. Sections are numbered in ascending order from the Terzaghi Dam to the Yalakom confluence. Sections 1–3 are in Reach 4 and sections 4-8 are in Reach 3.

3.3.3 Sockeye Salmon

Visual counts of Sockeye Salmon were conducted from September 7 to October 12, at which point spawning was assessed to be complete and no individuals were observed. A peak live fish count of 40 individuals occurred on September 14. Relative abundance of spawners was highest from Longskinny to Plunge Pool (Section 1; 39.3 to 40.0 rkm), where 58% of total counts were observed, and lowest from Eagle to Cobra, where no fish were observed (Section 6; 38.2 to 38.8 rkm; Figure 21).Sockeye Salmon were concentrated in Reach 4 from Terzaghi Dam to Eagle, and were also found in Reach 3 in lower abundances from Fraser Lake to the Counter Site (Section 5-8).

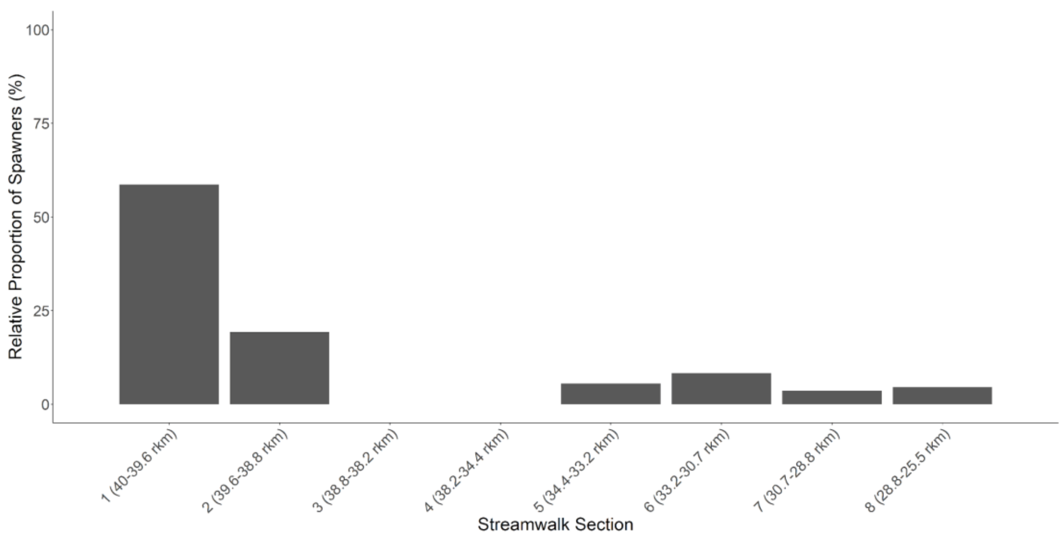

Figure 21: Cumulative proportion of Sockeye spawners observed in the various streamwalk sections of Reaches 3 and 4 in the LBR in 2018. Sections are numbered in ascending order from the Terzaghi Dam to the Yalakom confluence. Sections 1–3 are in Reach 4 and sections 4-8 are in Reach 3.

3.3.4 Coho Salmon

Visual counts of Coho Salmon were conducted from October 24 to December 12, at which point spawning was assessed to be complete and no individuals were observed. A peak live fish count of 209 fish was observed on November 15. Relative abundance of spawners was highest from Terzaghi Dam to Longskinny (Section 1; 39.3 to 40.0 rkm), where 45% of total counts were observed, and lowest from the counter to the Yalakom where no fish were observed (Figure 22). Spawner distribution was spread across all streamwalk sections and was highest from Terzaghi Dam to Longskinny and at Fraser Lake. Water clarity was similar to the Chinook Salmon migration period; however, discharge is ramped down to 1.5 $m^3 s^{-1}$ and visibility is improved in many sections. A single tagged Coho Salmon (51) was observed during Reach 2 streamwalks in the river area covered by the fixed receiver upstream of the Camoo FSR Bridge.

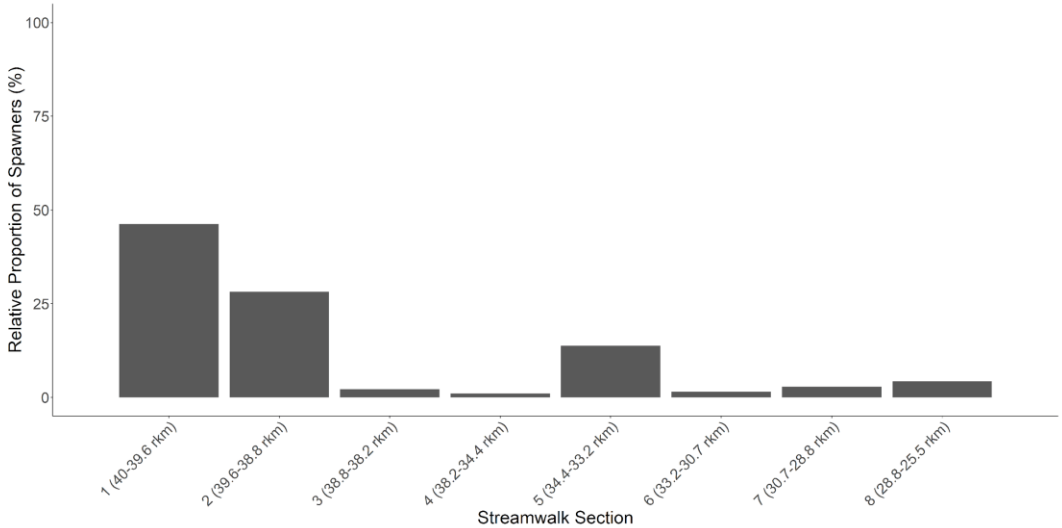

***Figure 22:** Cumulative proportion of Coho spawners observed in the various streamwalk sections of Reach 3 and 4 of the Lower Bridge River in 2018. Sections are numbered in ascending order from the Terzaghi Dam to the Yalakom confluence. Sections 1–3 are in Reach 4 and sections 4-8 are in Reach 3.*

3.4 AUC Abundance Estimates

3.4.1 Chinook Salmon

2018

The maximum likelihood estimate of Chinook Salmon abundance between the Yalakom River and Terzaghi Dam was 25 individuals (95% confidence intervals: 14-44; Figure 23; Table 1). This estimate is limited to before fence installation on August 29 and should be regarded as a minimum run estimate. The fence did not permit the calculation of SL or OE, therefore, historic averages (10.5 days and 0.5 for SL and OE, respectively) were used to calculate the estimate.

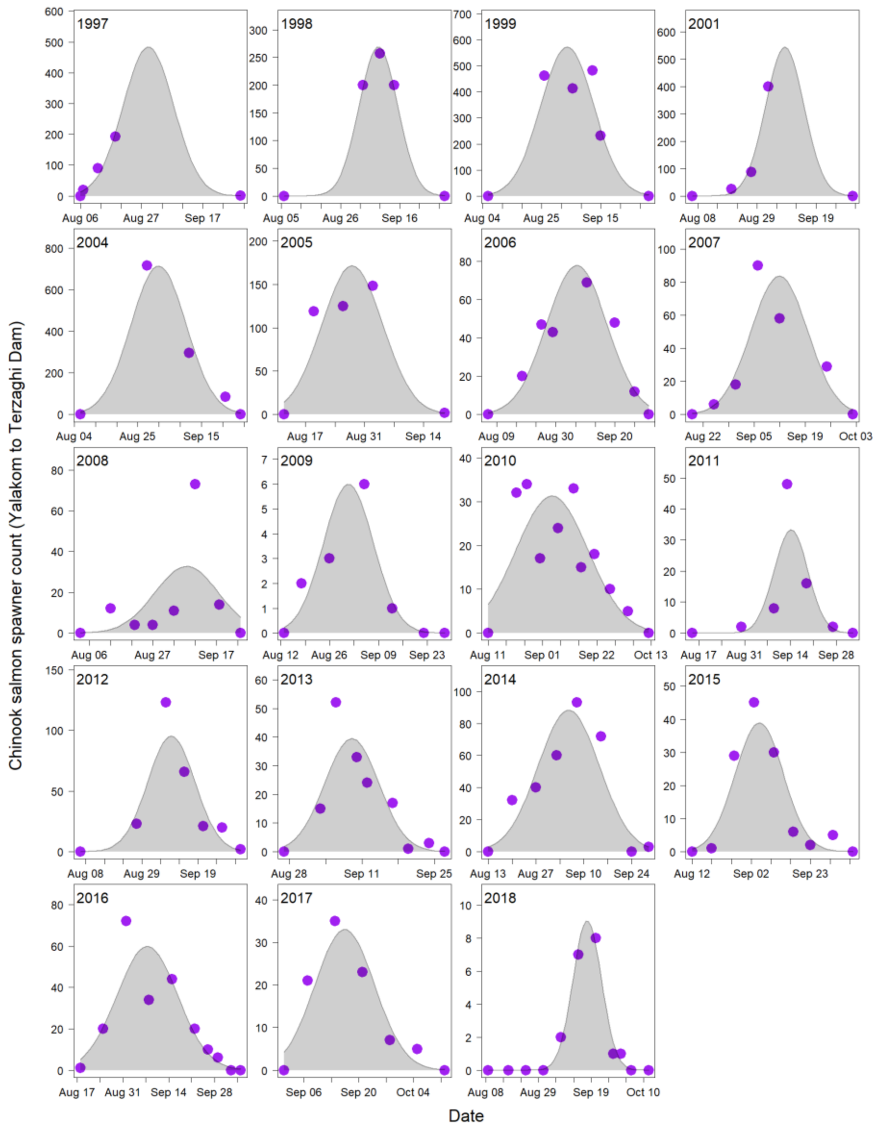

***Figure 23:** Chinook Salmon adult spawner counts (purple points) to the modelled arrival timing (grey shaded area) in the Lower Bridge River from 1997 to 2018. Note that there are different date ranges between years.*

Historic

Population abundances since 1993 varied from a minimum estimate of 21 fish in 2009 to a maximum of 3,106 in 2004 (Figure 24). Data will support future analysis comparing streamwalk estimates with counter estimates (resistivity and sonar) to improve future abundance estimates (Figure 25). Counter estimates are typically about two times the abundance of AUC estimates, however, 2016 and 2018 estimates are partial as a result of high flows and fence installation.

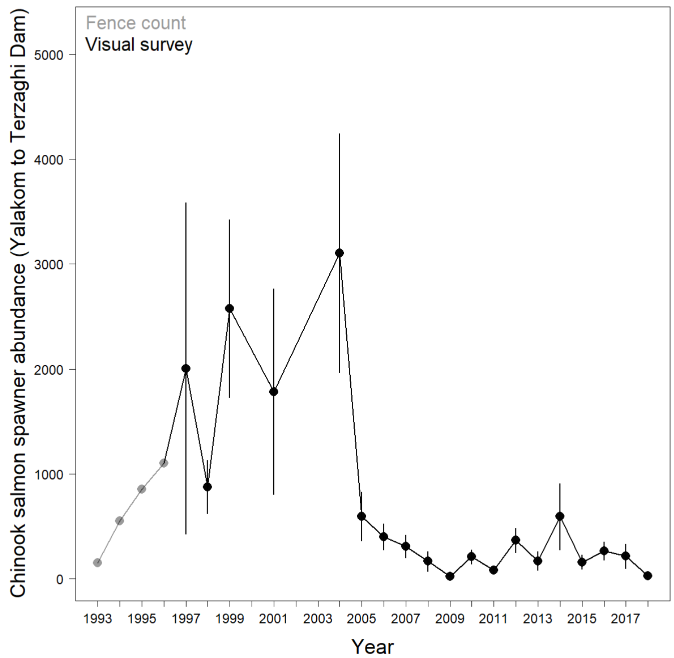

***Figure 24:* AUC and fence estimates for Chinook Salmon in the Lower Bridge River from 1993 to 2018. Vertical lines represent standard error around estimates.**

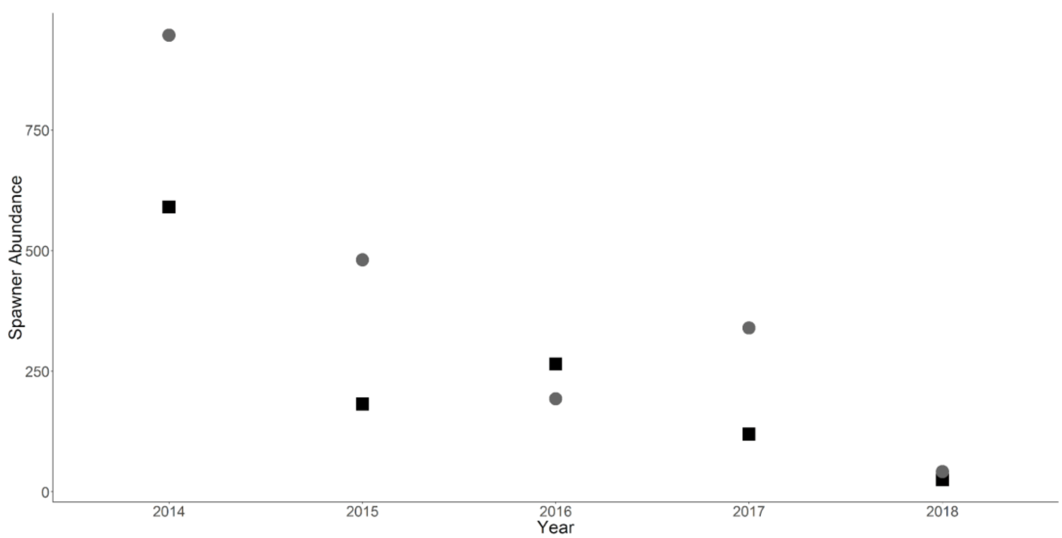

***Figure 25:* Chinook Salmon AUC streamwalk estimates (black squares) and estimates derived from counting technology (resistivity only 2014, 2015, resistivity and sonar: 2016, 2017 and 2018; grey circles). 2016 was the pilot study of combining resistivity and sonar counter data and did not cover the entire migration period. In 2018, the run was disrupted by a fish fence, so estimates were calculated prior to installation on August 29, before the historic peak run timing of Chinook.**

3.4.2 Coho Salmon

2018

The maximum likelihood estimate of Coho Salmon was 1,245 Coho (95% confidence intervals: 882-1627) in 2018 between the Yalakom River and Terzaghi Dam (Figure 26; Table 2). The calculated survey life and observer efficiencies for 2018 were 18 days and 0.20, respectively. These values were added to previous years observations to calculate a historic average for SL and OE over the study period (SL = 20 days and OE = 0.22) and used for model parameters.

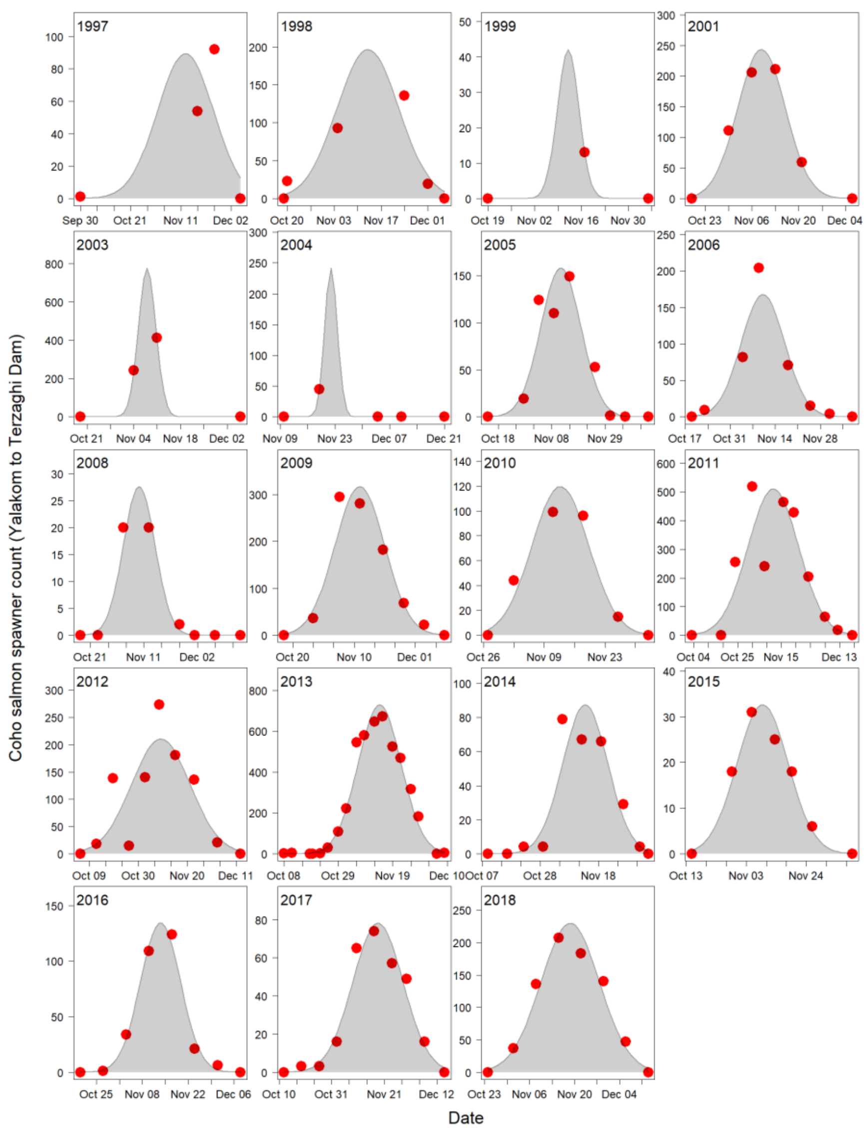

Figure 26: ***Coho Salmon adult spawner counts (red points) to the modelled arrival timing (grey shaded area) in the Lower Bridge River from 1997 to 2018. Note that there are different date ranges between years.***

Historic

Count data obtained from DFO was used to reconstruct AUC estimates for Coho from the Yalakom confluence to Terzaghi Dam (Reach 3 and 4) since 1997. Population abundance during this time varied from a minimum estimate of 78 fish in 1999 to a maximum of 3,539 in 2011 (Figure 27). Data will support future analysis comparing streamwalk estimates with resistivity and sonar counter estimates to improve future abundance estimates. Previous counter estimates have been 2-3 times higher than AUC estimates with greater accuracy, however, in 2018 for the first time the AUC estimate was about 2 times larger than the counter estimate (Figure 28).

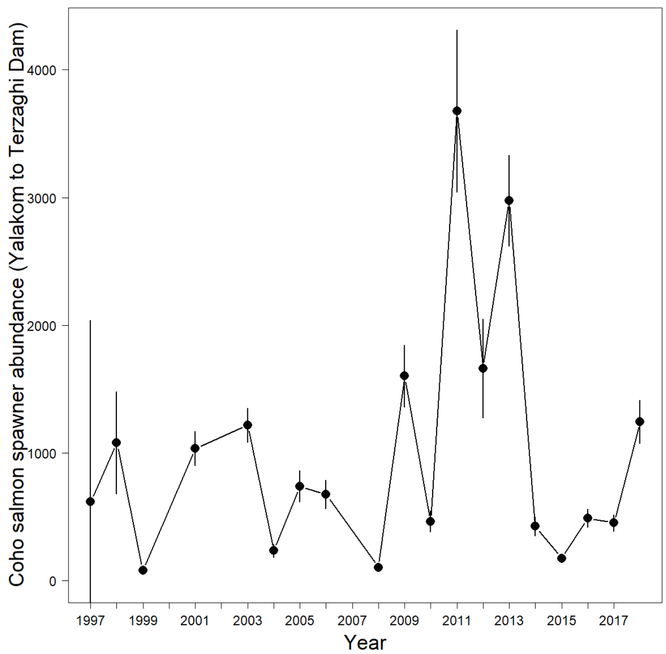

Figure 27: AUC estimates for Coho Salmon in the Lower Bridge River from 1997 to 2018. Vertical lines represent standard error around estimate.

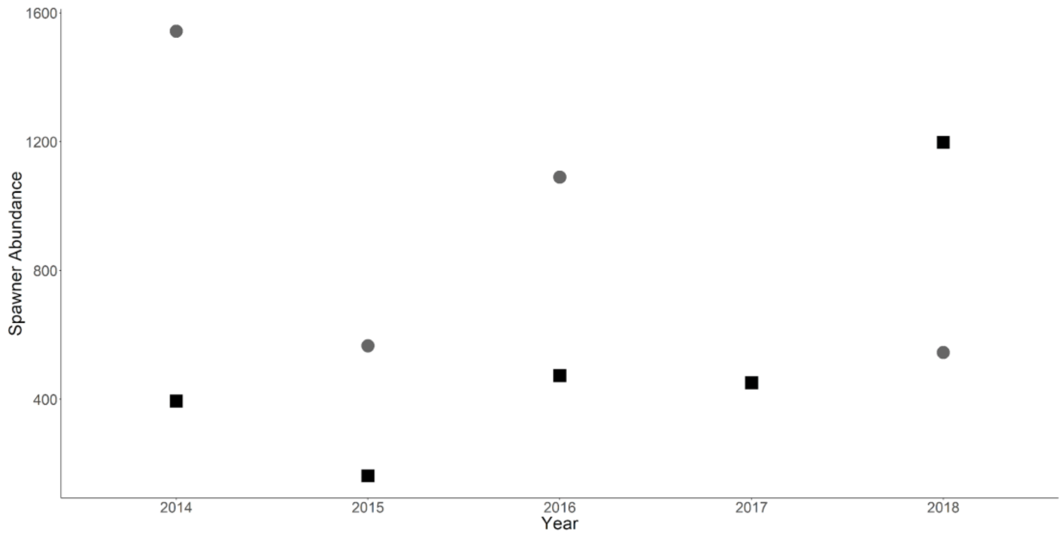

Figure 28: ***Coho Salmon AUC streamwalk estimates (black squares) and estimates derived from counting technology (resistivity only 2014, 2015, resistivity and sonar: 2016, 2017 and 2018; grey circles). No estimate was calculated in 2017 due to post-season data loss.***

3.5 Redd Surveys

3.5.1 Chinook Salmon Redds

Redd Characteristics

Three Chinook Salmon redds were observed in Reach 3 (n = 1) and 4 (n = 2) of the LBR. All measured redds in 2018 were in run habitat, consistent with observations from previous years (2014-2017). Significant differences were detected among years in water depth ($F^{4, 120} = 668$, $p < 0.001$), velocity ($F^{4, 120} = 3.34$, $p = 0.01$), and substrate size ($F^{3, 60} = 27.78$, $p < 0.001$). Redds sampled in 2018 had the lowest average water depths (Figure 29) and velocities (Figure 30). Average water depths were 0.4 or 0.5 m in all previous years, but 0.3 m in 2018, and average velocities ranged from 0.66 m s^{-1} to 0.78 m s^{-1} in previous years but were 0.48 m s^{-1} in 2018. Only three redds were measured in 2018, and one redd decreased the sample mean for both water depth and velocity. Substrate geometric mean (D_{50}) was twice as large in 2016, 2017 and 2018 (mean = 67 mm, 54 mm, 68 mm, respectively), than in 2015 (mean = 32Figure 31; Table 16). Water depths in 2015 were also significantly higher than all other sampled years, although velocities remained consistent (Table 16).

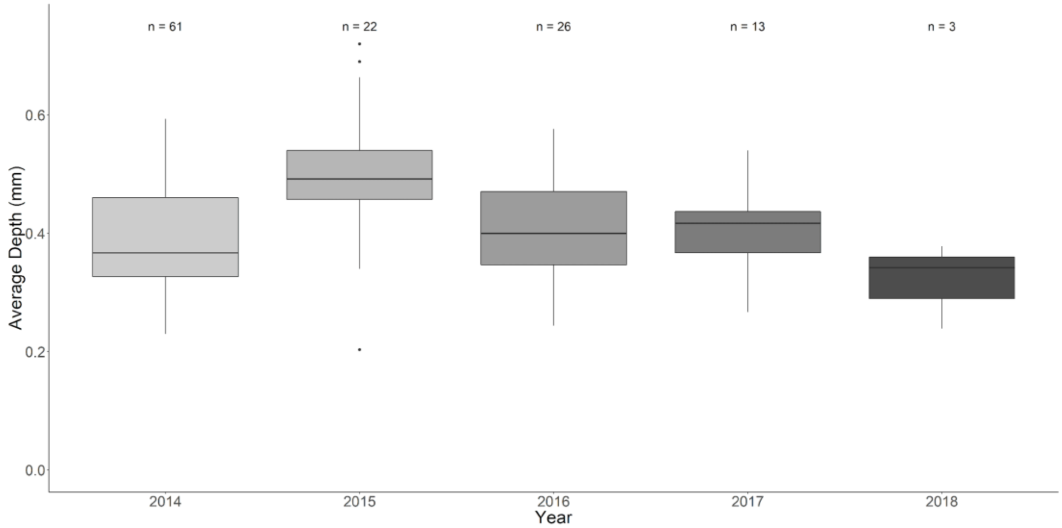

Figure 29: ***Water depths (m) measured at Chinook Salmon redds in the Lower Bridge River from 2014 to 2018. Solid lines denote the annual median water depth and sample size by year is annotated above respective boxes. Boxes represent the interquartile range (IQR). Lines represent the range excluding outliers, which are shown as points.***

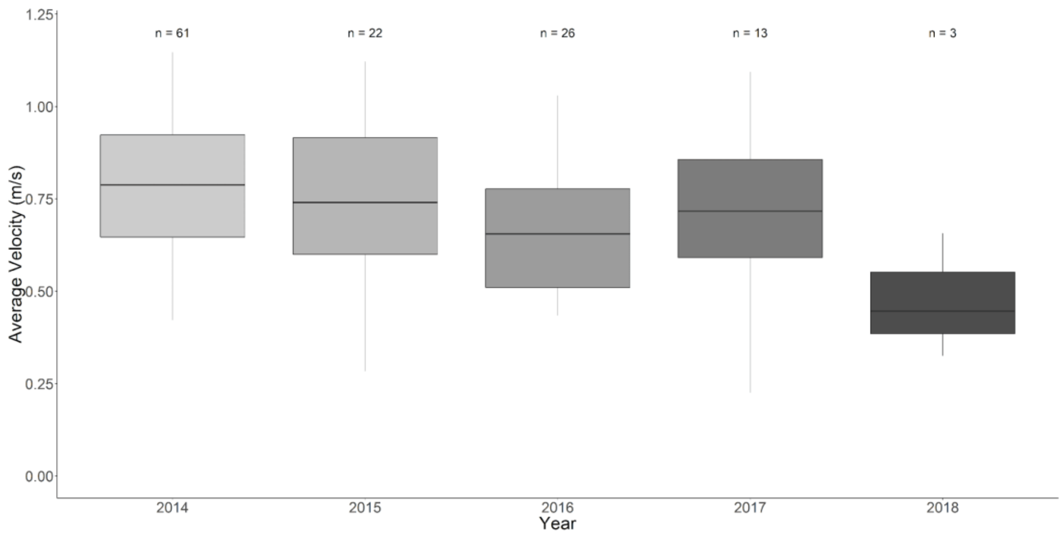

Figure 30: ***Water velocity (m^3 s^{-1}) measured at Chinook Salmon redds in the Lower Bridge River from 2014 to 2018. Solid lines denote the annual median water velocity and sample size by year is annotated above respective boxes. Boxes represent the interquartile range (IQR). Lines represent the range excluding outliers, which are shown as points.***

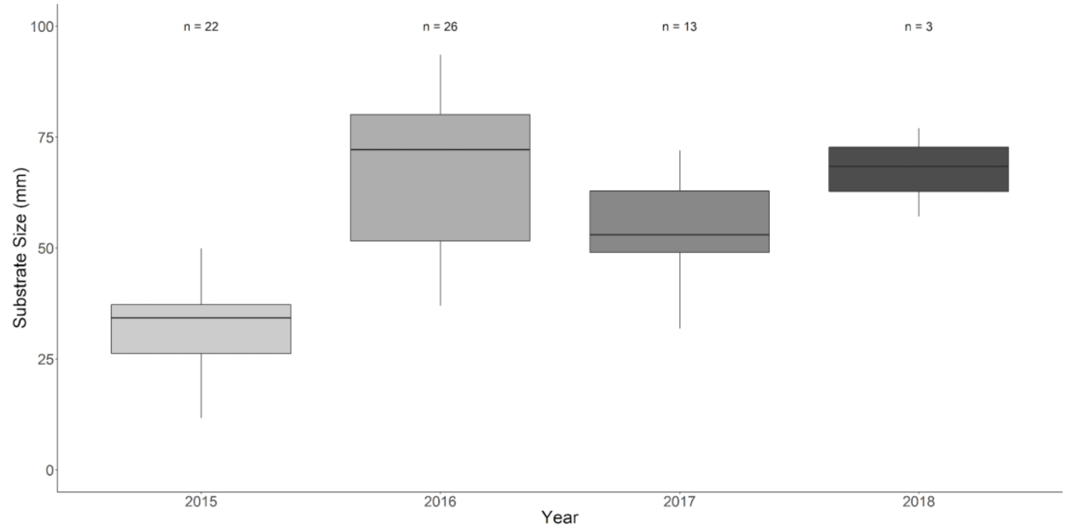

Figure 31: Geometric mean (D_{50}) of substrate measured at the tail spill of Chinook Salmon redds in the Lower Bridge River from 2015 to 2018. Solid lines denote the annual median D_{50} and sample size by year is annotated above respective boxes. Boxes represent the interquartile range (IQR). Lines represent the range excluding outliers, which are shown as points. Substrate assessments were not conducted prior to 2015.

Table 16: Tukey Test results to identify significant between year differences in redd habitat measures for Chinook Salmon.

	Water Depth (m)		Water Velocity (m s^{-1})		Substrate Geometric Mean (mm)	
	Difference	P-Value	Difference	P Value	Difference	P Value
2014-2015	0.11	< 0.001	-0.04	0.92	NA	NA
2014-2016	0.02	0.95	-0.11	0.08	NA	NA
2014-2017	0.01	1.00	-0.09	0.57	NA	NA
2014-2018	-0.07	0.65	-0.30	0.06	NA	NA
2015-2016	-0.09	0.01	-0.08	0.62	35.80	< 0.001
2015-2017	-0.10	0.02	-0.05	0.95	22.59	< 0.001
2015-2018	-0.18	0.01	-0.27	0.15	35.89	< 0.001
2016-2017	< -0.01	1.00	0.03	0.99	-13.21	0.03
2016-2018	-0.09	0.50	-0.19	0.47	0.09	1.00
2017-2018	-0.08	0.60	-0.22	0.37	13.30	0.45

Redd Distribution

Chinook Salmon continue to use spawning locations identified in previous years (2014 to 2017). Of the three redds surveyed in 2018, one was in Fraser Lake (34.4rkm), and two in Eagle (38.8 river km; Figure 32). Since the modified flow regime was implemented in the LBR, Chinook Salmon have started spawning above the Reach 3/4 boundary between Eagle and Bluenose (2 in 2016, 38.2 rkm), Eagle (2 in 2018) and Longskinny (1 in 2017, 39.6 rkm). There were no redds constructed in 2017 or 2018 between Bluenose and Cobra (38.2 to 32.2 rkm), and these were the first years where Fraser Lake was a key spawning location (**Error! Reference source not found.**). No redds were observed during Reach 2 streamwalks or Reach 1 spot counts.

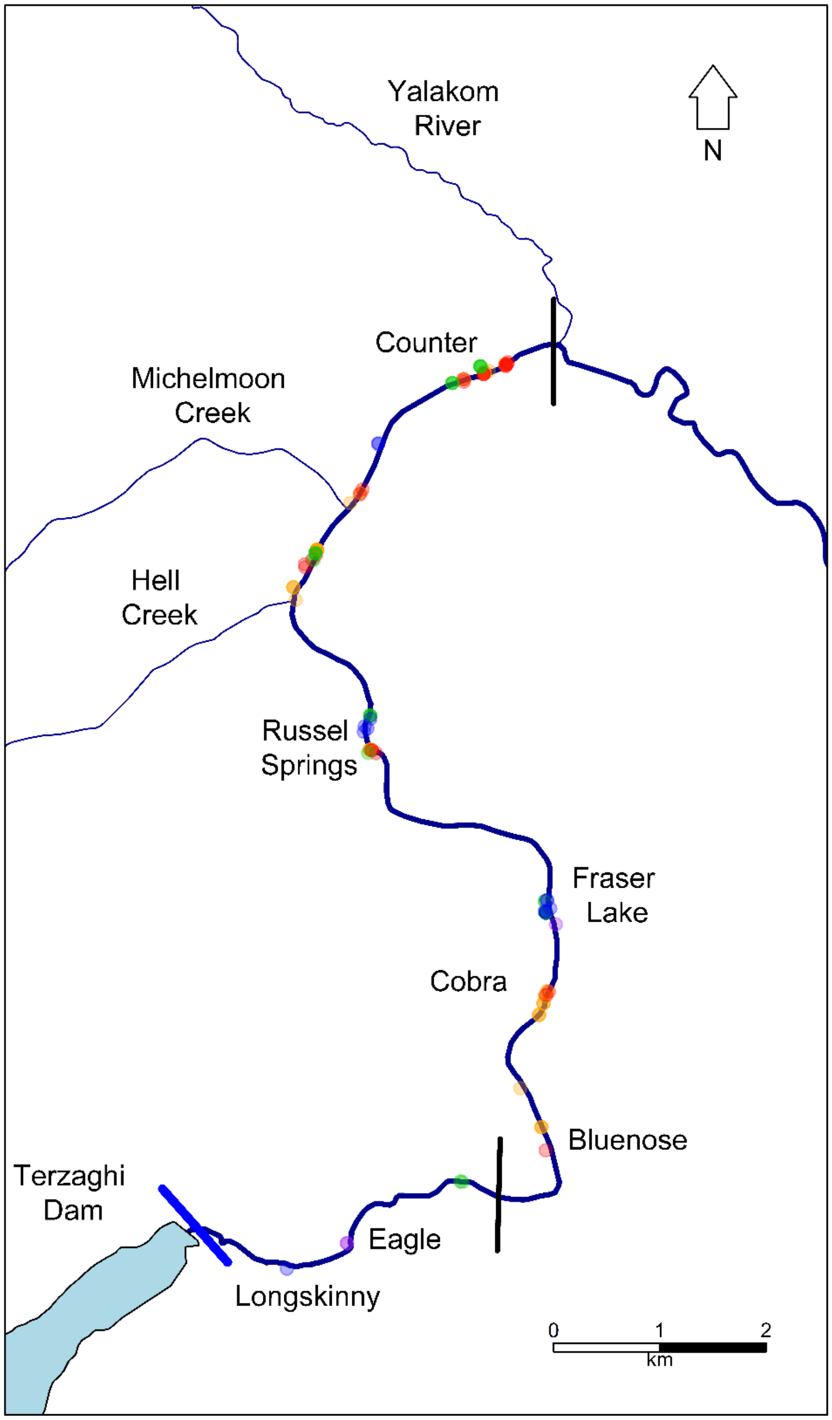

Figure 32: Location of Chinook Salmon redds in the Lower Bridge River in 2014 (orange), 2015 (red), 2016 (green), 2017 (blue) and 2018 (purple). Black lines indicate the boundary between reaches.

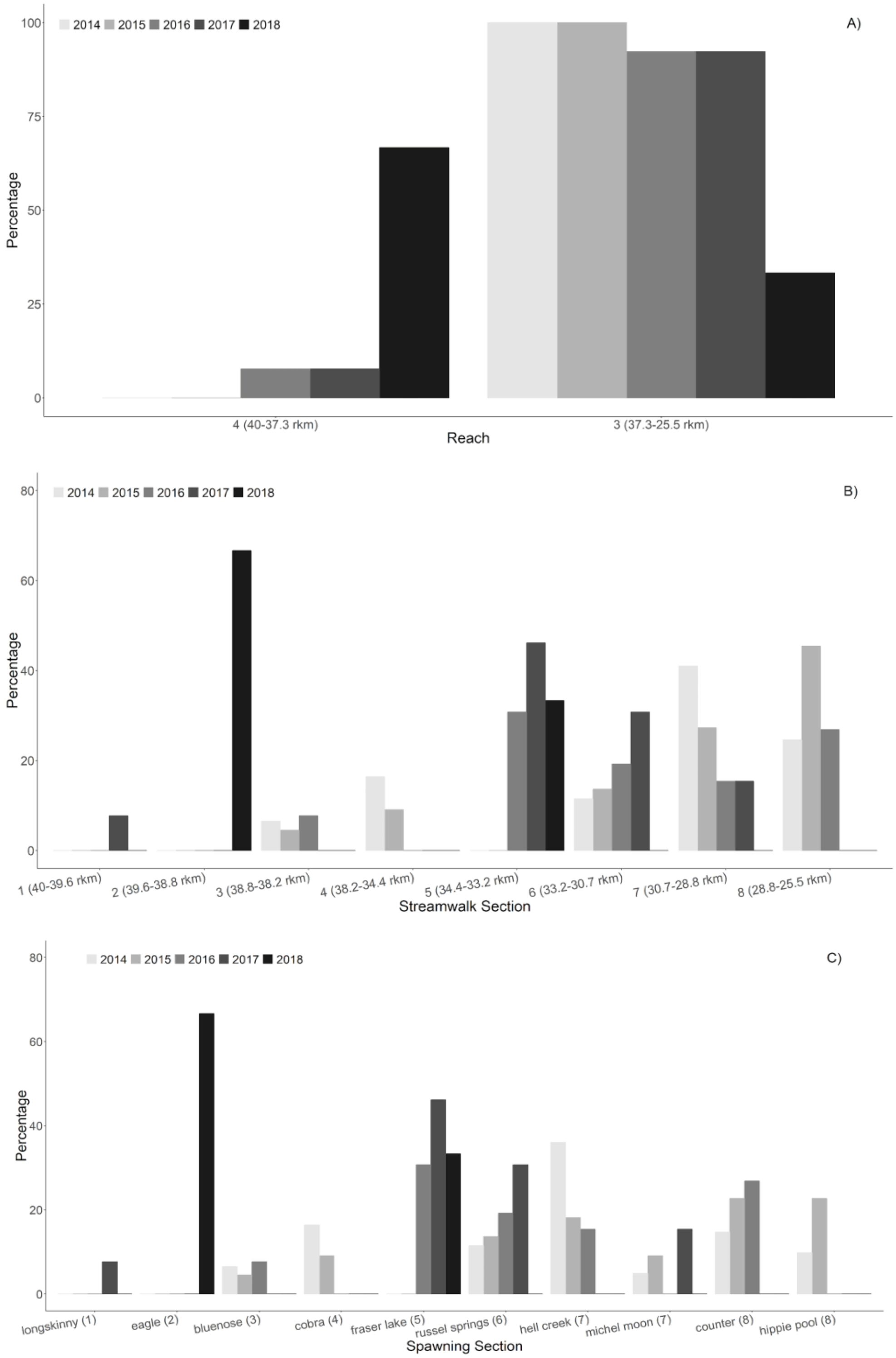

Figure 33: Percentage of Chinook redds by year across each surveyed A) reach, B) streamwalk section and C) spawning location within each streamwalk section (identified in parentheses). Redd surveys were conducted between 2014-2018 from Terzaghi Dam to the Yalakom confluence. Number of redds counted in each year was variable (n = 61, 22, 26, 13, 3 for each subsequent year) but it is notable that only percentages for 2018 only consider three redds.

3.5.2 Coho Salmon Redds

Redd Characteristics

Thirty-one Coho Salmon redds were observed in Reach 3 (n = 10) and 4 (n = 21) in the first year of successful Coho redd evaluations in the LBR. Redds sampled in 2018 had an average water depth of 0.32 m ± 0.10, velocity of 0.39 m s^{-1} ± 0.14 and substrate geometric mean of 36 mm ± 10. Depth and velocity of Coho redds were similar to Chinook redds in 2018 (0.3 m and 0.48 m s^{-1}, respectively), however, the geometric mean of substrate used was about half the size (68 mm in 2018). Coho Salmon redds were about three times smaller and narrower than Chinook Salmon measured from 2015-2018 (Coho = 1.39 x 0.85 m, Chinook = 420 x 245 m). Measured redds in 2018 were in either run (28/31) or riffle habitat (3/31), the three redds in riffle habitat were found at Fraser Lake (34.4 rkm).

Redd Distribution

Coho Salmon continue to use key spawning sections also identified for Chinook Salmon between 2014-2018 (Figure 34). Redds were located primarily in reach 4 (stream walk sections 1 and 2, 48% and 19% respectively), having 4 redds constructed just below Plunge Pool (39.9 rkm), 11 in Longskinny (39.6 rkm), 1 at the inflow to Eagle pool (39.1 rkm) and 5 at the outflow of Eagle pool (38.8 rkm; Figure 35). The 10 redds found in Reach 3 were located at Fraser Lake (5; 34.4rkm), Russel Springs (2; 33.2 rkm), Michel Moon (4; 28.3 rkm; Figure 36). No redds were observed during Reach 2 streamwalks or Reach 1 spot counts.

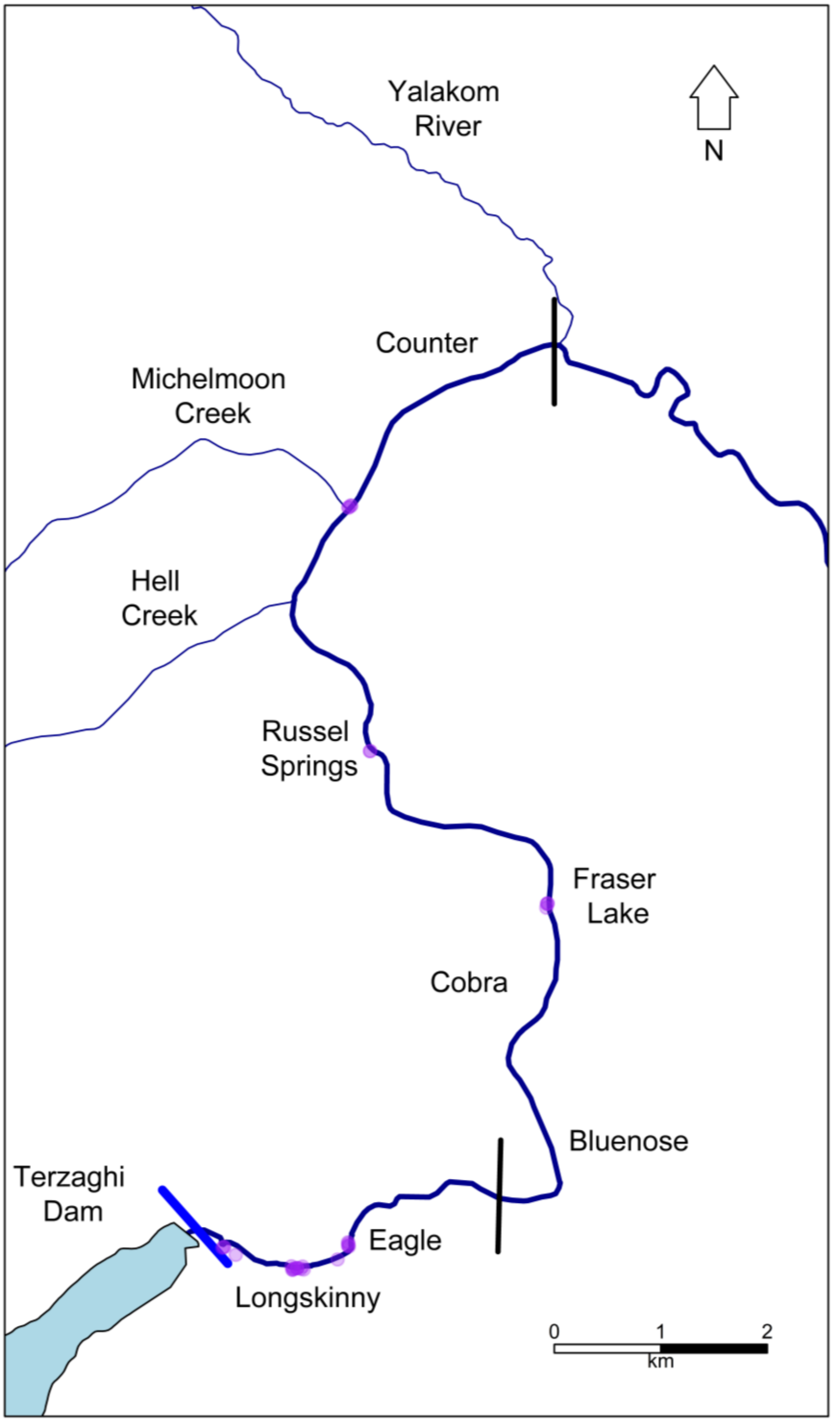

*Figure 34: **Location of Coho Salmon redds in the Lower Bridge River in 2018. Black lines indicate the boundary between reaches 2 and 3 and reaches 3 and 4.***

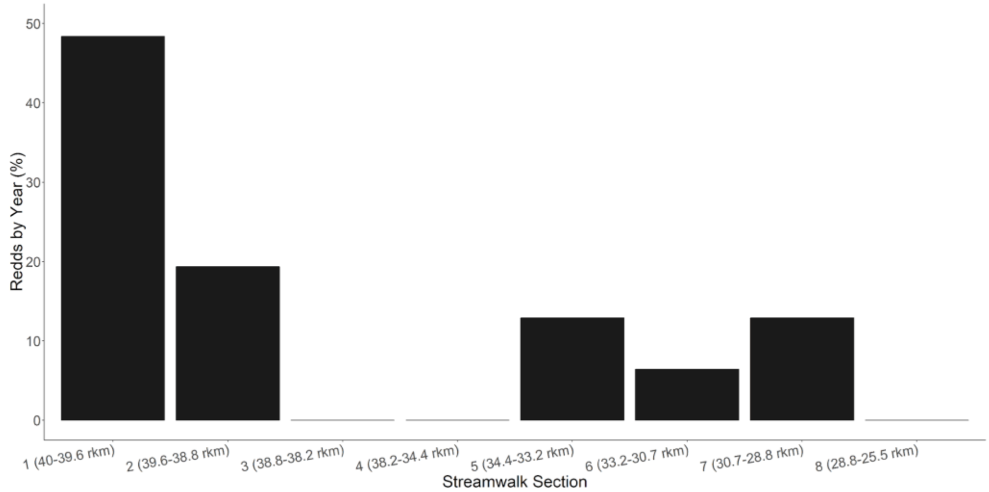

Figure 35: ***Relative proportion of surveyed Coho redds in 2018, distributed by streamwalk section, plotted from Terzaghi Dam to the Yalakom confluence (n = 31).***

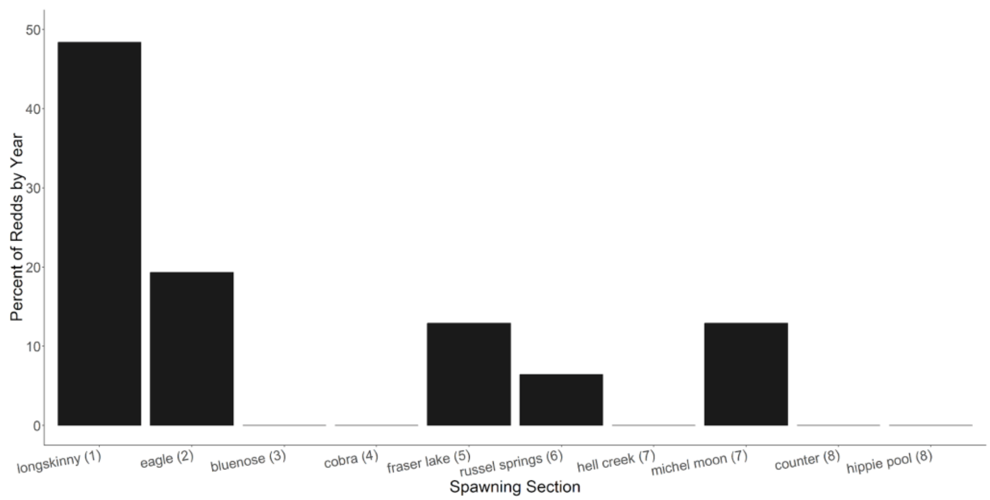

Figure 36: ***Relative proportion of surveyed Coho redds in 2018, distributed by unique spawning section, plotted from Terzaghi Dam to the Yalakom confluence (n = 31).***

3.6 Spawning Habitat Characteristics

Fifteen habitat units in Reach 3 and 4 (13 and 2, respectively) were observed to support Chinook Salmon spawning in previous years (telemetry, streamwalks and redd data; Figure 37). Across all habitat units, 63 transects were established in Reach 3 and 4 (n = 53 and 10, respectively), and covered 20,768 m^2 of stream (17,409 and 3359m^2, respectively). A total of 3727 m^2 of suitable chinook spawning habitat was calculated for all habitat units in spring 2018 (18% of total area surveyed), the majority located in Reach 3 (82%; Figure 38). In the Fall 2018 survey, a total of 3595 m^2 of suitable chinook spawning habitat was calculated across all habitat units (17% of total area surveyed), a reduction of 4% of WUA. Important spawning habitat for both Chinook and Coho salmon in 2018 was identified in Longskinny and Eagle in Reach 4 (39.6-38.8 rkm) and Fraser Lake in Reach 3 (34.4 rkm; see section 3.5). The percent WUA for Chinook Salmon in Longskinny and Fraser Lake (17 and 20% of total area surveyed) was reduced after the high flows of 2018 by 15% and 13%, respectively (Figure 38). Habitat surveys were not completed at Eagle in the Spring of 2018 but will be included for comparison in the future. There was no statistical difference between $\log_{10}$ WUA for Chinook Salmon before and after the high flows of 2018 (ANOVA: $F_{1, 26} = 0.01$, $p = 0.94$). Additional habitat transects were established in Reach 3 and 4, as well as a complete survey of potential spawning habitat in Reach 2 were completed in Fall 2018 and will be reported on in following years.

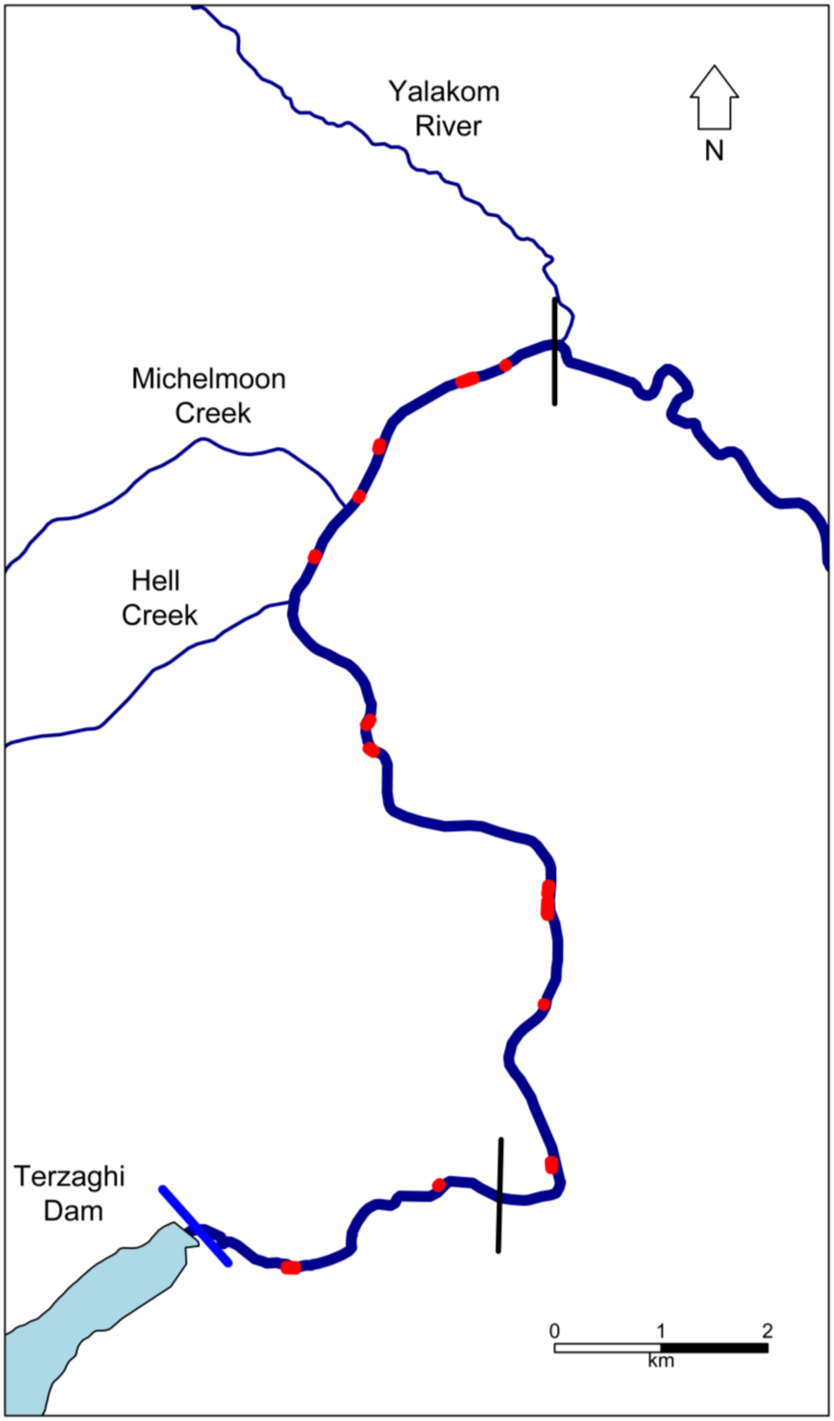

Figure 37: Polygons of Habitat Suitability Index sites/habitat units (red) where transects were completed in both the Spring and Fall in Reach 3 and 4 of the Lower Bridge River in 2018. Black lines indicate the boundary between Reach 2 and 3 and Reach 3 and 4.

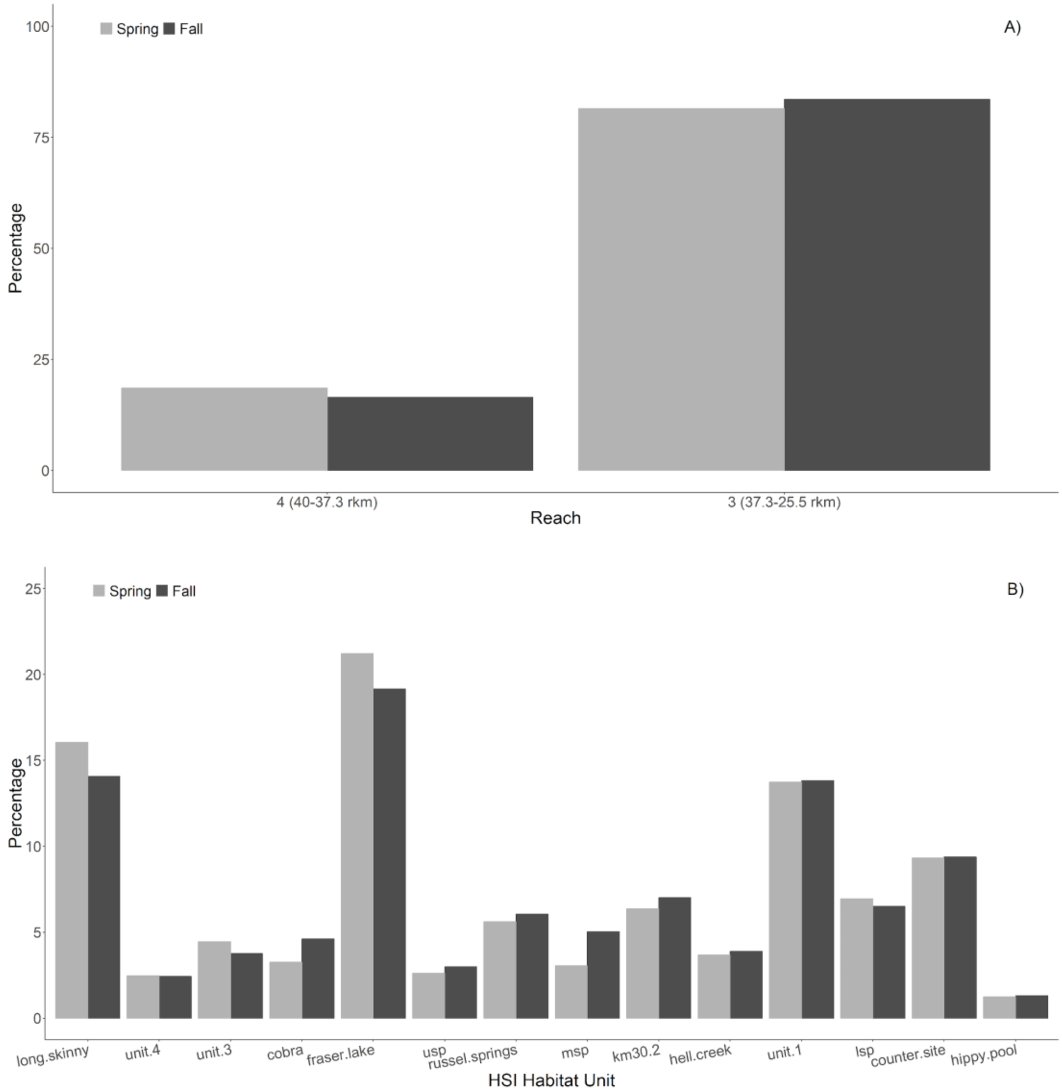

***Figure 38:** Percent of weighted usable Chinook Spawning area, separated by A) reach and B) unique habitat unit surveyed in the Spring and Fall of 2018.*

3.7 Ageing of Adult Salmon and Steelhead

Age was assigned according to the European age designation system (Koo 1962), which expresses age or age classes as two numbers separated by a decimal. The first number represents the number of years or winters the fish spent in freshwater and the second number represents the number of years or winters spent in the ocean. Collectively the two numbers can be added together to provide a total age or age class at maturity.

3.7.1 Steelhead Trout

A total of 46 Steelhead Trout scales were successfully aged between 2014 and 2018. Thirteen tagged fish did not enter the LBR in 2017 and 2018, based on radio telemetry and were assumed to not be of

LBR origin. Scale samples for these fish were not aged. Poor angling conditions in 2016 resulted in low capture rates and few Steelhead Trout moving into the LBR (n = 3). Taken together, the majority of sampled individuals were age 5 (2.3, 3.2), followed by ages 6 (3.3), 4 (2.2, 3.1), 3 (2.1) and 2 (1.1) (n = 31, 14, 13, 1, and 1, respectively), with fork lengths averaging 782 ± 114 mm, 786 ± 101mm, 735 ± 122mm, 800 and 635mm, respectively (Figure 39; Appendix 4). Overall, there did not appear to be difference in average size among age classes; no statistical testing was conducted.

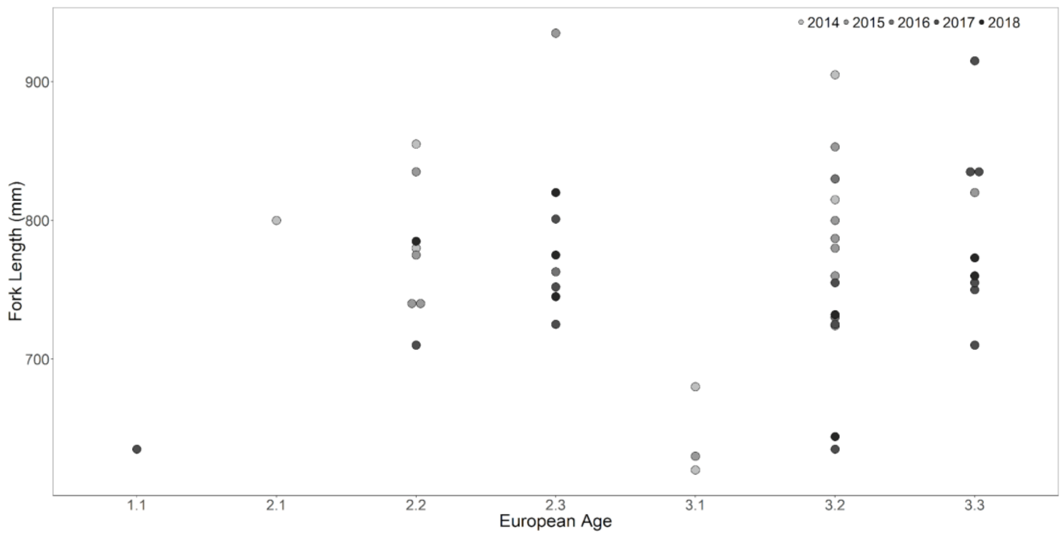

***Figure 39:** Length-at-age of Steelhead Trout sampled from 2014 to 2018 (n = 62). European age classifications are shown. The first number represents years in freshwater and the second years in the ocean. Added together, the two numbers provide a total age or age class at maturity.*

Six distinct age classes were identified among all the fish sampled (Figure 40). The dominant age class by year was: 2.2 in 2014, 3.2 in 2015 and 2016, 3.3 in 2017 and 2.3 in 2018. In 2016, there was a shift in the dominant age class of spawners from age 5 (3.2) to age 6 (3.3) in 2017 (brood year 2011) and back to age 5 (2.3) in 2018 (brood year 2013). Returning fish in 2017 and 2018 at had 2 or more winters in saltwater (except a 1.1 in 2017) which would preclude them high flows in the Lower Bridge River (Spring 2016) as juveniles. Scales collected in 2017 and 2018 did not show evidence of repeat spawning, a behavior that was observed through scale analysis in previous years.

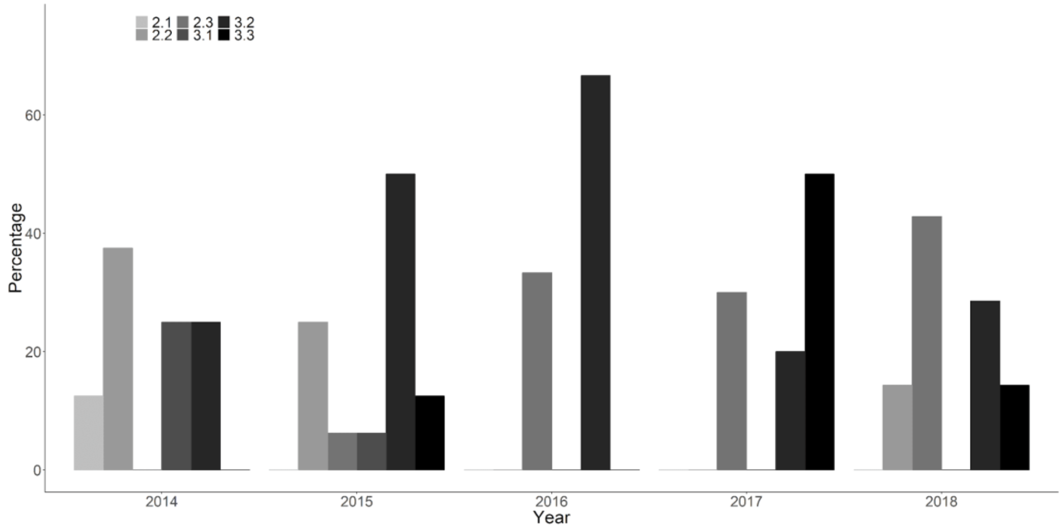

Figure 40: Relative proportion of Steelhead Trout age classes by year from 2014 to 2018.

3.7.2 Chinook Salmon

A total of 50 Chinook Salmon scales were successfully aged between 2014 and 2018. One tagged fish did not enter the LBR in 2017 and 2018, based on radio telemetry and were assumed to not be of LBR origin. Scale samples for these fish were not aged. The majority of sampled individuals were age 4 (1.3, n = 45), compared to age 3 (1.2, n = 3), with fork lengths (mean ± S.D) averaging 812 ± 111 mm and 673 ± 29 mm, respectively (Figure 41; Appendix 4). Individuals returning as 3-year-old fish (all 1.2) consistently had smaller fork lengths among spawners.

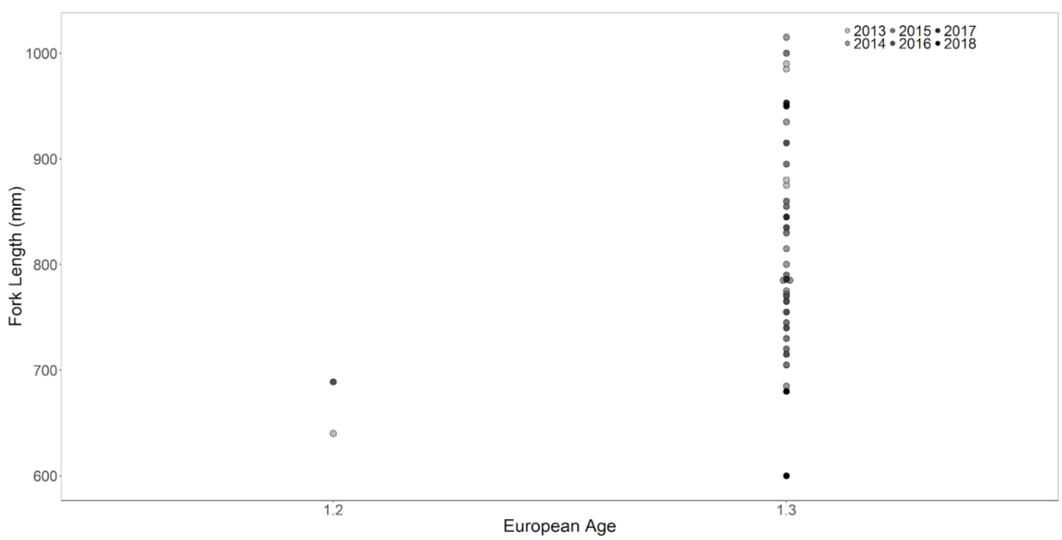

Figure 41: Length-at-age of Chinook Salmon by year sampled from 2013 to 2018 (n = 48). European age classifications are shown. The first number represents years in freshwater and the second years in the ocean. Added together, the two numbers provide a total age or age class at maturity.

Two distinct age classes were identified among the Chinook Salmon scales. Most of the LBR spawners returned at age 4 (1.3), and few individuals returned at age 3 (1.2) (Figure 42). All of the scales read displayed a yearling (stream-type) life history with juveniles spending one winter in freshwater. Poor returns and capture efficiency in 2017 and 2018 limited our analysis to 3 and 2 individuals, respectively, all displayed a life history of 1.3 (brood year 2013 and 2014, respectively). No adults from which scales were collected would have experienced high flows in the Lower Bridge River (Spring 2016) as juveniles.

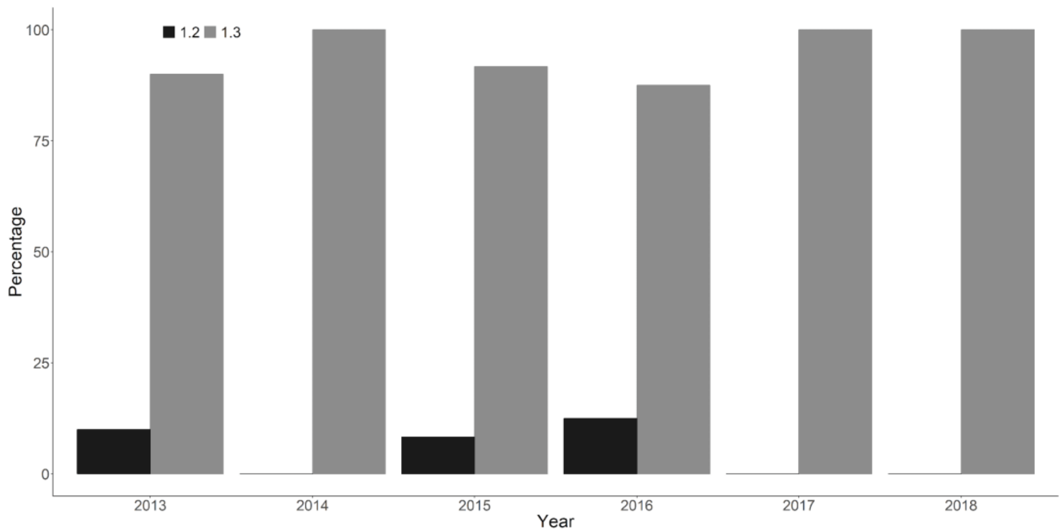

Figure 42: Relative proportion of Chinook Salmon age classes by year from 2013 to 2018.

3.7.3 Coho Salmon

In total of 153 Coho Salmon scales were analyzed from 2011 to 2018. Twenty scales were removed from the sample due to high amounts of scale resorption or because the fish were not of Bridge River origin based on radio telemetry. The majority of sampled individuals were age 2 (1.1, n = 123), compared to age 3 (2.1, n = 43), with fork lengths averaging 624 ± 115 mm and 632 ± 67 mm, respectively (Figure 43; Appendix 4). Overall, there did not appear to be an average size difference between the age classes observed, however, the range in fork lengths was considerably smaller for age 3 individuals.

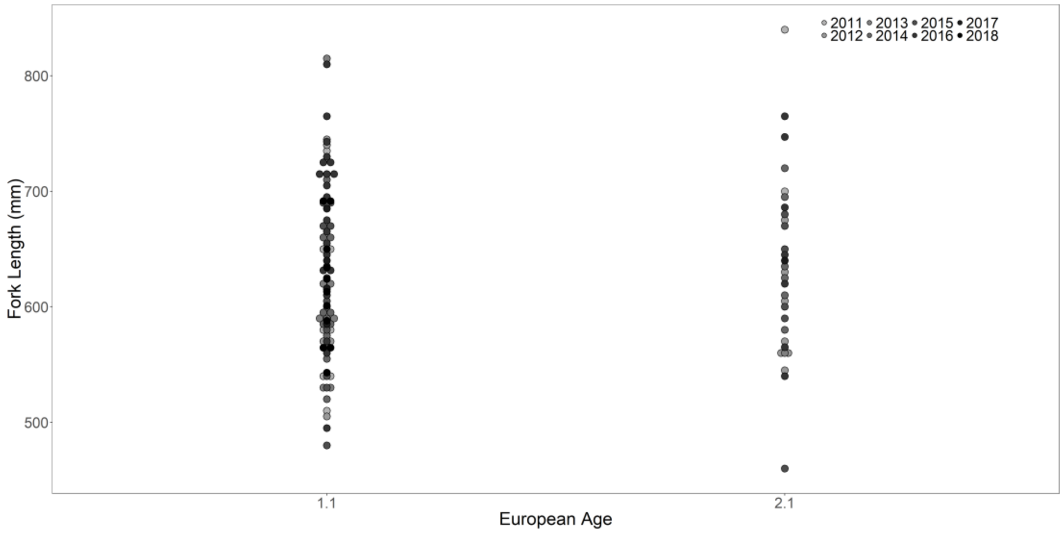

Figure 43: Length-at-age of Coho Salmon sampled from 2011 to 2018 (n = 153). European age classifications are shown. The first number represents years in freshwater and the second years in the ocean. Added together, the two numbers provide a total age or age class at maturity. Note a female in 2014 exhibited an age 3 (1.2) life history, however, was removed from the above figure for clarity.

LBR Coho Salmon returned most frequently at age 2 (1.1) followed by age 3 (2.1, Figure 44). Three distinct age classes were identified among Coho Salmon: 1.1, 1.2 and 2.1. All age classes displayed similar juvenile life histories, whereby juveniles spent 1-2 years (winters) in freshwater before out-migrating as smolts. Only one individual had a 1.2 age (2014), where it spent 1 winter in freshwater and 2 in saltwater. In 2017 and 2018, age 1.1 was the only life history displayed in fish that spawned in the LBR. All 2018 Coho Salmon (n = 17), represented the 2015 brood year and first returning salmon affected by the high flow regime in 2016.

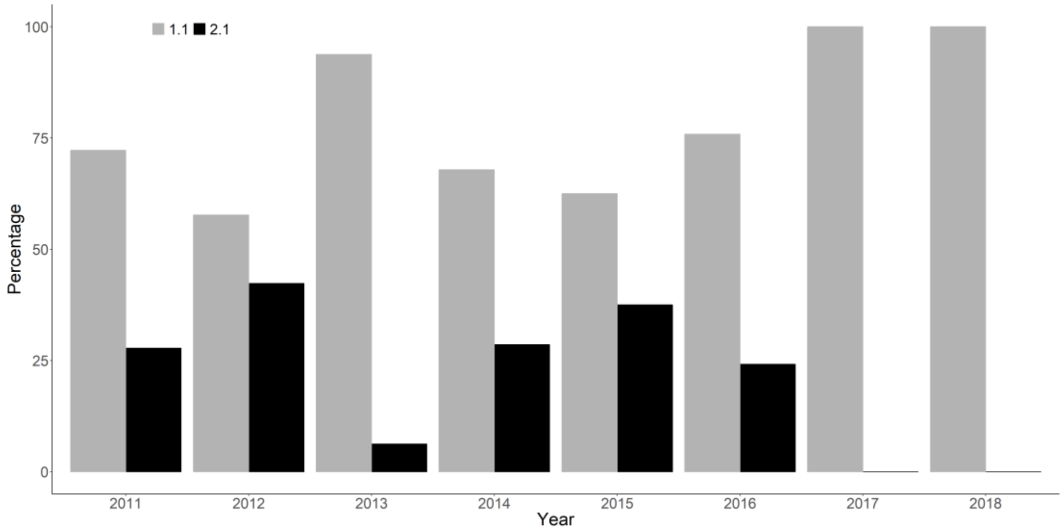

Figure 44: Relative proportion of Coho Salmon age classes by year from 2011 to 2018. Note a female in 2014 exhibited an age 3 (1.2) life history, however, was removed from the above figure for clarity.

4.0 Discussion

BRGMON-3 continues to collect data on adult abundance estimates and habitat quantity and quality needed to support the interpretation of results of BRGMON-1, in which juvenile salmonid standing crop abundance and biomass will be used to evaluate the effects of different flow regimes in the LBR. The spawner abundance data collected under this monitor cannot be used as a direct indicator of the effect of the instream flow regime, nor can changes in spawner abundance be used as a response to flow impacts. Combining BRGMON-3 spawner abundance data with juvenile productivity, life history and movement data collected in BRGMON-1 will improve the quality of the primary aquatic benefit response measure, juvenile standing crop abundance and biomass. However, redd and reach-wide habitat assessments will additionally evaluate how quantity and quality of available spawning and rearing habitat is affected by different flow treatments. This work contributes to addressing the primary management question of BRGMON-1 that aims to determine how informative the use of juvenile salmonid standing crop biomass is as the primary indicator of impact of flow. BRGMON-3 also addresses two management questions:

1) What is the annual abundance, timing, and distribution of adult salmon and steelhead spawning in the Lower Bridge River and are these aspects of spawning affected by the instream flow regime?
2) What is the quality and quantity of spawning habitat in the Lower Bridge River and how is spawning habitat affected by the instream flow regime?

Monitoring to support these management questions will also address new monitoring objectives that have been added in response to the high flows on the Lower Bridge River that have occurred since 2016. These questions are:

3) Have flow releases from Terzaghi Dam under the modified flow regime affected the quality and quantity of spawning habitat available in the Lower Bridge River? If so, what are the potential effects on fish and what mitigation options are available?

4) Have flow releases from Terzaghi Dam under the modified flow regime affected the distribution of adult spawning in the Lower Bridge River? If so, what are the potential effects on spawning success and what mitigation options are available?

Steelhead, Chinook and Coho Salmon abundance have been estimated using counting technologies since 2012. Resistivity counter estimates were calculated for all species in 2014 and 2015. In 2016 the high flow regime significantly damaged counter infrastructure and we have since successfully combined resistivity and sonar counting technologies. Nonetheless, high flows and other modifications have challenged enumeration efforts. Discharges above the counter operation threshold of 20 $m^3 s^{-1}$ have occurred since 2016 during the Steelhead migration, preventing a complete abundance estimate. The installation of a fish fence in 2018 prevented a complete abundance estimate for Chinook and for Coho, only a partial abundance estimate is available in 2017 due to post-season data loss. Complete estimates are available for Chinook and Coho in 2017 and 2018, respectively. Despite these methodological changes and data gaps, a combination of various methods have helped ensure quality enumeration estimates. For example, telemetry provides important data on fish movement and residence times, metrics that are included to improve the accuracy of streamwalk derived abundance estimates.

High discharges from Terzaghi Dam are projected to continue for several years, and there are uncertainties regarding the effects of these changes to fish communities in the LBR. To fully understand effects of flow to juvenile standing crop abundance and biomass in BRGMON-1, changes to spawner abundance and distribution, habitat characteristics and age classes given flow across monitor years will be taken into account during a synthesis. Beginning in 2018, this monitoring program began to address uncertainties regarding the quality of spawning habitat for Chinook Salmon in the LBR. Redd surveys completed from 2014 to 2018 have identified and characterised the habitat conditions used by spawning Chinook and Coho (2018 only). This, along with reach wide habitat assessments, will aim to estimate the quantity and quality of habitat in the LBR.

Given differences in life history characteristics among species that result in variations in the flow characteristics experienced, enumeration and monitoring methods were adapted as necessary to effectively address management questions for each species. Accordingly, results are herein discussed by species.

4.1 Steelhead Trout

Although Steelhead Trout estimates were low (14 fish in 2018), they were also incomplete given challenges with operating electronic counter equipment during high flows. We therefore emphasize that this be considered a minimum count, and that continued monitoring and analysis is required. Given that the high flow regime will continue, IFR will work towards developing a model to estimate Steelhead Salmon abundance after the removal of counting equipment. For example, we may be able to use available data to estimate Steelhead spawner abundances for times that the counter is not operational using a model that integrates raw counts from counter and run-timing determined by radio telemetry (Korman et al 2007). Briefly, the model estimates the proportion of fish counted each day and the fraction of the total run that is present on that day. Telemetry data can inform the fraction of the run that is present each day and can be estimated based on the cumulative proportion of the run that has arrived and the cumulative proportion that has left (Korman and Schick 2017).

Enumeration and Tagging

Steelhead Trout enumeration will continue to be a challenge during high flow periods because they migrate during freshet and the ascending limb of the discharge curve. Telemetry data suggest that the counters were likely operating during a portion of the peak migration; most radio-tagged fish (63%) moved past the counter site before May 9, 2018, when flows were below 15 $m^3 s^{-1}$ and counting equipment was still in place. However, delaying the ramp up in discharge from Terzaghi Dam, ideally until mid- to late- May, would enable enumeration of a higher percentage of the upstream Steelhead migration, thereby improving spawner abundance estimates, and decrease the need to make inferences of future abundance using modelled run timing curves. The telemetry component of the study will continue to provide valuable information, especially during high flows when counters aren't operational. Data on Steelhead Trout migration timing and spawning locations in the LBR can inform how high discharge during this critical life stage is affecting steelhead spawning behaviour and success. For the first time during this monitor, four radio-tagged individuals were assumed to have spawned in Reach 2. Increased effort of mobile tracking will occur in Reach 2 to provide more accurate locations of spawning areas in this reach.

High discharge during the steelhead spawning period will likely have a negative effect on spawning migration and selection of spawning location. Under high discharges, Steelhead will be required to expend more energy during spawning, and some spawning locations may not be available. If spawning is successful, redds may also be scoured during the high discharge in July More detailed mobile tracking in the future will help identify specific locations where fish may be spawning so that the areas could be assessed for redds post high flows.

Scale Analysis

Steelhead Trout display a variety of life history characteristics, with six distinct age classes. Age of individuals ranged from 2 to 6 years and multiple saltwater checks observed on scales provides evidence of repeat spawning behavior, although not observed in 2017 and 2018 scales. Age 4 (2.2 or 3.1) and 5 (2.3 or 3.2) fish dominated returns in 2014 and 2015, respectively. In 2016, few fish were captured, and all fish that moved into the LBR were age 5, characterized by 2.3 (n = 1) and 3.2 (n = 2). There appears to be a shift towards older individuals returning to spawn compared to earlier years of the monitor, age 5 and 6 fish dominated returns from 2016 to 2018. No scale samples collected in 2017 or 2018 were from fish that would have been exposed to the high flow regime in the LBR, beginning in 2016. Of course, repeat spawners have returned in previous years, however, longer residency in freshwater, saltwater or both, may be indicative of habitat quality in each of these habitats. In the Keogh river, smolt age increased, from age 2 dominated to age 3 and 4 dominance, when fertilization additions ceased and when the number of Pink Salmon returns decreased dramatically (McCubbing et al. 2011). Mechanisms underlying this transition to older fish (e.g., freshwater or marine survival, habitat quality) in the Bridge River are unknown, but a more robust sample size would increase our confidence in making these inferences. These relationships are complex and will require further analysis and collaboration with BRGMON-1 to provide greater insight into the river conditions during the brood and rearing years of these fish.

4.2 Chinook Salmon

Discharge from Terzaghi Dam returned to WUP targets prior to the historic run timing of Chinook Salmon in 2018, and thus, unlike for Steelhead, electronic counters operated effectively throughout the spawning period. However, the installation of a full channel-spanning fish fence directly upstream of the electronic counters prevented upstream migration after August 31, having considerable impacts on counter data, the AUC estimate calculated using visual stream walk data, and Reach 3 and 4 redd surveys. Abundance estimates, telemetry data and redd surveys are therefore limited to only fish that passed upstream of the counter prior to installation on August 29. The 2018 counter estimate of 30 should therefore be considered a minimum, as it does not reflect the entire Chinook migration period.

Effects of Fish Fence Installation

The fish fence had considerable effects on migration of Chinook Salmon past the counter site into Reach 3. Counter operation under the current design (i.e. resistivity counter and sonar) have not recorded Chinook passing over the counter pad section (river right) until 2018. A single up count was visually confirmed after August 29, as individuals were likely looking for alternative ways around the obstruction. Down counts over the counter were likely a result of the recycling behavior exhibited below the fence, as there is limited holding water between the counter infrastructure and the fish fence. This behavior was also recorded by the sonar imaging, which showed a considerable increase in the recorded number of up and down movements immediately following fence installation. This increased the amount of processing time considerably, as an experienced technician must manually remove fish that recycled within the sonar beam to reduce errors of miscalculation from improper classification of up or down counts. Of the two fish captured in the LBR, neither moved upstream of the counter prior to August 29, or were captured by the fish fence. Detections from the telemetry station downstream of the counter infrastructure confirmed recycling behavior by repeated detections over the course of a few days. With so few individuals on spawning grounds, only three redds were surveyed for comparison with previous years.

Enumeration and Tagging

Chinook Salmon enumeration will continue to be a challenge if the fish fence is installed immediately upstream of the counter infrastructure. Abundance estimates were calculated using only the sonar, as no fish passed up or down over the counter pads prior to August 29. The linear model used to predict actual length from ARIS lengths was poor compared with previous years and biased low for the first time. There was evidence of 'shadows' on larger individuals that may have resulted in the over estimation of ARIS fish lengths. As a result, all fish with ARIS lengths above 800mm were manually counted by hand, while lengths below 800m were predicted using the linear model. This improved the accuracy of up models, but not down models. Accuracy of length data provided by the sonar can be reduced when fish spend too little time, move laterally in the beam, or swim too close to the sensor. More of these variables were observed this year and may be related to the recycling behaviour cause by the fence. There was much more variability in the measured lengths compared to previous years which likely limited the effectiveness of our model. It is possible that our calculated Chinook size cut off

(>650mm) is classifying Sockeye as Chinook, skewing spawner abundance estimates high. Measures will be taken in the future to improve the clarity of sonar images.

Despite consistent effort, angling produced poor results for Chinook Salmon in 2018. Poor catches may be related to continued low returns to the LBR , a trend that has been observed throughout the Fraser Watershed (Pacific Salmon Commission, 2019), combined with poor angling conditions, as previous quality angling sites have been infilled by gravel. The AUC model fit for Chinook Salmon in 2018 was similar to that of the counter (25 and 30, respectively), the lowest observed in the past five years. The AUC estimate has low uncertainty (narrow CIs) and previously was about three-fold (2.8) lower than the counter abundance estimate. Similar results were observed in 2015 and 2014, when the AUC estimates were 2.5 and 2.0 times lower respectively than the resistivity counter estimate (Melville et al. 2015 and Burnett et al. 2016). The discrepancy between the two estimates could be a result of poor model fit from sonar measurements, or linked back to limitations of visual count surveys, which are subjective in nature and rely on the ability of each surveyor to minimize their observation errors.

The primary source of error in AUC estimates is OE, which can bias towards both over- or under-estimating spawner abundance, and can vary among individual observers, survey days and systems (Grant et al. 2007, Muhlfeld et al. 2006). OE is the ratio of the number of spawners observed *versus* the true number of spawners present. This source of error is common to any form of visual stock assessment survey methodology, but the degree to which it contributes to error in population estimates depends on the unique set of survey conditions such as water clarity, depth, light conditions, habitat complexity, spawner density and observer experience (Gallagher and Gallagher 2005). Importantly, with the installation of the fish fence and low number of tagged fish, OE for 2018 could not be calculated and instead, standard metrics (OE =0.5 and SL = 10.5 days) were used in the AUC calculation (Ramos-Espinoza et al. 2018). This OE value could be an overestimation and thus could be underestimating the population. Additional data will inform the range in OE for various river conditions, particularly in years with smaller spawner sample sizes, and can be used to improve the precision of AUC estimates from years in which OE can not be directly calculated.

Spawning Habitat

Water depths and velocities at redds were the lowest observed, but with only 3 redds surveyed it is challenging to infer changes in spawner habitat preference. Similar to the high flow years of 2016 and 2017, the geometric mean of spawning substrate has increased 2-fold from survey years prior to high flows. The smaller substrate may have been mobilized during the high flows and the remaining substrate is getting larger, though is still of suitable size for Chinook Salmon spawning (Riebe et al. 2014). Distribution of redds appears to be shifting further upstream towards Terzaghi Dam since 2017, away from previously used sites in Streamwalk sections 7 and 8 (Russel Springs to counter). Fraser Lake has become an important spawning site for Chinook Salmon since 2017 and this was the first year that redds were surveyed at Eagle (Streamwalk Section 2, Reach 4).

There are potential consequences to an upstream shift in spawning habitat into Reach 4, as warmer dam discharge temperatures may cause earlier emergence of fry than occurred prior to the modified flow regime. Timing of emergence has evolved to precisely optimize fry survival in response to local environmental cyclesRamos-Espinoza et al. (2018) found that the warmer water temperatures in Reach 4 would result in 50% fry emergence based on accumulated thermal units (ATUs) by January. In comparison, water temperatures in other areas downstream in the LBR are cooler resulting in later emergence. Therefore, if the modified flow regime leads to selection of habitat for spawning that would expose redds to higher temperatures, effects to juvenile survival, monitored in BRGMON-1, are possible

Redd data was also used to inform the specific location of habitat surveys, initiated in 2018 to determine the quantity and quality of suitable spawning habitat for Chinook Salmon in the LBR. Available spawning habitat was reduced by 4% across Reach 3 and 4 in the summer survey relative to the fall survey, which represents a reduction in approximately 13 reddsbased on average dimensions from Chinook redd surveys 2015-2018. However, differences were not statistically significant. Both redd surveys and streamwalks have identified Longskinny, Eagle, Fraser Lake and Russel Springs as important spawning locations for Chinook Salmon in recent years. Longskinny and Fraser Lake lost 92 and 102 m^2 of habitat, respectively (19 redds collectively), while Russel Springs and the mid spawning platform (Fraser Lake to Russel Springs) gained 18 m^2 of habitat (approximately 2 redds). The spawning area at Eagle was not included in the spring sampling (pre-2018 flow) but will be included in future habitat surveys. Surveys will include potential spawning areas across the entirety of Reach 2 and select areas in Reach 1 (access limited), to quantify the amount of Chinook spawning area present. Data were provided to Kerr Wood Leidal (KWL) for further substrate analysis and modelling (Lower Bridge River Pilot Spawning Gravel Supplementation). Continued habitat data collection will provide valuable information regarding both availability and distribution of suitable spawning areas for Chinook Salmon in response to the modified flow regime in the LBR.

Scale Analysis

Chinook Salmon displayed two life history characteristics, either returning at age 3 (1.2) or 4 (1.3), both ages having spent a single year in freshwater. Returning fish in 2017 and 2018 all showed a 1.3 life history characteristic (brood year 2013 and 2014, respectively), which meant that they were not exposed to the high flow regime in Spring 2016. Most of the returning adults were age 4 (1.3, also referred to as 5_2 (Gilbert-Rich method), a finding that is consistent with historical observations (Richard Bailey, personal communication). Individuals returning at age 3 were consistently the smallest fish measured, which may have consequences on fecundity or reproductive success (McPhail 2007). Due to the recent low numbers of juveniles observed in BRGMON-1 stock assessment surveys since 2017, it has been suggested that LBR Chinook Salmon have shifted from stream-type to ocean-type life history strategy. Our data, however, suggests that there has been no change in the life history of LBR Chinook Salmon, although continued collection of scales and otoliths will shed valuable insight into whether a life history change has occurred in more recent years (i.e., 2012-2018).

4.3 Coho Salmon

Coho Salmon estimates by both the counter and AUC were higher than those observed in the previous four years. This was the first occurrence for Coho Salmon that the AUC estimate was higher than the counter abundance. This was also the first year of successful Coho redd surveys in Reach 3 and 4.

Enumeration and Tagging

The counter (multibeam sonar only) was operational throughout the entire spawning period of Coho Salmon (October 1 – December 6) and estimated that 545 Coho Salmon moved above the counter site and spawned throughout Reach 3 and 4. Similar to Chinook, the linear model used to predict actual length from ARIS lengths was poor compared with previous years and again biased low. The same 'shadows' around fish were seen again during the Coho migration, overestimating ARIS fish lengths. ARIS lengths above 800 mm were again manually counted by hand, while lengths below 800m were predicted using the linear model. As with Chinook, this improved the up accuracy but not the down accuracy of linear models. Additionally, there was much more variability in measured lengths compared to previous years which likely limited the model effectiveness, and it is possible that large resident fish were misclassified as Coho Salmon (<650mm). Measures will be taken in the future to improve the clarity of sonar images. Down counts were also removed after November 25 as the distribution of down counts across the migration period was multi-model and likely incorporated kelting behaviors. November 25th was determined by using the date where 95% of all down counts have been observed based on a normal distribution of the kelt timing period and aligned with the observed increase in down counts towards the end of November.

Nearly half of the 25 coho that were tagged following capture by angling in Reach 1 and 2 spawned in Reach 3 and 4, in locations consistent with previous monitoring years (Ramos-Espinoza et al. 2018. The AUC model for Coho Salmon in 2018 estimated an abundance of 1,245, the highest observed since 2013. This estimate was two times higher than the counter estimate, which was the first time this has been observed during this monitor. AUC estimates are strongly influenced by OE and SL, which are the primary source of error in these estimates (Grant et al. 2007, Muhlfeld et al. 2006). Even small changes in these parameters can cause large fluctuation in abundance estimates, which is the primary source of errors in these estimates. In a review study by Grant et al. (2007) of visual enumeration surveys for 26 Lower Fraser area streams an average OE of 0.68 was estimated for all assessed streams, and all but one stream was above 0.5. If we were to use their mean the estimate the abundance estimate would decrease significantly (>50%). The continued high tag deployment for Coho will likely increase our confidence around the OE and SL estimates, improving the precision of future AUC estimates.

Coho Salmon returning in 2018 represent the 2015 brood year and first generation of salmon post-high flows to return and spawn in the LBR. This was the lowest adult abundance observed by the counter over the course of this monitor. Conversely, the AUC estimate was the highest observed over the monitor, further years of enumeration data will clarify whether this was an anomaly or whether our visual observations are improving with updated OE and SL calculations.

Spawning Habitat

Redd surveys were completed for the first time in 2018 and 31 Coho redds were assessed. Redd distribution is concentrated in Reach 4 at Longskinny and Eagle and at locations also used by Chinook in Reach 3 (Fraser Lake, Russel Springs and Hell Creek), observations similar to streamwalk data, where Coho concentrate in sections 1 and 2 (Terzaghi Dam to Eagle). The observation that Coho are utilizing finer substrate at locations near the dam negates the argument made for Chinook that high discharges cause downstream mobilization of smaller substrate. However, individuals spawned predominantly in tail outs from large pools in Reach 4, potentially exploiting areas of small gravel deposition. The inclusion of Coho redd surveys will provide valuable information, especially with the depressed Chinook Salmon abundances.

Scale Analysis

Coho Salmon displayed two dominant life history characteristics, either returning at age 2 (1.1) or 3 (2.1), with both ages having spent a single year in saltwater. In 2017 and 2018, all Coho returned at age 2 (1.1) after only spending a single year in freshwater. The age 2 fish from 2018 would be brood from 2015, the first generation of juveniles affected by high flows. Continued collection of scales and otoliths will provide valuable information to BRGMON-1 stock assessment surveys.

Summary and Recommendations

Data presented herein summarizes the findings of BRGMON-3 in 2018, which was a high flow year in the Lower Bridge River with flows in May-July exceeding thediffering from the prescribed WUP 6 cms hydrograph. Observations made during this monitor will provide information to aide BRGMON-1, in which effects of instream flow regimes on juvenile standing crop abundance and biomass will be assessed. Steelhead Trout and Chinook Salmon returnes continue to see low numbers, as seen in other tributaries of the Fraser River, while Coho Salmon returns have been similar over the past four years. Redd surveys are becoming more challenging for Chinook Salmon given their low abundances, however, 2018 was the first year of successful Coho Salmon redd surveys and are scheduled to continue in the future. Habitat surveys were conducted for the first time in 2018, to evaluate change in potential spawning habitat in the LBR during the modified flow regime and so far there appears to be no significant changes in Reach 3 and 4 as a result of the 2018 flows; however, not data are available to compare with pre-high flow conditions. The fish fence used for Chinook brood stock collection disrupted much of the data collection for Chinook Salmon in Reach 3 and 4 and will continue to affect observations if methodology is not addressed. Recommendations for 2019 BRGMON-3 data collection include:

- Delay Terzaghi flow release above WUP target discharge until end of May/early June to allow for more accurate Steelhead Trout enumeration.
- Continued use of radio telemetry to improve estimates of Steelhead Trout spawning locations and Chinook and Coho Salmon AUC abundance estimates.
- Continued redd surveys combined with habitat surveys to compare species preferred habitat with available habitat in the LBR.
- If a fish fence is to be installed during the Chinook Salmon migration period, we recommend that it be moved greater than 250m upstream to minimize recycling over the counter while still allowing for an accurate abundance estimate.

InStream has gained significant improvements in the speed of sonar data processing since the start of the BRGMON-3 sonar data collection project. In 2017, the Echoview software preprocessed sonar data from the entire year in 204 days. Although the software preprocessing step required minimal human supervision, the amount of time used was significant and did not produce in-season estimates in a timely fashion. In 2018, the preprocessing speed was increased drastically due to improvements in the computer hardware and software. In total, sonar data for all species was pre-processed within 97 days. We anticipate the amount of time required for the pre-processing step of the 2019 sonar data to be similar to the pre-processing time in 2018, even with the addition of Pink Salmon in the system. As an additional improvement to data quality, changes in the mounting structure of the sonar in 2019 will enable the sonar to collect more accurate fish length data.

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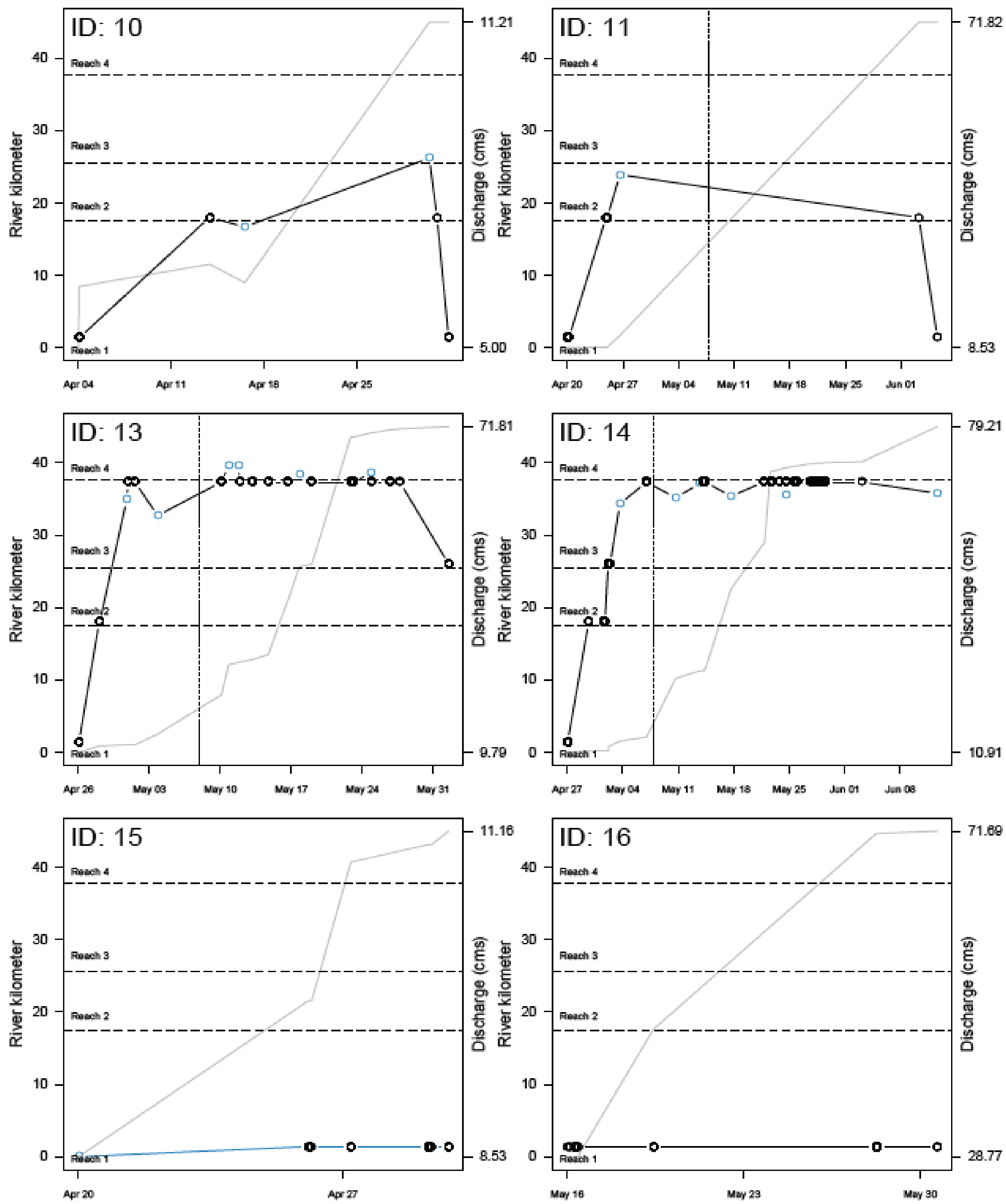
6.0 Appendices

Appendix 1

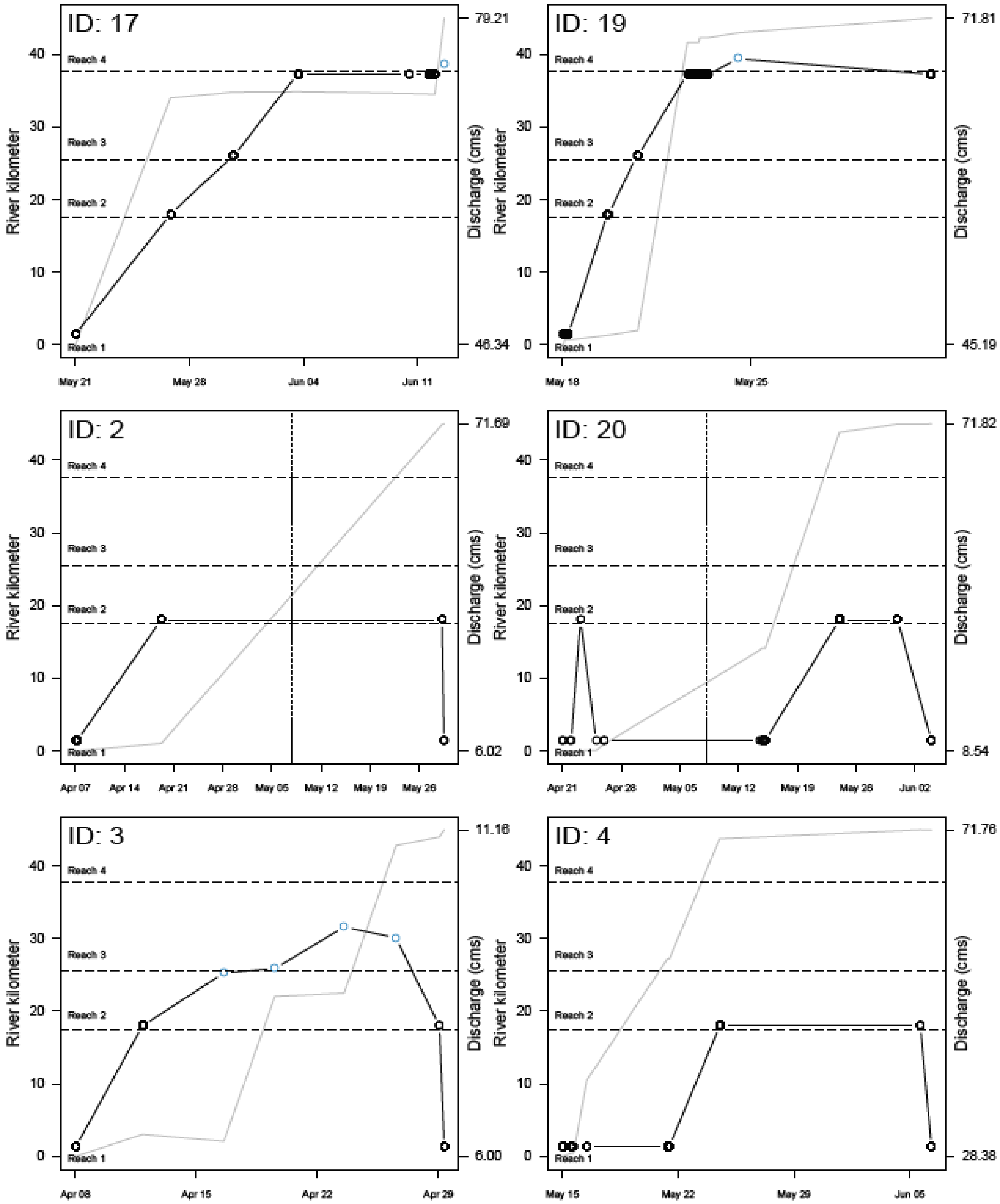
Date	Location	Tagging KM	Species	Sex	Fork Length (mm)	Freq	Code
2018-03-12	Seton Confluence	NA	SH	F	855	149.72	1
2018-03-14	Seton Confluence	NA	SH	F	745	149.74	2
2018-03-16	Seton Confluence	NA	SH	F	705	149.72	3
2018-03-16	Seton Confluence	NA	SH	F	644	149.74	4
2018-03-16	Seton Confluence	NA	SH	F	745	149.72	5
2018-03-16	Seton Confluence	NA	SH	F	773	149.74	6
2018-03-16	Seton Confluence	NA	SH	F	773	149.72	7
2018-03-19	Seton Confluence	NA	SH	F	775	149.74	8
2018-03-20	Seton Confluence	NA	SH	M	871	149.72	9
2018-03-20	Seton Confluence	NA	SH	F	785	149.74	10
2018-03-20	Seton Confluence	NA	SH	F	760	149.72	11
2018-03-25	Seton Confluence	NA	SH	M	660	149.74	12
2018-03-27	Seton Confluence	NA	SH	M	750	149.72	13
2018-03-29	Seton Confluence	NA	SH	M	752	149.74	14
2018-03-30	Seton Confluence	NA	SH	F	630	149.72	15
2018-04-02	Seton Confluence	NA	SH	M	870	149.74	16
2018-04-02	Seton Confluence	NA	SH	F	NA	149.72	17
2018-04-02	Seton Confluence	NA	SH	F	852	149.74	18
2018-04-18	Seton Confluence	NA	SH	F	732	149.72	19
2018-04-20	Seton Confluence	NA	SH	F	820	149.74	20
2018-07-27	Bridge Confluence	0.5	CH	F	950	149.72	28
2018-08-30	Yalakom	25	CH	F	680	149.72	26
2018-09-05	Yalakom	25	CH	F	600	149.74	27
2018-09-27	Bridge Confluence	0.5	CO	F	613	149.74	29
2018-09-27	Bridge Confluence	0.5	CO	M	564	149.72	30
2018-09-28	Bridge Confluence	0.5	CO	F	543	149.74	31
2018-09-29	Bridge Confluence	0.5	CO	M	650	149.72	32
2018-09-29	Bridge Confluence	0.5	CO	M	624	149.74	33
2018-09-29	Bridge Confluence	0.5	CO	M	515	149.72	34
2018-09-30	Bridge Confluence	0.5	CO	M	580	149.74	35
2018-09-30	Bridge Confluence	0.5	CO	M	690	149.74	36
2018-09-30	Bridge Confluence	0.5	CO	F	571	149.72	37
2018-10-03	Bridge Confluence	0.5	CO	M	591	149.74	38
2018-10-03	Bridge Confluence	0.5	CO	M	564	149.72	39
2018-10-04	Bridge Confluence	0.5	CO	F	622	149.74	40
2018-10-06	Camoo	18	CO	M	565	149.72	41
2018-10-15	Fish Pool	2	CO	F	571	149.74	42
2018-10-19	Bridge Confluence	0.5	CO	F	601	149.72	43
2018-10-22	Bridge Confluence	0.5	CO	F	543	149.74	44
2018-10-25	Bridge Confluence	0.5	CO	F	680	149.72	45
2018-10-25	Bridge Confluence	0.5	CO	F	570	149.74	46
2018-10-27	Bridge Confluence	0.5	CO	M	610	149.72	47
2018-10-29	Yalakom	17	CO	M	562	149.72	49
2018-11-03	Bridge Confluence	0.5	CO	M	610	149.74	48
2018-11-04	Bridge Confluence	0.5	CO	M	NA	149.74	50
2018-11-10	Camoo	18	CO	M	650	149.72	51
2018-11-10	Camoo	18	CO	F	610	149.74	52
2018-11-12	Bridge Confluence	0.5	CO	M	550	149.72	53

Salmon and trout that were collected and gastrically tagged with radio tags.

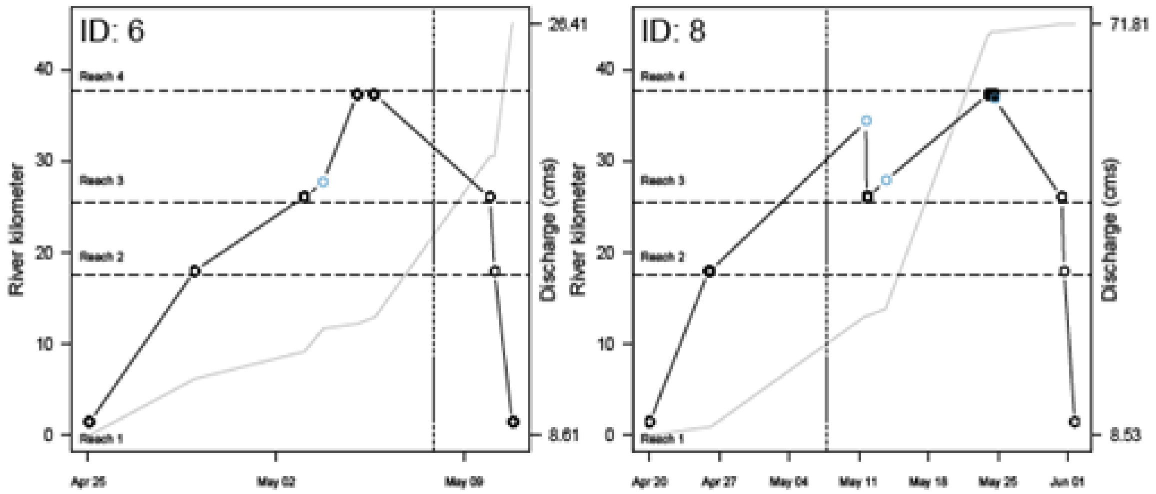
Appendix 2



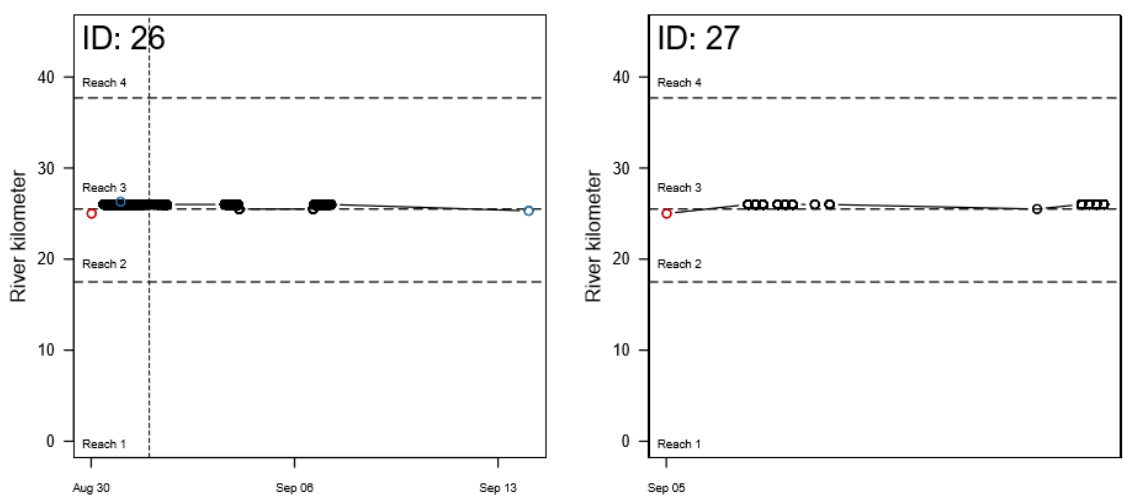
Detection histories of radio tagged adult Steelhead Trout in the Lower Bridge River in 2018. Black lines connect the data collected from fixed (black) and mobile (blue) telemetry. Grey lines correspond to the discharge in the Lower Bridge River at Terzaghi Dam. Dashed lines indicate boundaries between different reaches.



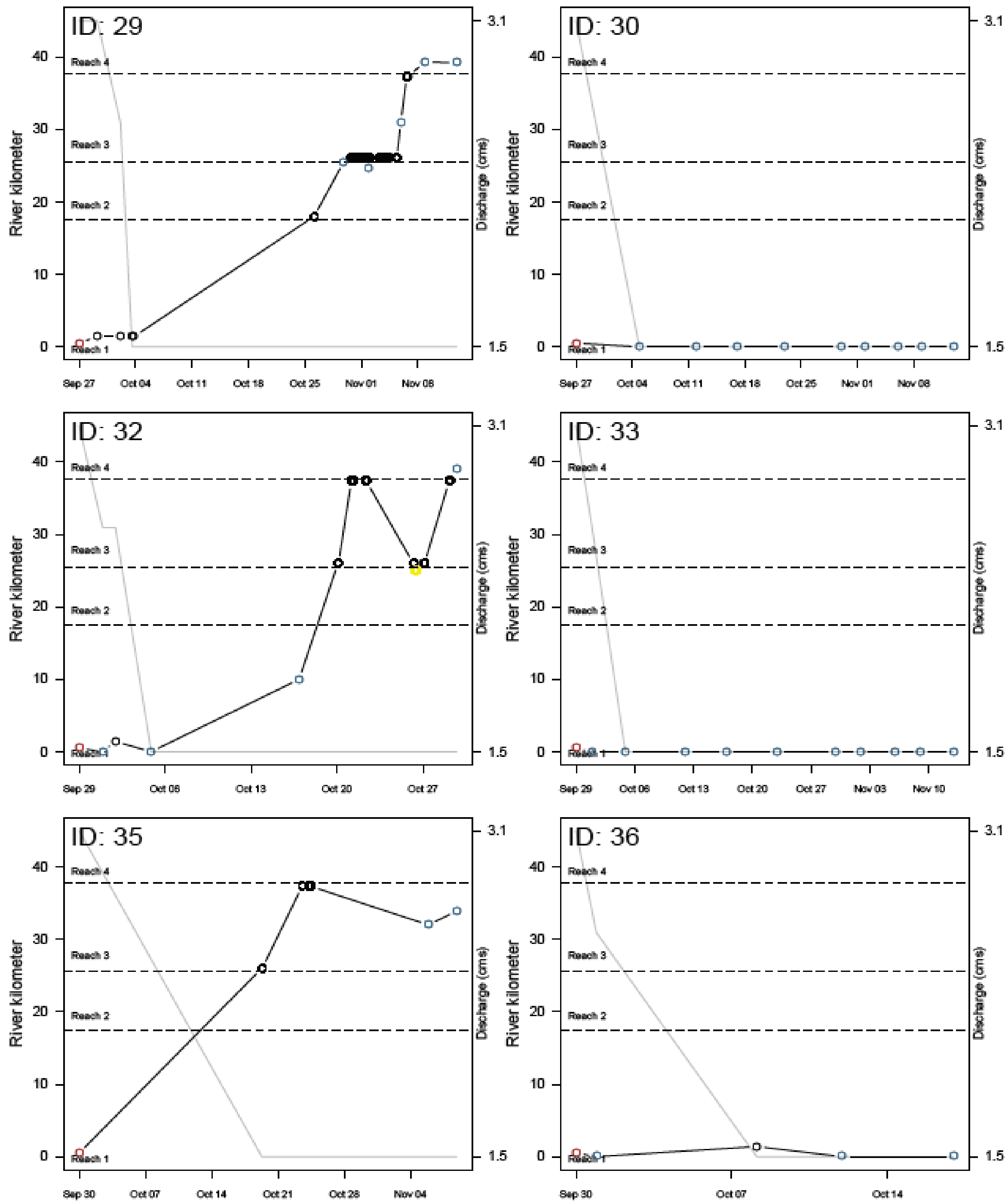
(Cont'd) Detection histories of radio tagged adult Steelhead Trout in the Lower Bridge River in 2018. Black lines connect the data collected from fixed (black) and mobile (blue) telemetry. Grey lines correspond to the discharge in the Lower Bridge River at Terzaghi Dam. Dashed lines indicate boundaries between different reaches.



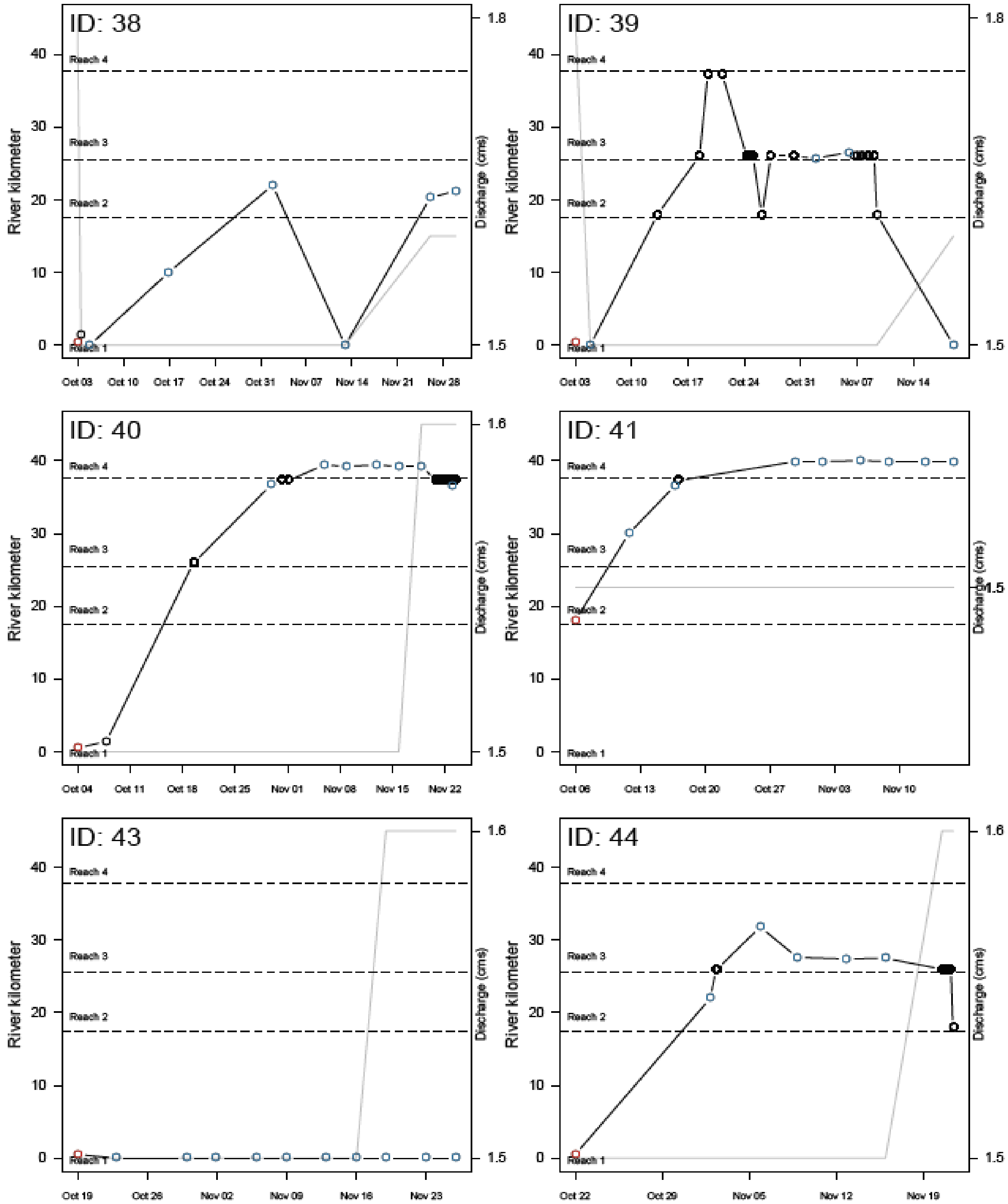
(Cont'd) Detection histories of radio tagged adult Steelhead Trout in the Lower Bridge River in 2018. Black lines connect the data collected from fixed (black) and mobile (blue) telemetry. Grey lines correspond to the discharge in the Lower Bridge River at Terzaghi Dam. Dashed lines indicate boundaries between different reaches.



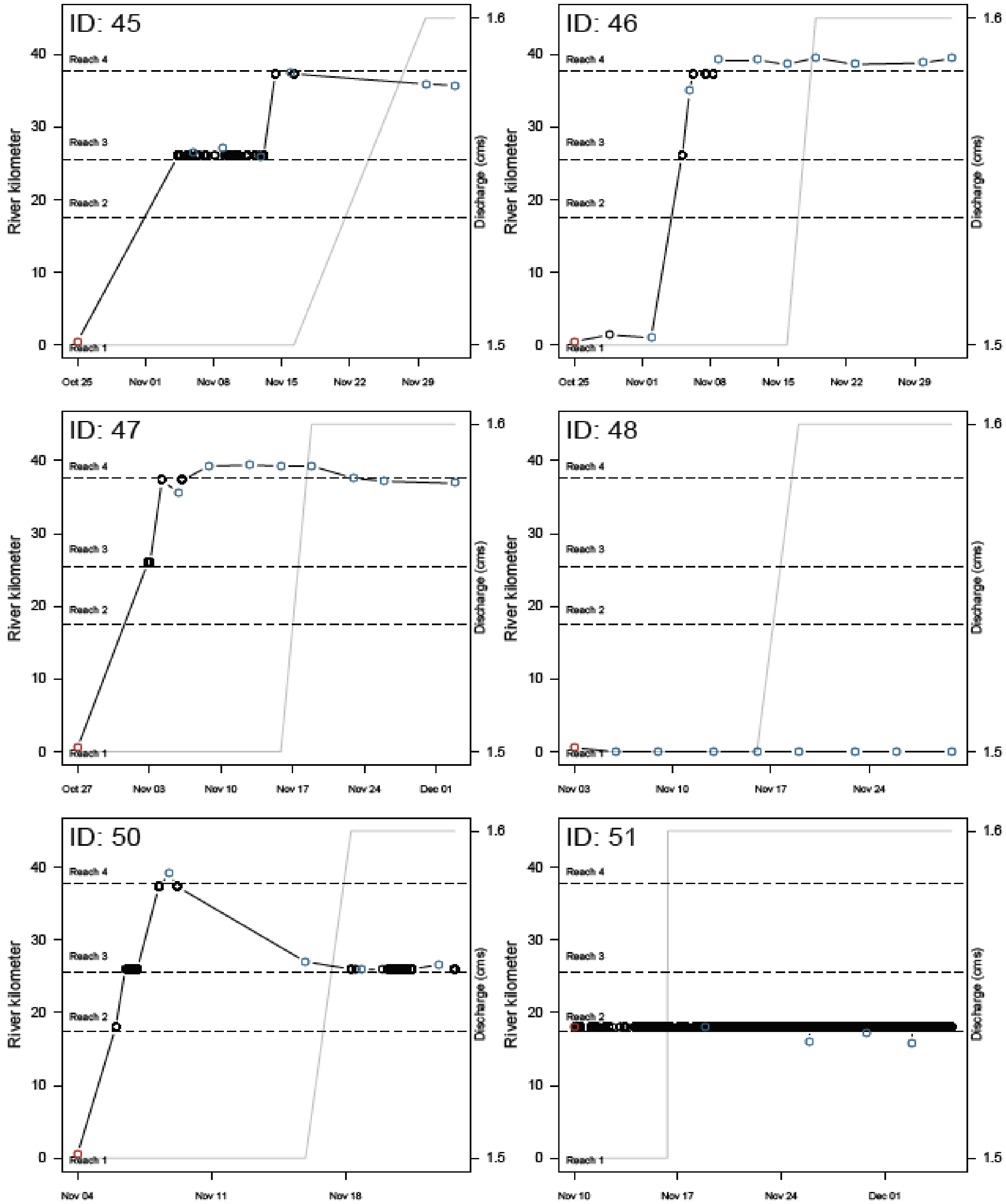
Detection histories of radio tagged adult Chinook Salmon in the Lower Bridge River in 2018. Black lines connect the release information (red) with data collected from fixed (black) and mobile (blue) telemetry. Dashed lines indicate boundaries between different reaches. Discharge in the Lower Bridge River was 3 m^3 s^{-1} throughout the migration with spawning period.



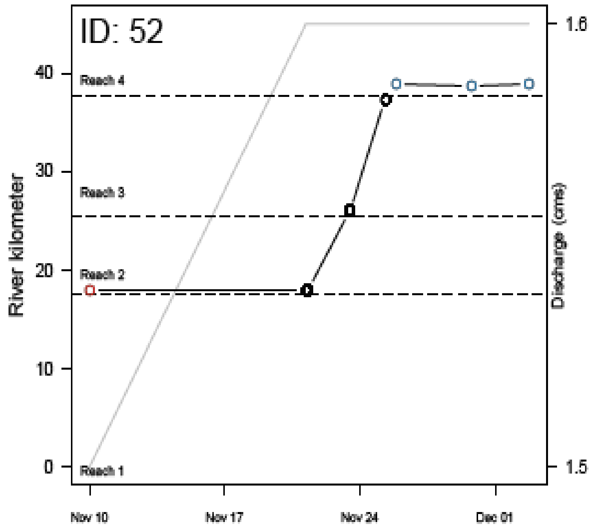
Detection histories of radio tagged adult Coho Salmon in the Lower Bridge River in 2018. Black lines connect the release information (red) with data collected from fixed (black) and mobile (blue) telemetry. Dashed lines indicate boundaries between different reaches. Discharge in the Lower Bridge River was 1.5 m³ s⁻¹ throughout the migration and spawning period.



(Cont'd). Detection histories of radio tagged adult Coho Salmon in the Lower Bridge River in 2018. Black lines connect the release information (red) with data collected from fixed (black) and mobile (blue) telemetry. Dashed lines indicate boundaries between different reaches. Discharge in the Lower Bridge River was 1.5 m^3 s^{-1} throughout the migration and spawning period.



(Cont'd). Detection histories of radio tagged adult Coho Salmon in the Lower Bridge River in 2018. Black lines connect the release information (red) with data collected from fixed (black) and mobile (blue) telemetry. Dashed lines indicate boundaries between different reaches. Discharge in the Lower Bridge River was 1.5 $m^3 s^{-1}$ throughout the migration and spawning period.



(Cont'd). Detection histories of radio tagged adult Coho Salmon in the Lower Bridge River in 2018. Black lines connect the release information (red) with data collected from fixed (black) and mobile (blue) telemetry. Dashed lines indicate boundaries between different reaches. Discharge in the Lower Bridge River was 1.5 $m^3 s^{-1}$ throughout the migration and spawning period.

Appendix 3

Date	% Cloud Cover	Air Temp	Water Visibility (m)	Section 1 (untagged)	Section 1 (tagged)	Section 2 (untagged)	Section 2 (tagged)	Section 3 (untagged)	Section 3 (tagged)	Section 4 (untagged)	Section 4 (tagged)
08-17-2018	0-10	NA	0.75	0	0	0	0	0	0	0	0
08-24-2018	80	NA	0.56	0	0	0	0	0	0	0	0
08-09-2018	0	41	NA	0	0	0	0	0	0	0	0
08-31-2018	40	23.3	NA	0	0	0	0	0	0	0	0
09-07-2018	25	22.6	0.50	0	0	0	0	0	0	0	0
09-14-2018	100	13.6	NA	0	0	2	0	0	0	0	0
09-21-2018	100	14.2	0.50	0	0	4	0	0	0	0	0
09-28-2018	15	12.6	NA	0	0	0	0	0	0	0	0
10-01-2018	NA	13.4	0.70	1	0	0	0	0	0	0	0
10-05-2018	100	5.6	0.7	0	0	0	0	0	0	0	0

Date	Section 5 (untagged)	Section 5 (tagged)	Section 6 (untagged)	Section 6 (tagged)	Section 7 (untagged)	Section 7 (tagged)	Section 8 (untagged)	Section 8 (tagged)	Mortalities	Total	Tagged Fish
08-17-2018	0	0	0	0	0	0	0	0	0	0	0
08-24-2018	0	0	0	0	0	0	0	0	0	0	0
08-09-2018	0	0	0	0	0	0	0	0	0	0	0
08-31-2018	0	0	0	0	0	0	0	0	0	0	0
09-07-2018	2	0	0	0	0	0	0	0	0	2	0
09-14-2018	0	0	5	0	0	0	0	0	0	7	0
09-21-2018	4	0	0	0	0	0	0	0	0	8	0
09-28-2018	1	0	0	0	0	0	0	0	0	1	0
10-01-2018	0	0	0	0	0	0	0	0	0	1	0
10-05-2018	0	0	0	0	0	0	0	0	0	0	0

Chinook Salmon visual survey data by stream walk section in 2018.

Date	% Cloud Cover	Air Temp	Water Visibility (m)	Section 1 (untagged)	Section 1 (tagged)	Section 2 (untagged)	Section 2 (tagged)	Section 3 (untagged)	Section 3 (tagged)	Section 4 (untagged)	Section 4 (tagged)
10-12-2018	0	5	0.90	0	0	0	0	0	0	0	0
10-17-2018	10	5	0.8	0	0	0	0	0	0	0	0
10-24-2018	20	6	1.0	0	0	0	0	0	0	0	0
11-01-2018	100	NA	NA	18	0	2	0	0	0	0	0
11-08-2018	80	NA	NA	66	1	34	0	0	0	0	0
11-15-2018	100	NA	NA	104	1	61	1	0	0	0	0
11-22-2018	100	2	NA	87	1	50	1	0	0	0	0
11-29-2018	45	NA	NA	65	1	37	0	0	0	7	0
12-06-2018	100	-5	NA	3	1	25	1	16	0	1	0
12-13-2018	30	NA	NA	0	0	0	0	0	0	0	0

Date	Section 5 (untagged)	Section 5 (tagged)	Section 6 (untagged)	Section 6 (tagged)	Section 7 (untagged)	Section 7 (tagged)	Section 8 (untagged)	Section 8 (tagged)	Mortalities	Total	Tagged Fish
10-12-2018	0	0	0	0	0	0	0	0	0	0	0
10-17-2018	0	0	0	0	0	0	0	0	0	0	0
10-24-2018	0	0	0	0	0	0	0	0	0	0	0
11-01-2018	9	0	0	0	0	0	8	0	0	37	0
11-08-2018	6	0	7	0	8	0	14	0	0	136	1
11-15-2018	23	0	4	0	6	0	7	0	2	207	2
11-22-2018	34	0	0	0	7	0	3	0	2	183	2
11-29-2018	30	0	0	0	0	0	0	0	4	140	1
12-06-2018	0	0	0	0	0	0	0	0	0	47	2
12-13-2018	0	0	0	0	0	0	0	0	0	0	0

Coho Salmon visual survey data by stream walk section in 2018.

Appendix 4:

Date	Species	Location	Fork Length (mm)	Sex	European Age	Total Age
2017-02-21	Steelhead	Seton Confluence	915	Female	3.3	6
2017-02-22	Steelhead	Seton Confluence	726	Female	2.3	5
2017-02-24	Steelhead	Seton Confluence	750	Female	3.3	6
2017-03-02	Steelhead	Seton Confluence	635	Female	3.2	5
2017-03-03	Steelhead	Seton Confluence	835	Female	3.3	6
2017-03-03	Steelhead	Seton Confluence	710	Male	3.3	6
2017-03-17	Steelhead	Seton Confluence	752	Female	2.3	5
2017-03-20	Steelhead	Seton Confluence	770	Male	2.3	5
2017-03-20	Steelhead	Seton Confluence	725	Female	2.3	5
2017-03-21	Steelhead	Seton Confluence	755	Female	3.2	5
2017-03-21	Steelhead	Seton Confluence	725	Female	3.2	5
2017-03-22	Steelhead	Seton Confluence	880	Female	3.3	6
2017-03-23	Steelhead	Seton Confluence	755	Female	3.3	6
2017-03-25	Steelhead	Seton Confluence	801	Female	2.3	5
2017-03-30	Steelhead	Seton Confluence	835	Female	3.3	6
2017-08-18	Chinook	Bridge Confluence	786	Female	1.3	4
2017-08-20	Chinook	Bridge Confluence	953	Male	1.3	4
2017-09-05	Chinook	Bridge Confluence	845	Female	1.3	4
2017-10-06	Coho	Bridge Confluence	585	Male	1.1	2
2017-10-06	Coho	Bridge Confluence	685	Male	1.1	2
2017-10-10	Coho	Bridge Confluence	595	Male	1.1	2
2017-10-10	Coho	Bridge Confluence	590	Male	1.1	2
2017-10-12	Steelhead	Bridge Confluence	635	Female	1.1	2
2017-10-14	Coho	Bridge Confluence	539	Female	2.1	3
2017-10-16	Steelhead	Bridge Confluence	710	Female	2.2	4
2017-10-19	Coho	Bridge Confluence	630	Male	1.1	2
2017-10-19	Coho	Bridge Confluence	640	Female	2.1	3
2017-10-20	Coho	Bridge Confluence	575	Male	1.1	2
2017-10-20	Coho	Bridge Confluence	640	Male	1.1	2
2017-10-21	Coho	Bridge Confluence	655	Male	2.1	3
2017-10-22	Coho	Bridge Confluence	560	Female	1.1	2
2017-10-23	Coho	Bridge Confluence	622	Female	1.1	2
2017-10-23	Coho	Bridge Confluence	616	Male	1.1	2
2017-10-24	Coho	Bridge Confluence	610	Male	1.1	2
2017-10-24	Coho	Bridge Confluence	617	Male	1.1	2
2017-10-25	Coho	Bridge Confluence	635	Female	2.1	3

Age analysis of salmon and trout that spawned in the LBR in 2017 and 2018.

Date	Species	Location	Fork Length (mm)	Sex	European Age	Total Age
2018-03-03	Steelhead	Seton Confluence	855	Female	3.3	6
2018-03-13	Steelhead	Seton Confluence	870	Male	2.3	5
2018-03-14	Steelhead	Seton Confluence	745	Female	2.3	5
2018-03-15	Steelhead	Seton Confluence	644	Female	3.2	5
2018-03-15	Steelhead	Seton Confluence	705	Female	3.3	6
2018-03-16	Steelhead	Seton Confluence	773	Female	3.3	6
2018-03-19	Steelhead	Seton Confluence	775	Female	2.3	5
2018-03-20	Steelhead	Seton Confluence	785	Female	2.2	4
2018-03-20	Steelhead	Seton Confluence	871	Male	2.3	5
2018-03-20	Steelhead	Seton Confluence	760	Female	3.3	6
2018-03-24	Steelhead	Seton Confluence	660	Male	2.2	4
2018-03-30	Steelhead	Seton Confluence	630	Female	3.3	6
2018-04-03	Steelhead	Seton Confluence	852	Female	2.3	5
2018-04-18	Steelhead	Seton Confluence	732	Female	3.2	5
2018-04-26	Steelhead	Seton Confluence	820	Female	2.3	5
2018-07-27	Chinook	Bridge Confluence	950	Female	1.3	4
2018-08-30	Chinook	Yalakom Confluence	680	Female	1.3	4
2018-09-05	Chinook	Below Yalakom	600	Female	1.3	4
2018-09-27	Coho	Bridge Confluence	613	NA	1.1	2
2018-09-27	Coho	Bridge Confluence	564	Male	1.1	2
2018-09-28	Coho	Bridge Confluence	588	Male	1.1	2
2018-09-29	Coho	Bridge Confluence	515	Male	1.1	2
2018-09-29	Coho	Bridge Confluence	650	Male	1.1	2
2018-09-29	Coho	Bridge Confluence	624	Male	1.1	2
2018-09-30	Coho	Bridge Confluence	690	NA	1.1	2
2018-09-30	Coho	Bridge Confluence		NA	1.1	2
2018-10-03	Coho	Bridge Confluence		NA	1.1	2
2018-10-06	Coho	Camoo FSR Bridge	565	Male	1.1	2
2018-10-15	Coho	Bridge Confluence	571	Female	1.1	2
2018-10-18	Coho	Bridge Confluence		NA	1.1	2
2018-10-18	Coho	Bridge Confluence		NA	1.1	2
2018-10-18	Coho	Bridge Confluence	693	Female	1.1	2
2018-10-19	Coho	Bridge Confluence	634	Male	1.1	2
2018-10-19	Coho	Bridge Confluence	601	Female	1.1	2
2018-10-22	Coho	Bridge Confluence	543	Female	1.1	2
2018-10-22	Steelhead	Bridge Confluence	855	Female	2.3	5

(Cont'd) Age analysis of salmon and trout that spawned in the LBR in 2017 and 2018.