Bridge River Project Water Use Plan

Lower Bridge River Adult Salmon and Steelhead Enumeration

Implementation Year 9

Reference: BRGMON-3

Study Period: March 2020 – December 2020

Carson White, Annika Putt, Daniel Ramos-Espinoza, Michael Chung and Katrina Cook

InStream Fisheries Research Inc.
215 – 2323 Boundary Road
Vancouver, BC
V5M 4V8

April 6, 2021

Lower Bridge River Adult Salmon and Steelhead Enumeration, 2020

BRGMON-3, Year 9

Carson White, Annika Putt, Daniel Ramos-Espinoza, Michael Chung, and Katrina Cook

Prepared for:

St'át'imc Eco-Resources
10 Scotchman Road
PO Box 103
Lillooet, BC V0K 1V0

BC Hydro
6911 Southpoint Drive
Burnaby, BC V3N 4X8

Prepared by:

Instream Fisheries Research
1121A Enterprise Way
Squamish BC, V8B 0E8

February 21, 2023

White, C.*, Putt, A., Ramos-Espinoza, D., Chung, M., and Cook, K. 2021. Lower Bridge River Adult Salmon and Steelhead Enumeration, 2020. Report prepared for St'át'imc Eco-Resources and BC Hydro. 89 pp + appendices.

*Corresponding author

Executive Summary

The Lower Bridge River Adult Salmon and Steelhead Enumeration program (BRGMON-3) monitors adult salmonids in the Lower Bridge River (LBR) to support evaluation of the effects of flow releases from Terzaghi Dam on salmon productivity. Monitoring in 2020 (Year 9 of 10) consisted of:

1. Electronic enumeration of Steelhead Trout, Chinook Salmon, and Coho Salmon.
2. Radio telemetry to inform species-specific spawning location, migration rates, migration timing, and residence times.
3. Visual surveys to enumerate Chinook and Coho Salmon using Area Under the Curve (AUC) analyses.
4. Redd surveys to determine Chinook and Coho Salmon spawning distributions and record habitat quality at confirmed spawning locations.
5. Ageing analyses to evaluate life history characteristics and high flow exposure.

Management questions were first defined in 2018 and revised in 2019. The management questions address two operational regimes: Water Use Planning (WUP; 2011-2015, 2019-2020) and Modified Operations (MOD; 2016-2018). The WUP proposed an instream flow regime of three alternative base flows for evaluation (1, 3, and 6 m^3s^{-1}), with maximum flows not exceeding 20 m^3s^{-1}. These flows were exceeded in MOD years. Despite this delineation, data collected since 2011 describe how flow regime affects adult salmonids in the LBR, and therefore all relevant data are used to answer each question.

WUP Management Questions:

MQ1: What is the annual abundance, timing, and distribution of adult salmon and steelhead spawning in the LBR and are these aspects of spawning affected by the instream flow regime?

We determined annual abundance in the LBR using electronic counter data for Steelhead Trout, Chinook and Coho Salmon and AUC analyses of visual survey data for Chinook and Coho Salmon. Migration timing was assessed using peak count dates from electronic counters and movement data from radio telemetry. Radio telemetry, visual surveys, and redd surveys were used to inform spawner distribution.

Escapement estimates in 2020 suggested a continued trend of low abundance in the LBR (Steelhead Trout 62, Chinook Salmon 98, Coho Salmon 539). Steelhead Trout abundance was consistent with the mean since 2015 (mean 42 SD 21), but 5X lower than a peak recorded in 2014 (238). Chinook Salmon have been depressed since 2005 (as indicated by historic visual survey estimates), and the 2020 estimate was the second lowest escapement during BRGMON-3 (the 2018 estimate was 42). Coho Salmon abundances have been variable since 1997 but have remained low since 2013.

Escapement estimates in 2020 were confounded by a rockslide on the Fraser River and operation of a fish fence for Chinook Salmon broodstock collection. The Fraser River rockslide may have inflated escapement for all species due to increased straying of adults from other systems into the LBR. The effects of the rockslide cannot be distinguished from flow changes, making it difficult to determine how operations affected adult abundance in 2020. Additionally, the Chinook Salmon broodstock collection fence, operated from 2018 through 2020 in Reach 3, prevented complete Chinook Salmon escapement estimates, further inhibiting our ability to determine the effects of flow regime on LBR adult Chinook Salmon.

It is difficult to evaluate the effects of flow regime on adult abundance because anadromous salmonids spend a significant portion of their life cycle outside of the LBR. LBR flows are consistently at WUP targets during the Chinook and Coho Salmon enumeration periods (regardless of flow regime), and any effects of flow regime would likely have been incurred during the juvenile rearing stage. The effect of flow on fish abundance is more comprehensively assessed by BRGMON-1 using productivity metrics that incorporate both adult and juvenile abundance (i.e., egg-to-fry or adult-to-fry survival). BRGMON-3 is limited to evaluating the direct effects of flow regime on adult Steelhead Trout, Chinook Salmon, and Coho Salmon when they are present in the LBR during spawning migrations, and thus far we have found no clear link between spawner escapement and LBR flow.

Preliminary analyses of migration timing for Steelhead Trout and Chinook and Coho Salmon indicate consistency 2011, suggesting migration timing is not strongly affected by instream flow regime. Spawning distributions for all species have remained similar over the course of BRGMON-3. In 2018 and 2019 there was evidence that Chinook Salmon spawning had increased in Reach 4 and decreased in Reach 3, but this was not observed in 2020; however, the broodstock collection fence likely affected spawner distribution.

MQ2: What is the quality and quantity of spawning habitat in the LBR and how is spawning habitat affected by the instream flow regime?

During the instream flow regime redd surveys were used to assess spawning habitat quality (depth, velocity, and substrate characteristics) and quantity. Redd surveys at confirmed spawning locations have been completed in the LBR for Chinook Salmon since 2014 and for Coho Salmon since 2018. Despite consistent effort, redd samples sizes have been low since the beginning of high flows in 2016. For Chinook Salmon, depth and velocity have been consistent among years and flow regimes. While substrate size has varied, it has remained within preferred ranges. Preliminary evidence suggests instream flow may affect critical Chinook Salmon spawning habitat through substrate redistribution; however, high quality spawning habitat is not limiting in the LBR. Coho Salmon spawning habitat has observed variability in water depth and velocity, while substrate size has increased since 2018, but measurements are still within their preferred range.

MOD Management Questions:

MQ3: Have flow releases from Terzaghi Dam under the modified flow regime affected the quality and quantity of spawning habitat available in the LBR? If so, what are the potential effects on fish and what mitigation options are available?

Effects of flow releases during the modified regime were assessed with Habitat Suitability Index (HSI) surveys. HIS surveys take measurements of depth, velocity, and substrate along a transect that are used to calculate spawning probability (0-1) based on species-specific preference curves. From this, Weighted Usable Area (WUA) is calculated by multiplying the surveyed area habitat size by the HSI score to quantify available spawning habitat. No HSI surveys were completed in 2020 as discharge from Terzaghi Dam did not exceed 20 m^3s^{-1}. There have been no significant differences in WUA across all years it has been recorded. In 2020, HSI data were reassessed visually within habitat units to observe small scale changes. Despite analyses from previous years detecting no significant differences in the total amount of WUA, the distribution of quality habitat within habitat units changed year to year. The consistency in total WUA between 2018 and 2019 suggest HSI surveys are a robust method of assessing spawning habitat quantity at a large scale, but differences in habitat quality at smaller scales may limit detailed evaluation.

Habitat transect data complement redd survey data and suggest that despite some changes in substrate size and distribution identified in 2019, spawning habitat is not limited for Chinook Salmon or Coho Salmon in the LBR. Continued monitoring is required to determine whether substrate redistribution is due to MOD flows, and whether this potential trend will lead to significant changes in spawning habitat quality and quantity in the LBR.

MQ4: Have flow releases from Terzaghi Dam under the modified flow regime affected the distribution of adult salmon and steelhead spawning in the LBR? If so, what are the potential effects on spawning success and what mitigation options are available?

Radio telemetry, visual surveys, and redd surveys were used to evaluate critical spawning habitat under both the WUP and MOD flow regimes. Spawner distributions of Steelhead Trout and Coho Salmon have remained consistent in Reach 3 and 4 between the two flow regimes, while Chinook Salmon showed increased preference for Reach 4 (relative to Reach 3) in 2018 and 2019. This trend was not observed in 2020, likely due to the broodstock fence that prevented migration into the upper sections of the LBR (Reach 3 and 4). Evaluating the effect of high flows on Chinook Salmon spawning distribution will continue to be confounded by the operation of the broodstock collection fence, as adults are collected at the fence and do not distribute and spawn naturally.

Several challenges have limited the ability of BRGMON-3 to assess the effects of flow regime on adult salmonid abundance, spawning timing, distribution, and critical spawning habitat in the LBR. Data collection and interpretation have been complicated by low adult salmon abundance (and therefore sample sizes), MOD flows, challenging visual conditions, a Chinook Salmon broodstock collection fence, and the Fraser River rockslide; however, monitoring remains on track to answer the management questions.

BRGMON-3 status of objectives, management questions, and hypothesis after Year 9.

Study Objectives	**Management Questions**	**Management Hypotheses**	**Year 9 (Fiscal Year 2020) Status**
Evaluate effects of Terzaghi Dam operations on the spawning habitat and distribution of Steelhead Trout, Chinook and Coho Salmon, and generate spawner abundances under alternative test flow regimes.	MQ1: What is the annual abundance, timing, and distribution of Steelhead Trout, Chinook and Coho Salmon 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 of Steelhead Trout, Chinook and Coho Salmon spawning in the Lower Bridge River. $H_{1.2}$: There is no relationship between the instream flow regime and the timing of Steelhead Trout, Chinook and Coho Salmon spawning in the Lower Bridge River. $H_{1.3}$: There is no relationship between the instream flow regime and the distribution of Steelhead Trout, Chinook and Coho Salmon spawning in the Lower Bridge River.	$H_{1,1}$ • Electronic counters and visual surveys were used to enumerate Steelhead Trout, Chinook, and Coho Salmon. • In 2020, counter estimates were 62 Steelhead Trout, 98 Chinook Salmon and 539 Coho Salmon, continuing a decline in abundance for all species since the monitor began. • Cannot support or reject $H_{1,1}$. Effects of flow regime on anadromous species are difficult to evaluate given a significant portion of life history is outside of the LBR. Effects of the instream flow regime abundance is more accurately evaluated by BRGMON-1. $H_{1,2}$ • Electronic counters and radio telemetry were used to evaluate migration timing. • Preliminary evidence suggests migration timing of all species has not changed across monitoring years. • Support for $H_{1,2}$. $H_{1,3}$ • Radio telemetry and visual surveys were used to evaluate spawner distribution. • The distribution of Steelhead Trout and Coho Salmon spawners has not changed during the instream flow regime, supporting $H_{1,3}$. Chinook Salmon spawned more frequently in Reach 4 relative to Reach 3 in 2018 and 2019, but this trend did not continue in 2020, providing additional support for $H_{1,3}$

Study Objectives	Management Questions	Management Hypotheses	Year 9 (Fiscal Year 2020) Status
Evaluate effects of Terzaghi Dam operations on the spawning habitat and distribution of Steelhead Trout, Chinook and Coho Salmon, and generate spawner abundances under alternative test flow regimes.	MQ2: 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?	$H_{2.1}$: The instream flow regime does not affect spawning habitat quality in the Lower Bridge River. $H_{2.2}$: The instream flow regime does not affect spawning habitat quantity in the Lower Bridge River.	• $H_{2.1}$ and $H_{2.2}$ were both evaluated by surveys of Chinook and Coho Salmon redds since 2014 and 2018, respectively. No Steelhead Trout redd surveys were conducted due to high flows and low visibility at the time of spawning. • Chinook and Coho Salmon redd depth and velocity have remained similar among years and flow regimes, while substrate has been variable but has consistently remained within species' preferred ranges. • Support for $H_{2.1}$ and $H_{2.2}$ for Chinook and Coho Salmon. Data not available for Steelhead Trout.

BRGMON-3 modified operations status of objectives, management questions, and hypothesis after Year 9.

Study Objectives	Management Questions	Management Hypotheses	Year 9 (Fiscal Year 2020) Status
Evaluate effects of the modified flow regime on the spawning habitat and distribution of Steelhead Trout, Chinook and Coho Salmon, and generate spawner abundances under alternative test flow regimes.	MQ3: 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?	$H_{3.1}$: Quality and quantity of spawning habitat in the Lower Bridge River has not been changed as a result of the modified flow regime.	• HSI surveys were used to evaluate habitat quality and quantity following high flows. • There was no statistical difference between WUA for Chinook Salmon spawning habitat in Reaches 3 and 4 of the LBR between 2017 and 2018/2019, suggesting high flows in the spring and summer of 2018 did not substantially affect spawning habitat in the LBR. • 2019 was the first year of monitoring at discharges when Coho Salmon spawn (1.5 m^3s^{-1}). Comparisons will be made in the future with additional high flow events. • Support for $H_{3.1}$ for Chinook Salmon
	MQ4: 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	$H_{4.1}$: Distribution of adult spawning in the Lower Bridge River has not been changed as a result of the modified flow regime.	• Radio telemetry, visual and redd surveys were used to evaluate spawner distribution following high flows. • Steelhead Trout continue to spawn in both Reach 3 and 4. • Few Chinook Salmon redds have been observed since the onset of MOD (2016), but Chinook Salmon appear to spawn in both Reach 3 and 4. • Coho Salmon continue to spawn in both Reach 3 and 4. • Support for $H_{4.1}$.

Acknowledgements

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

Table of Contents

List of Tables

List of Figures

1. Introduction

1.1 Background

The Bridge River provides important habitat for Pacific salmon and Steelhead Trout (*Oncorhynchus* spp.) and is an important cultural and sustaining resource for the St'át'imc Nation. As part of the Bridge-Seton power system, the Lower Bridge River (LBR) is impounded by Terzaghi Dam and is controlled by BC Hydro through the operation of Carpenter Reservoir and Bridge River Generating Stations 1 and 2 (BRGS). From 1960 to 2000, Bridge River flows were diverted through the BRGS to the Seton River catchment for power production at the Seton Generating Station (SGS; Figure 1), and the upper 4 kms of the Bridge River below Terzaghi Dam remained almost continuously dewatered (groundwater and small tributaries contributed ~1 m^3s^{-1} averaged across the year; Longe and Higgins 2002).The 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 public. In 1998, an agreement was reached among BC Hydro, Fisheries and Oceans Canada (DFO), and the BC Provincial Ministry of Environment stipulating that an instream flow test release and companion monitoring studies be implemented to determine the effect of flow releases on the LBR aquatic ecosystem. This agreement (called the interim flow order, IFO) resulted in water being released from Terzaghi Dam beginning on August 1, 2000, with an annual water budget of 3.0 m^3s^{-1} based on a semi-naturalized hydrograph from 2 to 5 m^3s^{-1}.

The IFO continued until the Bridge River Water Use Plan (WUP) was approved in 2011. The WUP proposed a 12-year flow release program to evaluate three alternative flow regimes (1, 3, and 6 m^3s^{-1}), intended to inform a long-term flow release strategy for the LBR. The WUP recommended monitoring the effects of flow on spawner abundance, habitat, and distribution, which resulted in the Adult Salmon and Steelhead Enumeration Program (BRGMON-3; Bridge-Seton WUP Monitoring Terms of Reference 2012). BRGMON-3 uses a combination of electronic fish counters, radio telemetry, visual surveys, and spawning habitat assessments to evaluate the impact of flow on adult spawning in the LBR. The monitor builds on previous monitoring conducted by the DFO and provides critical data to BRGMON-1, Lower Bridge River Aquatic Monitoring.

In 2016, safety concerns at the Lajoie Dam, upstream of the LBR, and critical infrastructure upgrades at the BRGS resulted in the need to increase LBR flow releases above the WUP specifications. The potential for high flows will continue until 2028 when modifications to Lajoie Dam and repairs at the BRGS are expected to be complete. The high flow releases in 2016 caused extensive damage to resistivity counter sensors, video validation equipment, and PIT telemetry gear, and therefore no resistivity counter data were collected in 2016. A combination of sonar and resistivity counter technologies were installed in 2017 (Burnett et al. 2017) and have been used since. High flow releases can also increase substrate mobilization and affect spawning and rearing habitat, and comprehensive spawning habitat surveys were implemented as part of BRGMON-3 in spring of 2018 following high flows in 2017.

In 2018 to 2020, a broodstock program was implemented in the LBR to enhance Chinook Salmon populations and a fish fence and trap box were installed directly upstream of the electronic counters (26 rkm). The catch data from fence operation was used in place of electronic fish counters to calculate a Chinook Salmon abundance estimate in the LBR. In addition, the landslide that occurred near the Big Bar ferry crossing on the Fraser River (~100 km north of Lillooet) in 2019 continued to impede the upstream migration of Fraser River salmon and Steelhead Trout. Spawner abundance, distribution, and migration timing were evaluated in 2020 as in previous years, but some individuals may not be of LBR origin.

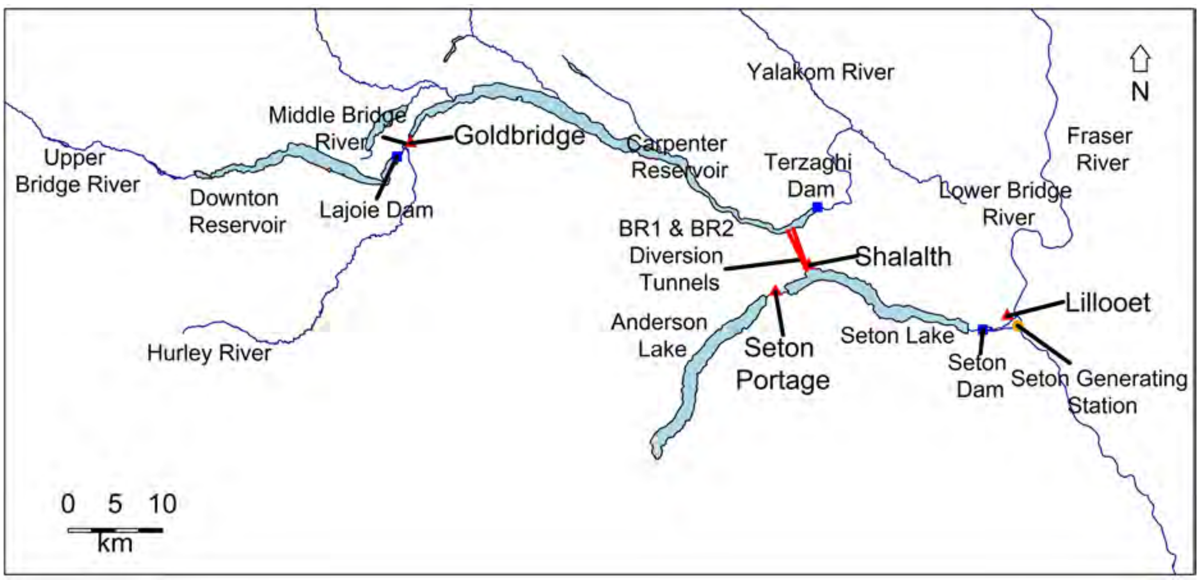


Figure 1: Bridge and Seton Watersheds showing Terzaghi Dam and diversion tunnels to Bridge River Generating Stations 1 and 2.

1.2 Management Questions and Objectives

Specific management questions were not listed in the original BRGMON-3 terms of reference (2012 TOR; BC Hydro 2012) as the monitor was designed to aid the interpretation of BRGMON-

1 results. The TOR were amended in 2018 (BC Hydro 2018) to include two management questions and associated hypotheses that are now addressed by BRGMON-3.

WUP 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?

    $H_{1.1}$ There is no relationship between the instream flow regime and the abundance of spawning salmon and steelhead in the Lower Bridge River.

    $H_{1.2}$ There is no relationship between the instream flow regime and the timing of spawning salmon and steelhead in the Lower Bridge River.

    $H_{1.3}$ There is no relationship between the instream flow regime and the distribution of spawning salmon and steelhead in the Lower Bridge River.

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?

    $H_{2.1}$ The instream flow regime does not affect spawning habitat quality in the Lower Bridge River.

    $H_{2.2}$ The instream flow regime does not change spawning habitat quantity or distribution in the Lower Bridge River.

In addition to the above management questions, two additional management questions were added to the BRGMON-3 Scope of Services in 2019 in response to modified high flow operations (MOD).

MOD 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?

$H_{3.1}$ Quality and quantity of spawning habitat in the Lower Bridge River has not been changed as a result of the modified flow regime.

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?

$H_{4.1}$ Distribution of adult spawning in the Lower Bridge River has not been changed as a result of the modified flow regime.

The primary objective of BRGMON-3 is to inform BRGMON-1 juvenile stock recruitment models, which will be used to determine the response of salmonid productivity to instream flow regimes in the LBR. BRGMON-3 also addresses uncertainties surrounding the effects of flow regime on spawning timing, distribution, and spawning habitat quality and quantity. Monitoring objectives are met using a combination of adult enumeration (Steelhead Trout *Oncorhynchus mykiss*, Chinook Salmon *O. tshawytsch*, and Coho Salmon *O. kisutch*), visual surveys, radio telemetry, and spawning habitat assessments. BRGMON-3 was originally restricted to Reach 3 and 4; however, the TOR modification in 2018 expanded the study area to include Reach 1 and 2. This report focuses on the data collected in 2020, and comparisons with previous years are included where relevant and available (Table 1).

Table 1: Summary of data collected during BRGMON-3 monitoring.

Task	Components	Species	2020 Period	Prior Years of Data
Adult Salmonid Abundance (electronic methods)	Combination of resistivity counter and multi-beam sonar	Steelhead Trout	Mar 27 to Jun 10	2014*, 2015*, 2017-2019
		Chinook Salmon	July 20 to Aug 10	2014*, 2015*, 2016-2019
		Coho Salmon	Oct 7 to Dec 05	2013-2015*, 2016, 2018, 2019
Adult Salmonid Abundance (visual methods)	Area under the curve estimates calculated from visual counts	Steelhead Trout	NA	2014
		Chinook Salmon	July 27 to Sep 30	2011-2019
		Coho Salmon	Oct 1 to Dec 17	2011-2019
Compilation of Historic Visual Counts	Compiling historic visual surveys (helicopter and streamwalk) data provided by DFO	Steelhead Trout	NA	NA
		Chinook Salmon	NA	1997-1999, 2001, 2004-2010**
		Coho Salmon	NA	1997-1999, 2001, 2003-2006, 2008-2010
Radio Telemetry	Angling, tagging, and tracking movements	Steelhead Trout	Mar 15 to Jun 18	2011-2019
		Chinook Salmon	Aug 19 to Sep 30	2012-2019
		Coho Salmon	Oct 1 to Dec 10	2014-2019
Spawning Habitat Selection	Depth, velocity, and substrate surveys at observed redds following spawning	Steelhead Trout	NA	NA
		Chinook Salmon	Aug 31 and Sept 3	2014-2019
		Coho Salmon	Nov 29 and Dec 11	2018-2019
Scale Age Analysis	Ageing based on scale samples of individuals that spawned in the LBR	Steelhead Trout	Jan 1 to Feb 15	2014-2019
		Chinook Salmon	Jan 1 to Feb 15	2013-2019
		Coho Salmon	Jan 1 to Feb 15	2011-2019
High Flow Monitoring	Habitat suitability index based on instream measurements of depth, velocity, and substrate at previous known spawning locations	Steelhead Trout	NA	NA
		Chinook Salmon	NA	2017-2019***
		Coho Salmon	NA	2019

*Resistivity counter only; ** Fence count data from 1993-1996; *** 2017 and 2018 in Reach 3 and 4, 2019 in Reach 1-4.

2. Methods

2.1 Site Description

The LBR extends from the Terzaghi Dam 40 km downstream to its confluence with the Fraser River (Figure 2). The river is separated into four study reaches from downstream to upstream (Figure 2): Reach 1 extends from the Bridge-Fraser confluence to Camoo FSR Bridge (rkm 0-18); Reach 2 continues to the Yalakom-Bridge confluence (rkm 18-25.5); Reach 3 continues to 37.3 rkm (rkm 25.5-37.3); Reach 4 continues to Terzaghi Dam (rkm 37.3-40). Electronic counter infrastructure is located ~300 m upstream of the Yalakom River at the Reach 2/3 break. In 2020, discharge from Terzaghi Dam did not exceed 20 m^3s^{-1} (WUP target) during the high flow period from March to August (Figure 3). MOD flows occurred in 2016 through 2018, but in 2019 and 2020 flows did not surpass 20 m^3s^{-1}.

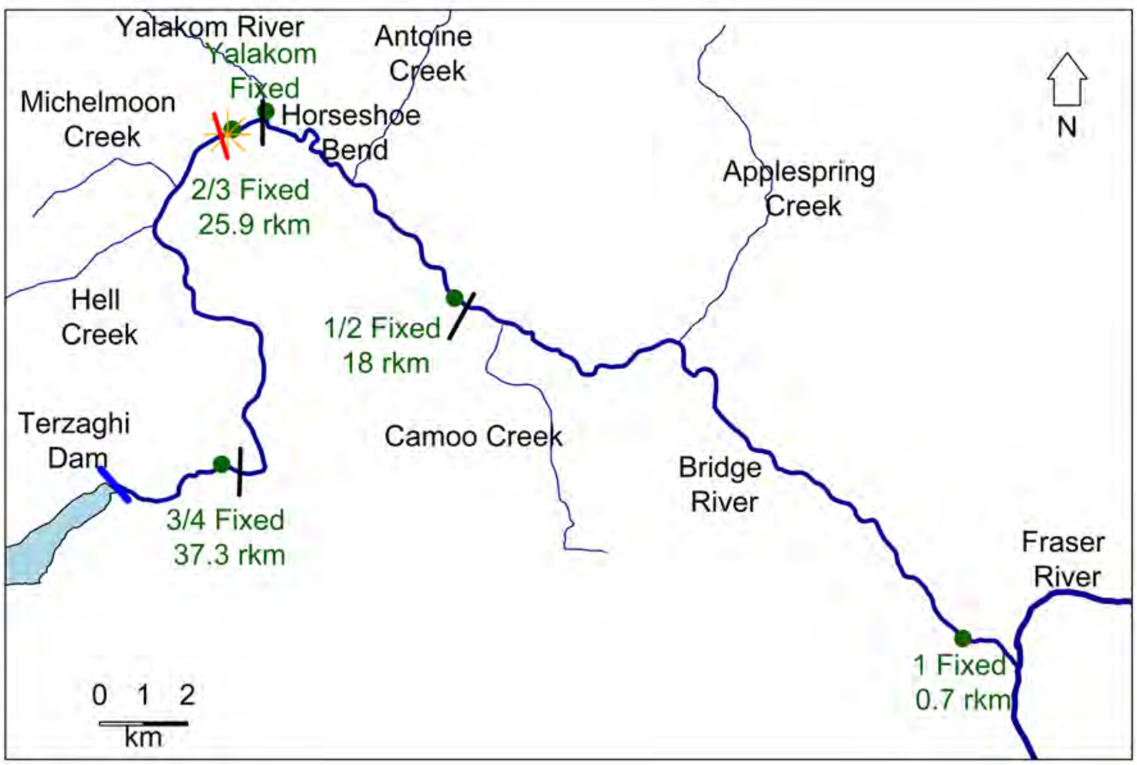


Figure 2: BRGMON-3 Lower Bridge River study area including reach breaks (red lines), fixed radio telemetry stations (green circles), and counter location (orange star).

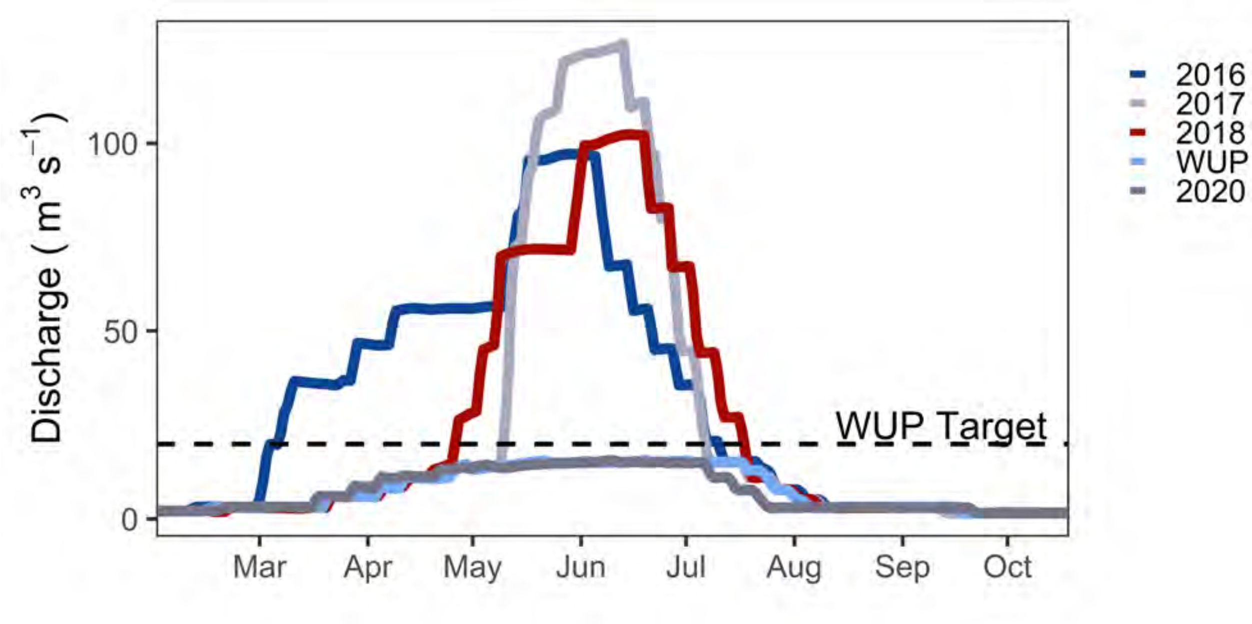


Figure *3*: Discharge from Terzaghi Dam into the Lower Bridge River from 2011 to 2020. Flows that remained within WUP targets (2011-2015 and 2019) are combined given their similarity (minor discharge variations occurred).

2.2 Electronic Counter Spawner Enumeration

BRGMON-3 uses electronic counters to produce annual estimates of Steelhead Trout, Chinook Salmon, and Coho Salmon abundance. Since the onset of high flow releases in 2016, a two-channel crump-weir resistivity counter operates on river right and an ARIS sonar operates on river left (Figure 4). Passage over the crump weir may not be possible at low flows, resulting in enumeration solely occurring via the sonar counter. The minimum water level for passage over the crump weir varies with fish size and migration timing, leading to species-specific enumeration methods (Table 2).

Table 2: Migration timing and electronic counter type and operational dates for Steelhead Trout, Chinook Salmon, and Coho Salmon in the Lower Bridge River during the 2020 monitoring season.

Species	Estimated Migration Timing	Operational Dates	Technology Used
Steelhead Trout	Apr 1 to Jun 1	Mar 27 to Jun 10	Combined resistivity and sonar
Chinook Salmon	Aug10 to Sep 30	July 20 to Aug 10*	Combined resistivity and sonar
Coho Salmon	Oct 1 to Dec 1	Oct 7 to Dec 05	Sonar

*Enumeration was compiled from broodstock fence data between August 10 and September 30

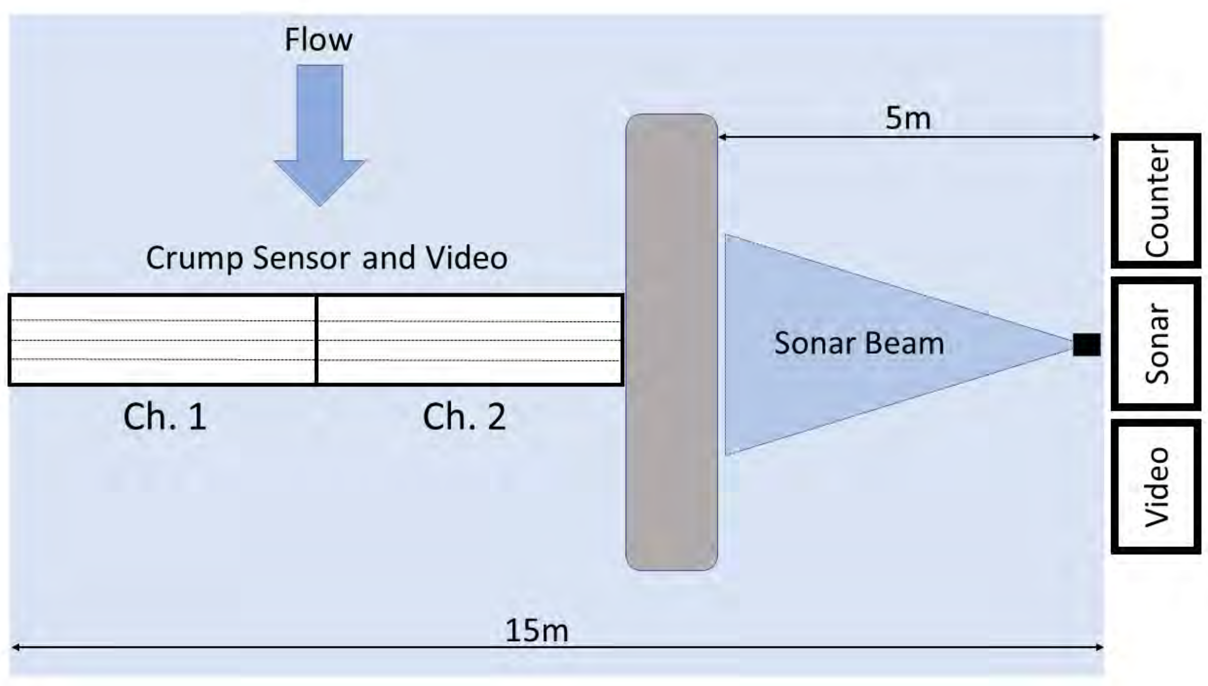


Figure 4: Configuration of the resistivity counter crump sensor, video validation system, multibeam sonar, and power system.

2.2.1 Resistivity Counter Abundance Estimates

Resistivity counters measure the resistance between two pairs of electrodes (lower-middle and middle-upper) as a function of water conductivity. Fish are more conductive than water, and when a fish swims over the electrodes the counter records a change in resistance. An internal algorithm then classifies each record as an up, down, or event by interpreting the characteristics of a sinusoidal curve created by the counter (i.e., a graphical trace). The counter also records the peak signal size (PSS), corresponding to the peak of the sinusoidal curve. If a record does not follow a typical fish trace but its PSS is above a pre-defined threshold, it is classified as an event. Events can be due to a fish not completely passing over all three electrodes, other objects or animals that cause a change in resistance, or from electrical noise. PSS is related to mass and can be used as a proxy for fish size or species, when size differs among species that spawn at similar times (McCubbing and Ignace 2000).

PSS cut-offs were developed for the LBR counter to differentiate Steelhead Trout and adult salmon from resident species (e.g., Rainbow Trout, Bull Trout, Mountain Whitefish). PSS frequency distributions were visually examined to identify troughs that indicated the descending limb of small-bodied residents and the ascending limb of larger salmon or Steelhead Trout. The point where the least overlap occurred was used as the PSS cut-off.

Counter Validation and Accuracy

Resistivity counters are subject to measurement error and must be validated to determine counter performance and estimate abundance. Continuous video data were collected for validation using four infrared cameras situated over the crump weir and connected to a digital video recorder (DVR4575, Swann®). White LED lights (3-watt, 300 Lumen) were installed alongside the cameras to improve the quality of night footage.

To determine counter accuracy, paired video validation and counter data were classified into three states:

1. True Positive (TP): The counter recorded a movement, and a fish was observed during validation.
2. False Positive (FP): The counter recorded a movement, but no fish were observed during validation.
3. False Negative (FN): The counter did not record a movement, but a fish was observed during validation.

The frequency of the above states was determined using a two-step validation process including targeted validation to identify FP and TP, and random validation to identify FN. During targeted validation, all counter records were matched to video data (plus one minute before and after) to determine the number of TPs and FPs. During random validation, a subset of randomly selected video segments were reviewed to determine a FN rate that could be applied to the full migration window. Validation date ranges were selected considering peak migration timings in 2014 (Melville et al. 2015) and 2015 (Burnett et al. 2016). Ten randomly selected 20-minute segments of video data per day were reviewed to validate both the Steelhead Trout (April 1 to May 12) and Chinook Salmon (July 29 to August 10) migrations.

Counter accuracy was calculated for upstream and downstream movements using the rates of *TP*, *FP*, and *FN* determined during validation:

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

where *A* is the accuracy, *TP* is the number of true positives from targeted validation, *FP* is the number of false positives from targeted validation, and *FN* is the estimated number of false negatives derived from random validation (i.e., the number of false negatives in the randomly validated subset multiplied by the total migration period).

Species Ratio

Chinook and Sockeye Salmon migration timing overlaps in the LBR. Where video data is not available, a species ratio was applied to the counter records to estimate species-specific abundance. First, a PSS of ≥ 60 was used to separate resident species from adult salmon. Species were identified during targeted and random video validation among remaining counter records. A species ratio was calculated based on the percentage of individuals identified as either Chinook or Sockeye Salmon and applied to unvalidated up and down counter records, or where species could not be identified. Few fish migrated into the LBR at the beginning of the Chinook Salmon migration period and there was a gap in video data between July 20 and 28. Thus, a species ratio calculated from fish observed after July 28 was applied to the beginning of the migration period.

Determining a species ratio was not required for Steelhead trout because their migration only overlaps with smaller resident fish that can be easily distinguished using the PSS.

Abundance Estimates

Species-specific net up counts (spawner abundance) were calculated using the equation:

(2)
$$E = \sum_{t=1}^{n} \left(\frac{U_t}{A_{up}} - \frac{D_t}{A_{down}} \right)$$

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 upstream counter accuracy, A_{down} is the downstream counter accuracy, and n is the final date of the upstream migration. Overlapping migrations can make it difficult to determine the start and end date for each species, and migration timing was defined using data from radio telemetry, stream-walks, video observations, and a previous telemetry study by Webb et al. (2000).

The use of accuracy in Equation 2 allows abundance to be estimated even in the event of missing data or changes in river conditions. Although days with missing data are not included in the validation process, accuracy calculated from outside these days can be used to obtain a full estimate of abundance.

2.2.2 Multibeam Sonar Abundance Estimates

An ARIS Explorer 1800 (Sound Metrics Corporation, Bellevue, Washington, USA) was used for Steelhead Trout and Chinook Salmon, while a Blueview P900 was used for Coho Salmon, because the ARIS was malfunctioning. The sonar unit was mounted to an aluminum bracket and positioned at half of the water depth and oriented horizontally across the channel. A tilt angle of 28° upstream was introduced in 2019 to increase the area covered by the sonar beam and increase the number and accuracy of length measurements.

Echoview post-processing software (Version 8; Echoview Software Pty Ltd., Hobart, Australia) was used to enumerate fish migrating through the sonar beam (ARIS or Blueview). Sonar data was imported into Echoview as a virtual echogram (objects are plotted in relation to beam angle and distance to the sonar head), background noise was reduced, and Echoview highlighted sections of sonar data that contained fish-like movements. These movements were then verified by an experienced analyst to determine the number of true fish movements.

Echoview produces estimates of fish length; however, these may be inaccurate due to the nature of the site and flow dynamics. A subset of fish lengths (Steelhead Trout 100%; pre-August 20 Chinook Salmon 18%; Coho Salmon 10%) were manually measured using the sonar's proprietary software (ARISFish, Sound Metrics Corporation, Bellevue, Washington, USA). Direction-specific linear models of ARISFish lengths vs lengths estimated by Echoview were used to predict the lengths of all other fish. Echoview length, distance from the sonar head, number of targets, and time in beam were included as potential covariates in the linear models and AICc model selection (corrected for small sample sizes) was used to determine the most parsimonious models.

Predicted lengths were used to differentiate Steelhead Trout and adult salmon from smaller resident fish species. A species-specific size cut-off was applied to predicted lengths to estimate the number of each species crossing upstream and downstream through the sonar beam. Size cut-offs were determined by length-frequency distributions based on previous years catch data for both the Seton River (Sockeye Salmon; BRGMON-14) and LBR (Steelhead Trout, Chinook, and Coho Salmon; BRGMON-3 and broodstock program; Appendix 1). A final net abundance was then estimated by subtracting downs from ups of the target species.

2.2.3 Chinook Salmon Enumeration

In previous years, flows from Terzaghi Dam were ramped down to WUP targets (3 m^3s^{-1}) by mid-August, prior to the estimated peak spawning period of Chinook Salmon. To accommodate for the Chinook Salmon broodstock program, a hydrograph of 3 m^3/s was achieved by August 8 to allow for the installation of a channel spanning fence on August 10. Both the resistivity and sonar counter were deployed on July 20 to observe any early migrants in response to the change in flow regime and used until August 10 when the fish fence was installed. After this date, the fish fence alone was used for Chinook Salmon enumeration and counts were added to electronic counter data to provide an abundance estimate.

2.2.4 Kelting or Downstream Movement

The downstream movement of adult salmonids following spawning can be a result of kelting, (in Steelhead Trout) where individuals migrate out of the LBR and return to the ocean, or moribund or dead individuals move past the counter as they yield to the flow (used for Coho Salmon only in 2020). To calculate an accurate abundance estimate, a date must be identified after which down counts because of kelting or moribund/dead individuals are not subtracted from the net abundance. The onset of the kelt out-migration for Steelhead Trout typically begins after mid-May and moribund/dead Coho Salmon begins after the first week of November. To estimate this date for abundance estimation purposes, counts from fish recycling (moving up and down over the counter sensor pads) and downstream moving fish due to kelting need be distinguished. One difference between recycling down counts and kelting down counts is that recycling does not produce a temporal pattern of down detections, while kelt detections produce a temporal pattern resembling a normal distribution. In other river systems where resistivity counters are deployed (e.g. Deadman and Bonaparte Rivers), a date is calculated from a normal distribution of down counts after a river-specific kelt date (based on historic counter data) has been set. The date after which 5% of down counts occurs on the ascending limb of the modelled normal distribution (Braun et al. 2017).

2.3 Radio Telemetry

2.3.1 Fish Capture, Tagging and Sampling

Radio telemetry was used to assess migration timing, spawner residence time (survey life, SL), spawner distributions, and visual survey observer efficiency (OE). SL and OE are key components of estimating abundance through area-under-the-curve (AUC) methods (see Section 2.5). Fish were captured by angling and 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 was active (presumed alive; 5 second burst rate) or inactive (presumed dead; 13 second burst rate), thus informing SL. External identification tags (Peterson discs) were applied to Chinook and Coho Salmon to estimate OE during visual surveys (no visual surveys occurred for Steelhead Trout). Fork length (mm) and sex were recorded during tagging, and scale samples were obtained for ageing analysis (see Section 2.7).

Tagging effort was distributed throughout each species' migration period: February through April for Steelhead Trout, August through September for Chinook Salmon, and October through November for Coho Salmon). Angling occurred ~8 rkm downstream of the Seton-Fraser confluence for Steelhead Trout and in Reach 1 and 2 of the LBR or Chinook and Coho Salmon.

2.3.2 Radio Tag Tracking

All reach boundaries had fixed radio receiver stations (herein, 'fixed stations') to assess entry and exit into corresponding reaches (Stations 1-4; Figure 2). Additional fixed stations were located on the Yalakom River ~100 m upstream of its confluence with the LBR (Station 5; Figure 2) and, during the Steelhead Trout migration period, in the Seton River downstream of the lower spawning channel. Each fixed station consisted of an Orion receiver (Sigma Eight Inc., Ontario, Canada) connected to a single 6-element Yagi antenna oriented perpendicular to flow. Fixed stations were operated from March to June for Steelhead Trout, August to October for Chinook Salmon, and October to December for Coho Salmon.

Mobile tracking (by foot and by vehicle) was conducted weekly during each species' spawning period using a hand-held SRX_400 receiver (Lotek Wireless, Ontario, Canada), and twice weekly during peak spawning for increased spatial and temporal resolution. The full lengths of Reach 3 and 4 were surveyed. Given access issues, Reach 1 was monitored at the LBR-Fraser confluence and Reach 2 at Antoine Creek and Horseshoe Bend (Figure 2).

2.3.3 Radio Telemetry Analyses

All detection data were collated and filtered to remove noise and erroneous data. Migration rate (in km day^{-1}) was calculated between reach boundaries by dividing the known kilometers between reaches by the number of days a fish took to move from one reach boundary to the next (i.e., the difference between first detection at an upstream reach and last detection at a downstream reach). SL in Reach 2 and 3 was calculated for each tagged fish based on the time spent above each reach boundary prior to assumed spawning. Detection efficiency of fixed stations was determined as the ratio of fish detected upstream previously detected downstream (efficiency could not be calculated for the most upstream Reach 3/4 fixed station).

2.4 Migration Timing

Species-specific peak migration timing (a proxy for peak spawn timing) was assessed for all years using count data from resistivity and sonar counters, and detection data. Normal distribution models of migration timing were developed for both counter data and telemetry data, and visually compared among years and data types.

For counter data, peak migration timing was established for each species by fitting a normal distribution to the peak up count and the standard deviation recorded by the counter, assumed to represent peak migration. For telemetry data, migration timing distributions were developed by determining when tagged fish moved upstream through study reaches. Telemetry data were collated for all available years and the date of entry into Reach 3 (i.e., past the counter site) was calculated for each tagged fish. Only species and year combinations with five or more individuals observed at a given fixed station were included. A normal distribution was then fit to the annual mean date and standard deviation of entry into Reach 3. For Steelhead Trout, which are primarily captured at the Seton-Fraser confluence, dates of entry into the LBR (Station 1) were also determined. For Coho Salmon in 2014 and 2015, PIT telemetry was used instead of radio telemetry to calculate date of entry above the counter site, which was used to develop migration timing distributions for those years (Burnett et al. 2016).

2.5 Visual Counts and AUC Population Estimates

2.5.1 Visual Counts

Visual surveys of Chinook and Coho Salmon were conducted in the LBR and used to estimate abundance using an AUC method (visual surveys are not performed for Steelhead Trout due to low visibility). Visual survey data were also used to evaluate spawning distribution and timing because of insufficient radio telemetry sample sizes in many years.

Visual surveys occurred from August 2 to December 3 for Chinook and Coho Salmon. During each survey, two observers walked downstream along the river's edge and recorded fish count, species, location, water clarity (Secchi disk), and cloud cover. Visual surveys have been performed in Reaches 2 through 4 since 2018. Visual surveys historically focused on Reach 3 and 4, which were subdivided into eight visual survey sections from Terzaghi Dam to the Yalakom River. Survey section boundaries are at Longskinny (39.6 rkm), Eagle (38.8 rkm), Bluenose (38.2 rkm), Cobra (34.4 rkm), Fraser Lake (33.2 rkm), Russel Springs (30.7 rkm), Hell Creek (28.8 rkm), and Yalakom (25.0 rkm; Figure 5). Surveys in Reach 2 occurred at <3.5 m^3s^{-1} from the upstream end of Horseshoe bend to Camoo FSR bridge (24.0-18 rkm). When LBR discharge was >3.5 m^3s^{-1}, spot counts in Reach 2 occurred at Horseshoe bend and Camoo FSR bridge. Spot counts were also conducted at the LBR confluence with the Fraser River throughout the Chinook and Coho Salmon migration. No visual surveys were conducted in Reach 1 due to lack of access.

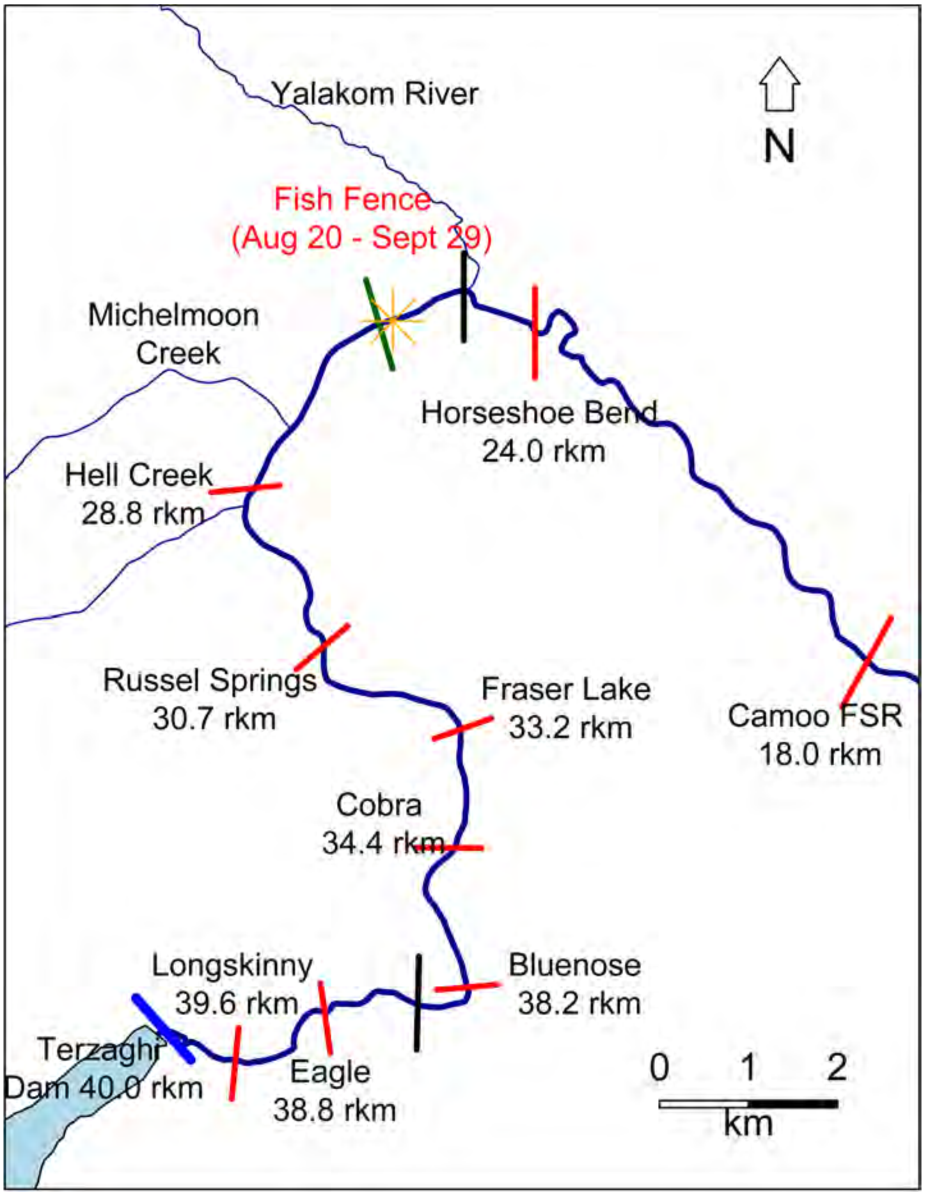


Figure 5: Visual survey boundaries (red lines), reach boundaries (black lines), counter location (orange star) and fish fence location (green line) in Reach 2 to 4 of the Lower Bridge River.

2.5.2 AUC Abundance Estimates

To estimate abundance, count data were modelled using a quasi-Poisson distribution with spawn-timing described by a normal distribution, and parameter estimates evaluated using maximum likelihood estimation (see details in Millar et al. 2012).

The number of observed spawners at time t (C_t) is

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

where *a* is the maximum height of the spawner count curve, m_s is the date of peak spawning, 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 3 becomes $\sqrt{2\pi\tau_s}$ and the equation can be expressed as

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

where F is the number of observed fish. The final abundance ($\hat{E}$) is then estimated (using maximum likelihood) by applying observer efficiency OE (*v*) and residence time (also called survey life; SL; *l*) to the expected number of observed spawners

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

$\hat{E}$ is estimated using maximum likelihood (ML), where $\hat{a}$ and $\hat{\tau}$ are the ML estimates of *a* and τ_s in Equation 4 $\hat{C}_t = \hat{a}\sqrt{2\pi\hat{\tau}_s}$).

Equation 5 can be re-expressed as a linear model, allowing the estimation to be performed as a log-linear equation with an over-dispersion correction factor. The correction accounts for instances where the variance of the spawner count exceeds the expected value. The expected number of observed fish $\hat{F}_G$can be estimated by

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

where β_0, β_1, β_2) are the regression coefficients of the log-linear model. Uncertainty in OE and SL are incorporated into the estimated 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).

2.5.3 Chinook Salmon Visual Enumeration

As with electronic counter estimates, Chinook Salmon abundance estimates using the AUC method were limited to fish that either had migrated past the counter site prior to fish fence installation on August 10 or were released post-capture upstream of the fence. Streamwalk section 8 (Hell Creek to Yalakom; rkm 25.0 to 28.8) was subdivided into upstream and downstream of the fish fence. Only fish that were counted upstream of the fence were included in the AUC estimate and broodstock collection data was added to this estimate for comparisons to electronic counter data.

2.5.4 Observer Efficiency and Survey Life

OE and SL parameters are difficult to estimate in the LBR due to high levels of glacial turbidity, low visibility, and low number of tagged individuals. Species-specific OE and SL have been collected since 2011 using a combination of radio telemetry, PIT telemetry, and visual surveys, but are highly uncertain. To estimate OE, the percentage of visually marked individuals (i.e., Peterson disc tags) observed during visual surveys was compared to the number of radio tagged fish known to be in the survey area. PIT telemetry was used for Coho Salmon during 2014 and 2015 to calculate SL, after which high flows made PIT telemetry unsuitable (Burnett et al. 2016). Individual SL was calculated as the time between Reach 3 entry and assumed mortality (i.e., the radio tag switched to 13 s burst rate) or downstream migration (kelting) was observed (for Steelhead). Most spawning occurs in Reach 3 and 4 of the LBR; date of entry into Reach 3 is used to differentiate migration from spawning behavior. The average SL was then calculated and used in the AUC model.

The availability of OE and SL data has been inconsistent, mostly due to low sample size in many years. Where year-specific OE and SL could not be obtained, averages among year-specific values were used. OE and SL were available for Chinook Salmon in 2012, 2013, 2014, and 2016 and for Coho Salmon in 2012, 2013, and 2016-2018 (Table 3; Appendix 2). Standard errors were the same for all years (i.e., standard error of all year-specific values). OE standard error was 0.139 for Chinook Salmon and 0.019 for Coho Salmon, while SL standard error was 0.65 for Chinook Salmon and 1.29 for Coho Salmon.

Table 3: Observer efficiency (OE) and survey life (SL) used during AUC abundance estimation for Chinook and Coho Salmon. Calculated values are bold, while all other values represent the average of calculated values.

	Chinook		**Coho**	
year	OE	SL	OE	SL
1997-2011	0.50	10.5	0.22	19.6
2012	**0.58**	**10.0**	**0.25**	**16.0**

2013	**0.28**	**11.0**	**0.27**	**19.0**
2014	**0.28**	**12.0**	0.22	19.6
2015	0.50	10.5	0.22	19.6
2016	**0.86**	**9.0**	**0.17**	**22.0**
2017	0.50	10.5	**0.19**	**23.0**
2018	0.50	10.5	**0.20**	**18.0**
2019	0.50	10.5	0.22	19.6
2020	0.50	10.5	0.22	19.6

2.5.5 AUC Reconstructions of Historic Count Data

A historic time series of AUC estimates using past count data obtained from the DFO was constructed for Coho and Chinook Salmon using the average OE and SL values. Helicopter count data were available from 1997 to 2004, and visual survey data were available from 2005 to 2010 (not all years were available for both species – see Appendix 2). Zero counts were not collected during all historic surveys (necessary for AUC modelling with low sample sizes) and zeros were added on August 8 and October 2 for Chinook Salmon and October 19 and December 6 for Coho Salmon, where necessary. A fish fence located in Fraser Lake (rkm 33.2) was also used to enumerate Chinook Salmon between 1993 to 1996. The fence data are assumed to be a complete population estimate, and the reconstructed AUC estimates help to complete the historic record from 1993 onwards.

Reconstructed AUC estimates are limited by a lack of accurate OE and SL data. For both Chinook and Coho Salmon, means and standard errors of OE and SL from years with OE and SL data were used during historic reconstructions (Appendix 2). Historic estimates will continue to be updated as more OE and SL data are collected; however, reconstructed AUC estimates should be considered highly uncertain given the lack of OE and SL data and the change in instream conditions since the 1990s.

2.6 Spawning Habitat

Spawning habitat was assessed using redd surveys, which quantified habitat characteristics within redds where spawners had been observed. Surveys of Chinook Salmon redds were conducted annually from 2014 to 2020 and in 2018 and 2020 for Coho Salmon. In 2017, an Instream Flow Incremental Methodology (IFIM) was initiated to assess Chinook Salmon spawning habitat in Reach 3 and 4, whereby water depth and velocity, and substrate size were measured in cross-sectional transects spanning the full width of the river. Recorded data were fit to habitat suitability index (HSI) curves to determine weighted usable area (WUA; Ptolemy 1994). HSI surveys were expanded in 2018 and 2019 to also include Reach 1 and 2, and to determine WUA for both Chinook and Coho Salmon (Figure 6).

Redd surveys and IFIM are complementary. Redd surveys evaluate spawning habitat selected for by active spawners, while HSI curves assess spawning habitat quantity throughout the LBR and to determine whether spawning habitat is limiting. No HSI surveys were introduced to determine the effects of high highs, and so were not completed in 2020 as flows did not exceed 20 m^3s^{-1} (WUP operating parameters). Redd surveys were the only habitat measure collected in 2020. However, previously collected WUA results were summarized by overlaying data on a map to observe annual habitat changes at select habitat units where Chinook Salmon spawning is known to occur.

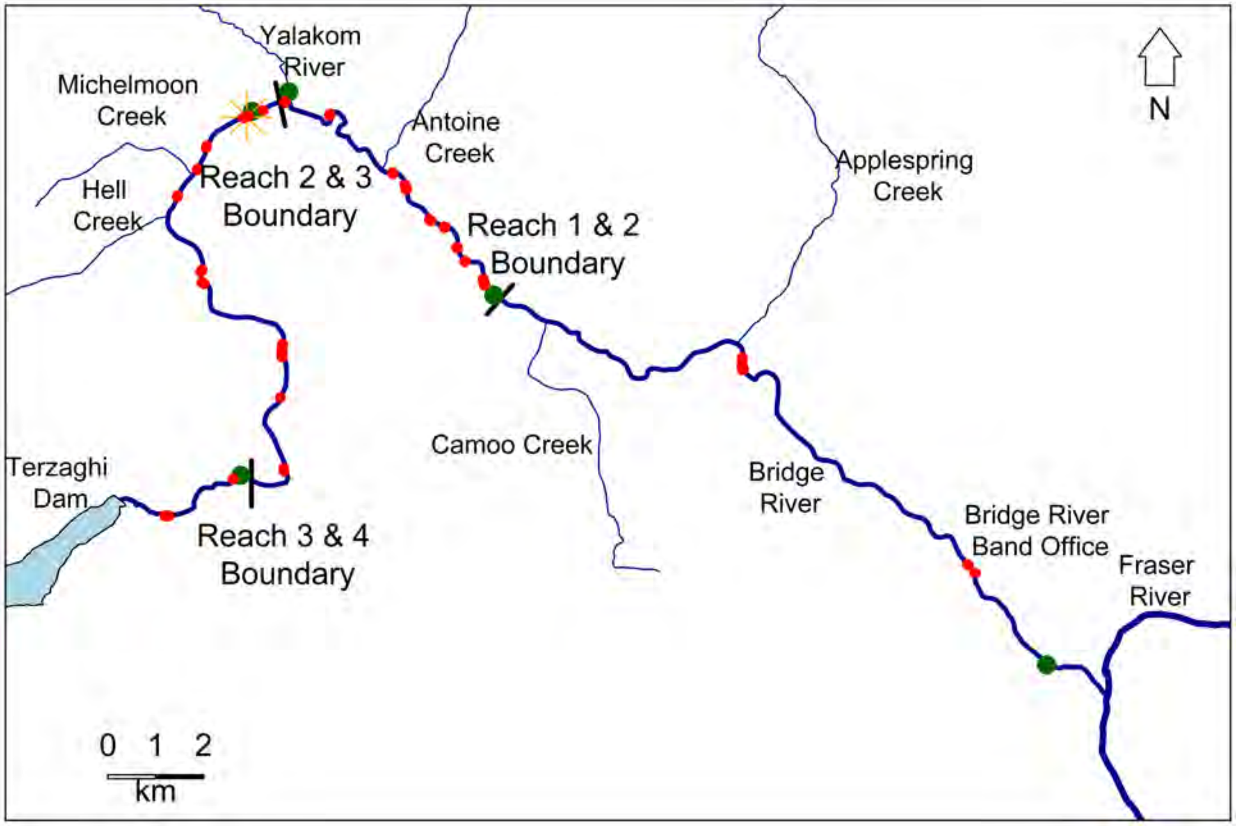


Figure 6: Habitat units (red) where transects were performed to assess Chinook and Coho Salmon spawning habitat. Green points show fixed radio stations and black lines indicate the boundary between study Reaches.

2.6.1 HSI Mapping

Maps of habitat suitability for spawning Chinook Salmon were developed for 2017, 2018, and 2019 at the Longskinny, Fraser Lake, Russel Springs, MSP (mid-spawning platform), LSP (lower-spawning platform), and Counter survey sites using ArcGIS Desktop 10.8.1. (ESRI, 2020). Maps were developed to visualize how habitat suitability is estimated using the methods described, and how habitat has changed at these sites over time. These specific sites were chosen because they represent areas where Chinook Salmon spawners have recently been observed. Cross-sectional transects were drawn perpendicular to the river using GPS coordinates collected during the habitat assessments. Rectangular "cells" were then created every meter along the transects, corresponding to the physical habitat data collected during the assessments. The length of each cell was approximately equal to half the distance to the next transect. Habitat suitability values for all three years were then applied to each cell and color-coded. Habitat suitability values closer to 1 (i.e., green-to-blue cells) indicate higher quality spawning habitat, while values closer to 0 (i.e., orange-to-red cells) indicate lower quality spawning habitat. Transect measurements with depths of 0 (e.g., exposed banks, islands, boulders) are represented in the maps as empty cells. Transects were manually aligned in ArcGIS using orthoimagery collected during low flows in October 2017; therefore, not all transects from 2018 and 2019 align perfectly with the background imagery. Nevertheless, these maps still help visualize how habitat suitability is estimated using the methods described herein, and how habitat has changed at these sites over time.

2.6.2 Redd Surveys

Redd surveys performed in Reach 3 and 4 measured depth, velocity, substrate characteristics, and dimensions at each redd. Depth and triplicate measures of velocity were taken using a flow meter (at 60% of the total depth; Swoffer Instruments, Model 2100) at the leading edge, adjacent to the tailspill of each redd (i.e., substrate mobilized by spawners during redd construction). The tailspill represents the substrate selected by spawners, and 20 pieces of substrate were randomly selected from the tailspill for measurement. The intermittent axis (2^{nd} largest length) was measured to determine the geometric mean particle size of preferred spawning substrate.

Measures of depth, velocity, and substrate size were compared to Chinook Salmon spawning preferences stated in the literature. Similar redd characteristics among years would suggest spawning site selection is consistent and that habitat availability is not limiting Chinook Salmon spawning in the LBR. A detailed quantitative analysis was not performed because in some years (particularly 2018 to 2020) few redds were sampled, and visual comparisons did not suggest differences among years. Redd data were also compared with results from the IFIM to determine whether there is evidence that spawning habitat availability has changed since 2014. Redd data could be used in future to develop HSI curves specific to the LBR, which would better inform changes in habitat availability due to alterations in flow regime.

Redd surveys were also used to compare distributions of confirmed spawning since 2014 for Chinook Salmon, and between 2018 and 2020 for Coho Salmon. This assessment is combined with visual surveys of migrating adults to inform whether flow regime has affected spawner distributions.

2.7 Ageing of Adult Salmon and Steelhead Trout

Scales were collected from Steelhead Trout and Chinook and Coho Salmon during angling and opportunistic sampling of moribund fish during visual surveys. Scale aging identifies the amount of time that an individual spends in fresh and salt water and can potentially signify changes in quality of the respective environments. Age classes exposed to high flows as juveniles will be monitored to observe potential changes to freshwater life history. Only age data of individuals known to have spawned in the LBR were included (e.g., excluding those radio- and PIT-tagged individuals migrated further up the Fraser River). It has been difficult to collect scales from Chinook Salmon, as abundances returning to the LBR have been low and scales have typically been resorbed by the time Chinook Salmon are captured.

Ageing followed methods outlined in Ward and Slaney (1988), where two people independently determined age ignorant of fish size and time of capture. Age was expressed as two numbers separated by a decimal (Koo 1962), where the first number is the number of years or winters spent in freshwater and the second number is the number of years or winters spent in the ocean. These two numbers summed together is the total age of the fish (ignoring larval stage). For example, a 1.2 represents an age 3 fish.

3. Results

3.1 Electronic Counter Spawner Enumeration

3.1.1 Steelhead Trout (Resistivity and Multibeam Sonar)

In 2020, Steelhead Trout were enumerated using both the resistivity counter and the ARIS sonar. After accounting for accuracy, the net upstream abundance of Steelhead Trout recorded by the resistivity counter between April 1 and June 8 was 50 and the sonar recorded 12 individuals between March 27 and June 11.

Species were identified during validation of the resistivity counter data as either Steelhead or other resident species. There was a positive relationship between standard length and PSS. A PSS of 80 was determined to distinguish Steelhead Trout from resident species passing in both directions on channel 2 and upstream on channel 1. With few individuals passing downstream on channel 1, a separate PSS cut-off of 39 was used to distinguish Steelhead Trout from resident species. The start of the kelt migration period was estimated to be May 19, when 5% of the down counts occurred after May 15. This date was also corroborated from radio telemetry data, as the average kelt date from 5 individuals was May 15 (Section 3.2.1). After May 19, all Steelhead Trout down counts were removed from the final population estimate. The counter upstream accuracy for channel 1 and 2 was 92% and 70% respectively. Downstream accuracies were, 68% and 100% for channel 1 and 2 respectively (Table 4).

All fish recorded by the sonar (n = 113) were manually measured using ARISfish software, precluding the need for a length model to correct for Echoview length measurement errors (White et al. 2019). A fork length cut-off of 600 mm was used to distinguish between Steelhead Trout (>600 mm) and resident species (<600 mm). This cut off was developed using LBR fork length data collected during angling from 2014 to 2020 and has been shown to minimize the amount of overlap between Steelhead Trout and other species (Appendix 1). As with the resistivity counter data, a kelt date of May 19, 2020 was applied and all Steelhead Trout passing downstream of the counter site after this date were removed from the total abundance estimate.

The total abundance of Steelhead Trout in 2020 was 62, combining estimates from the resistivity counter (n = 50) and sonar (12; Figure 7. This continues the trend of low returns of Steelhead Trout to the LBR since 2014 (Table 5).

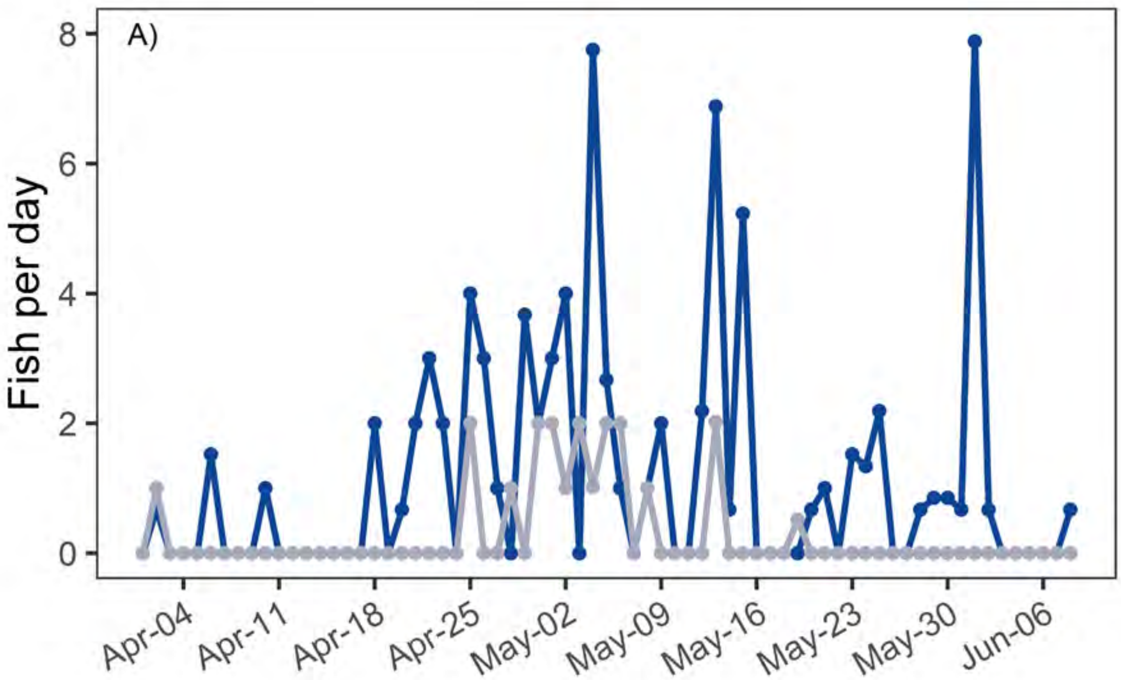
Table 4: Resistivity counter accuracy during the 2020 Steelhead Trout migration in the Lower Bridge River.

Channel	Direction	True Positive	False Positive	True Negative	False Negative	Accuracy
1	Up	12	1		0	92%
1	Down	NA	NA	NA	NA	68%*
2	Up	7	3		0	70%
2	Down	6	0		0	100%

*Insufficient sample size prevented the accuracy calculation for down counts on channel 1. Previous years accuracies were averaged and applied.

Table 5: Estimated abundance of Steelhead Trout in the Lower Bridge River since 2014 and summary data used to achieve estimates. The Fraser River rockslide may confound estimates in recent years because we expect increased straying.

Year	Abundance	Method	Comments
2014	238	Resistivity Counter	Complete Estimate
2015	59	Resistivity Counter	Complete Estimate
2016	NA	Resistivity Counter	High flows prevented the operation of the resistivity counter
2017	26	Resistivity Counter and Multibeam Sonar	Counting equipment removed early due to forecasted high flows
2018	14	Resistivity Counter and Multibeam Sonar	Counting equipment removed early due to forecasted high flows
2019	50	Resistivity Counter and Multibeam Sonar	Complete Estimate, affected by Fraser River rockslide
2020	62	Resistivity Counter and Multibeam Sonar	Complete Estimate, affected by Fraser River rockslide



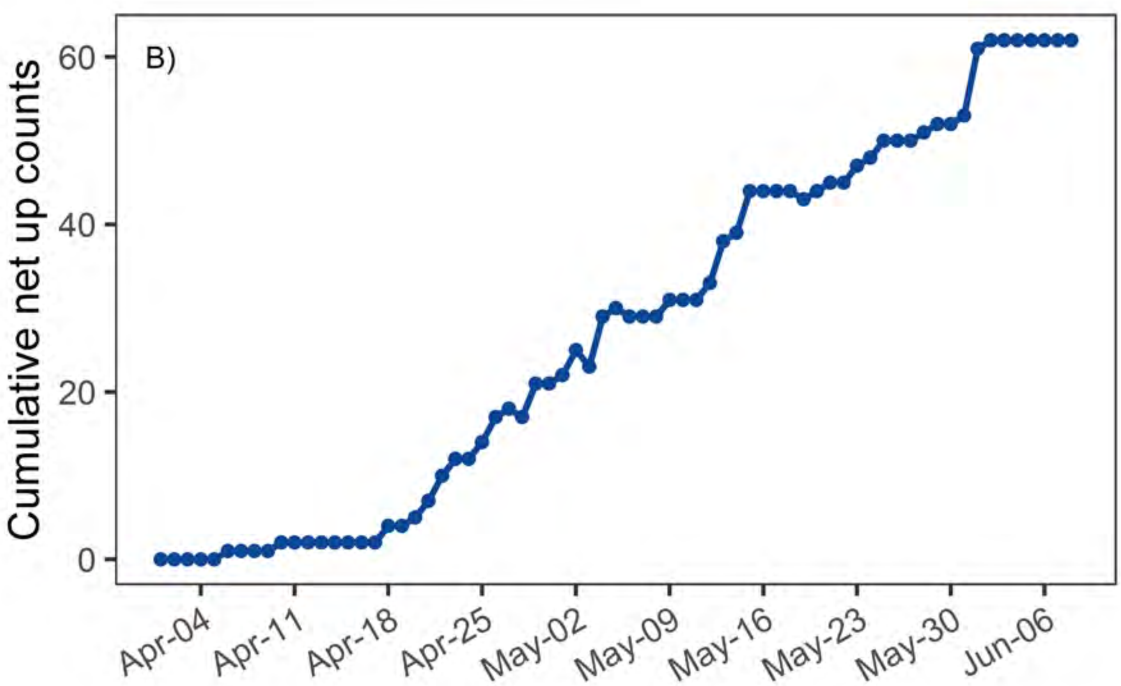


Figure 7: (A) Combined multibeam sonar and resistivity counter daily up (blue) and down (grey) counts and cumulative net up counts (B) for Steelhead Trout in the Lower Bridge River in 2020.

3.1.2 Chinook Salmon (Resistivity and Multibeam Sonar)

In 2020, Chinook Salmon were enumerated using the resistivity counter and the ARIS sonar between July 20 to August 10, after which counts from the fish fence were used. After accounting for accuracy, the net upstream abundance of Chinook Salmon recorded by the resistivity counter was 19 and the sonar recorded 1 net down.

Species were identified during validation as either Chinook or Sockeye Salmon, or resident species. Validation occurred for 47 hours of video data. The counter had 100% accuracy in both directions on Channel 1 and an accuracy of 88% and 100% on channel 2 for up and down counts, respectively (Table 6). A PSS cutoff of 60 was used to differentiate between salmon (Chinook and Sockeye) and resident species. A species ratio determined during validation was applied to differentiate counts of Sockeye and Chinook. Seven Chinook and 23 Sockeye salmon were identified during targeted validation, resulting in a Chinook Salmon ratio of 0.23 that was applied to all non-validated counter records.

The sonar recorded 402 fish tracks (295 ups and 107 downs) and 71 individuals (17.7% of events) were measured using ARISfish to develop the relationship between Echoview-derived and manually measured fish lengths. Lengths estimated by Echoview were positively related to the ARISFish lengths, but biased low. A single model for both up and down movements to improve the accuracy of fish length and therefore species classification, included only Echoview lengths ($R^2 = 0.82$, $p < 0.05$; Appendix 3). A fork length cut-off of 650 mm was used to distinguish between Chinook Salmon (>650 mm) and other salmon and resident species (<650 mm). This cut off was developed using LBR fork length data collected during angling from 2014 to 2020 and has been shown to minimize the amount of overlap between Chinook Salmon and other species (Appendix 1).

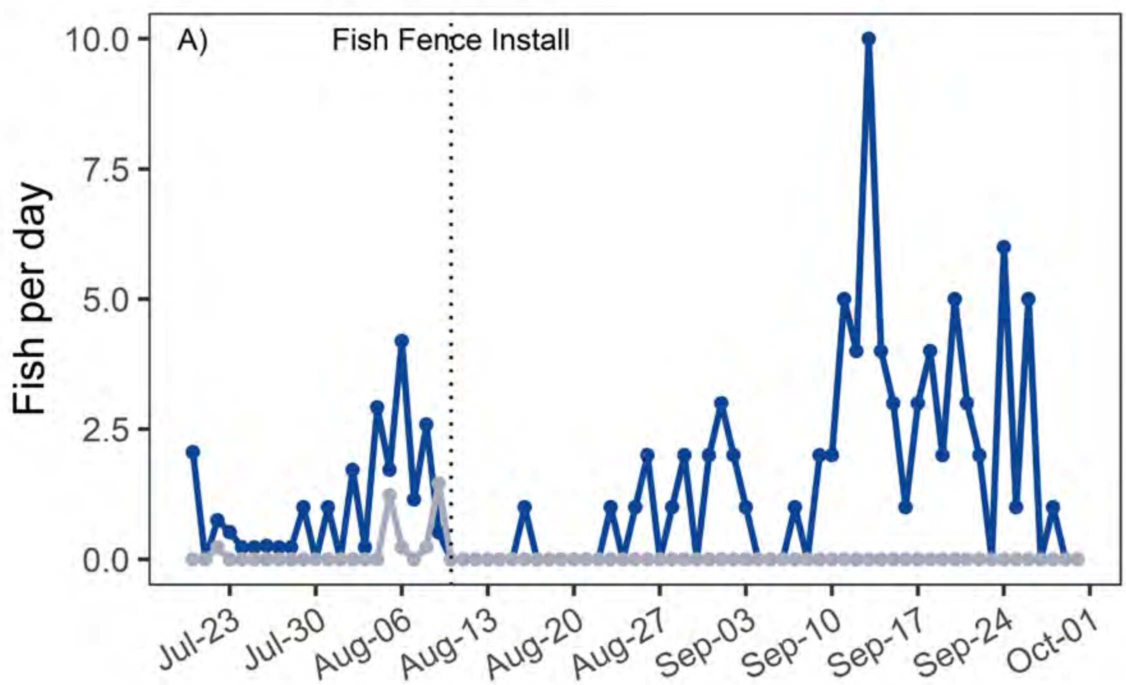
The partial abundance of Chinook Salmon measured by the electronic counters was 18 (19 [resistivity counter] - 1 [sonar]; Figure 8). After August 10, 80 Chinook Salmon were enumerated at the fish fence. The resulting estimate is 98 Chinook Salmon. It is difficult to compare Chinook Salmon escapement from 2020 to previous years due to the fence operation and the effects of the Fraser River rockslide, which resulted in increased straying. Despite these uncertainties, Chinook Salmon abundance in the LBR is low, and escapement estimates between 2018 and 2020 were the lowest since monitoring began in 2014 (Table 7).

Table 6: Resistivity counter accuracy during the 2020 Chinook Salmon migration in the Lower Bridge River.

Channel	Direction	True Positive	False Positive	True Negative	False Negative	Accuracy	Estimate
1	Up	23	0	0	0	100%	correct
	Down	0	0	0	0	100%	correct
2	Up	7	0	0	1	88%	under
	Down	0	0	0	0	100%	correct

Table 7: Estimated abundance of Chinook Salmon in the Lower Bridge River since 2014 and a summary data used to achieve estimates. A river-spanning fish fence for broodstock collection upstream of the counter site has interfered with counting and the Fraser River rockslide may confound estimates in recent years because we expect increased straying.

Year	Abundance	Method	Comments
2014	947	Resistivity Counter	Complete Estimate
2015	481	Resistivity Counter	Complete Estimate
2016	193	Resistivity Counter and Multibeam Sonar	Partial Estimate - testing of new multibeam sonar following infrastructure damage
2017	340	Resistivity Counter and Multibeam Sonar	Complete Estimate
2018	42	Resistivity Counter, Multibeam Sonar, and fence captures	Partial Estimate - fish fence limited estimate (pre-August 29)
2019	156	Resistivity Counter, Multibeam Sonar, and fence captures	Partial Estimate – fish fence limited estimate (pre-August 20), affected by Fraser River rockslide
2020	98	Resistivity Counter, Multibeam Sonar, and fence captures	Partial Estimate – fish fence limited estimates (pre-August 10), affected by Fraser River rockslide



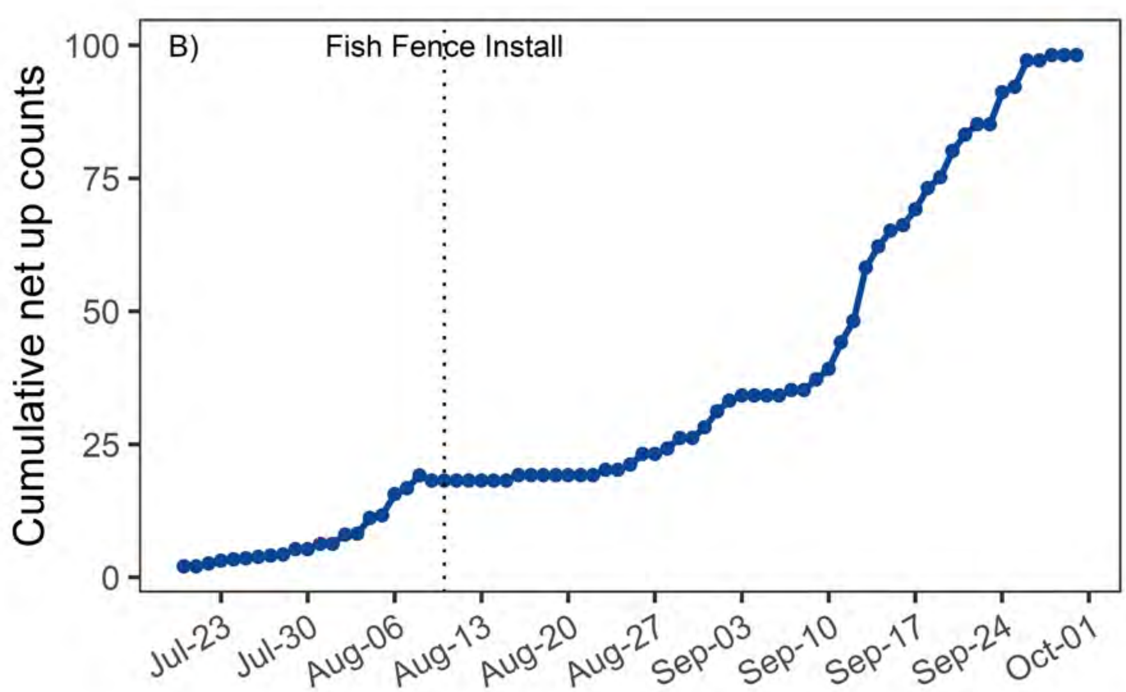


Figure 8: (A) combined multibeam sonar and resistivity counter and broodstock daily up (blue) and down (orange) counts and cumulative net up (B) counts for Chinook Salmon in the Lower Bridge River. The broodstock fence was installed on August 10th, after which all up counts were recorded from the fish trap.

3.1.3 Coho Salmon (Multibeam Sonar)

In 2020, Coho Salmon were enumerated solely using the Blueview sonar, as LBR discharge was too low (1.5 m^3/s) during the Coho Salmon migration to allow for passage over the resistivity counter. After applying the length model to improve species classification, the net upstream abundance of Coho Salmon recorded by the sonar between October 7 and December 3 was 539.

Echoview lengths were positively correlated to the ARISFish lengths, but biased low (Appendix 3). The most parsimonious model for up movements included Echoview lengths, number of targets, and target range mean (R^2 = 0.72, p < 0.01; Appendix 3), while the most parsimonious model for down movements included only Echoview lengths (R^2 = 0.84, p < 0.01; Appendix 3). These models were used to predict length for all sonar traces, and a fork length cut-off of 400 mm was then used to differentiate Coho Salmon (>400 mm) from all other species (<400 mm). This cut-off was developed using fork length data collected in the LBR during angling from 2014 to 2020 and minimizes the overlap between Coho Salmon and resident species (Appendix 1). The downward movement of Coho Salmon is often observed by moribund or dead individuals, which can affect abundance estimates. A date, like the kelt-date used in Steelhead Trout was applied to the Coho Salmon migration. The start of downward movement was estimated to be November 14, when 5% of the total down counts occurred after November 10. After this date, all Coho Salmon down counts were removed from the final population estimate.

The 2020 estimate is comparable to 2015 and 2018 and almost double the 2019 estimate (280; Figure 9; Table 8). As with other species, the Fraser River rockslide may have resulted in a high percentage of stray fish from other rivers and may not reflect the true abundance of LBR origin Coho Salmon.

Table 8: Summary of Coho Salmon electronic counter data used in abundance estimates.

Year	Abundance	Method	Comments
2014	1543	Resistivity Counter	Complete estimate
2015	566	Resistivity Counter	Complete estimate
2016	1090	Multibeam Sonar	Complete estimate - testing of new multibeam sonar following infrastructure damage
2017	NA	Multibeam Sonar	Partial estimate - Post season data loss
2018	545	Multibeam Sonar	Complete estimate
2019	280	Multibeam Sonar	Complete estimate, affected by Fraser River rockslide
2020	539	Multibeam Sonar	Complete estimate, affected by Fraser River rockslide

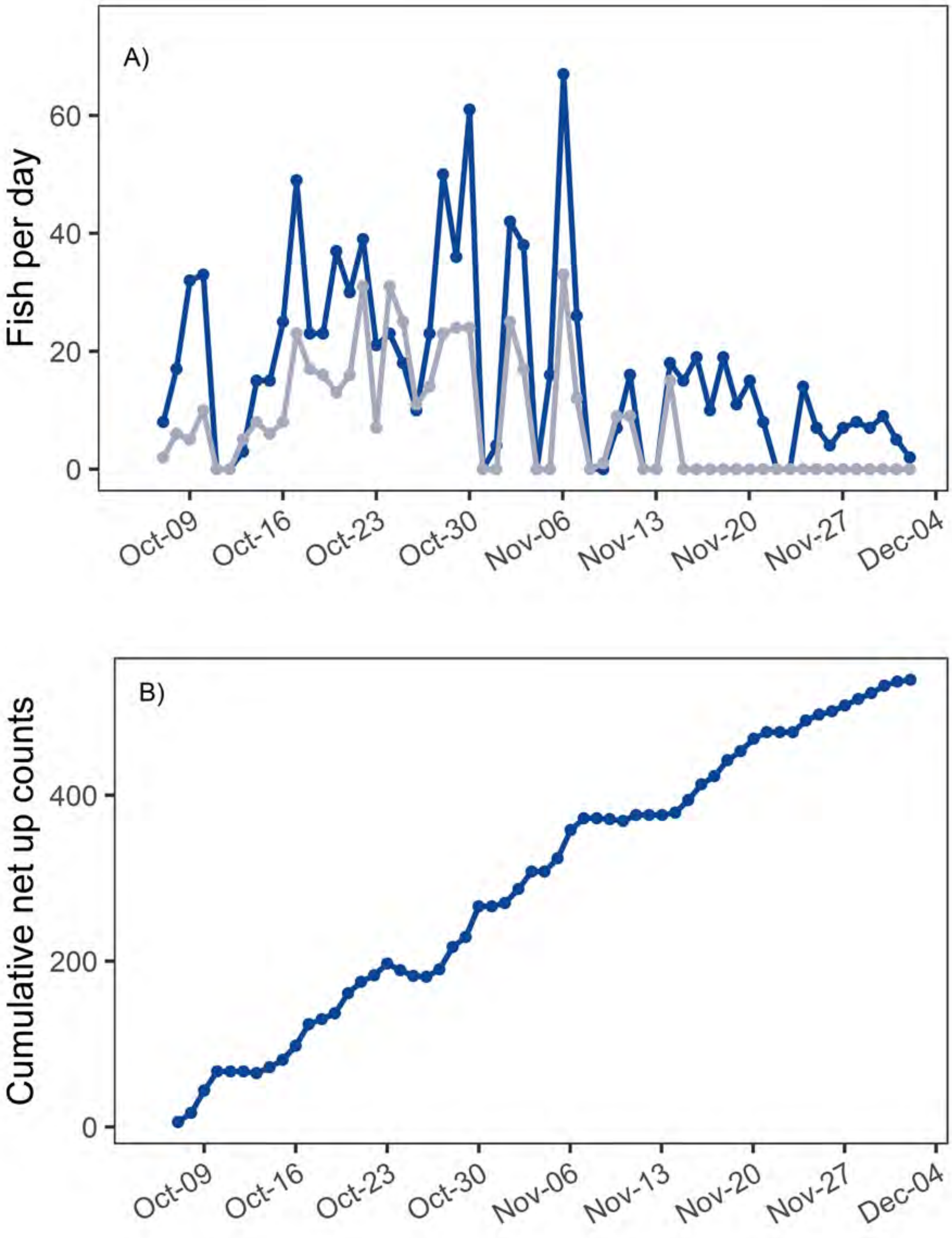


Figure 9: (A) sonar derived daily up (blue) and down (grey) counts and cumulative net up (B) counts for Coho Salmon in the Lower Bridge River in 2020.

3.2 Spawning Distribution (Radio Telemetry)

Radio telemetry was used to assess spawning distributions for Steelhead Trout. For Chinook and Coho Salmon, sample sizes were low (driven by low tag deployment, and few tagged individuals entering the LBR), and visual survey data were also used to inform spawner distributions (see Sections 3.4.3 and 3.5). Detection efficiency was high at all fixed receiver stations during the Steelhead Trout migration (80.0% at Station 1, 77.8% at Station 2, and 66.7% at Station 3). Detection efficiency could not be calculated for Chinook or Coho Salmon due to limited post-tagging migration into the LBR.

3.2.1 Steelhead Trout

Eighteen Steelhead Trout (4 males, 14 females) were tagged at the Seton-Fraser confluence from February 12 to April 15, 2020. Of these fish, 12 individuals were detected by either fixed receivers or mobile tracking following tagging (Appendix 4). Telemetry detections indicated that Steelhead Trout entered the LBR throughout April and spawned from late-April through mid-May. Spawning locations were determined for nine Steelhead Trout, five of which spawned in Reach 3 (4 at the counter site and 1 at Fraser Lake), and four of which spawned in Reach 4 (Longskinny to Eagle; Figure 10). Steelhead continue to utilize Reach 3 and 4 to spawn, as in previous years (Figure 11). Of the 3 fish with unknown spawning locations; one was detected near the confluence of the Seton and Fraser Rivers by mobile tracking, one was detected within the Seton River and one was detected briefly at the Reach 1/2 fixed telemetry station. Kelting behavior was observed for five Steelhead Trout, which migrated out of the Bridge River system in mid- to late-May (Appendix 5). The mean residence time in 2020 was 23.1 ± 9.1 days above Reach 2 and 17.6 ± 11.6 days above Reach 3. Steelhead Trout that showed directed upstream migrations in the LBR had a mean migration rate of 2.2 ± 2.3 km day^{-1} (Appendix 4).

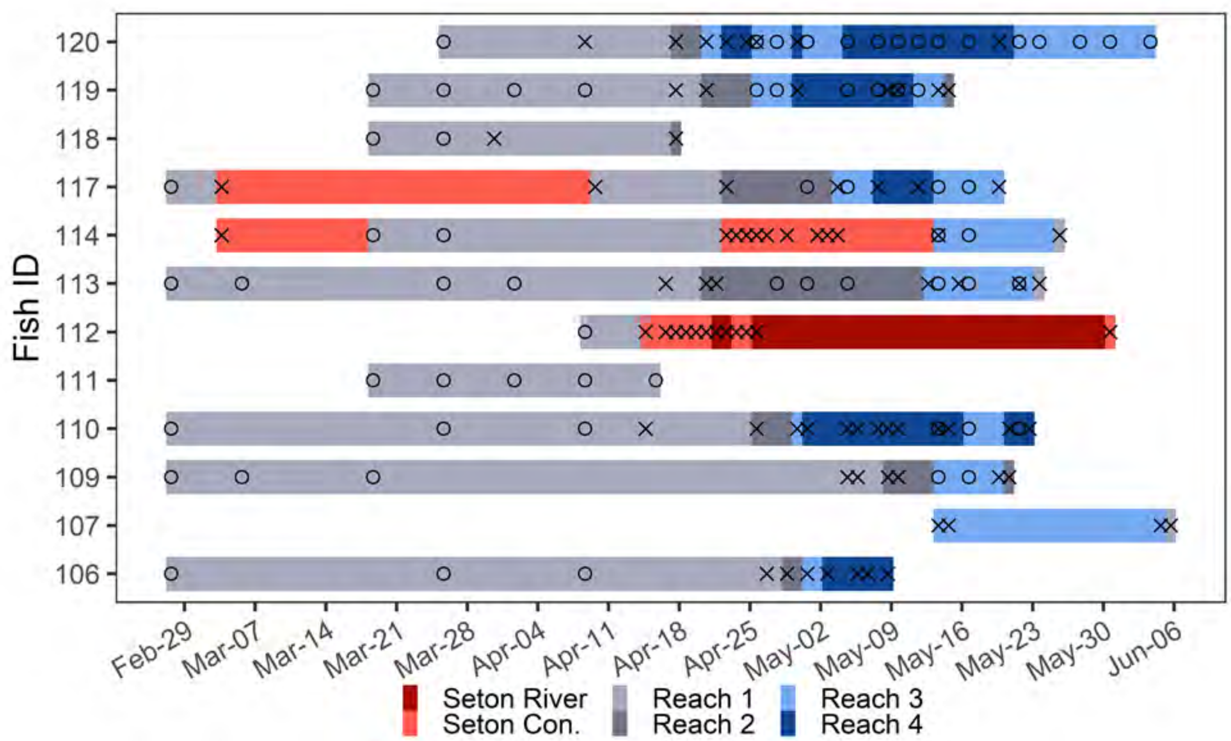


Figure 10: Time series of radio-tagged Steelhead Trout in the Seton and Lower Bridge River in 2020. o denotes mobile tracking detections, × denotes fixed receiver detections.

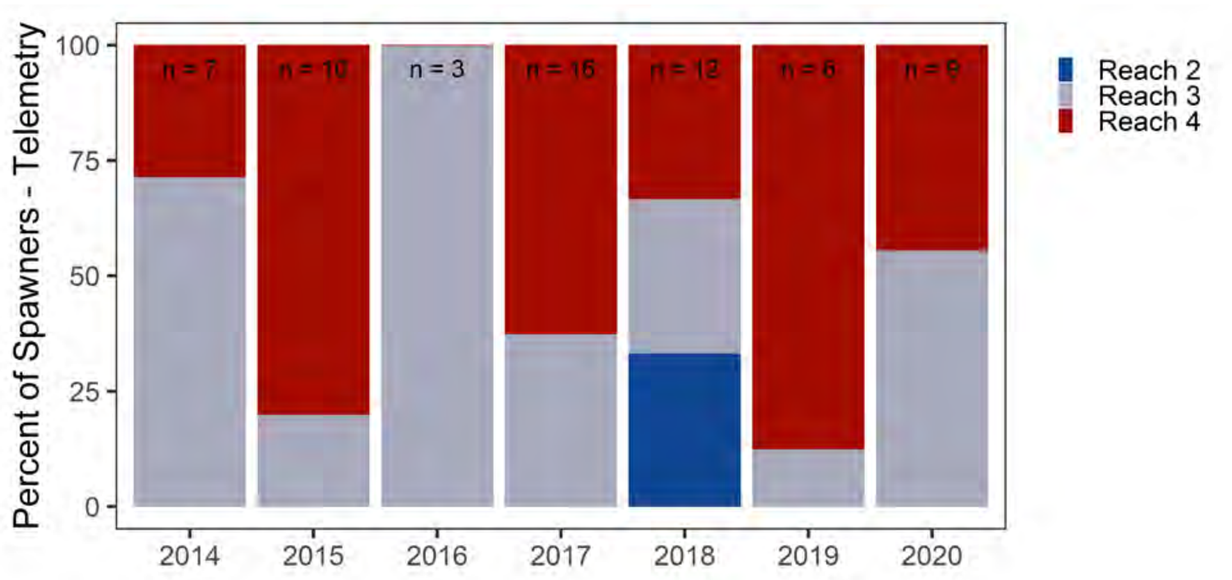


Figure 11: Relative proportion of estimated spawning locations in Reach 2, 3 and 4, for Steelhead Trout based on radio telemetry.

3.2.2 Chinook Salmon

Five Chinook Salmon (4 female and 1 male) were tagged in 2020 between August 16 and 30 at Hippie Pool (n = 2; 25.4 rkm), the Bridge-Yalakom confluence (n = 2; 25.0 rkm), and the Camoo FSR bridge (n = 1; 18 rkm; Appendix 4). Of the five fish tagged, three were detected by either fixed or mobile telemetry receivers. The two fish tagged at the Bridge-Yalakom confluence were estimated to have spawned below the fish fence and the fish tagged at the Camoo FSR bridge was estimated to have spawned just upstream of its tagging location (Figure 12; Appendix 4). Residence time and migration speed could not be estimated for Chinook Salmon in 2020 due to little movement.

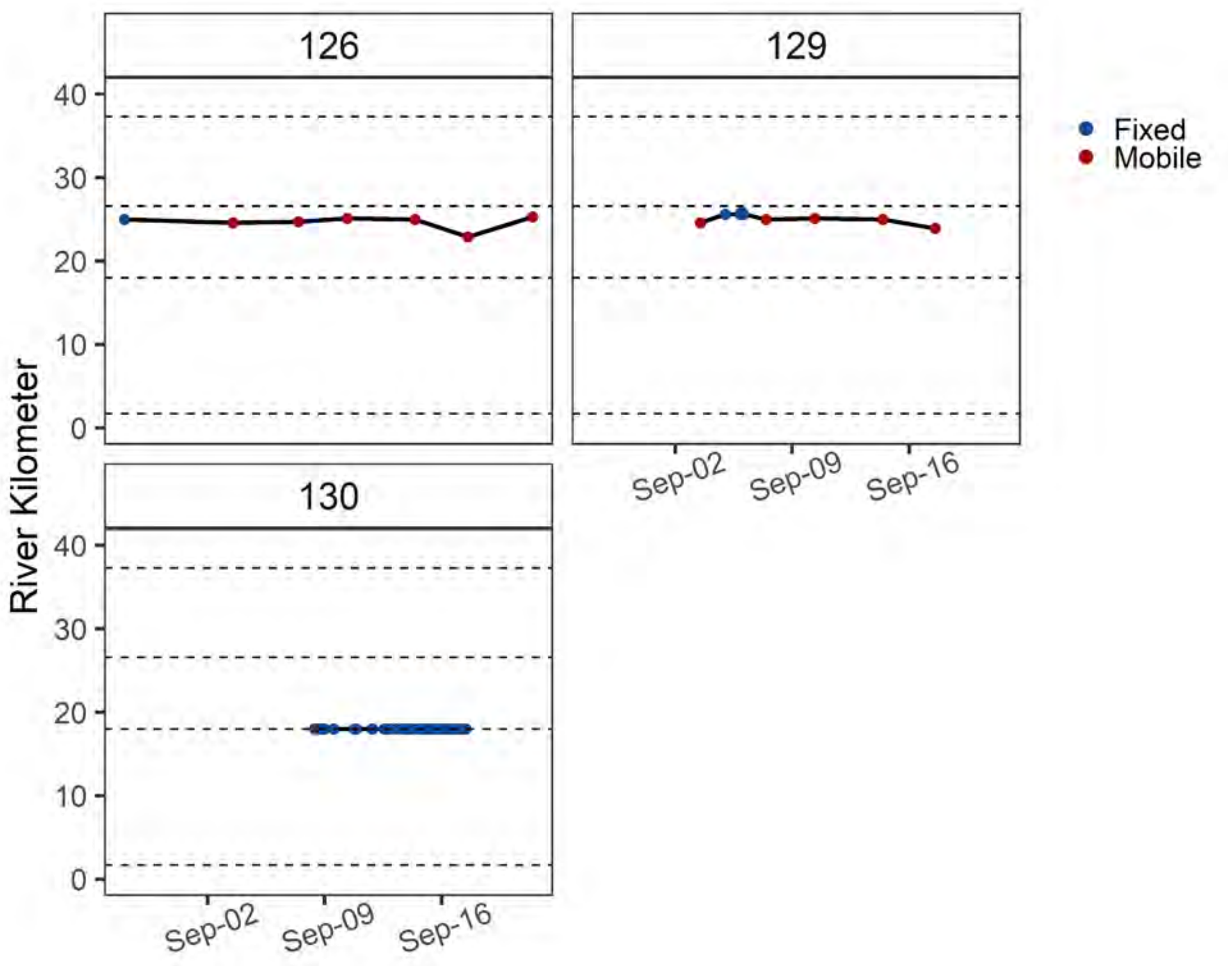


Figure 12: Detection histories of radio-tagged Chinook Salmon in the Lower Bridge River in 2020. The number above plots refers to the radio tag ID.

3.2.3 Coho Salmon

Twelve Coho Salmon (5 males and 7 females) were tagged between October 10 and November 18 at the Bridge River – Fraser River confluence (n = 11; 0.5 rkm), and Hippy Pool (n = 1; 25.4 rkm; Figure 13, Appendix 4). Eight were detected by either fixed or mobile telemetry receivers and four fish were suspected to spawn in Reach 3 and 4. One fish spawned between Terzaghi Dam and Longskinny, one between the fish fence and Russel and two between Hell Creek and the fish counter. The other four fish were detected briefly at the Reach 1 receiver before exiting the LBR. One individual (tag 136) was detected at DFO managed telemetry stations downstream of the Bridge River. The remaining fish had unknown fates. Residence time was 21.5 ± 3.2 days above Reach 2 and 17.0 ± 5.3 days above Reach 3, and migration speed was 2.2 ± 0.7 km day^{-1} (Appendix 4).

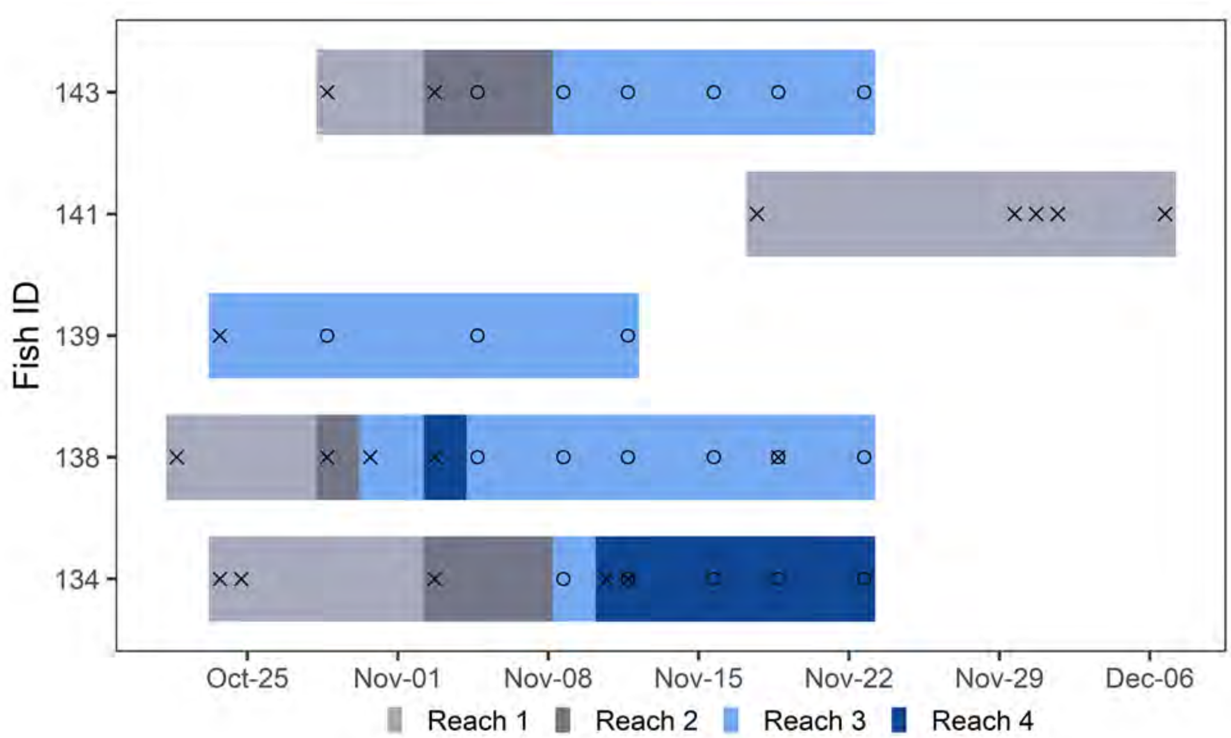


Figure 13: Time series of radio-tagged Coho Salmon in the Lower Bridge River in 2020. o denotes mobile tracking detections, × denotes fixed receiver detections.

3.3 Migration Timing

Migration timing was assessed among years and between counter data and radio telemetry data, where available, to determine whether changes in migration timing have occurred in response to changes to instream flow regime in the LBR.

Table 9: Radio telemetry and counter estimates, where available, were used to derive migration timing curves for Steelhead Trout and Chinook and Coho Salmon in the LBR. Years where a method was not available are denoted by NA. Radio telemetry data with <5 individuals were not included in the analysis. Confounded counter estimates (as specified) were not used.

Year	Steelhead Trout		Chinook Salmon		Coho Salmon	
	Radio Telemetry n	Counter Estimate	Radio Telemetry n	Counter Estimate	Radio Telemetry n	Counter Estimate
2012	NA	NA	15	NA	25	NA
2013	NA	NA	26	NA	19	Y
2014	8	Y	17	Y	15*	Y
2015	10	Y	14	Y	14*	Y
2016	2	N (damaged)	14	Y	30	Y
2017	16	Y	2	Y	8	N (data loss)
2018	8	Y	2	N (fish fence)	12	Y
2019	8	Y	1	N (fish fence)	0	Y
2020	7	Y	0	N (fish fence)	4	Y

* PIT telemetry was used instead of radio telemetry.

3.3.1 Steelhead Trout

Steelhead Trout telemetry data were available for 2014 through 2020, while counter data were available for 2014, 2015, and 2017 through 2020 (Table 9). Distributions of timing past the counter site were relatively consistent among years and between data types, indicating Steelhead Trout typically spawn in the first or second week of May. Migrating spawners were exposed to high flows from 2016 to 2018, but these years do not appear to differ from others (Table 10; Figure 14).

Timing distributions were also assessed from radio telemetry data for entry into Reach 1. Entry into Reach 1 was relatively consistent apart from 2017, when peak entry into the LBR occurred approximately 2-3 weeks earlier than any other year (n = 9; Table 10; Figure 15).

Table 10: Minimum, maximum and mean dates, with standard deviation, of entry into Reach 3 by Steelhead Trout recorded by electronic counters and radio telemetry.

	Counter				Radio Telemetry			
	Min	max	mean	std (days)	min	max	mean	std (days)
2014	NA	NA	NA	NA	04-17	05-21	05-05	14.2
2015	04-09	06-04	04-25	30.7	04-18	05-12	05-01	7.0
2016	NA	NA	NA	NA	NA	NA	NA	NA
2017*	04-22	05-08	05-03	6.7	04-14	05-20	04-30	8.8
2018*	03-22	05-08	04-29	11.7	04-20	05-31	05-07	13.1
2019	04-22	05-14	05-03	5.9	04-21	05-18	05-02	9.5
2020	04-02	06-08	05-04	15.5	04-21	05-14	05-05	8.8

*electronic counters were removed mid-May due to forecasted high flows above operating threshold.

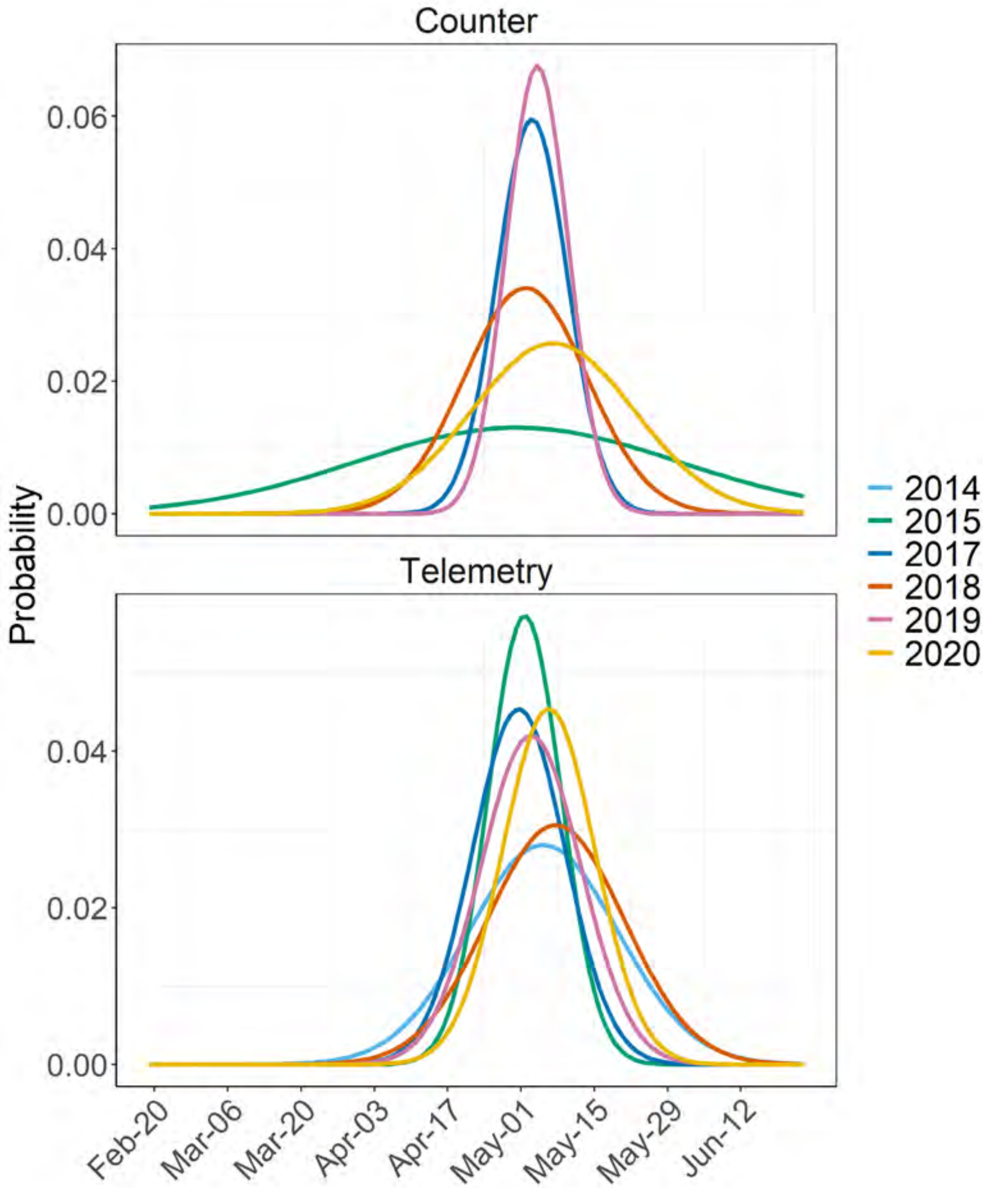


Figure 14: Normal distributions of Steelhead Trout migration timing from electronic counters (top) and Reach 3 telemetry data (bottom) from 2014-2020. Years with low sample size (n<5) or incomplete estimates were removed.

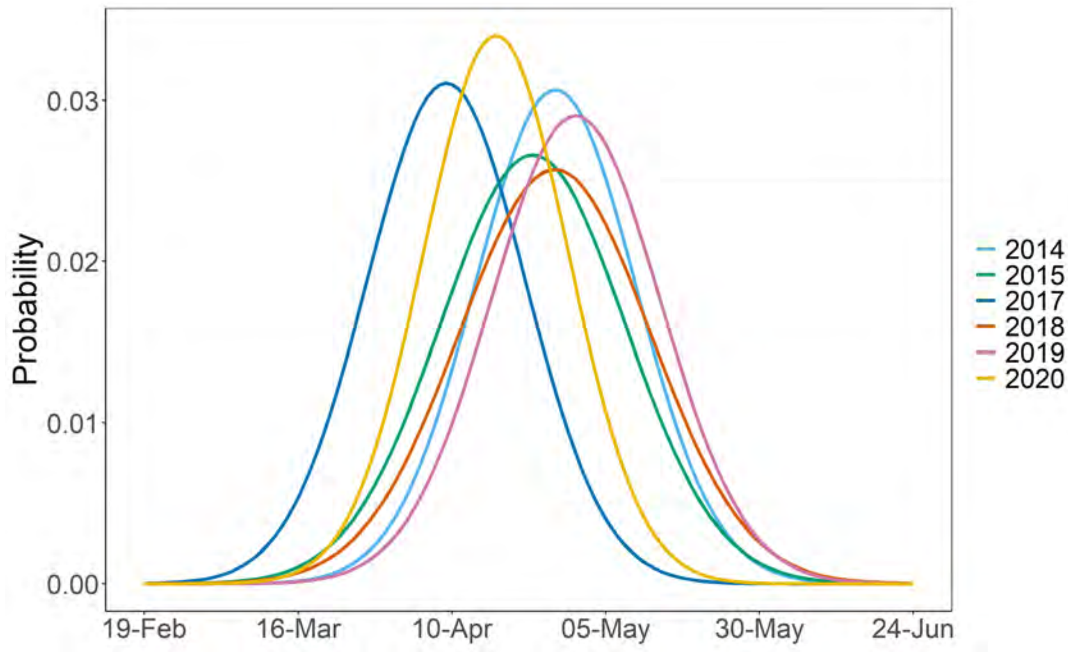


Figure 15: Normal distributions of Steelhead Trout entry into Reach 1 derived from telemetry from 2014 to 2020. Years with low sample sizes (n<5) were removed.

3.3.2 Chinook Salmon

To assess Chinook Salmon migration timing, telemetry data were available from 2012 to 2016, and counter data from 2014 to 2015 and 2017 (Table 9). Limited angling success since 2017 has prevented the use of telemetry data and counter data is not available from 2018 because of installation of the fish fence. Migration timing distributions were relatively consistent among years and between the counter and telemetry data and indicate Chinook Salmon typically spawn in the last week of August or beginning of September. There does not appear to be evidence that migration timings have shifted during BRGMON-3, outside of 2017 where peak migration occurred in the second week of September (Figure 16). Chinook Salmon migrate in August and September and are subjected to a consistent flow regime (3 m^3s^{-1}). Assessing migration timing in Chinook Salmon will continue to be limited, provided the fish fence remains in its current location.

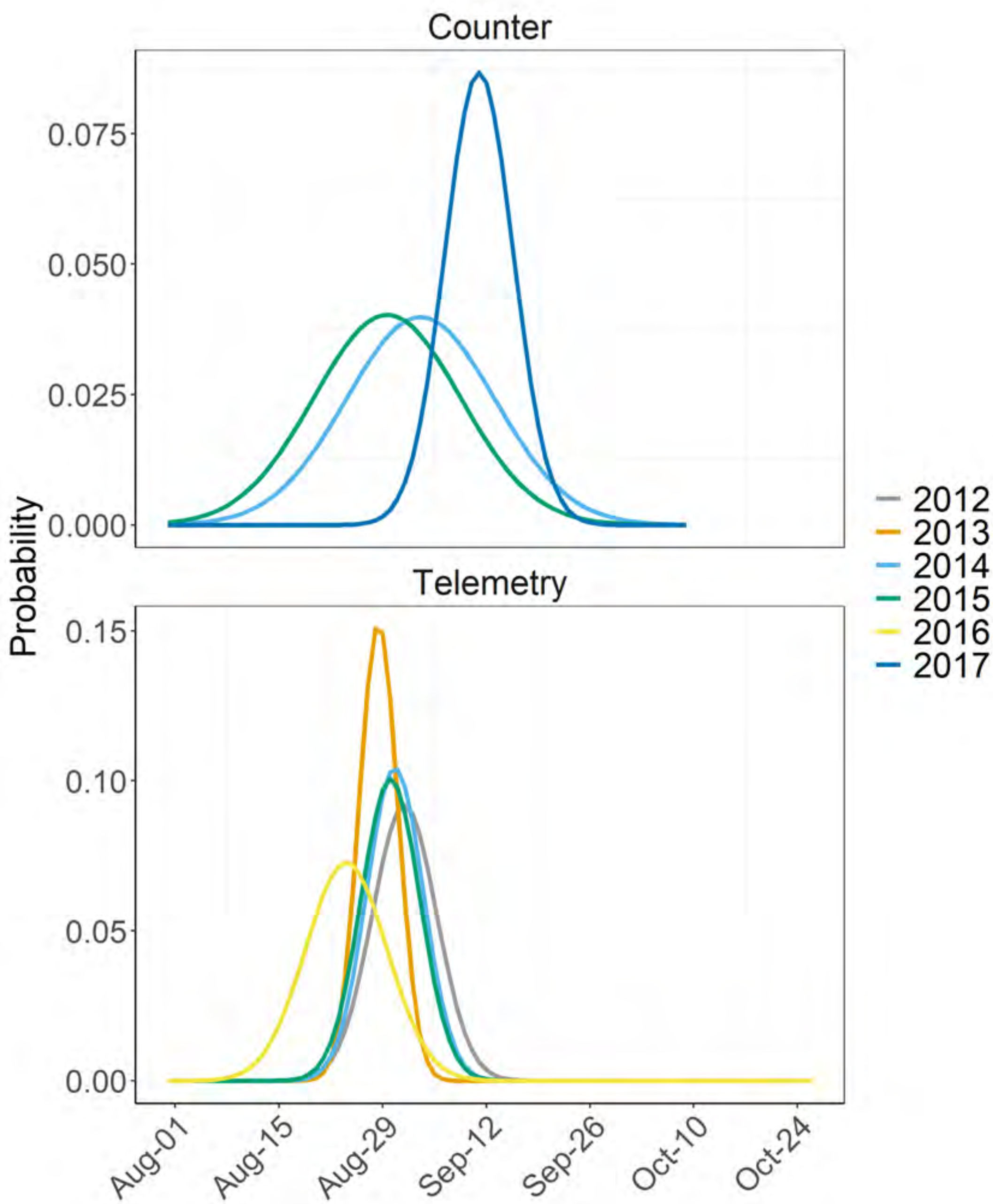


Figure 16: Normal distribution of Chinook Salmon peak migration timing from electronic counters (top) and Reach 3 telemetry data (bottom) from 2012-2017. Years with low sample size (n<5) or incomplete estimates were removed.

3.3.3 Coho Salmon

For Coho Salmon, telemetry data were available for 2012 to 2018 and 2020 (2014 and 2015 used PIT telemetry) and electronic counter data were available in all years since 2013, except 2017

(Table 9). Migration timing distributions were relatively consistent among years and between the counter and telemetry data and indicate Coho Salmon typically spawn in the last week of October (Figure 17). Like Chinook Salmon, Coho Salmon migrate in October and November and are subjected to a consistent flow regime (1.5 m^3s^{-1}).

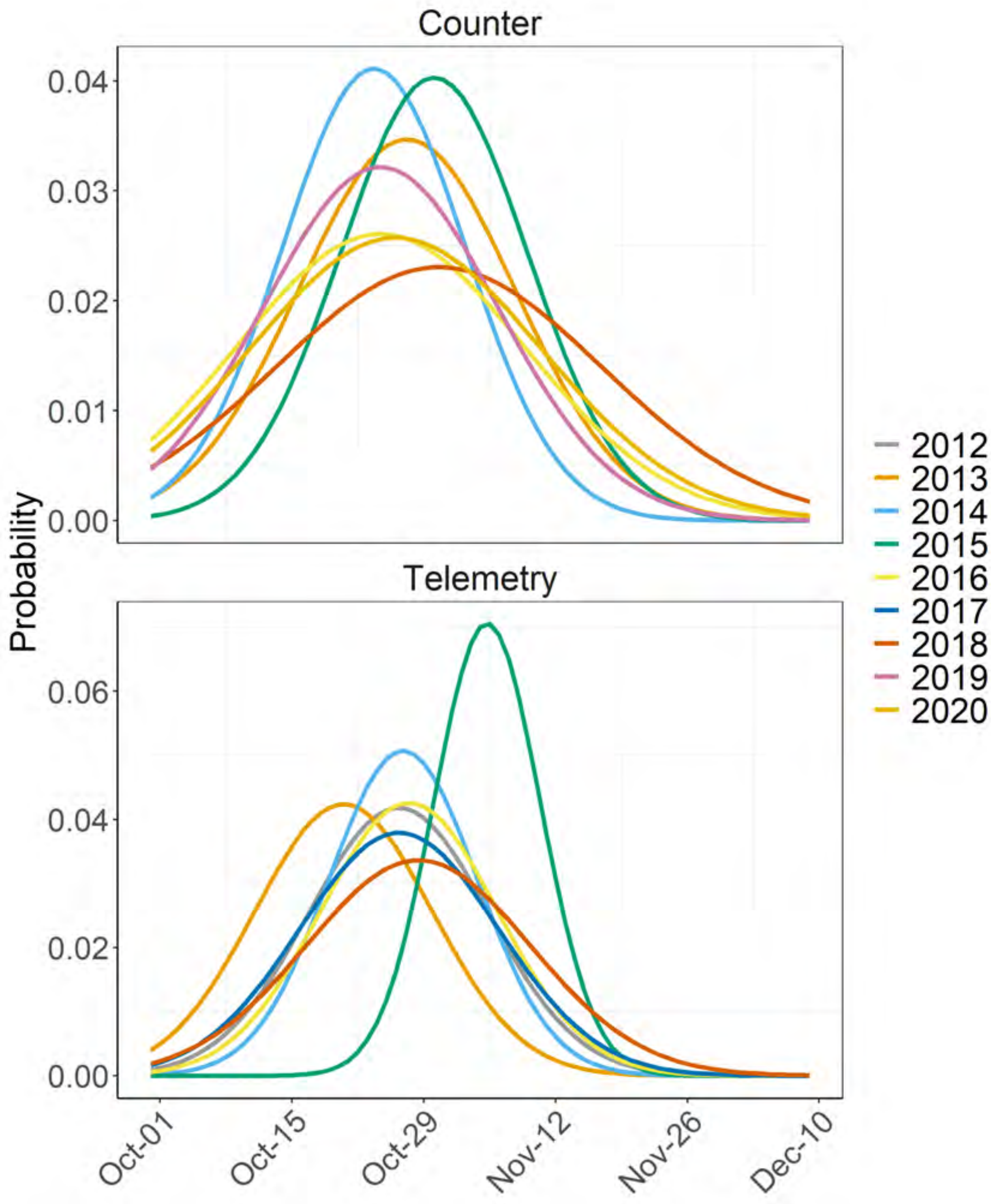


Figure 17: Normal distribution of Coho Salmon peak migration timing from electronic counters (top) and Reach 3 telemetry data (bottom) from 2012-2020. Years with low sample size (n<5) or incomplete estimates were removed.

3.4 Visual Counts and AUC Population Estimates

3.4.1 Chinook Salmon

Visual surveys of Chinook Salmon began on July 23, 2020 and continued until October 1, 2020, when no fish were observed. Our surveys only assessed fish that were able to pass the fish fence prior to installation on August 10, 2020. Chinook Salmon captured by the fish fence will be added to the AUC estimate based on fish above the fence for comparison with the electronic counter estimate.

Water visibility was relatively good throughout the Chinook Salmon migration period in 2020, where secchi disc measurements were 1.8 m ± 0.75 (August 6 to September 17; Appendix 6). This relatively higher water visibility would suggest an improved OE value; however, as in previous years with the fish fence operating, OE could not be calculated as no tagged individuals migrated past the fence. Chinook Salmon were first observed on August 13 (n = 8), and a peak count of 24 fish occurred on September 3; however, all fish observed on September 3 were located downstream of the fish fence. In 2020, the largest cumulative percentage of spawners observed above the fish fence were located between Fraser Lake and Cobra in Reach 3 (n = 6; rkm 33.2 to 34.4), followed by Longskinny to Terzaghi Dam (n = 4; rkm 39.6 to 40.0). Visual survey data collected in 2018 and 2019 suggested an increase in the use of Reach 4 for Chinook Salmon to spawn; however, this year's data is very sparse and does not follow that trend, including only 12 individuals counted above the fish fence (Figure 18). Should fence operation continue in its current form, evaluating the effects of the instream flow regime on spawner distribution will be challenging.

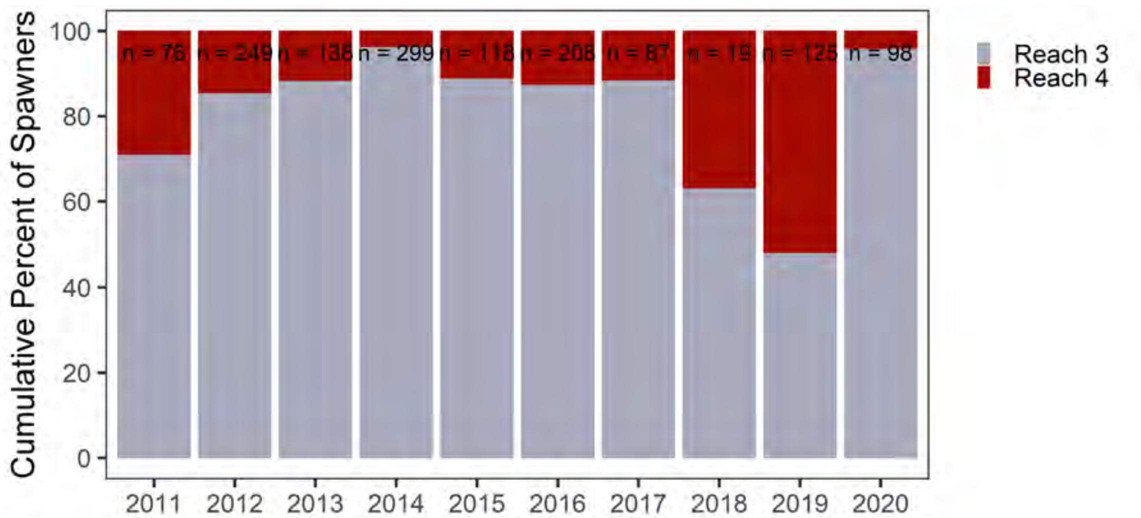


Figure 18: Cumulative proportion of Chinook Salmon spawners observed during visual surveys in Reach 3 and 4 of the LBR.

AUC Abundance Estimate

The 2020 AUC abundance of Chinook Salmon between the fish fence and Terzaghi Dam was 16 (Appendix 7). After August 10, 80 Chinook Salmon were enumerated at the fish fence, resulting in a coarse Chinook Salmon spawner escapement of 96. There was insufficient radio tag and visual tag data to estimate OE and SL for 2020 and, therefore, average values were used (10.5 days and 0.5 for SL and OE, respectively). AUC estimates were compared with abundance estimated by electronic counters (Figure 19). Abundance estimates between 2018 and 2020 when the fish fence was operated and abundances were relatively low, follow a 1:1 relationship; however, counter estimates have been higher in previous years (i.e., AUC underestimates the true abundance).

Average values of OE and SL and historic count data obtained from DFO were used to reconstruct Chinook Salmon population abundance since 1997. The time series was extended to 1993 using consensus fish counts obtained from a channel-spanning fish fence (33.2 rkm). The reconstructed time-series is highly uncertain given the variation in methods, the low number of visual counts in some years, and the uncertainty in OE and SL; however, the reconstructed time series provides a very basic understanding of how Chinook Salmon abundance has changed in the LBR since the 1990s (Figure 20). In particular, the time series indicates that abundance decreased in the mid-2000s and has not since recovered. It is important to note that fence counts from 1993 to 1996 were low relative to AUC estimates from the 2000s. This is likely because prior to 1999, no water was released from Terzaghi Dam and a large percentage of preferred spawning habitat may have been located downstream of the counting fence. The fish fence was also located at Fraser Lake (33.2 rkm), whereas streamwalk counts were recorded from Terzaghi Dam to the Yalakom-Bridge confluence (25.0 – 40.0 rkm).

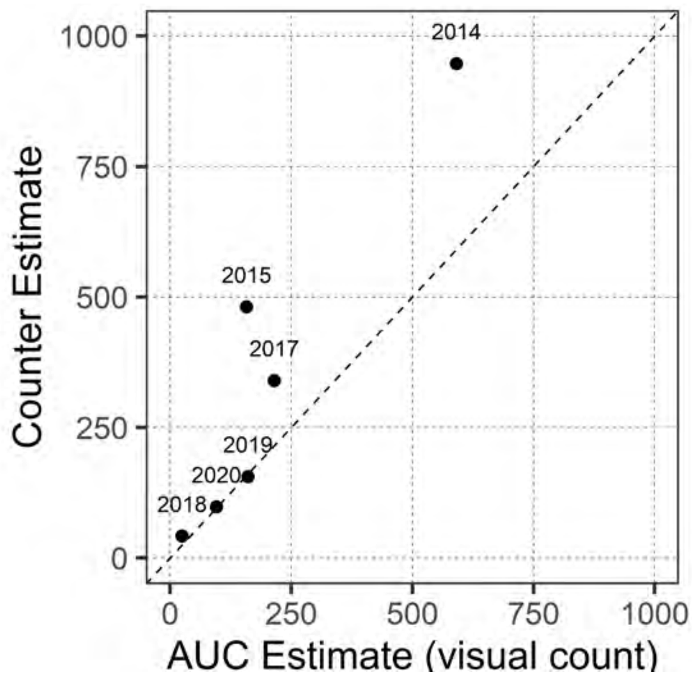


Figure 19: Comparison of Chinook Salmon AUC visual survey estimates, and estimates derived from counting technology. The 2016 point was removed from this figure as the counter estimate did not reflect the entire migration period. Dashed line represents a ratio of 1:1.

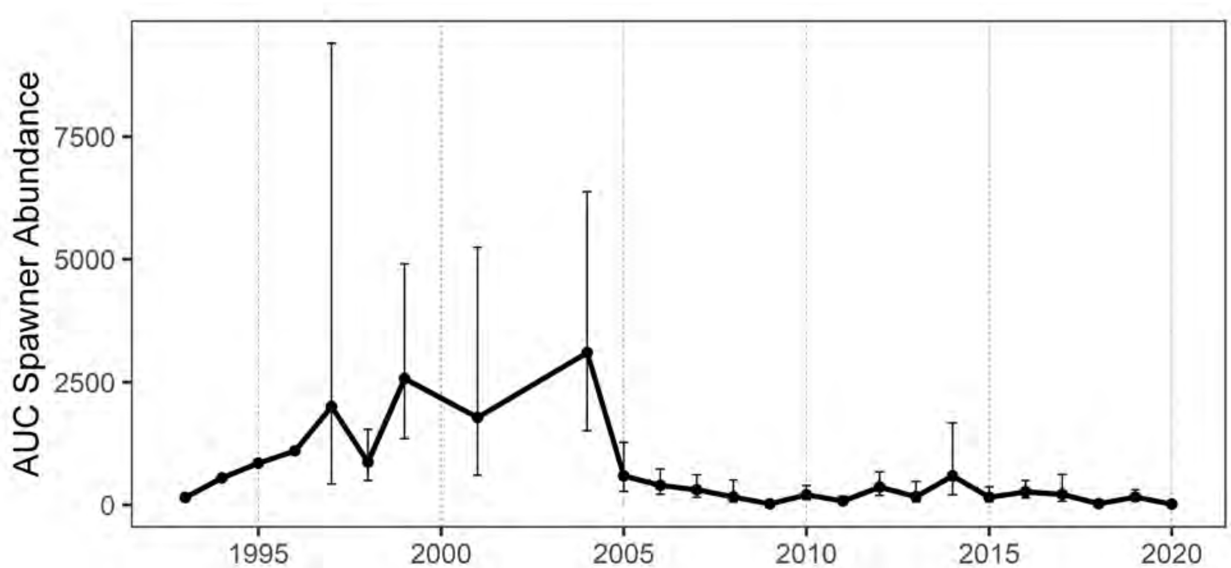


Figure 20: AUC and fence estimates for Chinook Salmon in the Lower Bridge River from 1993 to 2020. Vertical lines represent 95% confidence limits around estimates.

3.4.2 Coho Salmon

Visual counts of Coho Salmon were conducted from October 1 to December 17. The first Coho Salmon was observed on October 8 and a peak count of 112 fish was recorded on November 19. Water clarity during the Coho Salmon migration period was low (mean = 0.44 m ± 0.26).

In 2020, the highest cumulative percentage of spawners (47%) was observed from Plunge Pool to Longskinny in Reach 4 (rkm 39.6 to 40.0) and 82% of spawners were observed in Reach 4 (rkm 37.3 to 40.0; Appendix 6). There is a trend of a gradual increase in preference towards Reach 4 among spawners since 2012 (Figure 21).

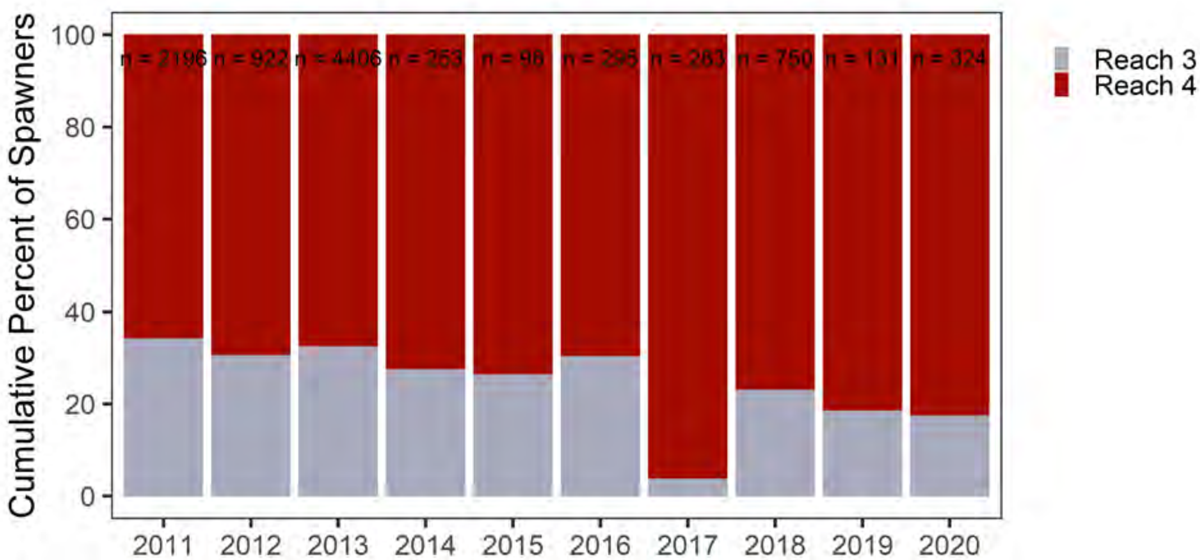


Figure 21: Cumulative proportion of Coho Salmon spawners observed during visual surveys in Reach 3 and 4 of the LBR.

AUC Abundance Estimate

Estimated AUC abundance of Coho Salmon in 2020 between the Yalakom River and Terzaghi Dam was 537 (95% CI: 345-835; Appendix 7), the second highest abundance calculated since counter infrastructure was installed (1,245 in 2018). There was insufficient radio tag and visual tag data to estimate OE and SL for 2020, and therefore average values were used (19.6 days and 0.2 for SL and OE, respectively). The AUC model fit in 2020 was poor when compared to previous years. The peak count of 112 Coho Salmon on November 19 was two-fold higher than the next closest estimate of 48 on November 26 and the normal distribution did not fit the observed visual counts well (Figure 22).

AUC estimates were compared with abundance estimated by electronic counters (Figure 23). In 2019 and 2020, counter and AUC estimates were comparable. The counter estimates were higher in three years and 2018 was the only year where counter estimates were lower than AUC (Figure 23). Additional years of data may reveal 2018 to be an outlier. Average values of OE and SL and historic count data obtained from the DFO were used to reconstruct Coho Salmon population abundance since 1997. The reconstructed time-series is highly uncertain given the variation in methods, low number of visual surveys in some years, and the uncertainty in OE and SL. Estimated abundance ranged from 78 fish in 1999 to a 3,539 in 2011 (Figure 24).

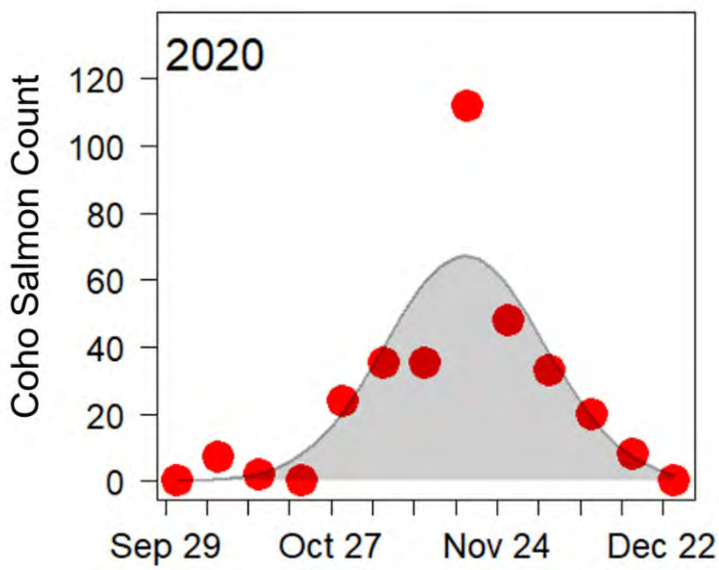


Figure 22: AUC model fit to streamwalk counts for Coho Salmon in 2020

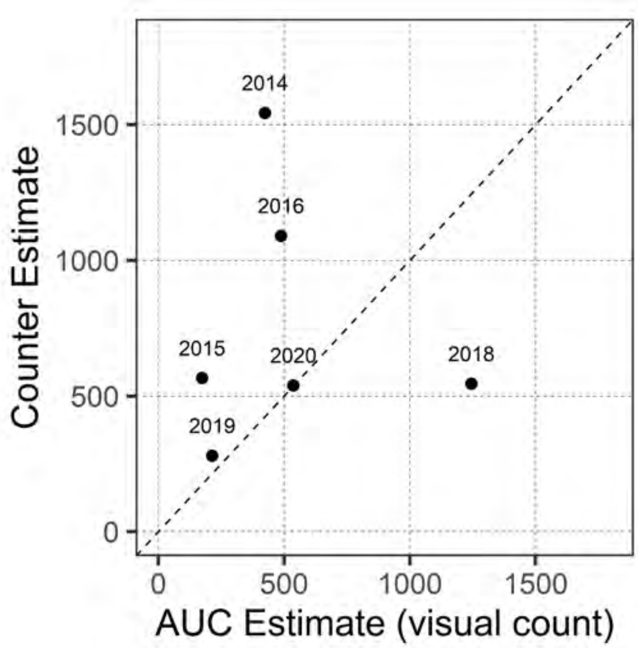


Figure 23: Comparison of Coho Salmon AUC visual survey estimates, and estimates derived from counting technology. No electronic data is available for 2017. Dashed line represents a ratio of 1:1.

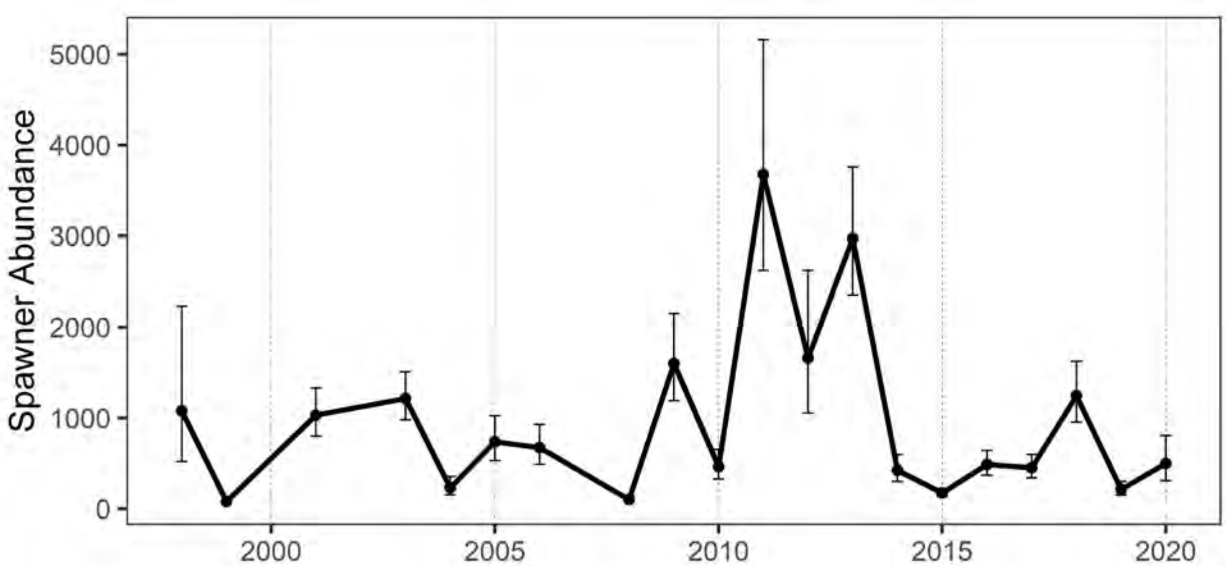


Figure 24: AUC estimates for Coho Salmon in the Lower Bridge River from 1997 to 2020. Vertical lines represent 95% confidence limits around estimate.

3.5 Spawning Habitat

3.5.1 Instream Flow Incremental Methodology (IFIM)

Chinook Salmon WUA

In 2019, transect data were applied to established HSI curves for Chinook Salmon (Ptolemy 1994) and the total WUA in all sampled habitats was 13,978 m^2 (White et al. 2021). The largest amounts of WUA and the highest percent WUA of the total area surveyed were found in Reach 1 and Reach 2. Specifically, WUA was concentrated above the Camoo FSR bridge (16.2%) and below Antoine Creek (11.2%) in Reach 2 (for Chinook Salmon; Appendix 8). Chinook Salmon WUA data are available for all reaches in 2018 and 2019, and a comparison between these two years found no significant difference in the amount of WUA (White et al. 2021).

WUA Mapping

HSI polygons were compared from 2017 to 2019 for select habitat units based on recent use by Chinook Salmon spawners. Total HSI area decreased in Longskinny and Fraser Lake, increased in MSP and remained similar for Russel Springs, Counter Site and LSP (White et al. 2021). Even with annual variability along transects, general patterns of habitat distribution were consistent across years (Figure 25; Figure 26). Chinook redds were overlayed by year and occurred in locations where suitable habitat was calculated. In recent years, the downstream end of longskinny has been a preferred spawning location for all species (Steelhead Trout, and Chinook, Sockeye, Pink and Coho Salmon), while spawning at Fraser Lake and Russel Springs has decreased. Chinook redds located at the Counter Site in 2019 were all located downstream of the broodstock fence.

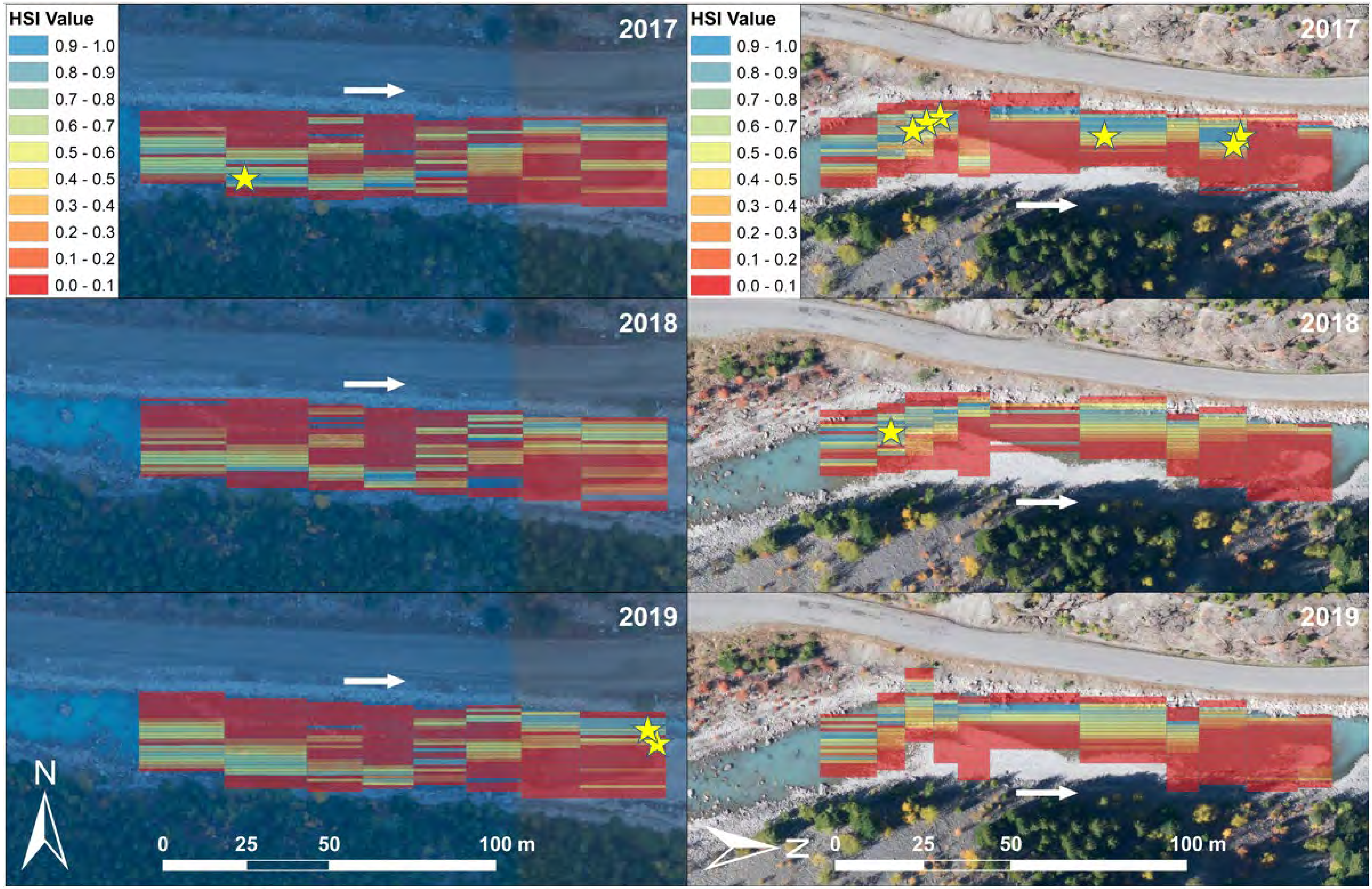


Figure 25: HSI polygons overlayed with 2017 orthoimagery from 2017 to 2019 for Longskinny (39.6 rkm; left) and Fraser Lake (33.2 rkm; right), with colors representing 10 percentile bins from red (least unsuitable) to blue (most suitable). Yellow stars are surveyed redds during that specific year.

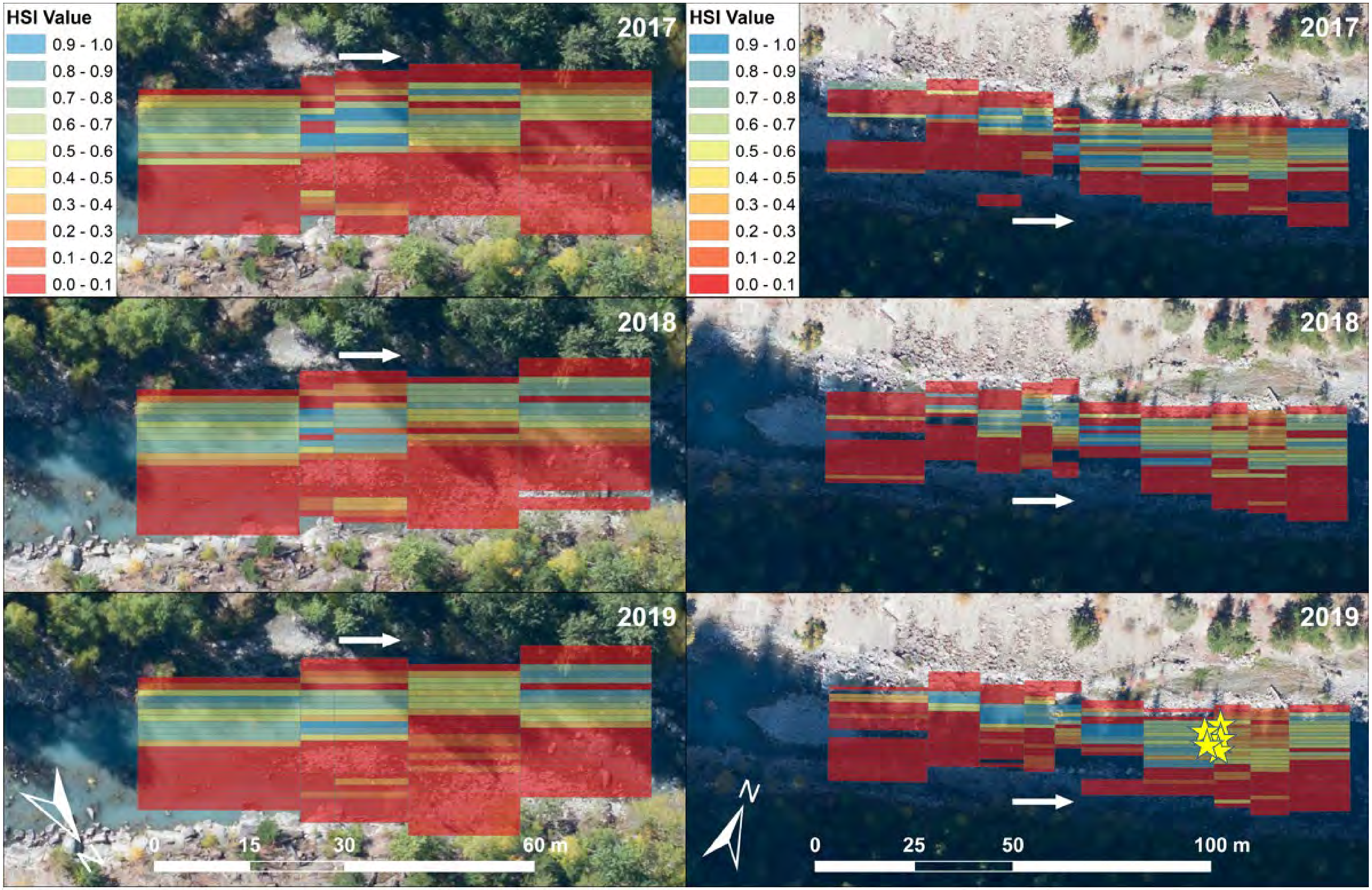


Figure 26: HSI polygons overlayed with 2017 orthoimagery from 2017 to 2019 for Russel Springs/MSP (30.7 rkm; left) and Counter Site/LSP (25.6 rkm; right), with colors representing 10 percentile bins from red (least unsuitable) to blue (most suitable). Yellow stars are surveyed redds during that specific year.

3.5.2 Redd Surveys

Chinook Salmon

In 2020, five Chinook Salmon redds were observed in Reach 3. All redds were in run habitat, consistent with observations since 2014. Depths and water velocities at redd locations were similar between years and within ranges outlined by Ptolemy (1994; Figure 27). Substrate size was variable, but within species preferences of 25-150 mm (Groves and Chandler 1999).

Installation of the fish fence limited movement to historical spawning locations and the redds surveyed above the fence were early migrants that passed the counter site prior to fence operation. All five redds surveyed were in Reach 3 (Figure 28). Redds were in Fraser Lake (n = 2; rkm 33.2), the counter site (n = 1; rkm 25.5), Hippie Pool (n = 1; rkm 25.4) and at the Yalakom-Bridge confluence (n = 1; rkm 25). No redds were observed during Reach 2 visual surveys or Reach 1 spot counts or in Reach 4. Reach 3 has been preferred in all years but 2018. In 2014 and 2015, prior to the implementation of the MOD flow regime, Chinook Salmon redds were only observed in Reach 3 (Figure 28; Appendix 9).

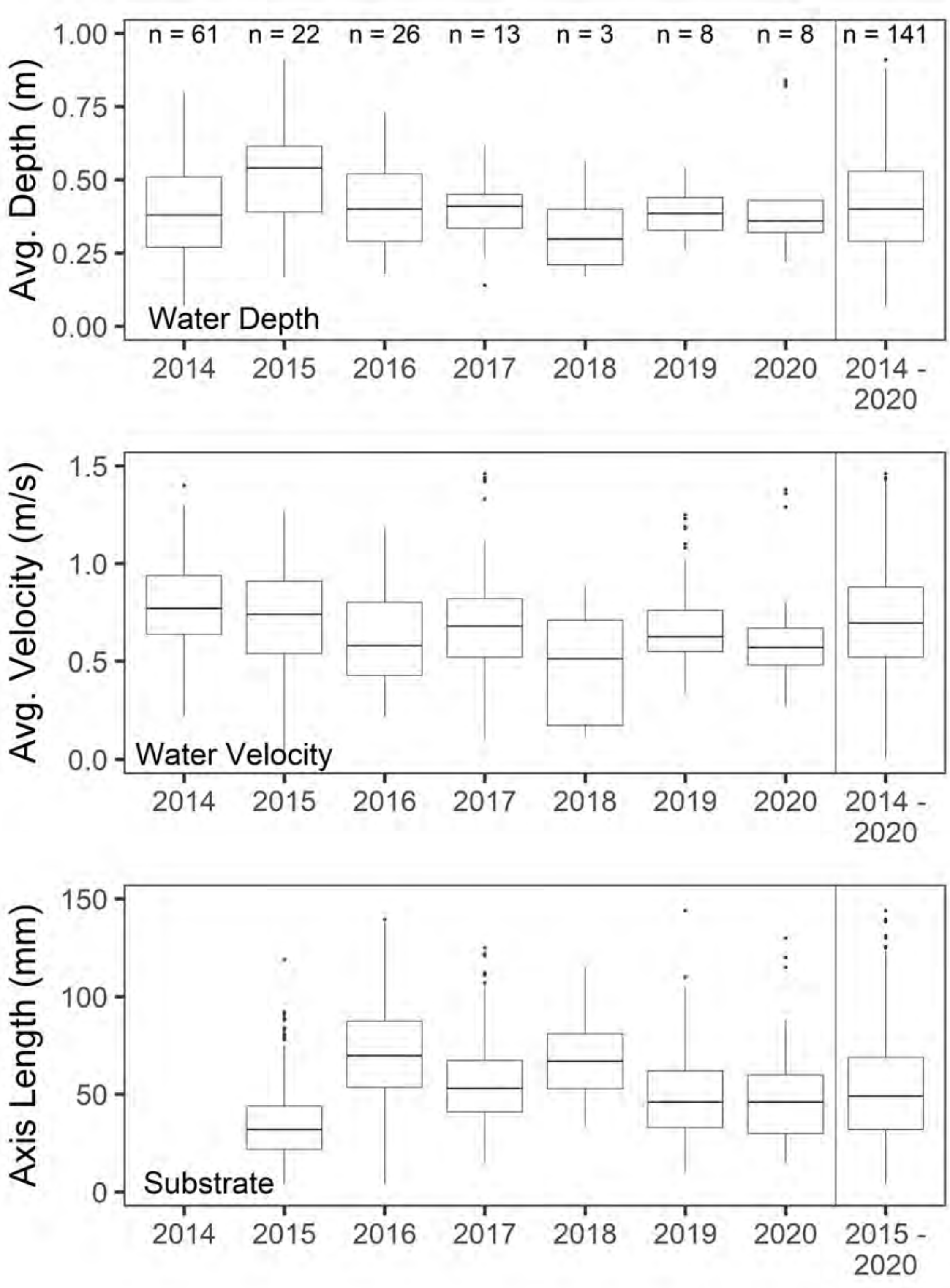


Figure 27: Water velocities (ms^{-1}), depths (m) and substrate size (axis length; mm) measured at Chinook Salmon redds in the Lower Bridge River from 2014 to 2020 and for all data combined. Solid lines denote the annual median water depth, boxes represent the interquartile range (IQR). Lines represent the range excluding outliers, which are shown as points. Substrate surveys were not conducted in 2014.

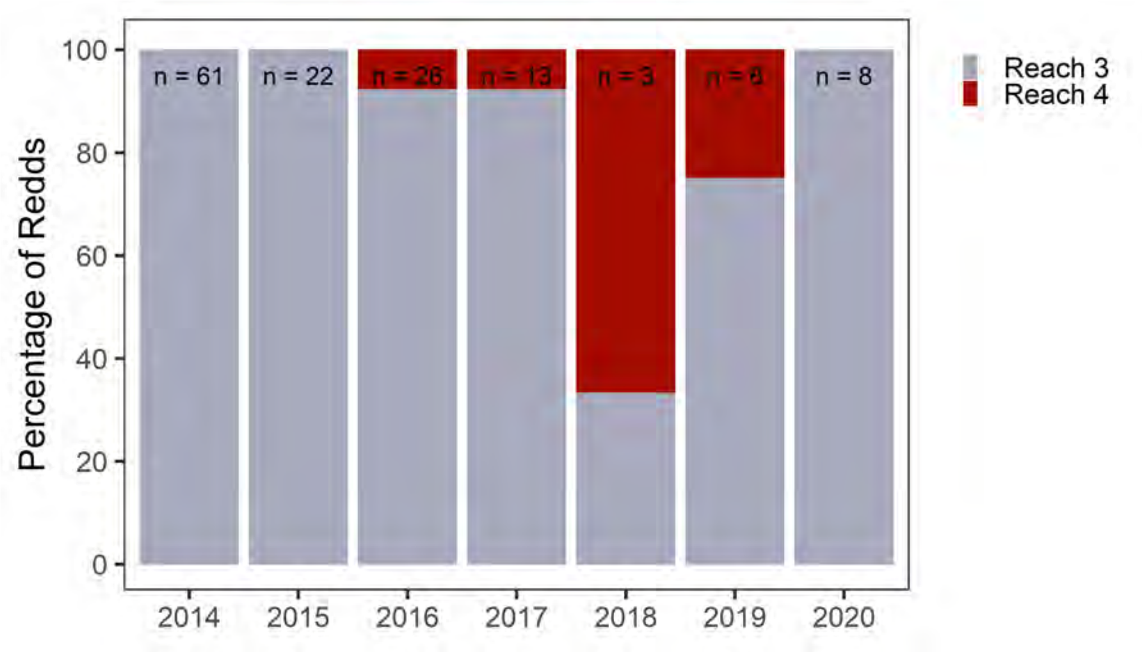


Figure 28: Proportion of Chinook Salmon redds observed in Reach 3 and 4 of the LBR.

Coho Salmon

In 2020, seven Coho Salmon redds were observed in Reach 3 and 4 (n = 5 and 2, respectively). All redds were in run habitat, consistent with observations since 2018. Depths and water velocities and substrate size at redd locations were variable between years and were consistent with average preferences of >18 cm and 0.3 – 0.91 ms^{-1} of water depth and velocity, respectively (Levy and Staney 1993) and substrate size between 13-102mm (Reisner and Bjornn 1979; Figure 29)

Of the seven Coho Salmon redds sampled; two were in Longskinny (rkm 39.6), three were in Eagle (rkm 38.8) one was in Fraser Lake (rkm 33.2) and one was in Russel Springs (rkm 30.7). No redds were observed during Reach 2 visual surveys or Reach 1 spot counts. Inferring changes in redd distributions is limited to only three years of data following the MOD flow regime; however, from 2018 to 2020 there appears to be a preference to spawn in Reach 4 (Figure 30; Appendix 9).

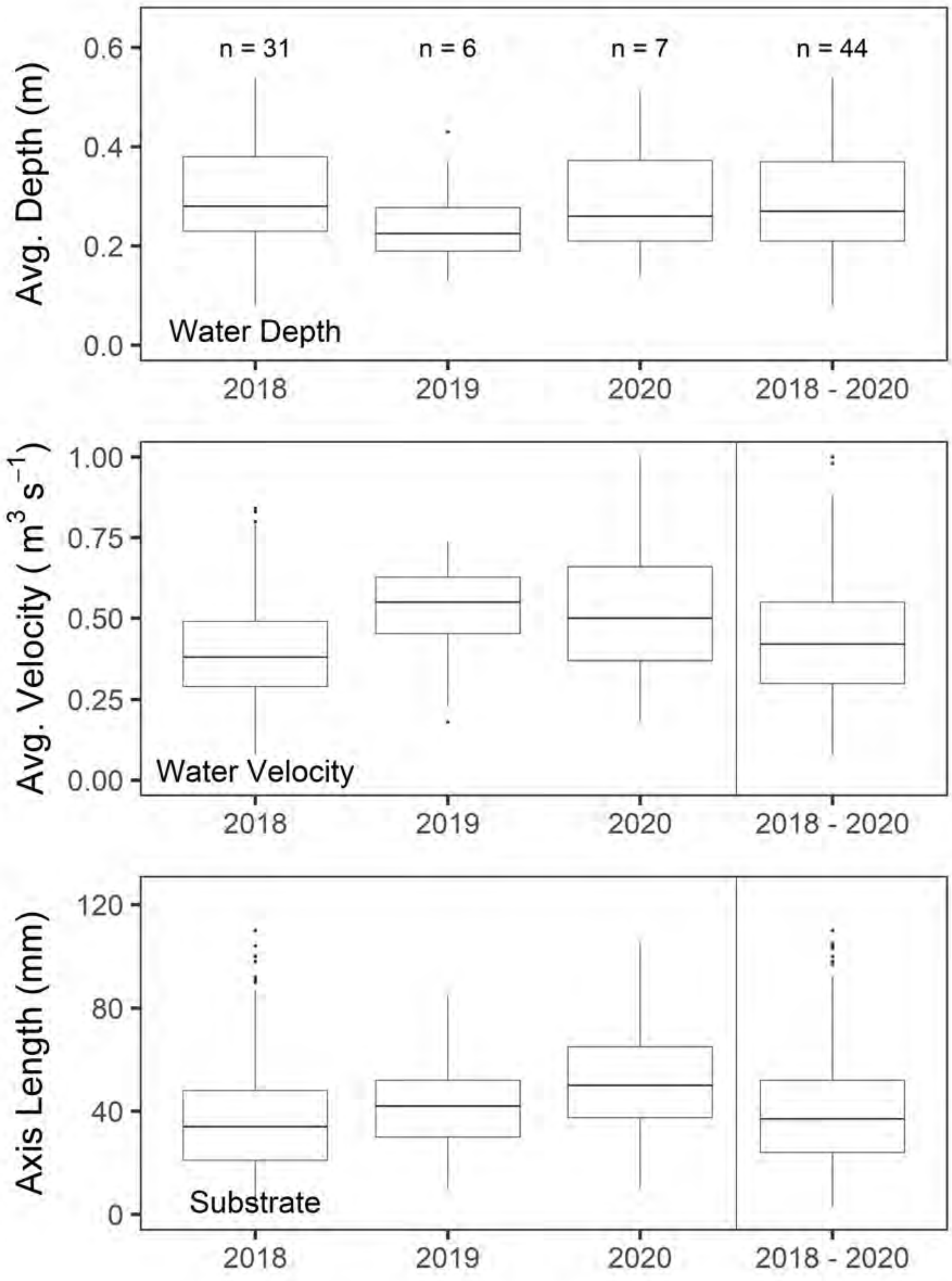


Figure 29: Water velocities (ms^{-1}), depths (m) and substrate (mm) measured at Coho Salmon redds in the Lower Bridge River from 2018 to 2020 and for all data combined. Solid lines denote the annual median water depth, boxes represent the interquartile range (IQR). Lines represent the range excluding outliers, which are shown as points.

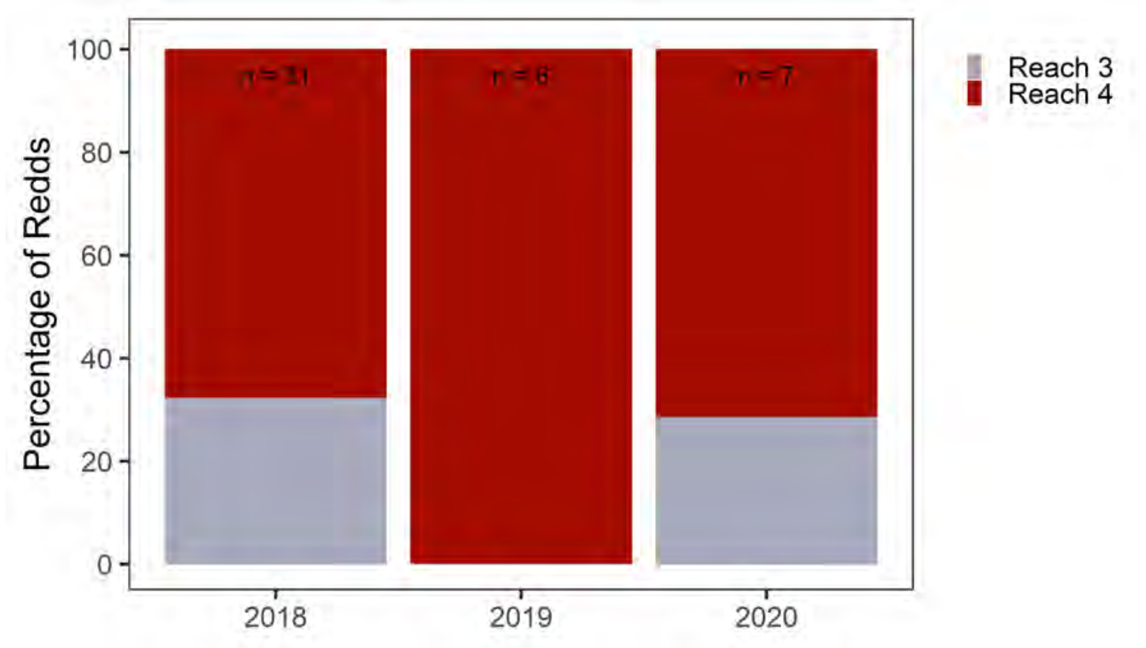


Figure 30: Proportion of Coho Salmon redds observed in Reach 3 and 4 of the LBR.

3.6 Ageing of Adult Salmon and Steelhead Trout

3.6.1 Steelhead Trout

Nine scales from Steelhead Trout assumed to have spawned in the LBR in 2020 were aged. Since 2014, 58 Steelhead Trout scales have been aged. The dominant age classes of fish with confirmed spawning in the LBR were age 5 (i.e., 2.3, 3.2), followed by age 4 (2.2, 3.1), and age 6 (3.3; Figure 31; Appendix 10). Scale ages suggest the proportion of spawners residing in saltwater for 2+ years has increased since 2014 (Appendix 10). Also, scales collected in 2020 did not show evidence of repeat spawning, which has been observed during scale analysis in previous years.

The ages of all Steelhead Trout captured and aged between 2018 and 2020 were examined to determine whether these fish were exposed to high flows as juveniles. Fish that smolted in 2016 were not considered to have been exposed to high flows as they likely migrated prior. Of all adults aged in 2018 and 2019, only two in 2019 were exposed to high flows in 2016 (Table 11). In 2020, the dominant age class was 2.2, with all juveniles experiencing high flows in both freshwater years. This is the highest proportion of age four fish observed since 2014 (Table 11).

Table 11: Steelhead Trout ages collected from tagged individuals from 2018 to 2020, indicating brood and smolt year, exposure to high flows, and sample size.

Year	Age	Brood Year	Smolt Year	High Flow Exposure (years)	Sample Size
2018	2.1	2015	2017	2016	0
	2.2	2014	2016	NA	2
	2.3	2013	2015	NA	7
	3.1	2014	2017	2016, 2017	0
	3.2	2013	2016	NA	2
	3.3	2012	2015	NA	5
2019	2.1	2016	2018	2017	0
	2.2	2015	2017	2016	0
	2.3	2014	2016	NA	1
	3.1	2015	2018	2016, 2017	0
	3.2	2014	2017	2016	2
	3.3	2013	2016	NA	6
2020	2.1	2017	2019	2018	0
	2.2	2016	2018	2016, 2017	8
	2.3	2015	2017	2017	0
	3.1	2016	2019	2017, 2018	0
	3.2	2015	2018	2017, 2018	1
	3.3	2014	2017	2017	0

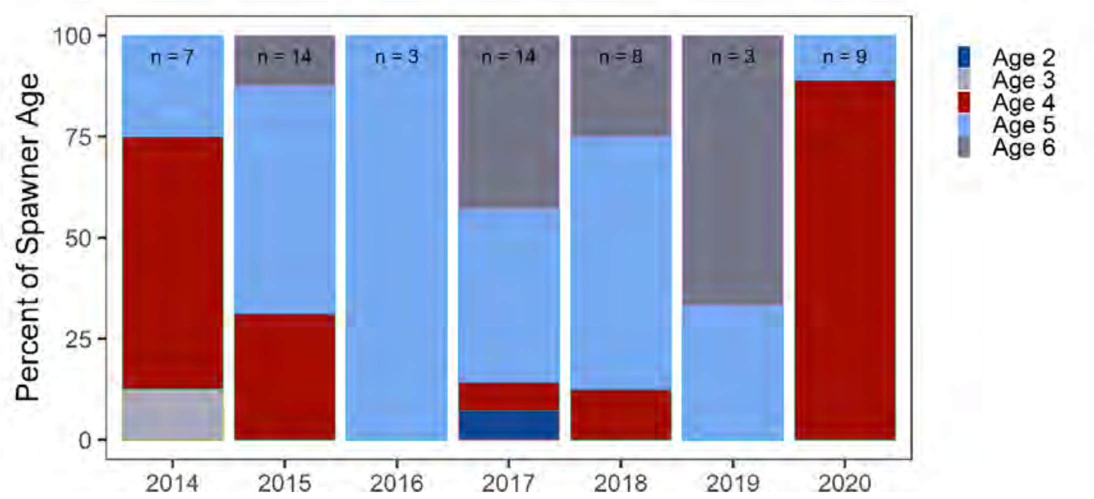


Figure 31: Relative proportion of Steelhead Trout total age classes by year from 2014 to 2020.

3.6.2 Chinook Salmon

All three Chinook Salmon scales aged in 2020 were assessed as age 1.3 and would have experienced high flows in the LBR as juveniles in the spring of 2017. Since 2014, 58 Chinook Salmon scales have been aged. All scales displayed a yearling (stream-type) life history, with juveniles spending one winter in freshwater. Since 2013, most Chinook have been age 4 with a few age 3 (1.2) individuals (Figure 32; Appendix 10).

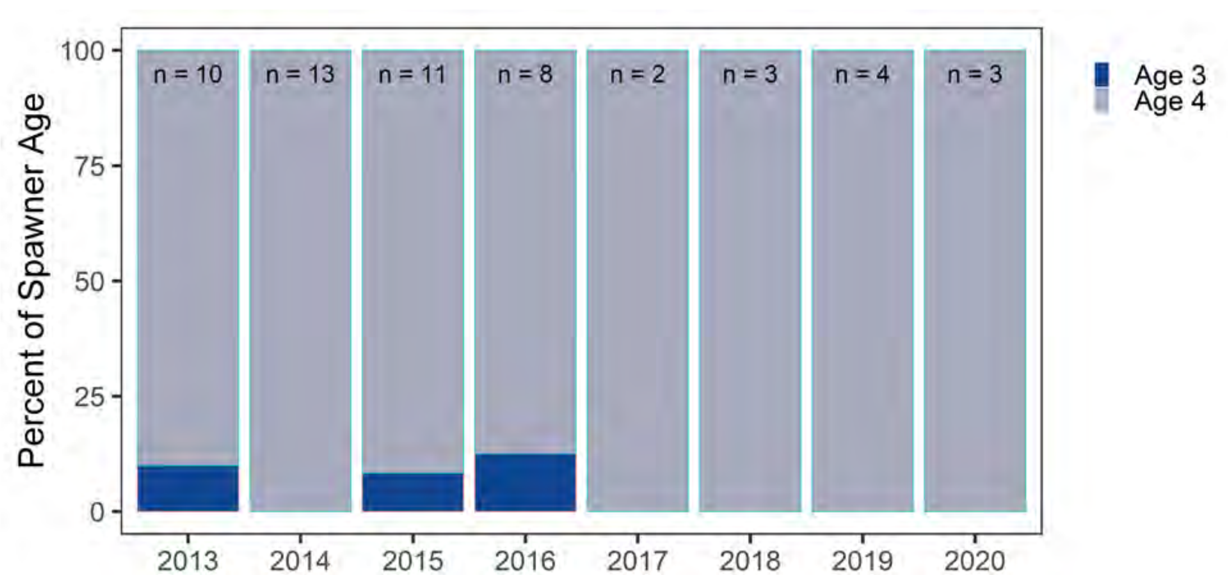


Figure 32: Relative proportion of Chinook Salmon total age classes by year from 2013 to 2020.

3.6.3 Coho Salmon

Four Coho Salmon scales collected during visual surveys in Reach 3 and 4 were aged in 2020 that were age 1.1. Since 2011, 162 Coho Salmon scales have been aged. LBR Coho Salmon returned most frequently at age 2 (1.1) followed by age 3 (2.1; Figure 33). All scales displayed similar juvenile life histories, with juveniles spending 1-2 years in freshwater before out-migrating as smolts. Coho Salmon returning at age 1.1 in 2020 would have experienced high flows in the LBR as juveniles in the spring of 2018.

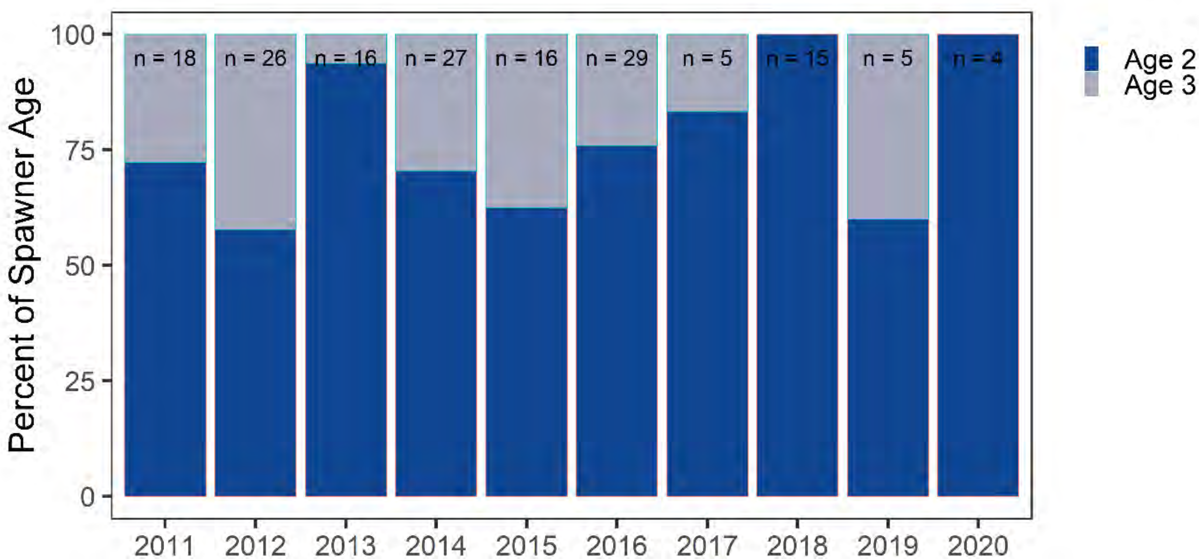


Figure 33: Relative proportion of Coho Salmon age classes by year from 2011 to 2020.

4. Discussion

BRGMON-3 monitors adult abundance and habitat quantity and quality. The results support BRGMON-1, which evaluates the effects of LBR flow regime on salmonid productivity. The monitor also evaluates the effects of WUP and MOD flows on adult salmonid abundance, migration timing, spawner distribution, and quantity and quality of spawning habitat in the LBR. As of 2019, BRGMON-3 addresses four management questions: two related to WUP flows, and two related to MOD flows. Monitoring in 2020 builds upon data from 2012 to 2019 and will be used to answer the management questions and inform future monitoring.

4.1 Terzaghi Dam Operating Parameters

The LBR flows outlined during the WUP process and stipulated in the original BRGMON-3 TOR were 3 m^3s^{-1}/year from August 2000 to April 2011, and 6 m^3s^{-1}/year from May 1, 2011 to April 15, 2015. Flows in 2016 through 2018 exceeded the 20 m^3s^{-1} WUP operating parameters and fall under the MOD regime. In 2019 and 2020 flows remained below 20 m^3s^{-1}, and are, therefore, not technically MOD operation years. The MOD regime was implemented due to limited storage potential at La Joie Dam, an issue that likely will not be resolved until 2028 when modifications to address dam safety risks are expected to be complete.

MOD discharges have involved several flow variances, but all exceeded 50 m^3s^{-1} by early May and returned to WUP targeted flows prior to the beginning of Chinook Salmon migration period in mid-August. Adult Chinook and Coho Salmon experience a consistent flow regime of 3.0 and 1.5 m^3s^{-1} for their respective spawning periods, while Steelhead Trout experience an ascending hydrograph during peak spawn timing (mid-May) and are likely the adult species most impacted by the MOD flow regime when they are present in the LBR for spawning. For example, during MOD years 2016 through 2018, LBR discharge on May 15 was >50 m^3s^{-1} but was <20 m^3s^{-1} during WUP years and in 2020.

4.2 BRGMON-3 Management Questions

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?

Abundance

Steelhead Trout abundance has declined over the course of this monitor (2014-2020; no previous abundance estimates available), while Chinook Salmon and Coho Salmon abundances have been declining in the LBR since before the implementation of BRGMON-3 (1993-2013). Although Steelhead Trout abundance in 2020 was 62, which is slightly higher than the 2019 estimate of 50, it is still considerably lower than the first year of counter operation in 2014 (238). Chinook Salmon abundance in 2020 was 98, the second lowest observed over the monitor (2018 = 42). Coho Salmon abundance in 2020 was 539, which is less than the mean recorded over the monitor (761 ± 461).

MOD flows are only experienced by Steelhead Trout adults. Eggs and juveniles exposed to high flows may be negatively affected by high flows (Gendaszek et al. 2018); however, declines in adult abundance may also be a function of factors external to the LBR. It is difficult to determine the cause of declining abundance given challenges in monitoring (e.g., changes in counting methodology, installation of the fish fence for Chinook Salmon broodstock collection, increased straying due to the Fraser River rockslide) and uncertain conditions affecting salmonids outside of the LBR (e.g., ocean conditions, raising water temperatures, fishing pressures, disease, etc.). It is challenging to evaluate the effects of flow regime on adult abundance because anadromous salmonids spend a significant portion of their life cycle outside of the LBR.

LBR flows are consistently at WUP target values while Chinook and Coho Salmon adults are in the river for spawning, and effects of flow regime on abundance are more likely to be expressed in juveniles when flow variances are experienced. The effects of flow on fish abundance are more comprehensively addressed by BRGMON-1 using productivity, which incorporates both adult and juvenile abundance (i.e., egg-to-fry or adult-to-fry survival). BRGMON-3 is limited to evaluating the direct effects of flow regime on adult Steelhead Trout, Chinook Salmon, and Coho Salmon when they are present in the LBR during spawning migrations, and thus far there is no clear link between spawner escapement and LBR flow.

Adult abundance is estimated using two methods: electronic counters and AUC modeling using visual survey data (Chinook and Coho Salmon only). An interest of BRGMON-3 is to compare electronic counter and visual survey AUC abundance estimates to determine whether AUC estimates are biased, and if so, to back-calculate estimates of historical visual counts to produce more precise historic estimates. Current comparisons between counter and AUC estimates suggest similar results for Chinook Salmon when abundances are low (<160), and in most other years AUC estimates have been biased low. Comparisons for Coho Salmon are variable, with 2018 counter estimate being lower than the AUC estimate and the inverse relationship is observed for all other years. AUC estimates are highly uncertain in the LBR due to low counts, poor visual conditions, uncertainty in OE and SL, and, in some years, poor model fit. In addition, LBR discharge and turbidity have varied considerably from the 1990s to today (with unknown OE and SL) and extrapolating a relationship between counter and AUC estimates is therefore not feasible. Despite uncertainties, we will continue to compare abundance estimated from electric counter and visual surveys as results are valuable for understanding the utility and limitations of both current and historic AUC estimates.

Accurate year-specific OE and SL are important for reliable AUC analyses (Grant et al. 2007, Muhlfeld et al. 2006). OE can vary with observer experience and survey conditions, while SL varies with discharge and water temperature, all of which can change annually and throughout the monitoring period (Gallagher and Gallagher 2005). A sensitivity analysis of data collected to 2019 suggested AUC abundance is sensitive to both OE and SL, indicating that average values used for both current AUC estimates and historic reconstructions may result in unreliable abundance estimates (White et al. 2021). Year-specific OE and SL could only be calculated for four years for Chinook Salmon and five years for Coho Salmon, and average values were used in all other years and for historic reconstruction. Improving SL and OE estimates is challenging given low spawner abundances, but additional OE metrics could be included to better inform OE under ranging environmental conditions (e.g., water clarity). For example, counter estimates could be compared to the number of individuals observed upstream of the counter during visual surveys to obtain a second measure of OE for each year.

Migration Timing

Peak migration timing has been relatively consistent among monitoring years, suggesting no relationship between instream flow and migration timing in the LBR. Steelhead Trout are most vulnerable to MOD flows with entry into the LBR occurring during the ascending limb of the spring hydrograph. Despite experiencing variable discharge conditions throughout BRGMON-3, peak migration and entry into Reach 1 has remained relatively consistent for Steelhead Trout. Chinook and Coho Salmon typically migrate when LBR flows are at stable WUP targets (3.0 and 1.5 m^3s^{-1}, respectively) and are therefore unlikely to be significantly impacted by changes to spring flow regimes. The potential exception are early Chinook Salmon migrants present in the LBR during late July or early August that may be exposed to higher discharges. However, peak migration is typically late August or early September, when the hydrograph is stable at WUP target flows. In 2020, flows were ramped down earlier with the goal of installing the broodstock fence by August 10. As a result, counter equipment was deployed on July 20 and recorded a single Chinook Salmon up count when discharge was 15 m^3s^{-1}. Discharge did not reach 3.5 m^3s^{-1} until August 7 and a Chinook Salmon abundance of 16 individuals was recorded on that date.

Ageing analyses show Steelhead Trout, Chinook, and Coho Salmon spawners returning to the LBR in 2020, all experienced high flows as juveniles. Steelhead Trout have a more diverse life history, and BRGMON-3 ageing has identified six different life history types. Few adult Steelhead Trout cohorts aged in 2018 and 2019 were exposed to high flows as juveniles (8%). In 2020 the most common age was 2.2 (89%), all of which would have been exposed to high flows in 2017.

There is evidence from BRGMON-1 that high flows led to a reduction in juvenile salmon abundance; abundance declined by 77% relative to the 1 m^3s^{-1} flow trial, and 75% relative to and 3 m^3s^{-1} flow trial (Sneep et al. 2018). Most Chinook Salmon return to spawn at 1.3 years and Coho Salmon at 1.1 or 2.1, and we have not observed a substantial change in age class data since the onset of high flows, although the sample sizes for these two species have been low (<5) for the past three years.

Spawner Distribution

Our discussion on spawner distribution is incorporated with the second management question evaluating the effects of the MOD flow regime on spawner distributions in the LBR.

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?

Spawner distribution was evaluated using a combination of radio telemetry and redd and visual surveys. Preliminary data indicate no direct relationship between instream flow and distributions of spawning salmon and Steelhead Trout in the LBR. Competition for spawning habitat is likely low for all species given low spawner abundances in the LBR, and that habitat surveys indicated that spawning habitat is not limiting. Spawning for all species typically occurs in Reach 3 and 4 of the LBR. Steelhead Trout consistently spawn at surveyed habitats in Reach 3 and 4 and were observed spawning in Reach 2 for the first time in 2018. Despite limited success angling Chinook Salmon from 2017 to 2020, telemetry data, redd surveys, and visual surveys all suggest Chinook Salmon prefer to spawn in Reach 3. Increased spawning in Reach 4 was observed among Chinook Salmon in 2018 and 2019, but this trend did not continue in 2020. The broodstock collection program in 2018 to 2020 disrupted the natural migration of Chinook Salmon above the counter site and may have altered spawning site selection. Angling success for Coho Salmon has also decreased in 2019 and 2020, however, telemetry data, redd surveys, and visual surveys all suggest preference towards Reach 4. A consideration for all species is that the Fraser rockslide in 2019 resulted in an increased prevalence of stray fish in the LBR, and these individuals may have different spawning preferences (Keefer and Caudill 2014).

Increased spawning in Reach 4, as observed in 2018 and 2019 for Chinook Salmon, may affect juvenile survival due to variations in thermal regime (Geist et al. 2006). Releases from Terzaghi Dam are warmer than observed further downstream in the LBR and an upstream shift in spawning could accelerate gamete development and lead to early emergence. Accumulated thermal unit calculations for Chinook Salmon indicate that warmer water temperatures could lead to 50% hatch in January in Reach 4, as opposed to March in Reach 3 (Ramos-Espinoza et al., 2018). This difference in emergence timing could have implications for survival as juveniles may emerge sooner, be exposed to cooler conditions post-emergence, and have less immediate access to abundant food resources. The decrease of Chinook Salmon spawning in Reach 4 in 2020 could be attributed to the broodstock fence and few individuals on spawning grounds. Coho Salmon are likely less affected by early emergence as peak spawning occurs in early November.

In 1993, Chinook Salmon were primarily observed spawning between the upstream end of Horseshoe Bend in Reach 2 and Hell Creek in Reach 3 (23.7-29 rkm) The upper sections of Reach 3 were deemed unsuitable for spawning given larger substrate size (Lister and Beniston 1995). Lister and Beniston (1995) state that flow stability and groundwater influence in the upper portion of Reach 3 could produce favorable conditions for spawning salmon, despite no previous use. Historic data and current observations suggest Chinook Salmon spawner distributions have shifted upstream considerably since the 1990s. It is difficult to determine whether these changes are related to the instream flow regime, but prior to 1990 there were no flow releases from Terzaghi Dam and LBR flows slowly increased downstream of the dam due to tributary inflows. With the onset of discharge directly from Terzaghi Dam, gravel mobilization and increased available spawning area in Reach 3 and 4, could contribute to the shift in spawning distributions between the 1990s and today. However, spawner distributions may also have been impacted by factors outside of the flow regime.

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?

AND

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?

IFIM monitoring in 2017 through 2019 and redd surveys since 2014 suggest that access to abundant high-quality spawning habitat is not currently limited in the LBR. IFIM monitoring assesses the overall quantity and quality of habitat in the LBR, while redd surveys describe habitat characteristics in confirmed spawning locations. According to substrate data collected during HSI surveys (2017-2019), overall mean particle size decreased in the LBR following high flow events in 2018 (White et al. 2021). Despite this overall decrease, substrate size at confirmed redd locations has remained consistent since 2014, suggesting access to preferred spawning habitat is not a limiting factor for Chinook Salmon productivity in the LBR. Spawner distributions also indicate sufficient spawning habitat is available, as spawners are not observed in Reach 1 and 2 despite both reaches having abundant preferred spawning habitat.

Depth, velocity, and substrate composition at confirmed spawning locations have remained relatively consistent and within preferred ranges, which is expected given that spawners select areas according to species-specific preferences and are unlikely to construct redds outside of these ranges. The number of Chinook and Coho Salmon redds surveyed since 2018 has decreased, limiting meaningful comparison among recent years.

HSI surveys indicate that the overall quantity of high-quality Chinook Salmon spawning habitat has been consistent from 2017 through 2019 (no surveys in 2020), but the distribution of this habitat within reaches and habitat units has shifted. Habitat changes are potentially due to changes in substrate composition. Substrate size decreased in Reach 2, 3, and 4 from 2017 - 2018, which may be related to high flows between 2016 and 2018 (White et al. 2021). It should be noted that the effects of only one high flow event were monitored by these HSI surveys. Two high flow events occurred prior to HSI monitoring, which may have had a stronger effect on substrate composition by immediately flushing highly mobile particles downstream. In addition, substrate measurement can be biased (Olsen et al. 2005; Daniels and McCusker 2010), and different technicians have been involved in substrate measurements during both redd surveys and transect data collection. If substrate changes were flow related, we would expect the mobilization of smaller substrate to scour upstream habitats and infill downstream habitats, which has not been observed. Continued substrate monitoring is required to determine whether substrate size is affected by the MOD flow regime and how this may impact spawning habitat availability in the LBR.

We found no significant change in WUA between 2018 and 2019 (no high flow events occurred between these surveys) suggesting that our survey method is resilient to changing technicians and measurement errors. HSI surveys therefore show promise as a means of monitor spawning habitat quantity in the LBR; however, the HSI curves used here were developed for the full British Columbia range and may not be representative of the LBR (Ptolemy 1994). If data continue to be collected at confirmed redd locations, LBR-specific HSI curves could be developed. Custom HSI curves would more accurately evaluate whether changes spawner distributions are a function of habitat availability.

4.3 Additional Considerations

The Fraser River rockslide (2019) and a fish fence installed for Chinook Salmon broodstock collection (2018 - 2020) require further discussion given their potential to affect the behavior and abundance of adult salmonids. DNA analyses from the Chinook Salmon broodstock program indicated that a high proportion of stray Chinook Salmon were present in the LBR in 2019 and 2020, which was likely also the case for Steelhead Trout and Coho Salmon. Straying affects our ability to compare abundance over time, as abundance estimates in 2019 and 2020 include both stray fish and those of LBR origin. Migration timing, distribution of spawners, and redd surveys were also affected given that different Fraser River populations have specific run timing and spawning habitat preferences. Increased straying may provide both short- and long-term benefits to LBR salmonid populations by increasing abundance and genetic diversity (Keefer and Caudill 2014). The long-term effects of the Fraser River rockslide are unknown, and additional years of monitoring data will help to inform effects to behaviour and abundance.

A fish fence was operated for Chinook Salmon broodstock collection between August 10 and September 30, which impaired Chinook Salmon migration into preferred spawning habitat in Reach 3 and 4. Many individuals spawned immediately downstream of the fence, biasing comparisons of spawner distribution among monitoring years. The fence also prevented a complete Chinook Salmon abundance estimate for both electronic counters and visual counts. Enumerating Chinook Salmon and monitoring spawner distributions will be challenging if the fish fence continues to be operated immediately upstream of counter infrastructure, and continued fence operation will severely inhibit our ability to answer the BRGMON-3 management questions.

4.4 Summary and Recommendations

The results of BRGMON-3 inform BRGMON-1 analyses and provide insight into how instream flows in the LBR affect adult abundance, migration timing, spawner distribution, and spawning habitat quality and quantity. Despite changing methodologies, difficult survey conditions, and low abundances in recent years, BRGMON-3 is collecting valuable data that will be used to address the specific management questions outlined for the monitor. To date, although there have been shifts in adult salmonid spawner abundance, distribution, and habitat characteristics, there is no clear evidence that these changes are directly related to instream flow regimes. Additional data collection will further inform this conclusion. Particularly, visual OE and SL data are required to improve current and historic AUC abundance estimates and have not been calculated in recent years due to low tag deployment and few tags moving into Reach 3 and 4. Additional years of abundance and habitat data will help to determine whether the flow regime will affect the spawning success of adult salmonids in the LBR.

Of particular concern is the effect of the fish fence used to collect Chinook Salmon broodstock on the abundance, distribution, and timing of LBR Chinook Salmon and the effect of the Fraser River rockslide on rates of straying of all species into the LBR. The effect of these events on the ability of BRGMON-3 to collect informative data should be considered alongside their direct effects to migration and spawning success.

Recommendations for 2020 BRGMON-3 data collection include:

- Delay Terzaghi flow release above WUP target discharge until early June to allow for a complete Steelhead Trout enumeration.
- Continue use of radio telemetry to improve estimates of Steelhead Trout spawning locations and inform Chinook and Coho Salmon OE and SL for AUC abundance estimates. OE may also be improved by comparing the full counter estimate to the number of adults observed upstream of the fence during visual surveys. This would provide a second metric of OE that could be compared to or combined with the visual survey OE. This will be explored for next year's synthesis report for all years.
- Continue redd surveys and IFIM surveys following high flow events to compare preferred habitat with that available in the LBR.
- Modify visual surveys to subdivide sections in Reach 3 and 4 to increase the level of detail for evaluating changes in spawner distribution.
- 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. Also, electronic counters should be operated for 2 weeks prior to installation to observe any early migrants.

5. References

BC Hydro. 2012. Bridge Seton Water Use Plan Monitoring Program No. BRGMON-3 Lower Bridge River Adult Salmon and Steelhead Enumeration. Bridge-Seton Water Use Plan Monitoring Program Terms of Reference. 12 p.

BC Hydro. 2018. Bridge Seton Water Use Plan Monitoring Program No. BRGMON-3 Lower Bridge River Adult Salmon and Steelhead Enumeration. Bridge-Seton Water Use Plan Monitoring Program Terms of Reference, Revision 1. 16 p.

Braun, D., Ramos-Espinoza, D., and R. Bisson. 2017. Fish counter enumeration of Steelhead and Rainbow Trout on the Bonaparte River, 2017. Report prepared for Forests, Lands and Natural Resource Operations, Fish and Wildlife – Kamloops, 19 p.

Bridge-Seton Water Use Plan: Monitoring Program Terms of Reference, Water Use Planning, BC Hydro. January 2012.

Burnett, N.J., Ramos-Espinoza, D., and D.C. Braun. 2016. Lower Bridge River adult salmon and steelhead enumeration, 2015. Report prepared for St'át'imc Eco-Resources and BC Hydro. 74 p.

Burnett, N.J., Ramos-Espinoza, D., Chung, M., Braun, D.C., Buchanan, J., and M. Lefevre. 2017. Lower Bridge River adult salmon and steelhead enumeration, 2016. Report prepared for St'át'imc Eco-Resources and BC Hydro. 88 p.

Daniels, M.D., and M.H. McCusker. 2010. Operator bias characterizing stream substrates using Wolman pebble counts with a standard measurement template. Geomorphology, 115 (1-2): 194-198.

ESRI, 2020. ArcGIS Desktop: Release 10.8.1. Redlands, CA: Environmental Systems Research Institute.

Gallagher, S.P., and C.M. Gallagher. 2005. Discrimination of Chinook and Coho salmon and steelhead redds and evaluation of the use of redd data for estimating abundance in several unregulated streams in northern California. North American Journal of Fisheries Management. 25: 284-300.

Geist, D.R., Abernethy, C.S., Hand, K.D., Cullinan, V.I., Chandler, J.A. and Groves, P.A., 2006. Survival, development, and growth of fall Chinook salmon embryos, alevins, and fry exposed to variable thermal and dissolved oxygen regimes. Transactions of the American Fisheries Society, 135(6):1462-1477.

Gendaszek, A.S., Burton, K., Magirl, C.S., and Konrad, C.P. 2018. Streambed scour of salmon spawning habitat in a regulated river influenced by management of peak discharge. Freshwater Biology, 63: 917-927.

Grant, S.C.H., Kalyn, S.M., Mahoney, J.E., and J.A. Tadey. 2007. Coho (Oncorhynchus kisutch) and chum (O. keta) salmon visual enumeration surveys in twenty-six lower Fraser River area streams, 1999-2005. Canadian Technical Report of Fisheries and Aquatic Sciences 2964. Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada, 154.

Groves P.A., and J.A. Chandler. 1999. Spawning habitat used by fall Chinook Salmon in the Snake River. North American Journal of Fisheries Management, 19(4): 912-922

Keefer, M. L., & Caudill, C. C. (2014). Homing and straying by anadromous salmonids: A review of mechanisms and rates. Reviews in Fish Biology and Fisheries, 24: 333– 368.

Koo, T.S.Y. 1962. Age designation in studies of Alaska red salmon. Editor T.S.Y. Koo. University of Washington Publications in Fisheries p. 41-48.

Levy, D.A. and T.L. Slaney. 1993. A Review of Habitat Capacity for Salmon Spawning and Rearing. Report Prepared for Dept. of Fisheries and Oceans, Vancouver, BC. 51 pp.

Lister, D.B., Beniston, R.J., Kellerhals, R. and Miles, M., 1995. Rock size affects juvenile salmonid use of streambank riprap. River, coastal and shoreline protection: erosion control using riprap and armourstone. Edited by CR Thorne, SR Abt, FBJ Barends, ST Maynard, and KW Pilarczyk. John Wiley & Sons Ltd., New York, NY, pp.621-634.

Longe, R., and P.S. Higgins. 2002. Lower Bridge River Aquatic Monitoring: Year 2001 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, April 2002.

McCubbing, D.J.F., and D. Ignace. 2000. Salmonid Abundance Estimates on the Deadman River, resistivity counter video validation and abundance estimates. MEOLP Project Report.

Melville, C., Ramos-Espinoza, D., Braun, D.C., and D.J.F. McCubbing. 2015. Lower Bridge River adult salmon and steelhead enumeration, 2014. Prepared for St'át'imc Eco-Resources Ltd. and BC Hydro.

Millar, R.B., McKechnie, S., and C.E. Jordan. 2012. Simple estimators of salmonid abundance and its variance using a new area-under-the-curve method. Canadian Journal of Fisheries and Aquatic Sciences, 69:1002-1015.

Muhlfeld, C.C., Taper, M.L., and D.F. Staples. 2006. Observer error structure in Bull Trout redd counts in Montana streams: implication for inference on true redd numbers. Transaction of the American Fisheries Society. 135: 643-654.

Olsen, D.S., B.B. Roper, J.L. Kershner, R. Henderson, and E. Archer. 2005. Sources of variability in conducting pebble counts: their potential influence on the results of stream monitoring programs. Journal of the American Water Resources Association, 41(5):1225-1236

Ptolemy R. 1994. Delphi derived habitat suitability curves. Unpublished raw data.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Ramos-Espinoza, D., Chung, M., Poole, G., Melville, C., and C. White. 2018. Lower Bridge River adult salmon and steelhead enumeration, 2017. Report prepared for St’át’imc Eco-Resources and BC Hydro. 91 p.

Reisner, D.W., Bjornn T.C. 1979. Habitat requirements of anadromous salmonids. General Technical Report PNW-96 for USDA Forest Service. 63 p.

Sneep, J., Perrin, C., Bennett, S., Harding, J., and Korman J. (2018). Lower Bridge River aquatic monitoring, year 6 (2017) results. White, C., Ramos-Espinoza, D., Chung, M., Poole, G., Cook, K. 2019. Lower Bridge River adult salmon and steelhead enumeration, 2018. Report prepared for St’át’imc Eco-Resources and BC Hydro. 139 p.

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

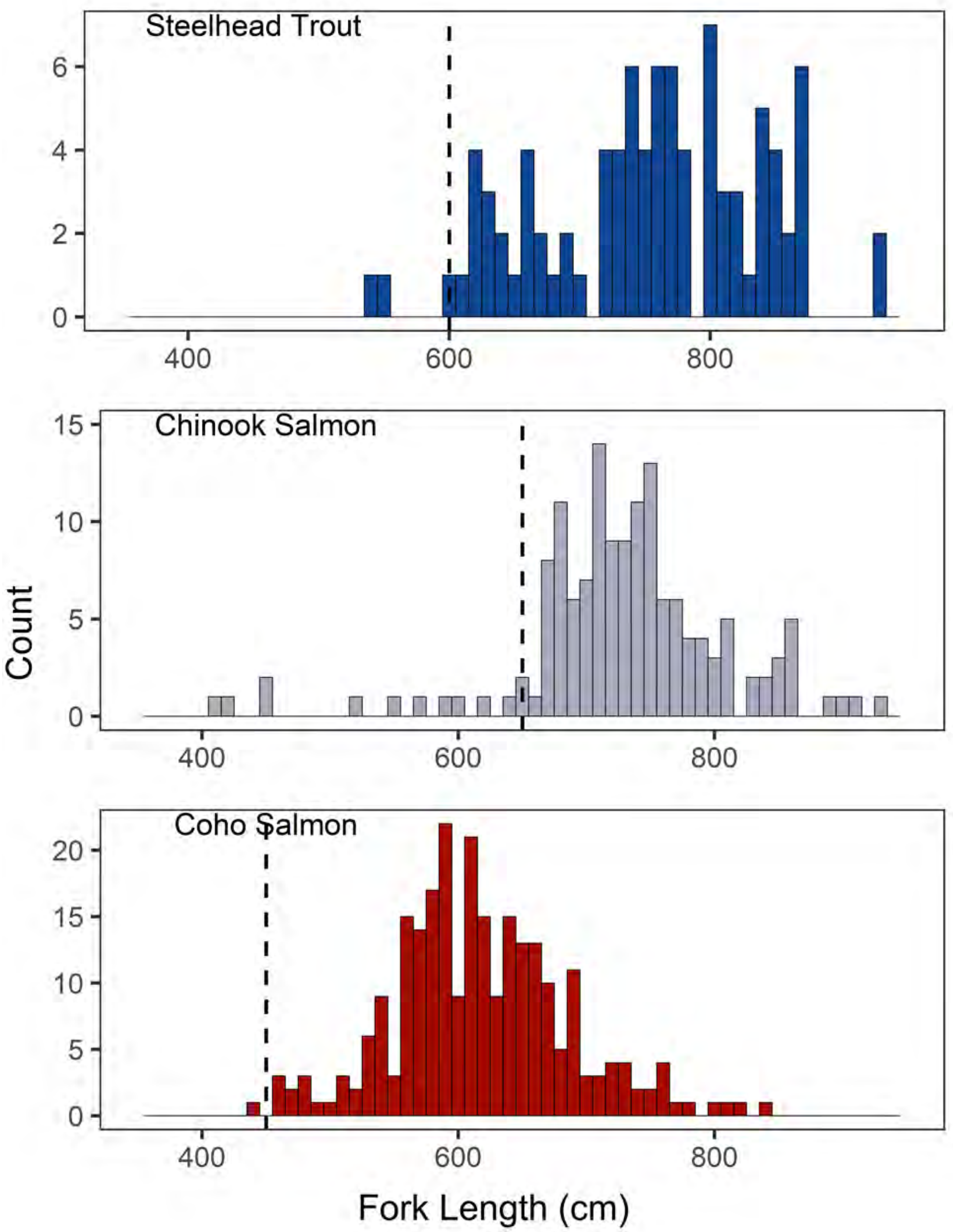
Webb, S, R. Bison, A. Caverly and J. Renn. 2000. The reproductive biology of Steelhead (Onchorhynchus mykiss) in the Bridge and Seton Rivers, as determined by radio telemetry 1996/97 and 1998/99. Technical report of the BC Ministry of Environment, Lands, and Parks, Kamloops, 42 pp.

White, C., Ramos-Espinoza, D., Chung, M., Poole, G., Cook, K. 2019. Lower Bridge River adult salmon and steelhead enumeration, 2018. Report prepared for St’át’imc Eco-Resources and BC Hydro. 120 p.

White, C., Ramos-Espinoza, D., Chung, M., Cook, K., Lingard, S., Putt, A., Pool, G. 2021. Lower Bridge River adult salmon and steelhead enumeration, 2019. Report prepared for St’át’imc Eco-Resources and BC Hydro. 117 p.

Appendix 1: Length-frequency Distribution

Steelhead Trout, and Chinook and Coho Salmon collected from BRGMON-3, BRGMON-14 and broodstock collection.



Appendix 2: AUC Metrics

Chinook Salmon AUC abundance estimates with standard error (SE) and upper and lower confidence intervals (CI) for the Lower Bridge River from 1993-2020. Abundance results are calculated considering estimates of observer efficiency (OE) and residences times (survey life; SL). OE and SL measures are bold face where calculations were based on observations, the remaining values are the calculated average of these measures.

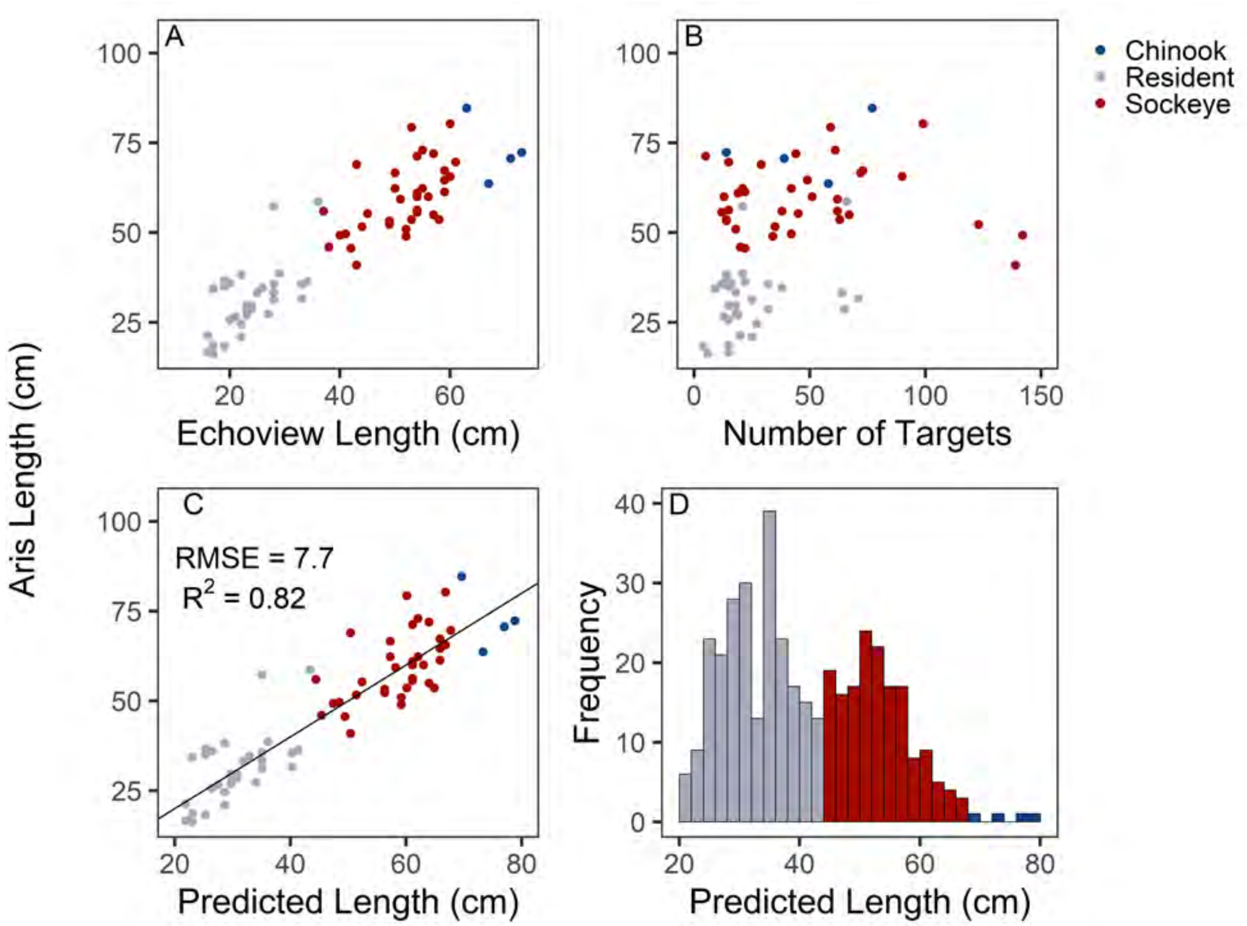
year	oe	oe.se	sl	sl.se	escapement	escapement.se	method	lower95CI	upper95CI
1993	NA	NA	NA	NA	151	0	fence count	151	151
1994	NA	NA	NA	NA	550	0	fence count	550	550
1995	NA	NA	NA	NA	851	0	fence count	851	851
1996	NA	NA	NA	NA	1100	0	fence count	1100	1100
1997	0.5	0.139	10.5	0.65	2005	1581	visual survey	427.2529	9406.115
1998	0.5	0.139	10.5	0.65	873	254	visual survey	494.1845	1542.997
1999	0.5	0.139	10.5	0.65	2576	847	visual survey	1352.164	4905.758
2001	0.5	0.139	10.5	0.65	1784	981	visual survey	607.1949	5243.568
2004	0.5	0.139	10.5	0.65	3106	1139	visual survey	1513.51	6374.429
2005	0.5	0.139	10.5	0.65	591	232	visual survey	273.9358	1273.612
2006	0.5	0.139	10.5	0.65	399	124	visual survey	217.4452	732.924
2007	0.5	0.139	10.5	0.65	309	108	visual survey	155.6962	612.6833
2008	0.5	0.139	10.5	0.65	164	94	visual survey	53.13421	506.8887
2009	0.5	0.139	10.5	0.65	21	7	visual survey	10.29999	40.82776
2010	0.5	0.139	10.5	0.65	208	67	visual survey	110.3265	391.9219
2011	0.5	0.139	10.5	0.65	82	33	visual survey	37.52313	178.6533
2012	0.58	0.139	10	0.65	364	114	visual survey	196.3604	673.5267
2013	0.28	0.139	11	0.65	168	90	visual survey	58.59576	478.8577
2014	0.28	0.139	12	0.65	591	314	visual survey	208.8122	1672.568
2015	0.5	0.139	10.5	0.65	158	68	visual survey	67.97145	369.5601
2016	0.28	0.139	10.5	0.65	473	247	visual survey	169.5826	1316.599
2017	0.5	0.139	10.5	0.65	120	42	visual survey	60.5576	239.318
2018	0.5	0.139	10.5	0.65	25	7	visual survey	13.77902	43.98417
2019	0.5	0.139	10.5	0.65	161	54	visual survey	83.94209	310.4006
2020	0.5	0.139	10.5	0.65	16	8	visual survey	6.250481	41.16546

Coho Salmon AUC abundance estimates with standard error (SE) and upper and lower confidence intervals (CI) for the Lower Bridge River from 1993-2020. Abundance results are calculated considering estimates of observer efficiency (OE) and residences times (survey life; SL). OE and SL measures are bold face where calculations were based on observations, the remaining values are the calculated average of these measures.

year	oe	oe.se	sl	sl.se	escapement	escapement.se	method	lower95CI	upper95CI
1997	0.216	0.019	19.6	1.29	619	1419	visual survey	6.940512	55245.03
1998	0.216	0.019	19.6	1.29	1079	400	visual survey	521.5082	2232.028
1999	0.216	0.019	19.6	1.29	81	NA	visual survey	NA	NA
2001	0.216	0.019	19.6	1.29	1033	134	visual survey	801.4703	1331.385
2003	0.216	0.019	19.6	1.29	1217	134	visual survey	980.5683	1510.181
2004	0.216	0.019	19.6	1.29	233	50	visual survey	152.892	356.0635
2005	0.216	0.019	19.6	1.29	739	123	visual survey	532.7264	1025.037
2006	0.216	0.019	19.6	1.29	674	110	visual survey	489.3859	929.0487
2008	0.216	0.019	19.6	1.29	102	16	visual survey	74.98446	138.9845
2009	0.216	0.019	19.6	1.29	1601	242	visual survey	1191.47	2152.115
2010	0.216	0.019	19.6	1.29	463	81	visual survey	328.8576	653.1707
2011	0.216	0.019	19.6	1.29	3678	636	visual survey	2620.984	5160.678
2012	0.25	0.019	16	1.29	1662	386	visual survey	1054.822	2618.98
2013	0.27	0.019	19	1.29	2974	355	visual survey	2353.094	3759.042
2014	0.216	0.019	19.6	1.29	424	74	visual survey	301.152	595.7595
2015	0.216	0.019	19.6	1.29	174	23	visual survey	134.5335	224.1282
2016	0.216	0.019	19.6	1.29	488	69	visual survey	370.3827	642.3499
2017	0.19	0.019	23	1.29	451	65	visual survey	339.2249	599.3597
2018	0.216	0.019	19.6	1.29	1245	169	visual survey	953.8967	1624.493
2019	0.216	0.019	19.6	1.29	216	35	visual survey	156.9518	298.351
2020	0.216	0.019	19.6	1.29	537	121	visual survey	344.9745	834.9001

Appendix 3: Sonar Length Modelling and Linear Model Coefficients

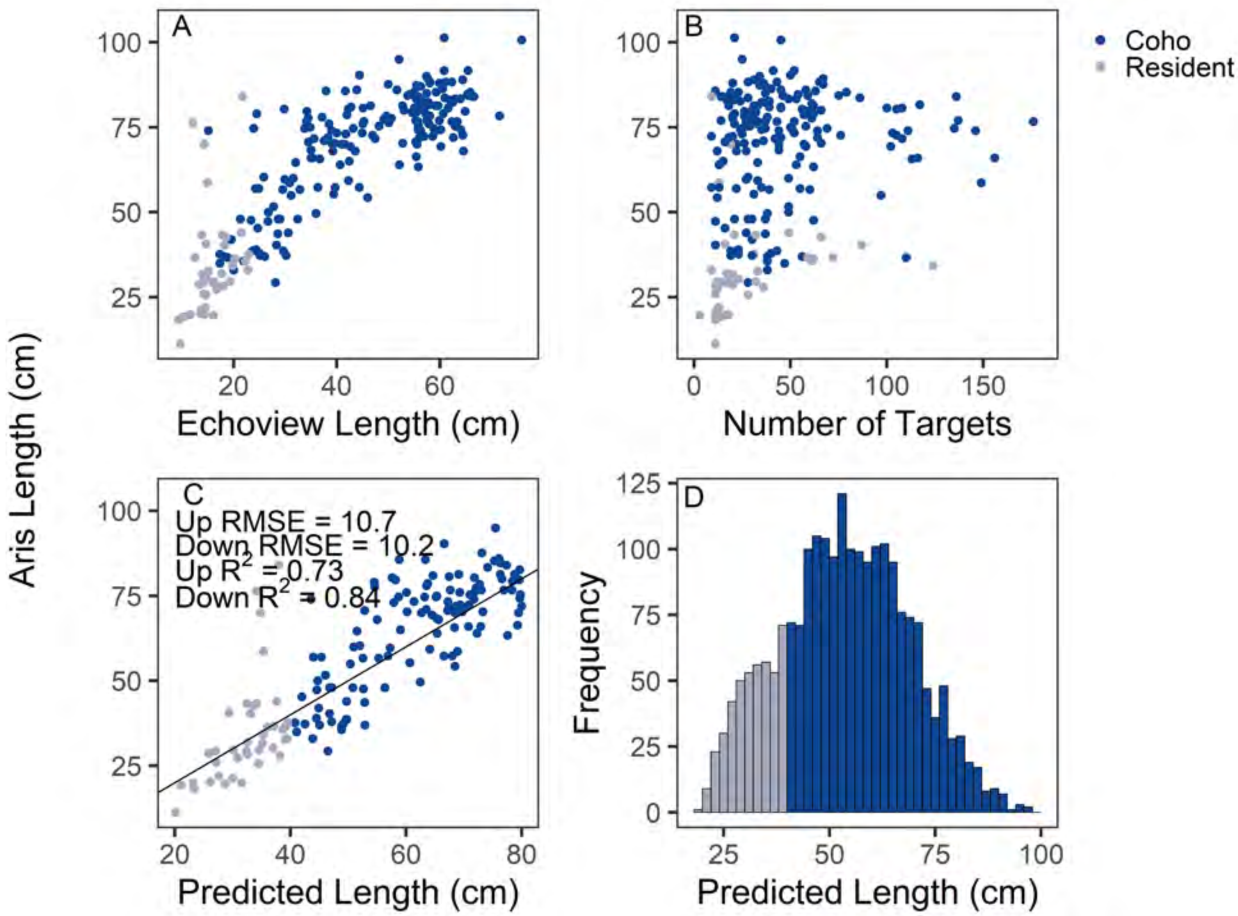
Manually measured fish length in ARISFish software in relation to (A) Echoview generated length and (B) distance from sonar. (C) Observed ARISfish lengths in relation to predicted lengths from a linear model that included Echoview length. Black line indicates unity (1:1). (D) Histogram of the predicted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



Model output and AICc for predicting ARIS lengths from Echoview target length, number of targets, and target mean range. Predicted lengths were used to distinguish Chinook Salmon and enumerate abundance.

Intercept	log Number of Targets	log Target Length Mean	log Target Range Mean	R^2	df	ΔAIC
0.7424		0.8449		0.8205	3	0
0.729	0.02319	0.8271		0.822	4	1.65
0.7531		0.844	-0.00629	0.8205	4	2.24
0.7396	0.02319	0.8263	-0.00622	0.822	5	3.96

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. Grey, and blue correspond to resident fish Coho Salmon, respectively. Dots are fish observed using Echoview.



Model output and AICc for predicting ARIS lengths of "up" fish from Echoview target length, number of targets, and target mean range. Predicted lengths were used to distinguish Coho Salmon and enumerate abundance.

Intercept	log Number of Targets	log Target Length Mean	log Target Range Mean	R^2	df	ΔAIC
1.379	0.09696	0.6183	0.15910	0.72660	5	0.00
1.530	0.12280	0.6033		0.70870	4	5.08
1.595		0.6352	0.21590	0.70270	4	7.44
1.908		0.6196		0.66640	3	18.53

Model output and AICc for predicting ARIS lengths of "down" fish from Echoview target length, number of targets, and target mean range. Predicted lengths were used to distinguish Coho Salmon and enumerate abundance.

Intercept	log Number of Targets	log Target Length Mean	log Target Range Mean	R^2	df	ΔAIC
1.213		0.7871		0.84230	3	0.00
1.167	0.03136	0.7694		0.84440	4	0.69
1.185		0.7791	0.05083	0.84400	4	1.00
1.156	0.02489	0.7674	0.03586	0.84510	5	2.37

Appendix 4: Radio Tagging

Tagging information and spawning distribution of radio-tagged Steelhead Trout in the Lower Bridge River in 2020, including calculated migration rates and residence time in specific reaches. All fish were tagged at the Seton-Fraser confluence.

Tag #	Sex	Fork Length (mm)	Tagging Date	Entry Date to LBR	End Date	Assumed Spawning Reach (1-4)	Assumed Spawning Section (1-8)	Reach 2 Residence Time (days)	Reach 3 Residence Time (days)	Kelt Date Past the Counter	Migration Rate (km day^{-1})
106	F	800	02-12	04-27	05-09	4	2	9.8	7.6	NA	6.1
107	M	620	02-13	NA	06-06	NA	NA	NA	NA	NA	NA
108	F	690	02-24	NA	NA	NA	NA	NA	NA	NA	NA
109	F	695	02-24	05-05	05-21	3	8	11.8	NA	05-20	5.1
110	F	660	02-24	04-15	05-23	3	4	26.9	23.4	05-23	1.4
111	M	870	02-25	NA	NA	NA	NA	NA	NA	NA	NA
112	M	815	02-26	NA	NA	NA	NA	NA	NA	NA	NA
113	F	744	02-26	04-17	05-24	3	8	30.7	8.3	05-22	1.0
114	F	763	02-27	NA	05-26	3	8	NA	NA	NA	NA
115	F	773	02-27	NA	NA	NA	NA	NA	NA	NA	NA
117	F	777	02-27	04-10	05-20	3	4	24.3	NA	05-20	0.9
118	F	805	02-29	03-31	04-18	NA	NA	NA	NA	NA	NA
119	F	770	03-13	04-18	05-15	4	1	24.3	NA	05-14	0.6
120	F	855	03-25	04-09	05-22	4	1	34.1	31.0	NA	0.4
123	F	805	04-02	NA	NA	NA	NA	NA	NA	NA	NA
121	M	865	04-07	NA	NA	NA	NA	NA	NA	NA	NA
124	F	815	04-15	NA	NA	NA	NA	NA	NA	NA	NA
							Mean	**23.1**	**17.6**	**05-19**	**2.2**
							Std	**9.1**	**11.6**	**3.5 days**	**2.3**

Tagging information and spawning distribution of radio-tagged Chinook Salmon in the Lower Bridge River in 2020, including tagging location and assumed spawning location.

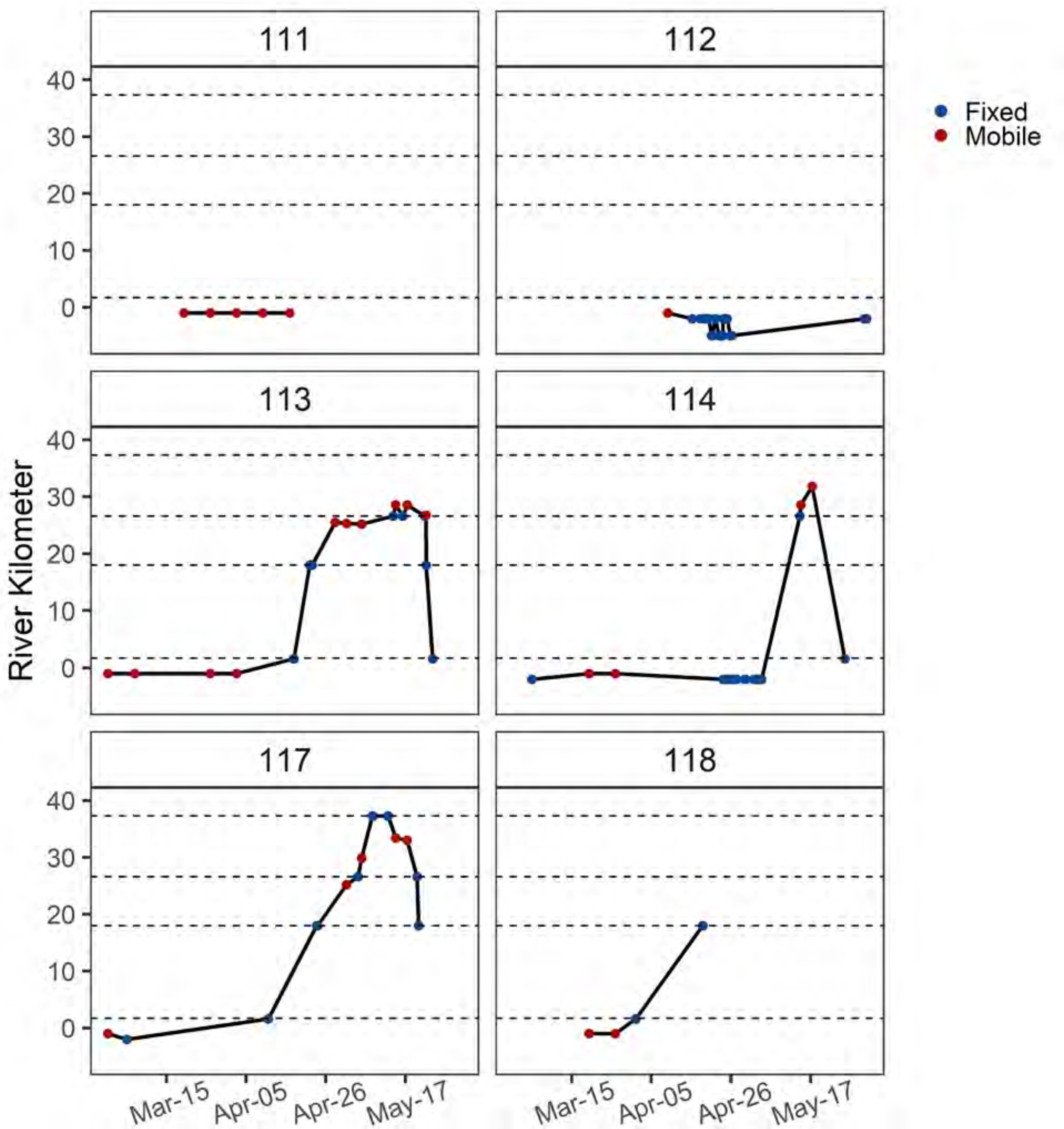
Tag #	Sex	Fork Length (mm)	Tagging Date	Tagging Location	End Date	Assumed Spawning Reach
125	F	795	08-16	Hippie Pool	NA	NA
126	F	803	08-22	Yalakom Confluence	08-28	Reach 2/3
128	M	665	08-24	Hippie Pool	NA	NA
129	F	744	08-30	Yalakom Confluence	09-06	Reach 2/3
130	F	687	08-30	Camoo Bridge	09-17	Camoo

Tagging information and spawning distribution of radio-tagged Coho Salmon in the Lower Bridge River in 2020, including capture location, calculated migration rates and residence time in specific reaches.

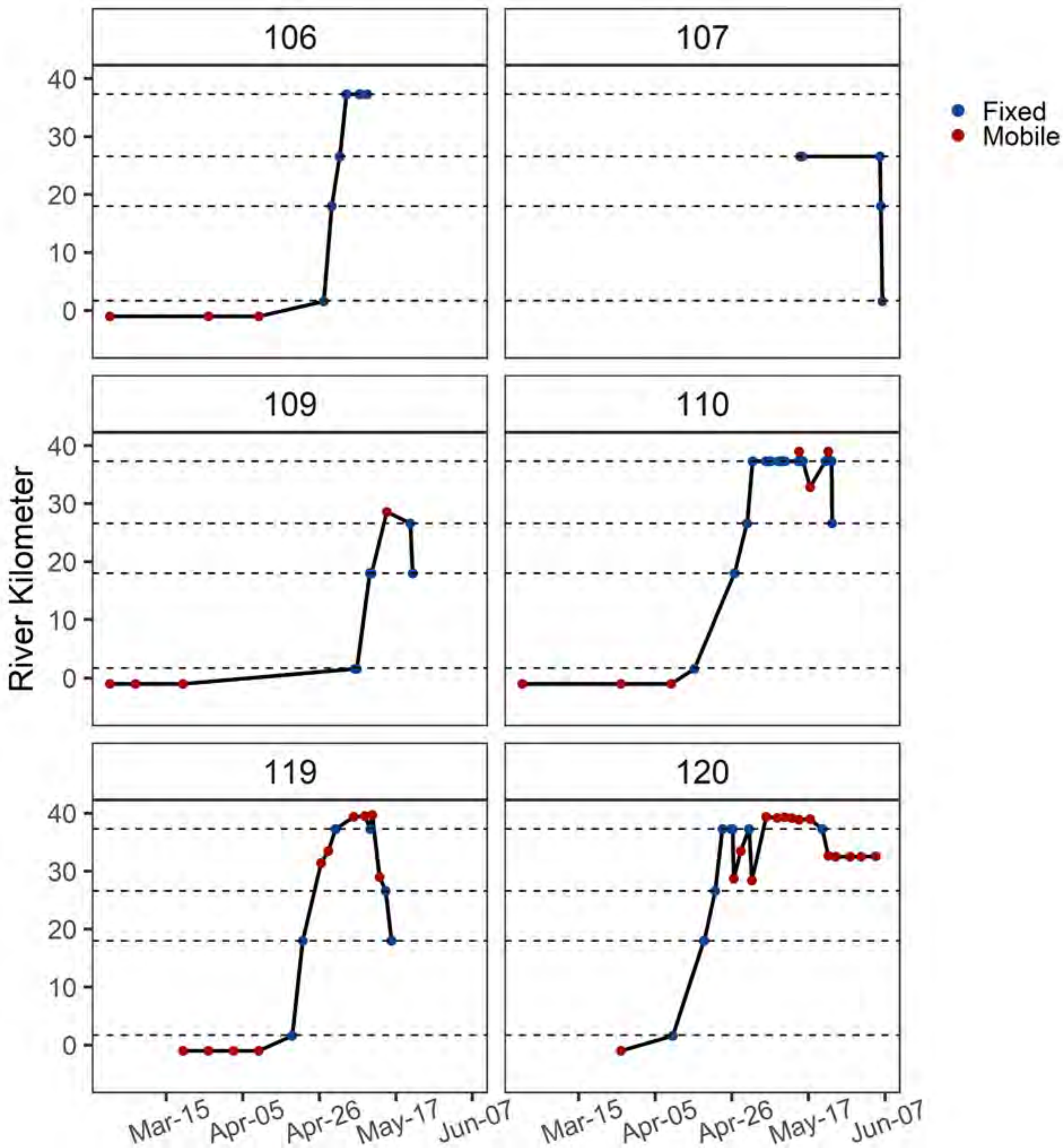
Tag #	Sex	Fork Length (mm)	Tagging Date	Tagging Location	End Date	Assumed Spawning Reach	Assumed Spawning Section	Reach 2 Residence Time (days)	Reach 3 Residence Time (days)	Migration Rate (km day^{-1})
133	M	649	10-10	Camoo Bridge	NA	NA	NA	NA	NA	NA
134	F	610	10-13	Bridge Confluence	11-23	Reach 4	Plunge Pool to Longskinny	19.6	11.6	1.4
135	F	730	10-14	Bridge Confluence	NA	NA	NA	NA	NA	NA
136	F	766	10-17	Bridge Confluence	NA	NA	NA	NA	NA	NA
138	F	550	10-18	Bridge Confluence	11-23	Reach 3	Fish Fence to Russel	25.2	23.3	2.8
139	M	665	10-19	Bridge Confluence	11-12	Reach 3	Hell to Counter	NA	19.3	NA
140	F	595	10-19	Bridge Confluence	NA	NA	NA	NA	NA	NA
143	M	665	10-28	Bridge Confluence	11-23	Reach 3	Hell to Counter	19.5	14.0	2.3
144	F	800	11-14	Bridge Confluence	NA	NA	NA	NA	NA	NA
141	M	610	11-15	Bridge Confluence	NA	NA	NA	NA	NA	NA
146	M	530	11-18	Bridge Confluence	NA	NA	NA	NA	NA	NA
145	F	570	11-18	Bridge Confluence	NA	NA	NA	NA	NA	NA
							Mean	**21.5**	**17.0**	**2.2**
							Std	**3.2**	**5.3**	**0.7**

Appendix 5: Graphical Fish Traces

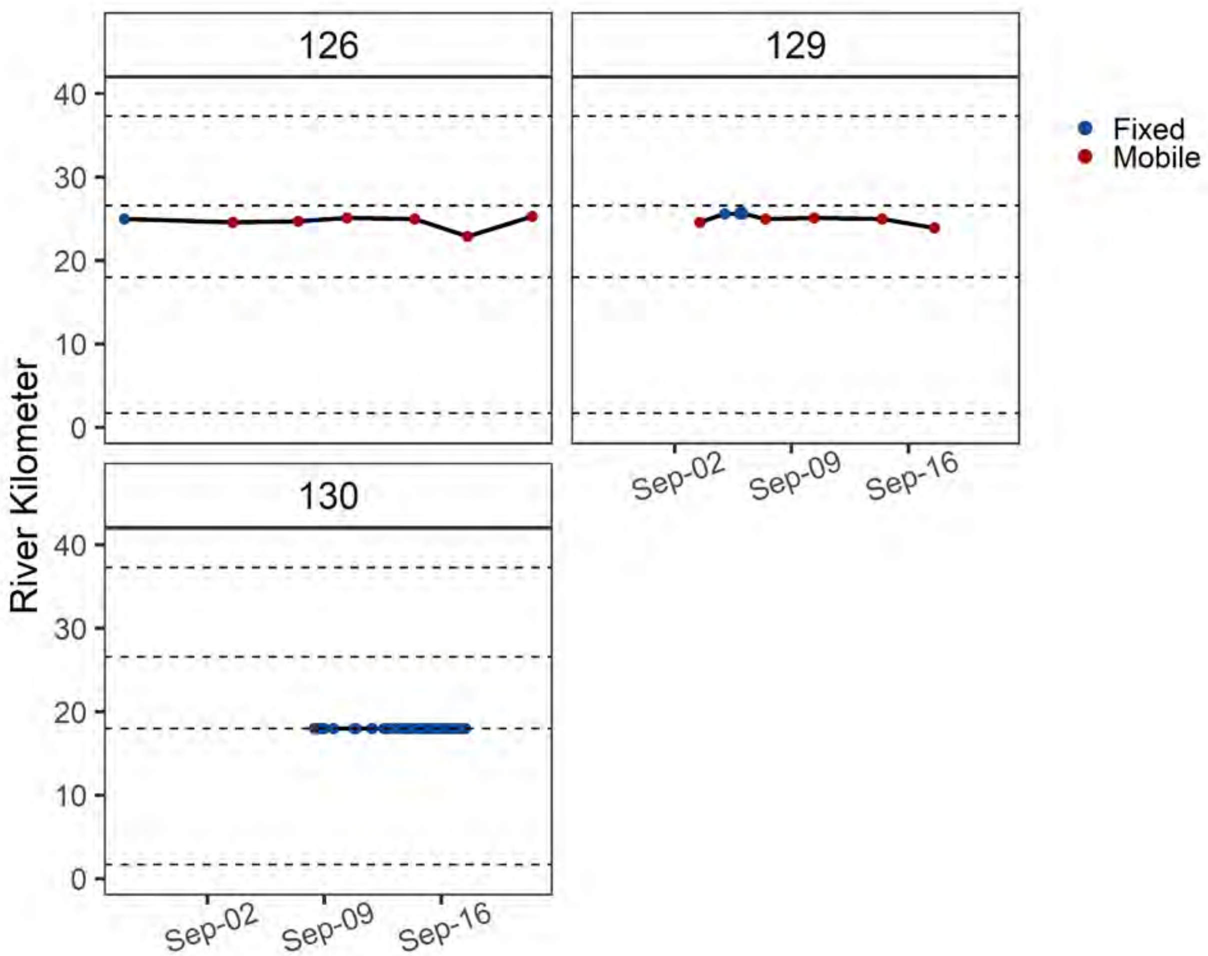
Detection histories of all radio tagged adult Steelhead Trout in the Lower Bridge River in 2020. Black lines connect the data collected from fixed (blue) and mobile (red) telemetry. Dashed lines indicate boundaries between different reaches. Observations below 0 river kms are sites located in the Seton River.



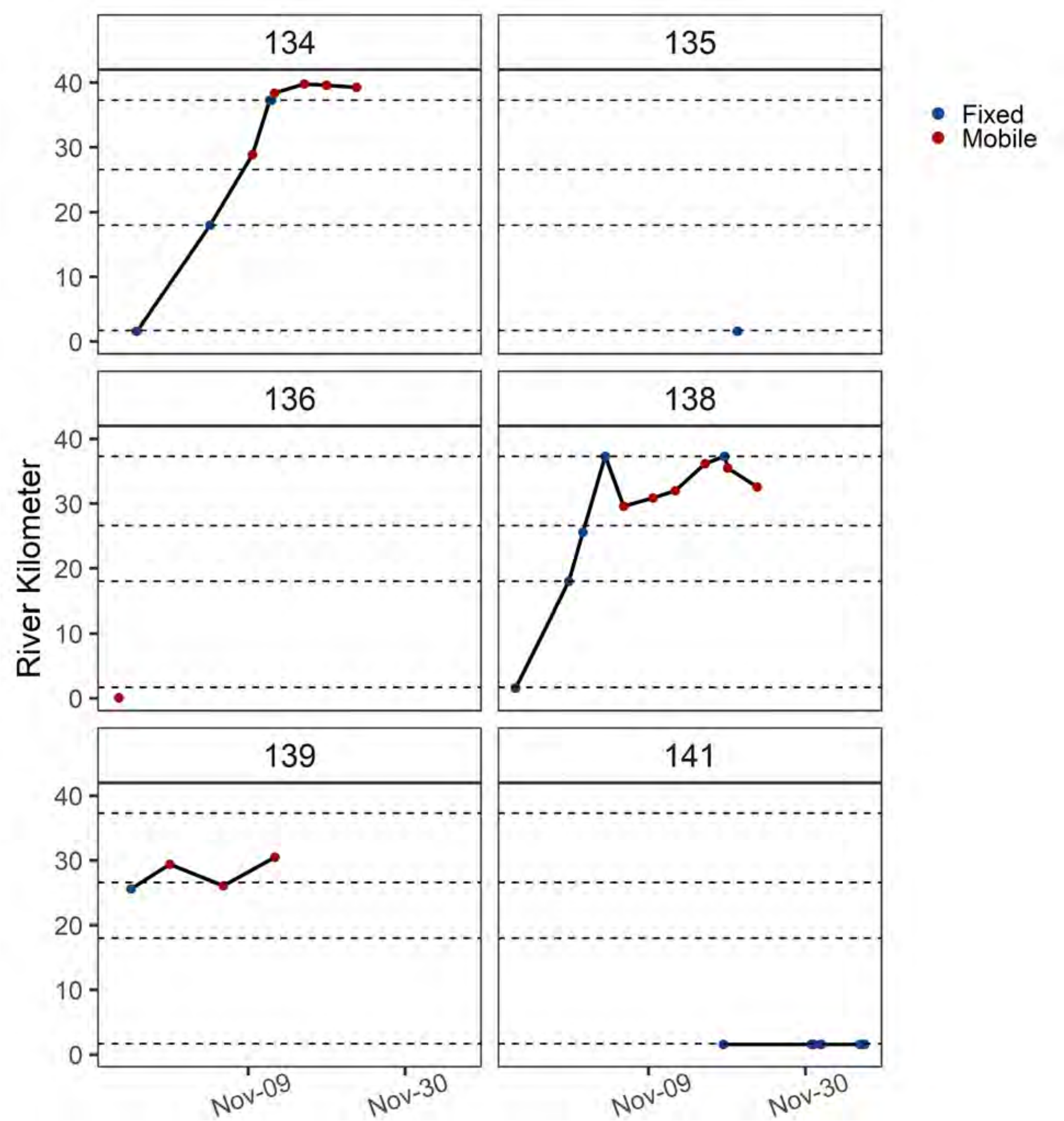
Con't: Detection histories of all radio tagged adult Steelhead Trout in the Lower Bridge River in 2020. Black lines connect the data collected from fixed (blue) and mobile (red) telemetry. Dashed lines indicate boundaries between different reaches. Observations below 0 river kms are sites located in the Seton River.



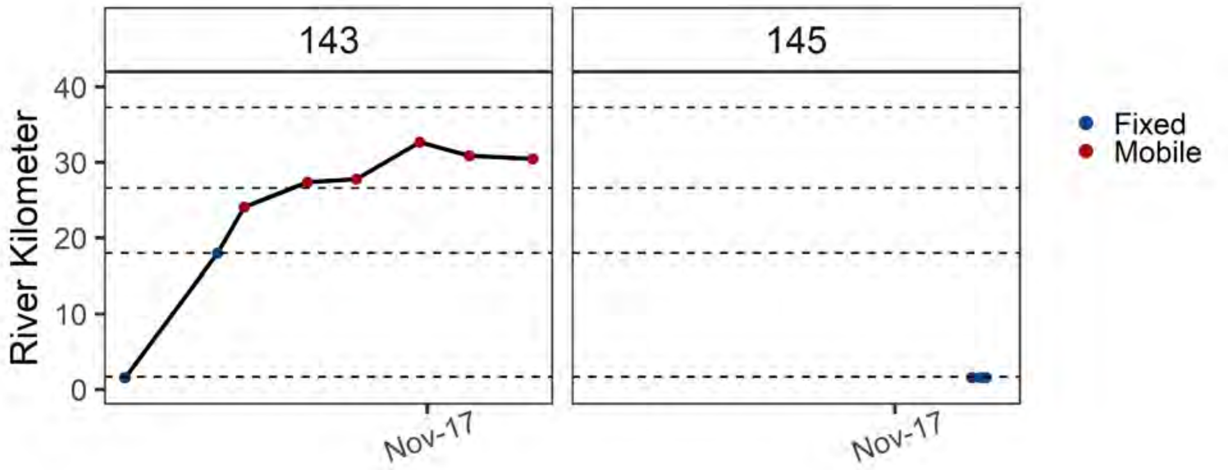
Detection histories of all radio tagged adult Chinook Salmon in the Lower Bridge River in 2020. Black lines connect the data collected from fixed (blue) and mobile (red) telemetry. Dashed lines indicate boundaries between different reaches.



Detection histories of all radio tagged adult Coho Salmon in the Lower Bridge River in 2020. Black lines connect the data collected from fixed (blue) and mobile (red) telemetry. Dashed lines indicate boundaries between different reaches.



Con't: Detection histories of all radio tagged adult Coho Salmon in the Lower Bridge River in 2020. Black lines connect the data collected from fixed (blue) and mobile (red) telemetry. Dashed lines indicate boundaries between different reaches.



Appendix 6: Visual Survey Count

Chinook Salmon visual survey data by visual survey section in 2020.

Date	Observers	% Cloud Cover	Water Visibility (m)	Plunge Pool to Longskinny	Plunge Pool to Longskinny (tagged)	Longskinny to Eagle	Longskinny to Eagle (tagged)	Eagle to Bluenose	Eagle to Bluenose (tagged)	Bluenose to Cobra	Bluenose to Cobra (tagged)	Mortalities
07-23	RJ, BC,CL	10	0.20	0	0	0	0	0	0	0	0	0
07-30	RJ,WP,TR	0	0.25	0	0	0	0	0	0	0	0	0
08-06	RJ,WP,DM	100	1.00	0	0	0	0	0	0	0	0	0
08-13	RJ,DM,TR	80	2.00	3	0	0	0	0	0	0	0	0
08-20	RJ,DM,WP,MA	100	2.50	1	0	0	0	0	0	0	0	0
08-27	WP,KA	5	NA	0	0	0	0	0	0	0	0	0
09-03	RJ,WP,MT,SM	0	2.50	0	0	0	0	0	0	0	0	0
09-10	WP,MT	0	2.00	0	0	0	0	0	0	0	0	0
09-17	WP,DM	0	0.75	0	0	0	0	0	0	0	0	0
09-24	WP,DM	90	0.4	0	0	0	0	0	0	0	0	1
10-01	WP,DM	100	0.27	0	0	0	0	0	0	0	0	0

Date	Cobra to Fish Fence	Cobra to Fish Fence (tagged)	Fish Fence (excluding FF) to Russel	Fish Fence (excluding FF) to Russel (tagged)	Russel to Hell	Russel to Hell (tagged)	Hell to Counter	Hell to Counter (tagged)	Counter to Yalakom	Counter to Yalakom (tagged)	Total	Above Fence Total
07-23	0	0	0	0	0	0	0	0	0	0	0	0
07-30	0	0	0	0	0	0	0	0	0	0	0	0
08-06	0	0	0	0	0	0	0	0	0	0	0	0
08-13	1	0	0	0	0	0	0	0	4	0	8	4
08-20	3	0	0	0	0	0	0	0	6	1	11	4
08-27	2	0	0	0	0	0	0	0	7	1	10	2
09-03	0	0	0	0	0	0	0	0	24	0	24	0
09-10	0	0	0	0	1	0	0	0	11	0	12	1
09-17	0	0	0	0	0	0	0	0	18	0	18	0
09-24	0	0	0	0	0	0	1	0	14	0	15	1
10-01	0	0	0	0	0	0	0	0	0	0	0	0

Compiled observations of spawning distribution of Chinook Salmon across streamwalk sections in Reach 3 and 4 of the LBR from all visual surveys (2013-2020).

Streamwalk			**Year**								
Section	Description	River KM	2013	2014	2015	2016	2017	2018	2019	2020	Total
1	Terzaghi Dam to Longskinny	40.0 to 39.6	11	6	8	20	9	1	31	4	90
2	Longskinny to Eagle	39.6 to 38.8	4	5	5	6	1	6	34	0	61
3	Eagle to Bluenose	38.8 to 38.2	1	0	0	0	0	0	0	0	1
4	Bluenose to Cobra	38.2 to 34.4	20	16	6	0	4	0	0	0	46
5	Cobra to Fraser Lake	34.4 to 33.2	17	56	6	64	32	7	13	6	201
6	Fraser Lake to Russel Springs	33.2 to 30.7	7	14	6	14	10	5	6	0	62
7	Russel Springs to Hell Creek	30.7 to 28.8	17	5	8	43	21	0	1	1	96
8	Hell Creek to Yalakom	28.8 to 25.5	61	197	79	55	10	0	31	87	520
		Total	**138**	**299**	**118**	**202**	**87**	**19**	**116**	**98**	**1077**

Coho Salmon visual survey data by visual survey section in 2020.

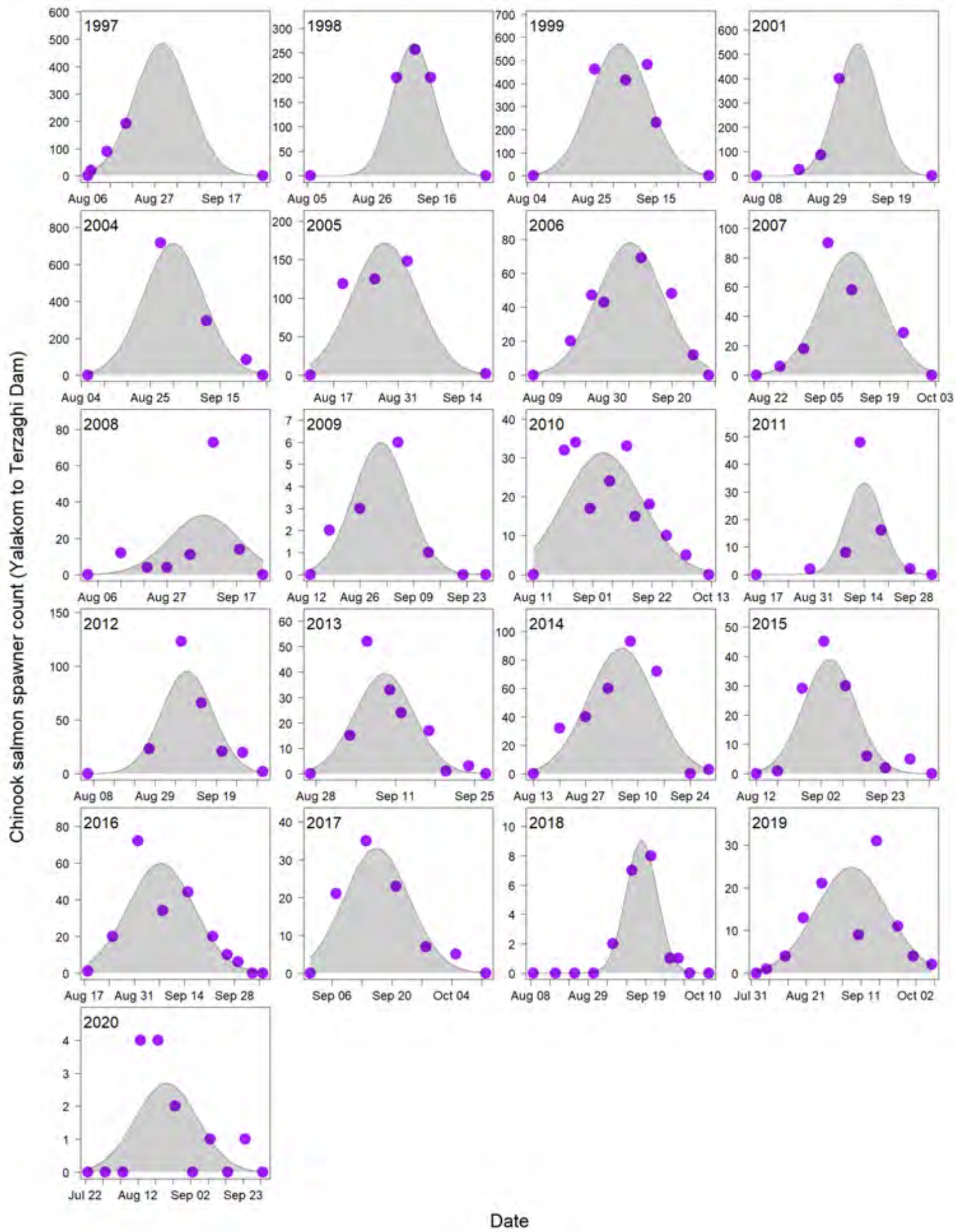
Date	Observers	% Cloud Cover	Water Visibility (m)	Plunge Pool to Longskinny	Plunge Pool to Longskinny (tagged)	Longskinny to Eagle	Longskinny to Eagle (tagged)	Eagle to Bluenose	Eagle to Bluenose (tagged)	Bluenose to Cobra	Bluenose to Cobra (tagged)
2020-10-01	WP,DM	100	0.27	0	0	0	0	0	0	0	0
2020-10-08	RJ,WP	100	0.20	5	0	2	0	0	0	0	0
2020-10-15	CB,DM	100	0.20	1	0	1	0	0	0	0	0
2020-10-22	DM,BP	20	0.32	0	0	0	0	0	0	0	0
2020-10-29	RJ,RB	100	0.20	10	0	0	0	0	0	0	0
2020-11-05	RJ,DM	100	0.60	16	0	18	0	0	0	0	0
2020-11-12	DM,WP	90	0.60	19	0	16	0	0	0	0	0
2020-11-19	CB,RB	10	0.20	64	0	24	0	0	0	0	0
2020-11-26	DM,WP	100	0.90	23	0	4	0	5	0	1	0
2020-12-03	BP,CB	80	4.5?	0	0	16	0	17	0	0	0
2020-12-10	WP,RB	100	0.7	8	0	10	0	0	0	0	0
2020-12-17	DM,RB,MA	100	0.70	6	0	2	0	0	0	0	0

Date	Cobra to Fish Fence	Cobra to Fish Fence (tagged)	Fish Fence (excluding FF) to Russel	Fish Fence (excluding FF) to Russel (tagged)	Russel to Hell	Russel to Hell (tagged)	Hell to Counter	Hell to Counter (tagged)	Counter to Yalakom	Counter to Yalakom (tagged)	Total	Mortalities
2020-10-01	0	0	0	0	0	0	0	0	0	0	0	0
2020-10-08	0	0	0	0	0	0	0	0	0	0	7	0
2020-10-15	0	0	0	0	0	0	0	0	0	0	2	0
2020-10-22	0	0	0	0	0	0	0	0	0	0	0	0
2020-10-29	5	0	4	0	5	0	0	0	0	0	24	1
2020-11-05	0	0	0	0	0	0	1	0	0	0	35	1
2020-11-12	0	0	0	0	0	0	0	0	0	0	35	1
2020-11-19	24	0	0	0	0	0	0	0	0	0	112	0
2020-11-26	8	0	7	0	0	0	0	0	0	0	48	0
2020-12-03	0	0	0	0	0	0	0	0	0	0	33	2
2020-12-10	0	0	2	0	0	0	0	0	0	0	20	0
2020-12-17	0	0	0	0	0	0	0	0	0	0	8	0

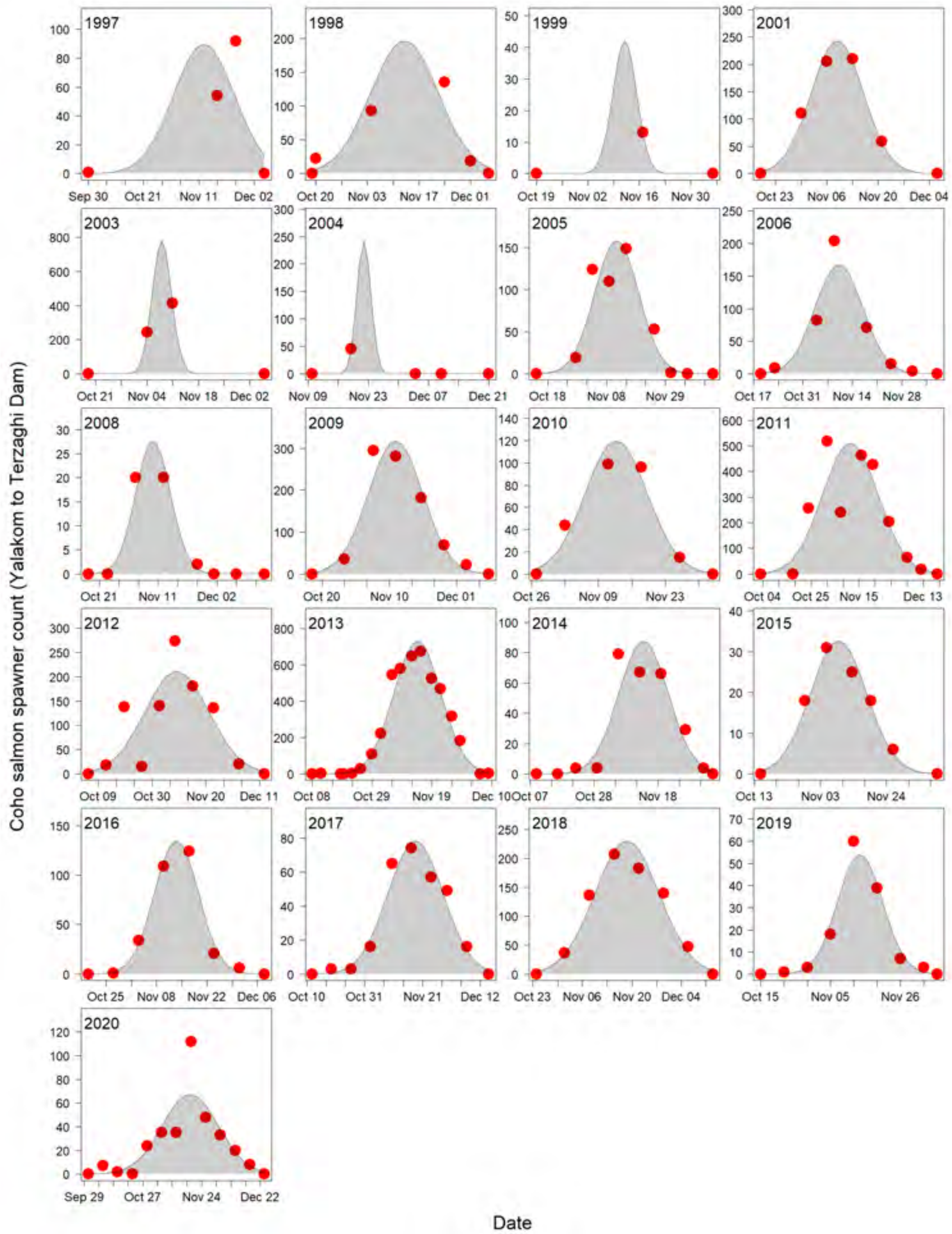
Compiled observations of spawning distribution of Coho Salmon across streamwalk sections in Reach 3 and 4 of the LBR from all visual surveys (2013-2020).

Streamwalk			Year									
Section	**Description**	**River km**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**
1	Terzaghi Dam to Longskinny	40.0 to 39.6	324	1715	104	61	139	189	348	34.5	152	3066.5
2	Longskinny to Eagle	39.6 to 38.8	92	1186	73	7	66	83	212	71	93	1883
3	Eagle to Bluenose	38.8 to 38.2	223	70	6	4	0	0	16	0	22	341
4	Bluenose to Cobra	38.2 to 34.4	64	745	23	15	0	0	8	0	1	856
5	Cobra to Fraser Lake	34.4 to 33.2	151	352	24	10	72	5	102	1	37	754
6	Fraser Lake to Russel Springs	33.2 to 30.7	26	127	2	0	4	3	11	13	13	199
7	Russel Springs to Hell Creek	30.7 to 28.8	23	33	0	1	8	3	21	2.5	5	96.5
8	Hell Creek to Yalakom	28.8 to 25.5	19	177	21	0	6	0	32	8	1	264
		Total	**922**	**4405**	**253**	**98**	**295**	**283**	**750**	**130**	**324**	**7460**

Appendix 7: Historical AUC Estimates



Chinook Salmon adult spawner counts (purple points) to the modelled arrival timing (grey shaded area) in the Lower Bridge River from 1997 to 2020. Note that there are different date ranges between years.



Coho Salmon adult spawner counts (red points) to the modelled arrival timing (grey shaded area) in the Lower Bridge River from 1997 to 2020. Note that there are different date ranges between years.

Appendix 8: Habitat Suitability Index

Summary of the Chinook Salmon spawning habitat available in Reach 1 to 4 from HSI surveys (2017 - 2019).

		Spawning Habitat (m^2)		
Site	Reach	2017	2018	2019
Apple Springs Unit1	1	NA	1404.45	1467.68
Apple Springs Unit2	1	NA	122.69	631.88
Apple Springs Unit3	1	NA	327.11	319.51
Bridge River Office	1	NA	NA	257.80
Antoine Creek	2	NA	190.79	261.74
Below Antoine Creek	2	NA	1525.16	1609.91
Camoo FSR	2	NA	1331.40	2339.81
Horseshoe Bend	2	NA	671.85	673.88
wpt37	2	NA	677.13	992.74
wpt38	2	NA	661.11	732.15
wpt41	2	NA	274.63	378.57
wpt44	2	NA	563.75	855.78
Yalakom Confluence	2	NA	158.76	154.40
Cobra	3	67.46	141.74	120.02
Counter Site	3	249.84	307.19	198.32
Fraser Lake	3	580.40	512.03	530.40
Hell Creek	3	112.85	104.98	132.28
Hippy Pool	3	38.59	104.05	138.39
KM 30.2 Pool	3	244.48	288.44	288.23
KWL Site	3	NA	84.10	NA
Lower Spawning Platform	3	196.49	185.24	228.46
Michael Moon Creek	3	NA	268.05	NA
Mid Spawning Channel	3	78.78	200.10	139.33
Russel Springs	3	129.97	233.70	153.72
Unit 1	3	362.55	395.17	445.84
Unit 2	3	226.62	218.31	256.98
Unit 3	3	105.24	125.44	120.02
Unit 4	4	48.81	52.92	56.80
Upper Spawning Channel	4	57.98	96.45	96.59
Below Longskinny	4	NA	NA	24.39
Eagle	4	NA	158.57	154.10
Long Skinny	4	817.64	550.85	669.72

Summary of the Coho Salmon spawning habitat available in Reach 1 to 4 from HSI surveys in 2019.

Site	Reach	Spawning Habitat (m^2)
Apple Springs Unit1	1	1252.73
Apple Springs Unit2	1	446.85
Apple Springs Unit3	1	99.5
Bridge River Office	1	193.98
Antoine Creek	2	181.31
Below Antoine Creek	2	1359.01
Camoo FSR	2	3645.52
Horseshoe Bend	2	679
wpt37	2	674.75
wpt38	2	638.41
wpt41	2	361.66
wpt44	2	844.76
Yalakom Confluence	2	132.82
Cobra	3	84.15
Counter Site	3	175.83
Fraser Lake	3	204.23
Hell Creek	3	90.54
Lower Spawning Platform	3	88.85
Mid Spawning Channel	3	71.44
Russel Springs	3	87.25
Unit 1	3	389.18
Unit 2	3	118.78
Unit 3	3	202.05
Unit 4	4	9.89
Upper Spawning Channel	4	62.36
Eagle	4	241.82
Long Skinny	4	791.6

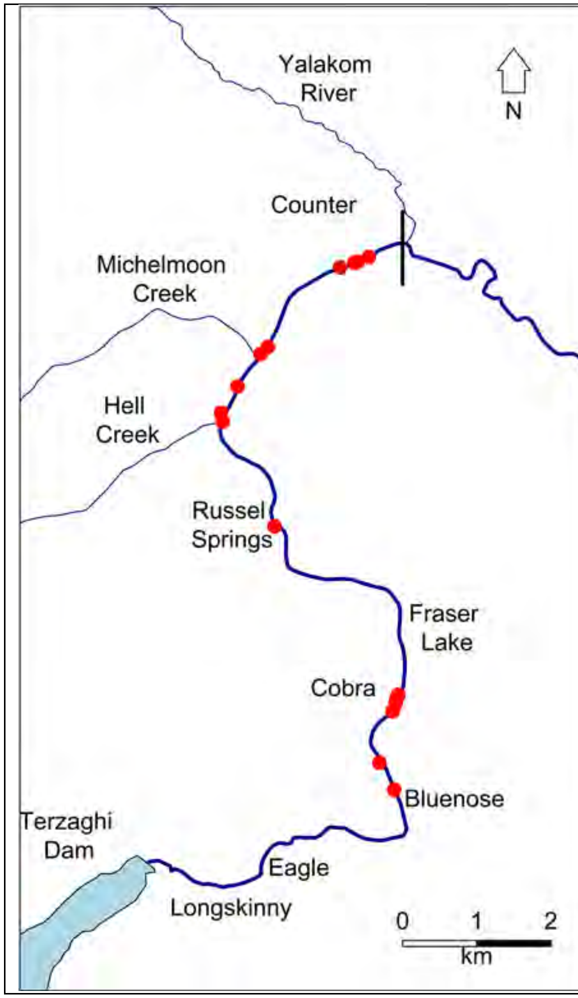
Appendix 9: Redd Distribution

Chinook Salmon redd distribution across streamwalk sections in Reach 3 and 4 of the LBR (2014-2020).

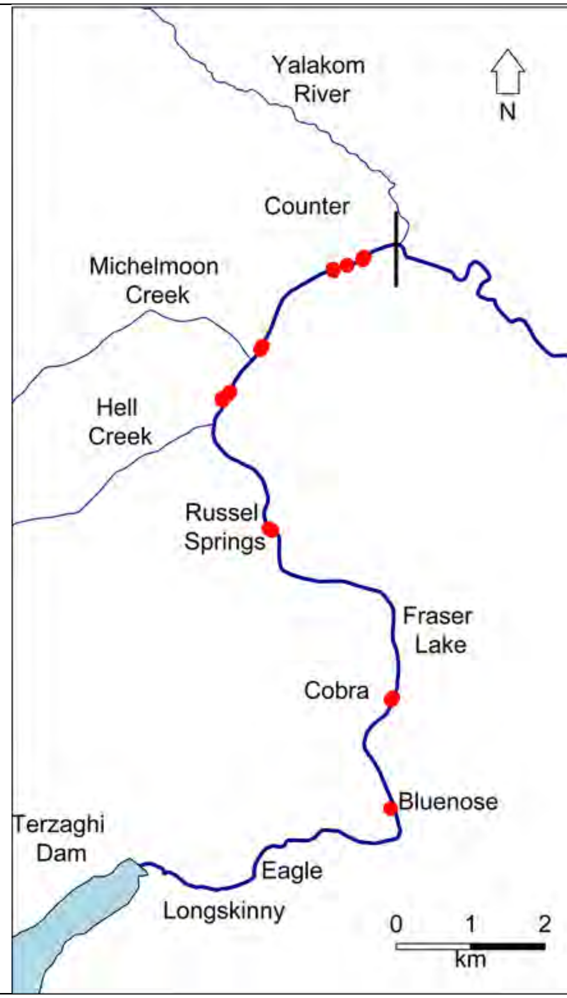
Streamwalk			**Year**							
Section	Description	RiverKM	2014	2015	2016	2017	2018	2019	2020	Total
1	Terzaghi Dam to Longskinny	40.0 to 39.6	0	0	0	1	0	1	0	2
2	Longskinny to Eagle	39.6 to 38.8	0	0	0	0	2	1	0	3
3	Eagle to Bluenose	38.8 to 38.2	4	1	2	0	0	0	0	7
4	Bluenose to Cobra	38.2 to 34.4	10	2	0	0	0	0	0	12
5	Cobra to Fraser Lake	34.4 to 33.2	0	0	8	6	1	0	0	15
6	Fraser Lake to Russel Springs	33.2 to 30.7	7	3	5	4	0	0	2	19
7	Russel Springs to Hell Creek	30.7 to 28.8	25	6	4	2	0	0	0	37
8	Hell Creek to Yalakom	28.8 to 25.5	15	10	7	0	0	6	3	38
		Total	61	22	26	13	3	8	5	133

Location of Chinook Salmon redds in the Lower Bridge River in 2014 - 2020. Black lines indicate the boundary between reaches.

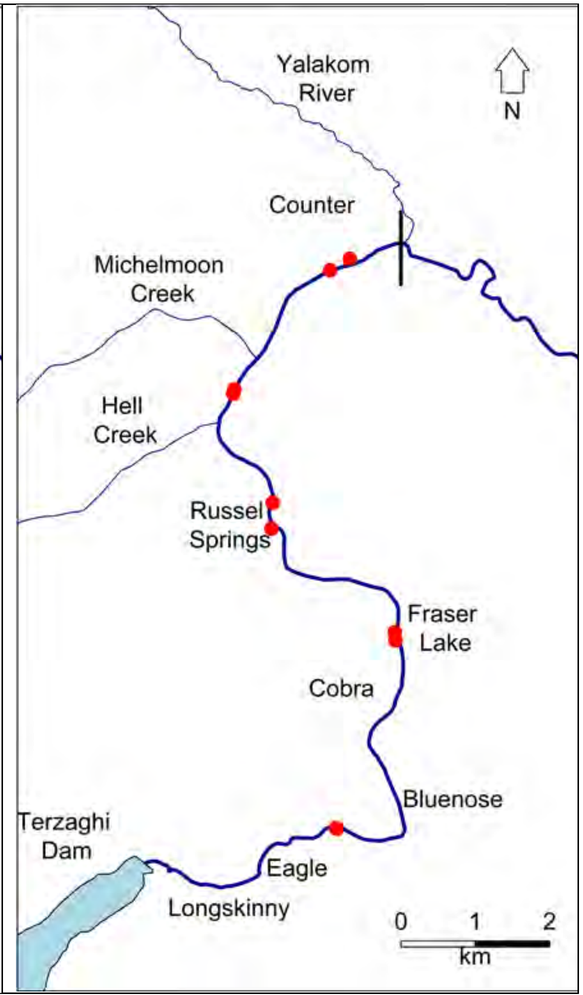
2014



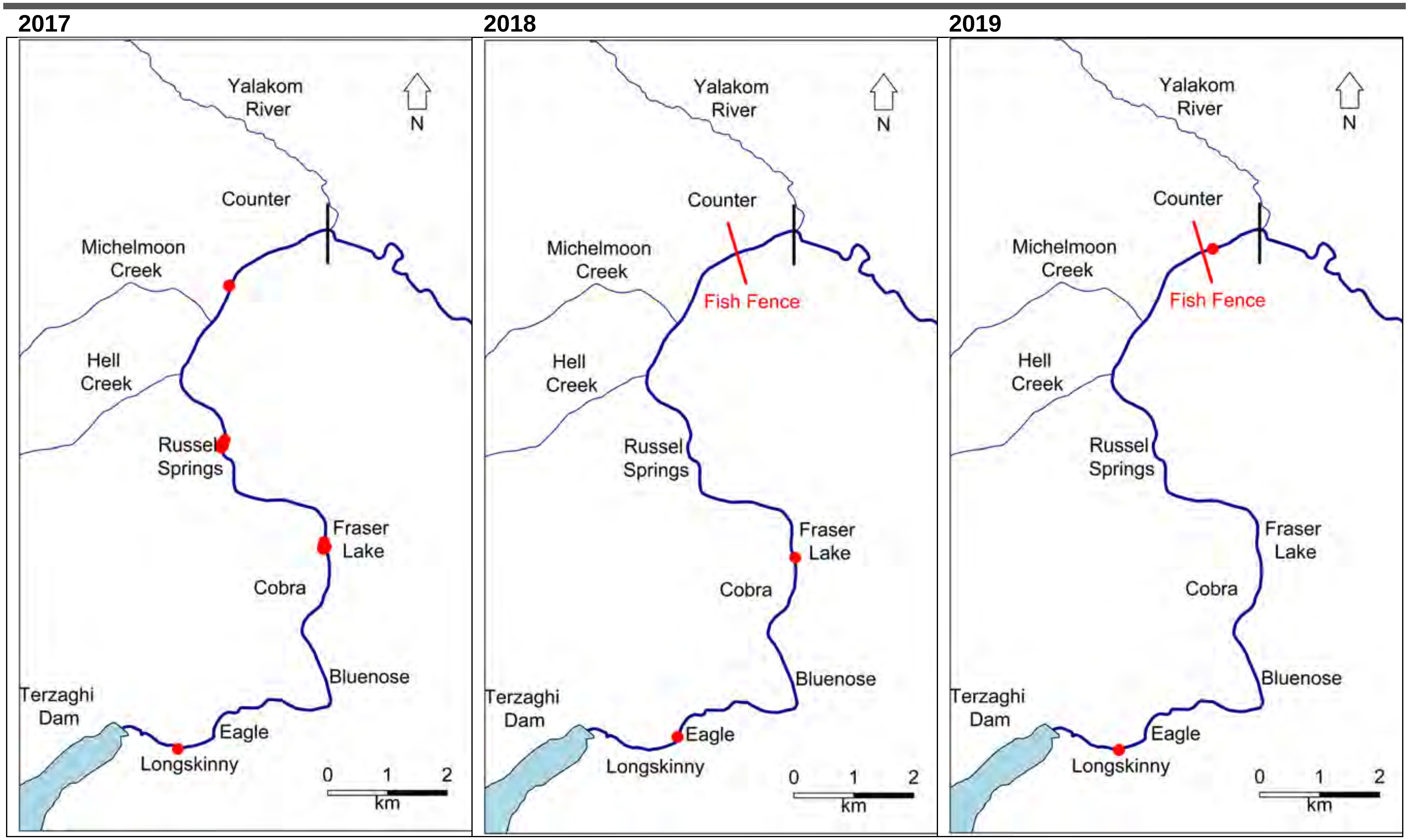
2015



2016

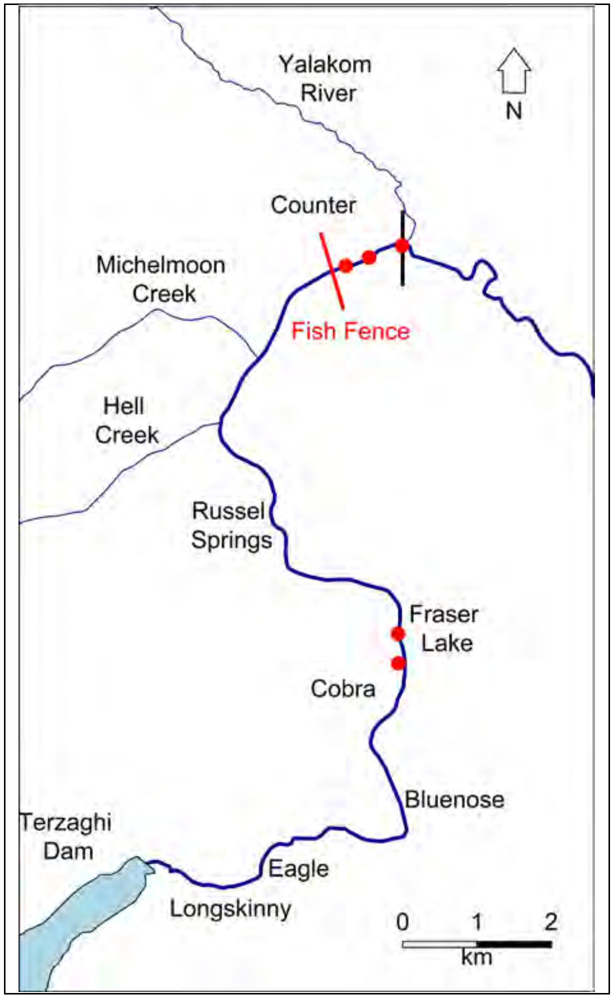


Con't: Location of Chinook Salmon redds in the Lower Bridge River in 2014 - 2020. Black lines indicate the boundary between reaches.


2017
2018
2019
Yalakom River
N
Counter
Michelmoon Creek
Hell Creek
Russel Springs
Fraser Lake
Cobra
Bluenose
Terzaghi Dam
Eagle
Longskinny
Fish Fence
0 1 2
km

Con't: Location of Chinook Salmon redds in the Lower Bridge River in 2014-2020. Black lines indicate the boundary between reaches.

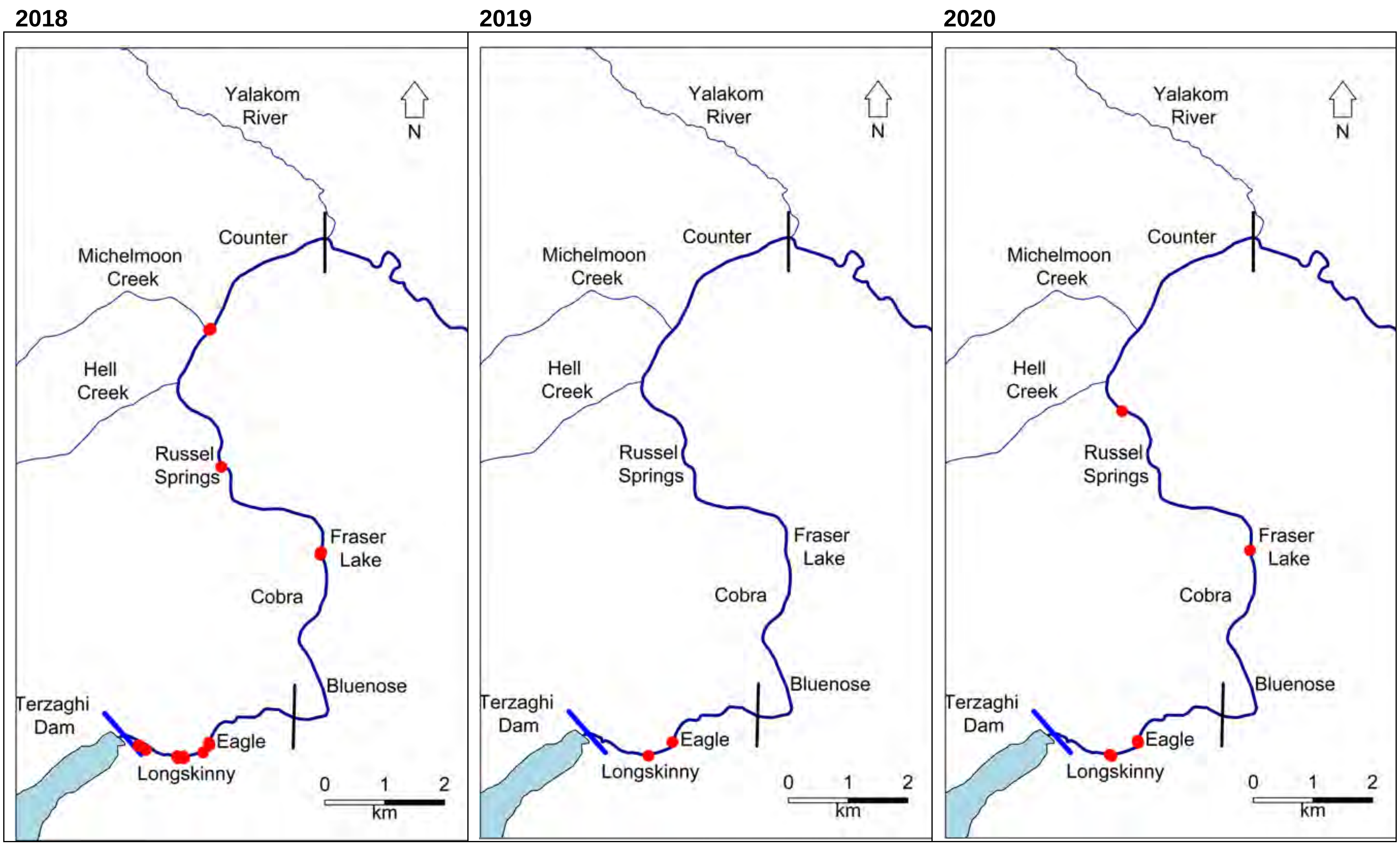
2020



Coho Salmon redd distribution across streamwalk sections in Reach 3 and 4 of the LBR (2018-2020).

Streamwalk			**Year**			
Section	Description	RiverKM	2018	2019	2020	Total
1	Terzaghi Dam to Longskinny	40.0 to 39.6	15	6	2	21
2	Longskinny to Eagle	39.6 to 38.8	6	2	3	8
3	Eagle to Bluenose	38.8 to 38.2	0	0	0	0
4	Bluenose to Cobra	38.2 to 34.4	0	0	0	0
5	Cobra to Fraser Lake	34.4 to 33.2	4	0	0	4
6	Fraser Lake to Russel Springs	33.2 to 30.7	2	0	2	2
7	Russel Springs to Hell Creek	30.7 to 28.8	4	0	0	4
8	Hell Creek to Yalakom	28.8 to 25.5	0	0	0	0
		Total	31	8	7	39

Location of Coho Salmon redds in the Lower Bridge River in 2018 - 2020. Black lines indicate the boundary between reaches.



Appendix 10: Scale Analysis

Summary of age analysis conducted during BRGMON-3. Age is shown using two methods: 1. Koo 1962 method, where freshwater age is separated from marine age by a decimal, and 2. the total age resulting from the summation of both freshwater and marine ages. Years where there were no sampled fish, readable scales, or fish not of LBR origin are indicated with (-).

Species	Age (Koo 1962)	Total Age	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Chinook	1.2	3	-	-	1	0	1	1	0	0	0	0	3
	1.3	4	-	-	9	13	11	7	3	3	4	3	53
Coho	1.1	2	13	15	15	19	10	22	12	17	3	4	130
	1.2	3	0	0	0	1	0	0	0	0	0	0	1
	2.1	3	5	11	1	8	6	7	4	0	2	0	44
Steelhead	1.1	2	-	-	-	0	0	0	1	0	0	0	1
	2.1	3	-	-	-	1	0	0	0	0	0	0	1
	2.2	4	-	-	-	3	4	0	1	2	0	8	18
	2.3	5	-	-	-	0	1	1	5	7	1	0	15
	3.1	4	-	-	-	2	1	0	0	0	0	0	3
	3.2	5	-	-	-	2	8	2	3	2	2	1	20
	3.3	6	-	-	-	0	2	0	7	5	6	0	20
		Total	18	26	26	49	44	40	36	36	18	16	309