Campbell River Project Water Use Plan

Quinsam and Salmon River Smolt and Spawner Abundance Assessments

Implementation Year 7

Reference: JHTMON-8

Year 7 Annual Monitoring Report

Study Period: April 1, 2020 to March 31, 2021

Laich-Kwil-Tach Environmental Assessment Ltd. Partnership and Ecofish Research Ltd.

December 16, 2021

JHTMON-8: Quinsam River Smolt and Spawner Abundance Assessment

Year 7 Annual Monitoring Report

Prepared for:

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Title page photographs – top left: Quinsam Hatchery salmon counting fence (June 06, 2019); top right: drift nets deployed in the Quinsam River (July 14, 2020); bottom left: water quality sampling in the Quinsam River (May 11, 2020); bottom right: LKT technician sampling at Quinsam Hatchery salmon counting fence (June 06, 2019).

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EXECUTIVE SUMMARY

Water Use Plans (WUPs) were developed for BC Hydro's hydroelectric facilities through a consultative process. As the Campbell River WUP process reached completion, uncertainties remained with respect to the effects of BC Hydro operations on aquatic resources. To address these uncertainties, several monitoring studies were initiated, including the *Quinsam River Smolt and Spawner Abundance Assessment* (JHTMON-8).

The main objective of the program is to understand whether BC Hydro operations, through changes to streamflow, were the primary cause of changes in fish abundance in the Quinsam River. JHTMON-8 involves monitoring fish abundance and multiple environmental factors (Table i). Final data analysis will involve examining links between fish abundance and environmental factors to better understand what limits fish production.

The JHTMON-8 management questions, hypotheses and current status are presented in Table ii. The JHTMON-8 monitoring program was initially developed to focus on the Salmon and Quinsam rivers; however, the Salmon River Diversion Dam was decommissioned in 2017, and the terms of reference for JHTMON-8 were revised in 2018 to solely focus on the Quinsam River watershed. The Quinsam River watershed has high fisheries values and includes the Quinsam River Diversion facility, which diverts a portion of the total annual flow to Lower Campbell Reservoir for hydroelectric power generation.

Table i. Summary of JHTMON-8 data collection methods.

Sampling Program	Lead Organization[1]	Method	Timing
Quinsam River Hatchery juvenile downstream migration	DFO/LKT	Fish fence	March – June
Salmon escapement surveys	DFO	Various	September – November
Water quality sampling	LKT	*In situ* and laboratory analysis	May – October
Invertebrate sampling	LKT	Drift sampling	May – October

[1] LKT, Laich-Kwil-Tach Environmental Assessment Ltd. Partnership; DFO, Fisheries and Oceans Canada

JHTMON-8 commenced in 2014 (Year 1) and seven years of data collection (Table i) have now been completed. In Year 10, the three management questions in Table ii will be addressed by testing six null hypotheses that are designed to test whether juvenile fish abundance varies among years (H_01) and, if so, whether abundance is related to:

- Habitat availability (H_02);
- Water quality (H_03);
- Floods (H_04);

- Food abundance (*H_05*); or
- The abundance of returning adult fish (*H_06*).

Species of primary interest are Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*) and steelhead (*O. mykiss*), although the study involves compiling adult escapement data for additional Pacific salmon species, as well as collecting abundance data for juvenile life stages of a range of species at the Quinsam Hatchery salmon counting fence.

Annual outmigration data provided by DFO for Years 1-7 vary the most for wild Chinook Salmon (~600 to ~360,000 fry) and are lower for wild Coho Salmon (~22,000 to ~57,000 smolts) and steelhead (~3,000 to ~13,000 smolts). A key result from Year 7 was the particularly high abundance of outmigrating juvenile Chinook Salmon recorded at the Quinsam Hatchery fence (~360,000), which was over three times higher than the maximum value previously recorded during JHTMON-8, and the highest value recorded overall in the period of record. Historical data compiled to date show considerable inter-annual variability in juvenile fish abundance, with JHTMON-8 priority species varying by at least a factor of four throughout the period of record.

Regarding *H_02* (habitat availability), we quantified the Weighted Usable Area (WUA; in m^2) for different life stages of priority species in Year 5. Variability in annual average spawning habitat WUA was similar among Chinook Salmon, Coho Salmon, and Pink Salmon, with maximum differences among years of approximately 100% (i.e., approximately two-fold differences). Annual average rearing and spawning habitat WUA for steelhead life stages varied throughout the dataset, with variability highest for steelhead spawning WUA. Flow-habitat relationships have not been previously developed for Pacific salmon rearing habitat. This issue is only potentially applicable to Coho Salmon because the other two species spend limited time rearing in the river. Accordingly, we plan to use steelhead fry rearing habitat WUA estimates as a proxy for juvenile Coho Salmon rearing habitat. Further analysis of WUA was not undertaken in Year 7, although the WUA calculations will be updated in Year 10 by updating the habitat time series using the latest flow data.

Water quality data (relevant to *H_03*) collected at an index site on the Quinsam River show that the river is typical of streams in coastal BC watersheds with low nutrient concentrations (oligotrophic), near-neutral pH, and low turbidity during baseflow. Measurements of some water quality variables were, at times, outside of the biological optimum ranges for fish species present in the watershed. Specifically, the mean weekly maximum water temperature values observed in Year 7 exceeded the upper limit of the optimum temperature ranges at times for the rearing life stage of juvenile Coho Salmon (34% of the period), Chinook Salmon (23% of the period), and Rainbow Trout (14% of the period). These exceedances of the upper limits of the optimum temperature ranges for the rearing life stage were consistent with results from Years 1 to 6. Furthermore, as observed in previous years, concentrations of dissolved oxygen less than the provincial guideline for the protection of buried embryos/alevins of some species were recorded in Year 7; however, these values were only marginally less than the guideline (up to ~0.55 mg/L below the guideline minimum during the incubation periods). A background water quality review undertaken in Year 2 and a screening analysis undertaken in Year 4 showed that interannual variability in many of the water quality variables was low. This feature may limit the power of the final analysis to quantify effects of water quality on fish abundance (if present), based on analysis of relationships between annual metrics of water quality and fish recruitment. It will therefore be important to continue to evaluate water quality results in the context of water quality guidelines to support qualitative conclusions regarding H_03. The low intra- and inter-annual variability in water quality data indicate that the data are representative of conditions experienced by fish, which supports an approach of comparing the measurements to water quality guidelines to draw inferences about habitat suitability for fish throughout the growing season.

To test H_04 (floods), flow data collected by the Water Survey of Canada were used to calculate a range of hydrological metrics based on a subset of the Indicators of Hydrologic Alteration (Richter *et al.* 1996). These metrics will be used to examine whether hydrologic variability among years affects juvenile fish abundance. Key observations to date include the occurrence of notable floods (>80 m^3/s) in December 2014 and November 2016, and the occurrence of low discharge (<1 m^3/s) each year during the summer period when the diversion facility was not operating.

Invertebrate drift biomass (relevant to H_05) on the Quinsam River generally tends to decline during the growing season. In Year 7, it was notable that total invertebrate drift biomass was higher than previous years. To date, total invertebrate biomass was the sole invertebrate biomass metric analyzed; however, an additional task undertaken in Year 7 was to quantify the sum of biomass associated only with EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa for all years of JHTMON-8. EPT taxa can be preferred invertebrate food sources for salmonids and therefore this metric potentially provides a more-direct indicator of food availability for fish than total biomass. Year 7 results indicated that there was generally a higher contribution to total biomass from non-EPT taxa in Year 7 compared to previous years. In Year 10, we will examine the relationship between invertebrate biomass (i.e., fish food) and juvenile fish abundance to test H_05. Interannual variability in invertebrate biomass has so far been generally low, despite the observations described above.

Pacific salmon escapement data collected by DFO have been compiled and analyzed each year to test H_06 (adult returns). In Year 7, data were available for the period to 2019 when, consistent with previous years, Pink, Coho and Chinook salmon were the most abundant returning species, in that order. Escapement of Chinook Salmon in the Quinsam River in 2019 (6,793) was above the mean value for the period of record (1953–2019), whereas estimated escapement of Coho Salmon in 2019 (11,671) was close to the mean value of the dataset. Pink Salmon escapement in the Quinsam River in 2019 (571,555) was higher than the mean value for the dataset (136,840). The estimated Chum Salmon escapement in 2019 (8) was particularly low as it was the 2nd lowest count recorded in the 60-year dataset, while the count in 1993 (6) was the lowest count. The Chum Salmon estimate is likely biased low as the sampling period did not capture the full duration of the migration period.

In Year 7, initial analysis was undertaken to develop and explore stock-recruitment relationships for priority species, thereby providing a valuable advancement of the study. When finalized, these relationships will be directly used to test H_06. Further, these relationships will support analysis to test the JHTMON-8 hypotheses by examining whether variability in the stock-recruitment relationships is related to environmental factors such as habitat area or invertebrate biomass. Such relationships will therefore allow for variability in spawner abundance to be accounted for when analyzing linkages between juvenile fish abundance and environmental factors.

Table ii. Status of JHTMON-8 objectives, management questions and hypotheses after Year 7.

Study Objective	Management Questions	Management Hypotheses	Year 7 (2020/2021) Status
The objective is to address the management questions by collecting data necessary to test the impact hypotheses. Analysis is designed to understand whether BC Hydro operations, through changes to flow, are the primary cause of historical changes in fish abundance. This study will reduce uncertainty about factors that limit fish abundance in the Quinsam River.	1. What are the primary factors that limit fish abundance in the Campbell River System and how are these factors influenced by BC Hydro operations? The stream of interest in this monitor is the Quinsam River. 2. Have WUP-based operations changed the influence of these primary factors on fish abundance, allowing carrying capacity to increase? 3. If the expected gains in fish abundance have not been fully realized, what factors if any are masking the response and are they influenced by BC Hydro operations?	*H_01: Annual population abundance does not vary with time (i.e., years) over the course of the Monitor*	-Juvenile fish have been sampled annually at the Quinsam Hatchery salmon counting fence to derive total outmigration estimates -Inter-annual variability has been observed in the abundance of priority species so we expect to reject this hypothesis in Year 10
		H_02: Annual population abundance is not correlated with annual habitat availability as measured by Weighted Usable Area (WUA)	-In Year 5, we used existing flow-habitat relationships to estimate WUA of habitat for priority species for 1975-2017 -Additional work relating to this hypothesis was not undertaken in Year 7; relationships will be updated in Year 10 for the final analysis to test this hypothesis
		H_03: Annual population abundance is not correlated with water quality	-Water quality has been measured each year through the growing season at a single index site -Water quality is generally within ranges to support healthy salmonid populations, although there are some exceptions -Analysis will be undertaken to test this hypothesis in Year 10. Low variability in independent variables is expected to limit the statistical power of this analysis; comparisons with water quality guidelines will be an important line of evidence.
		H_04: Annual population abundance is not correlated with the occurrence of flood events	-Flow data collected by the Water Survey of Canada have been used to calculate flow metrics that will be used in the final analysis -Flow metrics have been variable throughout the monitoring period, affected by background hydrological factors and BC Hydro operations

Study Objective	Management Questions	Management Hypotheses	Year 7 (2020/2021) Status
			-Floods have occurred during the JHTMON-8 monitoring period during sensitive life history periods (notably Pacific salmon incubation) -Analysis will be undertaken to test this hypothesis in Year 10
		$H_0$5: Annual population abundance is not correlated with food availability as measured by aquatic invertebrate sampling	-Aquatic invertebrate biomass has been measured each year through the growing season at a single index site -Clear seasonal patterns have been observed but inter-annual variability in mean invertebrate drift biomass is less clear -Analysis will be undertaken to test this hypothesis in Year 10, although low inter-annual variability in invertebrate biomass may limit the statistical power of this analysis. Supplementary lines of evidence such as comparisons with data from other watershed may be required in Year 10.
		$H_0$6: Annual smolt abundance is not correlated with the number of adult returns	-Adult salmon escapement data have been compiled annually from DFO records and will be used to construct updated spawner-recruitment curves to test this hypothesis in Year 10 -In Year 7, initial analysis was undertaken to develop and explore stock-recruitment relationships for priority species, thereby providing a valuable advancement of the study

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1. INTRODUCTION

1.1. Background

Water use planning exemplifies sustainable work in practice at BC Hydro. The goal is to provide a balance between the competing uses of water that include fish and wildlife, recreation, and power generation. Water Use Plans (WUPs) were developed for all BC Hydro's hydroelectric facilities through a consultative process involving local stakeholders, government agencies and First Nations. The framework for water use planning requires that a WUP be reviewed on a periodic basis and there is expected to be monitoring to address outstanding management questions in the years following the implementation of a WUP.

As the Campbell River WUP process reached completion, a number of uncertainties remained with respect to the effects of BC Hydro operations on aquatic resources. A key question throughout the WUP process was "what limits fish abundance?" For example, are fish abundance and biomass limited by available habitat, food, hydrological perturbations, or other ecological interactions? Answering this question is an important step to better understand how BC Hydro operations in the watershed affect fisheries, and to effectively manage water uses to protect and enhance aquatic resources. To address this uncertainty, monitoring programs were designed to assess whether fish benefits are being achieved under the WUP operating regime, and to evaluate whether limits to fish production could be improved by modifying operations in the future. The *Quinsam River Smolt and Spawner Abundance Assessment* (JHTMON-8) is one of several monitoring studies associated with the Campbell River WUP. JHTMON-8 focuses on monitoring fish populations and environmental factors that may influence fish abundance in the Quinsam River. Prior to Year 5, JHTMON-8 also focused on the Salmon River; however, this component of the program was removed following a revision to the terms of reference (BC Hydro 2018a) after the Salmon River Diversion Dam was decommissioned in 2017, meaning that there is no longer any mechanism for BC Hydro operations to affect fish populations in the Salmon River. Accordingly, the Salmon River is not considered further in this report.

This report describes fieldwork and analysis undertaken in Year 7 of JHTMON-8, which commenced on April 1, 2020. Detailed analysis that addresses the management questions based on data collected throughout all years of the study will be undertaken in Year 10.

1.2. The Quinsam River and Diversion

The Quinsam River is located to the west of the city of Campbell River on the east coast of Vancouver Island, British Columbia. The Quinsam River diversion facility has historically diverted a portion of water from the river mainstem to Lower Campbell Reservoir to generate hydroelectricity downstream at Ladore and John Hart generation stations (Map 1). Details of the diversion infrastructure and operations are summarized below based on the Campbell River System WUP (BC Hydro 2012).

The Quinsam River is the only major tributary of the lower Campbell River, entering the Campbell River approximately 3.5 km upstream of the mouth. The Quinsam flows through a series of lakes and has a mainstem length of 45 km (excluding lakes), a watershed area of 283 km^2, and a mean annual discharge near the mouth of 8.5 m^3/s. The river has high fisheries values, supporting an assemblage of native salmonid species (Burt 2003; see Table 1 for periodicity information). The Quinsam River Hatchery was constructed in 1957 and is located 3.3 km upstream from the confluence with the Campbell River. The hatchery has been active in the watershed, augmenting populations of Chinook Salmon, Pink Salmon, Coho Salmon and Cutthroat Trout since 2014 (Year 1), with Chum Salmon and steelhead also released in previous years (DFO 2017). Smolt and fry life stages that are ready for downstream migration to the ocean are released from the hatchery during the spring. In addition, juvenile Coho Salmon, steelhead and Chinook Salmon have been out-planted to the upper watershed since 1978 to promote adult returns upstream of the hatchery (Burt 2003).

The Quinsam River Diversion comprises a small concrete gravity storage dam, a concrete gravity diversion dam, a concrete flume and the natural waterways that convey water to Lower Campbell Reservoir. Non-diverted water is conveyed to the Quinsam River via an undersluice gate or the free crest weir. The dams were both constructed in 1957.

A total of 100 million m^3 is licensed to be diverted annually and the design capacity of the Quinsam River Diversion is 8.50 m^3/s. The WUP stipulates maximum down ramping rates (Table 2) and minimum flows (when naturally available) in the Quinsam River downstream of the diversion dam (Table 3).

Overview of the Quinsam River watershed

Legend

- Dam
- Stream

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 1 2 3 4 5 6 7 km

Scale: 1:180,000

NO.	DATE	REVISION	BY
1	2021-12-10	1230_BCH_CRFacilities_3603_20201210	CGA
2			
3			
4			
5			

Date Saved: 2021-12-10
Coordinate System: NAD 1983 UTM Zone 10N

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Map 1

Path: M:\Projects-Active\1230_JHTMON\MXD\Overview\1230_BCH_CRFacilities_3603_20201210.mxd

Table 1. Periodicity of important fish species in the Quinsam River system (from BC Hydro files for Campbell River Water Use Plan, dated 2001).

Species	Life History Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook Salmon	Adult migration												
	Spawning										P	P	
	Incubation												
	Emergence												
	Rearing												
	Juvenile migration				F	S							
Chum Salmon	Adult migration												
	Spawning											P P	
	Incubation												
	Emergence												
	Juvenile migration			F									
Coho Salmon	Adult migration												
	Spawning											P P P	
	Incubation												
	Emergence												
	Rearing												
	Juvenile migration			F	S								
Pink Salmon	Adult migration												
	Spawning									P			
	Incubation												
	Emergence												
	Juvenile migration			F									
Rainbow Trout	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Sockeye Salmon	Adult migration												
	Spawning												
	Incubation												
	Emergence												
	Rearing												
	Juvenile migration			F									
Steelhead (winter run)[1]	Adult migration												
	Spawning			P P									
	Incubation												
	Emergence												
	Rearing												
	Juvenile migration				S								

Critical times

F = fry migration begins, S = smolt migration begins, P = peak spawning

[1] There are no summer run Steelhead on the Quinsam River.

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Table 2. Quinsam River maximum permitted down ramping rates (BC Hydro 2012).

Stream	Discharge (m^3/s)	Maximum down ramping rate ($m^3/s/h$)
Quinsam River	> 4.0	8.5
	≤ 4.0	1.0
Quinsam Diversion	> 2.0	N/A
	≤ 2.0	1.0

Table 3. Minimum permitted discharge in the Quinsam River (BC Hydro 2012).

Date	Minimum discharge in Quinsam River (m^3/s)
Jan 1 to Apr 30	2.0
May 1 to Oct 31	1.0
Nov 1 to Dec 31	0.6

1.3. Background to Water Use Decision

The operating conditions (minimum flow requirements) prescribed in the WUP for the Quinsam Diversion (Table 3) match those of the "MinRisk 2c" option that was recommended by a Consultative Committee because it represented "the best trade off of all gains and losses" (Campbell River WUP CC 2004). This recommendation was based on evaluating a power/financial performance measure alongside the following four biological performance measures (Campbell River WUP CC 2004):

- Fish habitat risk: the average annual probability that Rainbow Trout and Chinook Salmon usable habitat will decline below 60% of the maximum available, calculated using a meta-analysis method);
- Fish passage (considered in JHTMON-6);
- Fish overwintering success; and
- Drawdown in Upper Quinsam Lake/Wokas Lake, with the assumption that drawdown has a negative effect on fish and wildlife resources.

The first two biological performance measures listed above were evaluated based on scores that were standardized to a scale from 0–1, whereas the second two measures were evaluated qualitatively by considering the direction of predicted change (Table 7-6 in Campbell River WUP CC 2004). The Quinsam Diversion operating conditions prescribed in the WUP are those that were evaluated to provide the best biological outcomes of the options consider that involved flow diversion.

1.4. Management Questions and Hypotheses

The JHTMON-8 monitoring program aims to address the following three management questions, with reference to the Quinsam River:

1. What are the primary factors that limit fish abundance in the Campbell River system and how are these factors influenced by BC Hydro operations?
2. Have WUP-based operations changed the influence of these primary factors on fish abundance, allowing carrying capacity to increase?
3. If the expected gains in fish abundance have not been fully realized, what factors if any are masking the response and are they influenced by BC Hydro operations?

In addressing the questions, the monitoring program is designed to test the following five null hypotheses:

$H_0 1$: Annual population abundance does not vary with time (i.e., years) over the course of the Monitor.

$H_0 2$: Annual population abundance is not correlated with annual habitat availability as measured by Weighted Usable Area.

$H_0 3$: Annual population abundance is not correlated with water quality.

$H_0 4$: Annual population abundance is not correlated with the occurrence of flood events.

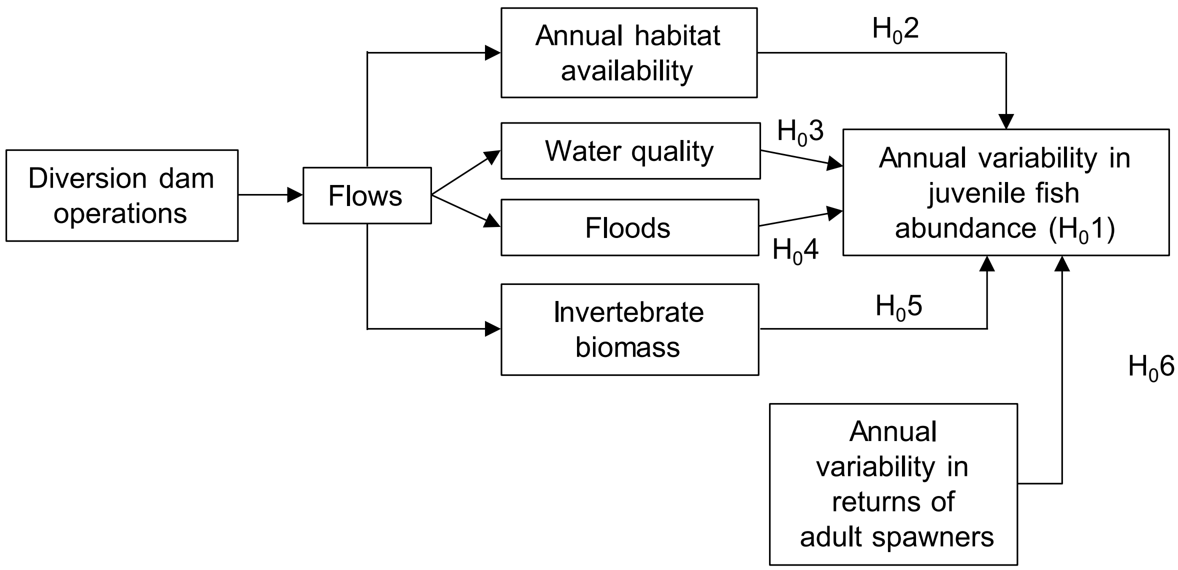
$H_0 5$: Annual population abundance is not correlated with food availability as measured by aquatic invertebrate sampling.

$H_0 6$: Annual smolt abundance is not correlated with the number of adult returns.

The basis of JHTMON-8 is outlined conceptually in Figure 1. The monitoring program is designed to first establish whether there is among-year variability in fish abundance ($H_0 1$). The program is then designed to collect data to examine whether inter-annual variability in fish abundance is related to important environmental factors that could be influenced by BC Hydro operations, specifically: Weighted Usable Area (WUA) of habitat ($H_0 2$); water quality ($H_0 3$); an accumulated flood risk index during the spawning and incubation periods ($H_0 4$), or; invertebrate abundance (food availability; $H_0 5$). The study will also investigate whether annual variability in juvenile fish abundance is affected by annual variability in salmon spawner escapement ($H_0 6$) – a factor that is not directly influenced by diversion dam operations.

The final step in the analysis will involve evaluating whether BC Hydro operations, via changes to flow, are the primary cause of any changes to environmental factors that are shown to be drivers of fish production. This step may require a mixture of quantitative and qualitative analysis as it will be easier to distinguish changes due to BC Hydro operations from those due to background variability for some factors (e.g., WUA) than others (e.g., invertebrate drift). To address Management Question 2, it will be necessary to compare pre-and post-WUP conditions, although this will not be possible for some components that lack pre-WUP data (e.g., invertebrate drift biomass). Such pre- and post-WUP comparisons will therefore focus on analyzing Quinsam River fish abundance, WUA, and flow data. We do not plan to compare changes in variables with targets that have been defined *a priori*, because we are not aware that these have developed[1]. Instead, conclusions about the biological significance of changes will be made based on multiple lines of evidence such as the effect size and, potentially, trends in other watersheds. Such conclusions may then inform decisions about whether changes to the WUP or alternative mitigation are necessary to achieve desired outcomes for fish.

Figure 1. Effect-pathway diagram showing the context of the six hypotheses that the JHTMON-8 monitoring program sets out to address.



1.5. Scope of the JHTMON-8 Study

1.5.1. Overview

The JHTMON-8 study has been designed to build upon monitoring that is already occurring in the Quinsam River watershed. This allows the study to integrate established work programs and provides an opportunity to incorporate historical data into the analyses.

Priority species for JHTMON-8 in the Quinsam River are Chinook Salmon, Coho Salmon and steelhead, although Pink Salmon is also of interest. Juvenile fisheries data for the Quinsam River are obtained via operation of a salmon counting fence at Quinsam River Hatchery to enumerate downstream juvenile migration of a range of species. In addition to these juvenile abundance datasets, adult escapement data obtained by Fisheries and Oceans Canada (DFO) for a range of Pacific salmon

[1] We recognize this is implied in Management Question 3 ("the expected gains"); however, we assume this relates to a general expectation that the WUP will qualitatively improve fish productivity in the Quinsam River.

species during routine monitoring are also considered as part of JHTMON-8. Water quality and invertebrates are sampled at a single index site and flow data are obtained from gauges maintained by Water Survey of Canada.

Further information about the scope and objectives of specific sampling programs is provided in the sub-sections below, which also includes an overview of how impact hypotheses will be tested for the Quinsam River in Year 10.

1.5.2. Fish Population Assessments

The JHTMON-8 juvenile fish sampling program is designed to ensure that the error associated with fish sampling methods is sufficiently small to assess among-year variability in fish abundance. The fish abundance data will first be used to test H_01: '*annual population abundance does not vary with time (i.e., years) over the course of the Monitor*' (Section 1.4).

The program was designed to enumerate both adult and juvenile life stages to allow relationships between the numbers of adult spawning fish and juvenile recruitment to be examined. This enables testing of H_06 *'annual smolt abundance is not correlated with the number of adult returns'* for the Quinsam River, which will help to tease apart the extent to which variations in abundance reflect either variations in adult returns (dependent on marine conditions and harvest) or variations in juvenile survival (dependent on freshwater conditions). This hypothesis will be tested for the Quinsam River, where the salmon counting fence is monitored to provide estimates of total juvenile fish outmigration. In Year 5, historical data collected at the Quinsam Hatchery salmon counting fence since the 1970s were collated, increasing the duration of the dataset available for this analysis. Testing H_06 will involve developing spawner recruitment relationships for wild stocks to evaluate whether there is a relationship between adult spawner abundance and associated smolt abundance. In Year 7, we undertook preliminary analysis to develop and examine stock-recruitment relationships that will be updated in Year 10.

For at least some species and life stages, we anticipate that biologically significant interannual variability in juvenile fish abundance will be detected, i.e., after accounting for sampling error, we will be confident that variability among years in juvenile abundance occurred at the watershed scale. It will then be necessary to use these data to test the remaining hypotheses to determine whether there are relationships between the observed variability in fish abundance, and variations in key environmental factors, namely habitat (H_02), water quality (H_03), floods (H_04) and food availability (H_05).

1.5.3. Weighted Usable Area (WUA) of Habitat

Changes to flow affect the width, depth and velocity of a stream, which in turn affect the extent and suitability of fish habitat. Changes to these factors have the potential to limit juvenile fish production by either changing spawning habitat or, for stream-rearing species, changing instream rearing habitat conditions. As part of JHTMON-8, annual WUA metrics will be calculated for the Quinsam River to quantify how habitat varies among years for individual life stages of priority fish species. WUA will be calculated using existing flow–habitat relationships that were developed based on field work that was undertaken by D. Burt and Associates to inform WUP development[2], as described in Solander *et al.* (2004). Analysis will then be undertaken in Year 10 to examine whether variation in juvenile fish abundance is related to variation in applicable WUA metrics that are specific to individual species and life stages. Results of this analysis will be used to test H_02: *annual population abundance is not correlated with annual habitat availability as measured by Weighted Usable Area.*

In Year 5, we reviewed flow–habitat relationships, compiled flow data, and completed analysis to estimate a range of WUA metrics for the period since 1974, which matches the period for which juvenile fish abundance data have been compiled for the Quinsam River (Abell *et al.* 2019). To test H_02, this WUA dataset will be updated in Year 10 using the existing flow–habitat relationships and the most recent flow data.

1.5.4. Water Quality

Healthy fish populations require water quality variables to be within confined ranges. This range of suitable conditions varies depending on the individual variable, fish species, and life stage. The objective of the JHTMON-8 water quality monitoring is to measure biologically important water quality variables to provide data to test H_03: '*annual population abundance is not correlated with water quality'* (Section 1.4). Approaches to incorporate water quality data into the final analysis were evaluated in the Year 4 Annual Report (Sharron *et al.* 2018) and complete analysis will be undertaken at the end of the ten-year monitor to examine whether water quality is expected to limit fish abundance. If a relationship is detected (i.e., the null hypothesis is rejected), then we will evaluate whether BC Hydro operations are likely to have adversely affected water quality. This will be done as part of this study to help address Management Question 1 and 2. If required, we expect this analysis to be predominantly qualitative and it will involve considering the pathways of effect by which BC Hydro operations may affect water quality.

Thus, a key assumption of this aspect of the study is that the water quality data collected suitably reflect variability of water quality in time and space, and are representative of the conditions experienced by fish communities (discussed further in Dinn *et al.* 2016). We recognize that grab sampling provides an instantaneous "snapshot" of water quality and therefore it will be necessary to critically evaluate whether the data are suitably representative of conditions at the site during the growing season. This evaluation will require considering the possible influence of biogeochemical processes (e.g., that drive diurnal variability in dissolved oxygen), in addition to assessment of temporal variability among measurements, e.g., by comparing measurements collected during the same month

[2] Note that, contrary to the revised TOR (BC Hydro 2018a), it is unnecessary to use information from JHTMON-6 as these relationships for the Quinsam River were developed prior to initiation of JHTMON-8. Developing flow-habitat relationships for the Salmon River was previously part of the scope of JHTMON-6; however, this is no longer applicable following decommissioning of the Salmon River Diversion. The current scope of JHTMON-6 includes quantifying flow-habitat relationships for the Quinsam River diversion route via Miller Creek, but not the Quinsam River mainstem (BC Hydro 2018b).

but during different years. A single mainstem index site was selected in the Quinsam River that was assumed to be representative of water quality in the wider watershed.

1.5.5. Floods

High flows have potential to adversely affect fish populations due to a variety of mechanisms that include redd scour, delayed redd construction, redd desiccation due to spawning occurring along channel margins during high flows, sediment intrusion, physical shock, or reduced holding opportunities shortly after emergence (reviewed in Gibbins *et al.* 2008). Discharge data are collected at numerous sites in the Quinsam River by the Water Survey of Canada. These data will be used to quantify the occurrence of high flow events during individual years to test H_04: '*annual population abundance is not correlated with the occurrence of flood events*' (Section 1.4).

During Year 3, we evaluated suitable hydrological metrics to quantify key flow characteristics that have potential to influence fish productivity (Abell *et al.* 2017). Based on this, we quantified the maximum daily mean discharge each year that occurs during the spawning and incubation periods of key species. In future years, we will consider calculating additional metrics (e.g., based on the duration of high flows), which can be easily calculated by modifying the existing code. Analysis will be undertaken in Year 10 to determine whether variability in these values explains variability in fish abundance, providing a test of H_04. The proposed analysis will focus on the spawning and incubation life stages because these life stages have been shown to be particularly sensitive to the effects of high flows (e.g., Cattanéo *et al.* 2002). We recognize that there is a range of mechanisms by which high flows can affect these life stages (see list above); therefore, if H_04 is rejected, it may be necessary to undertake further analysis to characterize the most sensitive periods and threshold flows at which high flow events adversely affect juvenile fish abundance. We also recognize that, although H_04 specifically focuses on floods, other aspects of hydrological variability could affect juvenile fish productivity. For example, the occurrence of low flows during summer can potentially limit the abundance of juvenile fish species that rear in freshwater throughout the summer, e.g., Coho Salmon (Matthews and Olson 1980). Accordingly, we propose to calculate a range of annual minimum flow metrics so that this analysis can be extended to evaluate whether low flows affect juvenile fish abundance; further details are provided in Section 2.3.

1.5.6. Invertebrate Drift

Invertebrates typically form the bulk of the diet of both juvenile and resident adult salmonids in rivers (Quinn 2005). Invertebrate populations can vary due to a range of factors and therefore variability in the abundance and biomass of invertebrates can limit the growth of salmonids in rivers. The objective of the JHTMON-8 invertebrate sampling is to provide data to test H_05 *annual population abundance is not correlated with food availability as measured by aquatic invertebrate sampling* (Section 1.4). Analysis will be undertaken in Year 10 to examine whether there are any relationships between fish abundance and food availability, as inferred from invertebrate biomass. If a relationship is detected (i.e., the null hypothesis is rejected), then we will evaluate whether BC Hydro operations are likely to have adversely affected invertebrate drift biomass. This will be done as part of this study to address Management Question 1 and 2. If required, we expect this analysis to be predominantly qualitative and it will involve considering the pathways of effect by which BC Hydro operations may affect invertebrate drift. These pathways relate to changes in flow and include changes to invertebrate habitat availability, in addition to changes to habitat suitability due to changes in flow velocity or sedimentation. These changes can affect total invertebrate biomass and thus food availability for fish. Further, effects may vary among invertebrate taxa, creating the potential for changes to invertebrate community structure and diversity, which can potentially influence the quality of food available for fish.

A key objective is therefore to collect invertebrate data that reflect variability in time and space of watershed invertebrate communities that are representative of the food available to salmonids. Invertebrate drift includes dislodged benthic invertebrates, terrestrial invertebrates entrained in the stream, and invertebrates originating from riparian areas. Johnson and Ringler (1980) studied the diets of Coho Salmon fry and steelhead fry and found that Coho Salmon fry fed more on terrestrial invertebrates than on aquatic invertebrates. The major terrestrial invertebrate groups that contributed to Coho Salmon fry diets were hymenopterans, coleopterans, homopterans, dipterans, and lepidopteran larvae. The main benthic groups were ephemeropterans, plecopterans, and trichopterans (EPT), as well as chironomids, and tipulids (both Diptera). Steelhead fry mainly fed on aquatic invertebrates, which were ephemeropterans, chironomids, trichopterans and tipulids. Based on Johnson and Ringler (1980), salmonids feed on a wide diversity of invertebrate taxa, including EPT taxa (indicative of good water quality) and other taxa such as dipterans that are more tolerant of disturbed environments. Other studies have also shown that a wide range of invertebrate taxa are present in drift and they provide an important food resource for salmonids, with all macroinvertebrates generally assumed to provide potential food for rearing salmonids once they are present in drift (e.g., Rader 1997). Based on these studies, we expect that total invertebrate drift biomass provides a suitable metric of food availability to rearing salmonids in the Quinsam River.

A single mainstem index site was selected that was assumed to be representative of the invertebrate communities present in the wider watershed. Invertebrate drift biomass is measured as a proxy for food availability, although invertebrate community composition is also examined to provide information on food quality. Drift sampling is undertaken during the growing season when rearing juvenile salmonid are actively feeding. In addition, a single kick net sample is collected in September. Kick sampling targets benthic invertebrates and is therefore less representative of the total abundance of food available to fish. However, kick sampling based on the Canadian Aquatic Biomonitoring Network (CABIN) protocol (Environment Canada 2012) has been used more widely to characterize stream invertebrate communities throughout Canada. Data collected using this method can be used to evaluate the wider ecological integrity of the streams, based on comparisons with the Environment Canada database of Georgia Basin reference sites (e.g., see Strachan *et al.* 2009).

2. METHODS

2.1. Fish Population Assessments

2.1.1. Quinsam River Salmon Escapement

Annual salmon spawner escapement estimates have been derived for the Quinsam River since the 1950s by DFO and its predecessors. Although these estimates are collected as part of wider salmon stock assessment work, they provide important data to support JHTMON-8. The results of summer and fall 2019 surveys were finalized during Year 7. These were obtained from DFO's New Salmon Escapement Database (nuSEDS) and are reported here alongside results from previous years. Data for the Quinsam River will support analysis scheduled for later during JHTMON-8 to examine relationships between abundance of adult spawning fish and corresponding counts of juvenile fish in successive years.

Methods used in the 2019 surveys are summarized in Table 4 for the Quinsam River, based on information provided in the nuSEDS database (DFO 2020). Methods undertaken in previous years of JHTMON-8 are summarized in previous annual reports. Surveys of individual species conducted by DFO conform to one of six estimate classification types, ranging from Type-1 (most rigorous, almost every fish counted individually) to Type-6 (least rigorous, determination of presence/absence only). The estimate classification types are reported in Table 4, with further general details about survey types provided in Table 5.

Table 4. Methods used for 2019 salmon spawner escapement counts on the Quinsam River (DFO 2020). See Table 5 for descriptions of estimate classification types.

	Salmon Species				
	Chinook	**Chum**	**Coho**	**Pink**	**Sockeye**
Estimate classification	2	3	2	2	3
Number of surveys	Unknown	Unknown	Unknown	Unknown	Unknown
Date of first inspection	22-Jul	1-Sep	15-Aug	20-Jul	2-Aug
Date of last inspection	21-Nov	1-Dec	19-Nov	3-Nov	1-Dec
Estimation method	Mark and recap. (Petersen)	Fixed site census	Fixed site census	Fixed site census	Fixed site census

Table 5. Summary of definitions of salmon spawner escapement estimate classification types reported in Table 4 (DFO 2020).

Estimate Classification Type	Abundance Estimate Type	Resolution	Analytical Methods	Reliability (Within Stock Comparisons)	Units	Accuracy	Precision
1	True	High resolution survey method(s): total, seasonal counts through fence or fishway with virtually no bypass	Simple	Reliable resolution of between year differences >10% (in absolute units)	Absolute abundance	Actual or assigned estimate and high	± 0%
2	True	High resolution survey method(s): high effort (5 or more trips), standard methods (e.g., equal effort surveys executed by walk, swim, overflight, etc.)	Simple to complex multi-step, but always rigorous	Reliable resolution of between year differences >25% (in absolute units)	Absolute abundance	Actual or assigned estimate and high	Actual estimate, high to moderate
3	Relative	Medium resolution survey method(s): high effort (5 or more trips), standard methods (e.g., mark-recapture, serial counts for area under curve, etc.)	Simple to complex multi-step, but always rigorous	Reliable resolution of between year differences >25% (in absolute units)	Relative abundance linked to method	Assigned range and medium to high	Assigned estimate, medium to high
4	Relative	Medium resolution survey method(s): low to moderate effort (1-4 trips), known survey method	Simple analysis by known methods	Reliable resolution of between year differences >200% (in relative units)	Relative abundance linked to method	Unknown assumed fairly constant	Unknown assumed fairly constant
5	Relative	Low resolution survey method(s): low effort (e.g., 1 trip), use of vaguely defined, inconsistent or poorly executed methods.	Unknown to ill defined inconsistent or poorly executed	Uncertain numeric comparisons, but high reliability for presence or absence	Relative abundance, but vague or no ID on method	Unknown assumed highly variable	Unknown assumed highly variable
6	Presence or absence	Any of above	N/A	Moderate to high reliability for presence/absence	Present or absent	Medium to high	Unknown

2.1.2. Quinsam River Hatchery Salmon Counting Fence Operations

The age of juvenile fish captured at the fence varies by species, reflecting differences in life histories. Coho Salmon, Cutthroat Trout, and steelhead are captured at the fence at the smolt stage (aged 1+ or older) and Chinook Salmon, Pink Salmon, and Chum Salmon at the fry stage (aged 0+). Pink Salmon and Chum Salmon emigrate from the river immediately or soon after emergence (Burt 2003). In the Quinsam River, Chinook Salmon migration from the rivers occurs either soon after emergence or a few months later. Those Chinook Salmon that rear for a full summer and winter before smolting are believed to do so in the estuary (Burt 2003). The strategies adopted by steelhead, Cutthroat Trout and Coho Salmon are more variable, and emigration from the river varies from emigrating during the first spring to emigrating three years after emergence.

In Year 7, sampling was undertaken from March 9 to June 13, 2020. Fish were caught using inclined plane traps (Wolf traps) that capture a proportion of the fish that migrate downstream through the fence, with the aim to capture salmonid fry and smolts as they outmigrate to the ocean (Figure 2). Traps were deployed continuously during the sampling period. Three traps are consistently used, but the number of openings varied during the sampling period. During the period of Pink Salmon fry migration, 16 openings are typically fished, while during the period of smolt migration five openings are typically fished (Forktamp, pers. comm. 2019). Pink Salmon fry typically migrate at night and therefore traps were set overnight from approximately 15:00 to 09:00 during sampling from March 9 to April 19, 2020. For the remainder of the sampling period, traps were set constantly during the times when fish were not being processed. Target species during this time were: steelhead (kelts and smolts), Coho Salmon (smolts), Chinook Salmon (fry), Chum Salmon (fry), Sockeye Salmon (fry), Cutthroat Trout (kelts and smolts) and Dolly Varden (smolts).

Total downstream migration estimates for individual species and life stages were calculated by dividing fish capture numbers by life-stage-specific (i.e., fry and smolt) capture efficiency coefficients. The capture efficiency estimates reflect inherent differences in catchability between life stages, differences in catchability due to variability in environmental conditions (e.g., flow) at the time of sampling, and the differences due to the way the traps are operated during the fry and smolt migration periods. The capture efficiency coefficients were derived from mark-recapture studies in the Quinsam River. For Pink Salmon fry, capture efficiency was estimated based on the results of releases of wild fish marked with Bismarck brown dye. The fish were captured in the trap, marked with the dye, and released approximately 350 m upstream of the fence. A total of three releases were undertaken on April 2, April 9, and April 16; a total of 14,378 fish were released (4,376–5,226 per experiment). Separate catch efficiency estimates were derived for Coho Salmon smolts based on three releases of wild Coho Salmon smolts marked with pelvic fin clips (alternating between right and left between experiments). As for fry, smolts were captured in the traps and released upstream of the traps. Releases were undertaken on May 13 (200 fish), May 21 (297 fish) and May 27 (178 fish), with a total of 675 fish released. Capture efficiency was calculated as k/K (where k is the number of marked fish recaptured and K is the total number of fish marked in the study). The capture efficiency coefficients are then applied in chronological order, matching the date of observed counts to the date of the last mark-recapture experiment. The capture efficiency coefficients were used to estimate the abundance of fry and smolts of all salmonids that emigrate during the respective fry or smolt trapping periods (Pink Salmon, Sockeye Salmon, Chum Salmon, Chinook Salmon, Coho Salmon, steelhead, Cutthroat Trout, undefined trout species), as well as lamprey and sculpin. Further details about the mark-recapture methods are provided in Ewart and Kerr (2014).

For Coho Salmon, separate counts were recorded for wild and 'colonized' smolts. Colonized refers to fish that were incubated at the hatchery and transplanted to the upper Quinsam River watershed as fry. All transplanted Coho Salmon were marked with an adipose fin clip. The abundance of colonized Coho Salmon was estimated with the assumption that they have equal catchabilities as wild fish.

Counts of wild Chinook Salmon were recorded; in 2020, no colonized Chinook Salmon were released into the upper Quinsam River watershed due to COVID-19 pandemic restrictions.

Quinsam Hatchery staff have out-planted salmon fry during each year of JHTMON-8 (in addition to previous years; Table 6). During 2014-2019 approximately 150,000 Coho Salmon fry were released in the Upper Quinsam Lake (note that releases also occurred in years prior to 2014). Chinook Salmon fry were released in the Lower Quinsam Lake in 2015 for the first time in 10 years; during 2015, 2017, 2018, and 2019 approximately 200,000 fry were released, while ~150,000 Chinook Salmon fry were released in 2016. In 2020, colonized Chinook Salmon were released early from the hatchery due to COVID-19 pandemic restrictions, and not counted (Table 6).

Figure 2. LKT technician undertaking a mark-recapture study at Quinsam Hatchery salmon counting fence, June 2019.

Table 6. Number released and dates of release of Coho and Chinook Salmon fry in the Quinsam watershed.

Species	Life Stage	Waterbody	Year[1]	Date of Release	Number Released	Comments
Coho Salmon	Fry	Upper Quinsam River	2019	7 Apr - 8 Apr	181,524	
			2018	6 May - 7 May	159,336	
			2017	23 May - 6 Jun	139,570	
			2016	30 May - 1 Jun	146,547	
			2015	29 Apr - 20 May	167,030	
			2014	9 Jun - 13 Jun	157,661	
Chinook Salmon	Fry	Lower Quinsam Lake	2020	n/a	0	Released early from hatchery[2]
			2019	7 May - 8 May	207,736	
			2018	7 May - 8 May	215,952	
			2017	9 May - unknown day in May	207,319	
			2016	12 May - 13 May	147,549	
			2015	11 May - 12 May	217,603	First time in 10 years

[1] Note that DFO annually reports the number of outplanted Chinook Salmon that same year and the number of outplanted Coho Salmon outplanted the previous year

[2] Due to the COVID-19 pandemic restrictions, colonized Chinook Salmon were released early from the hatchery

2.1.3. Quinsam River Salmon Stock Recruitment

As a supplementary task in Year 7, initial analysis was undertaken to develop and explore stock-recruitment relationships. These will be updated in Year 10 to support analysis to test the JHTMON-8 hypotheses by examining whether variability in the relationships is related to environmental factors such as habitat area or invertebrate biomass. Such relationships allow for interannual variability in spawner abundance to be accounted for when analyzing juvenile fish abundance, thereby isolating the potential effects of the environmental factors that are the subject of the study hypotheses.

Fish abundance in a watershed is directly related to the productivity of the stock, which may be affected by environmental and anthropogenic factors. Stock productivity is described by the stock-recruitment relationship (Hilborn and Walters 1992). Despite being a central problem in fisheries science, appropriately describing the relationship between parental stock and recruits remains extremely challenging. Historically, a major challenge has been whether recruitment is primarily related to spawning stock or environmental conditions (Quinn and Deriso 1999). Although many stock-recruitment models used today were developed in the 1950s or earlier (e.g., Ricker 1954), substantial progress has been made in the last two decades in describing how external factors affect the functional relationship between stock size and resulting recruitment (e.g., Olsen et al. 2011, Malick *et al.* 2017). Given the challenging nature of this task, we aimed to undertake preliminary analysis in Year 7 in anticipation of more detailed assessment in Year 10 of how environmental factors affect productivity of priority species.

Different formulations of the stock-recruitment relationship can be used to represent various hypothesized mechanisms that affect the production of recruits. The most commonly used models are considered in this report: i) density independent model, ii) Beverton-Holt, and iii) Ricker. Other formulations and variations exist (e.g., Cushing, Deriso-Schnute, Shepherd; Quinn and Deriso 1999), but the key mechanisms are captured by the three models mentioned and thus we did not consider these variations in Year 7. Additional models may be considered in Year 10 if deemed appropriate.

In the simplest case (i.e., density independent formulation), the agents of mortality affecting young fish, including predation and lack of food, act independently of how many eggs (or spawners) there are. Naturally, this assumption must have limits as it is not possible for a population to reproduce with the same average probability of success as the stock grows indefinitely. However, the assumption may hold over a range of stock sizes, and thus the density independent model may be a reasonable representation of stock-recruitment under particular conditions (Hilborn and Walters 1992).

The other two formulations we trialled are density-dependent formulations. The main difference between the Beverton-Holt and Ricker formulations of the stock recruitment function is that the former assumes that the mortality rate is linearly dependent on the number of fish alive in the cohort at any time, whereas the latter assumes that the mortality rate of eggs and juveniles is proportional to the initial cohort size (Hilborn and Walters 1992). The Beverton-Holt formulation can represent a wide variety of biological phenomena, including competition for food or space. Commonly discussed mechanisms that can lead to a Ricker-shaped recruitment curve are cannibalism of the juveniles by the adults, disease transmission, damage by adults of spawning sites (e.g., redd superimposition), and density-dependent growth coupled with size-dependent predation. However, it is relevant to recognize that when dealing with stock-recruitment curves, the individual influences of many biological processes are averaged. Thus, it is better to think about these as general statistical descriptions, rather than try to determine the most appropriate stock-recruitment curve from general principles (Hilborn and Walters 1992).

The formulations of the three models are:

Density Independent Model: $R = \alpha S$,

where R is recruitment, S is spawning stock abundance, and α is the number of recruits produced per unit of stock

Beverton-Holt Model: $R = \frac{aS}{b+S}$,

where a is the maximum number of recruits produced, and b is the spawning stock needed to produce (on average) recruitment equal to $a/2$.

Ricker Model: $R = Se^{a(1-\frac{S}{b})}$,

where e^a is the initial slope of the curve, and b is the value of S at which $R = S$

We fit the three stock-recruitment forms to two of the target species (Chinook Salmon and Coho Salmon), and two species of interest (Pink Salmon and Chum Salmon), using data described in Sections 2.1.1 and 2.1.2. Stock recruitment curves were not fit for steelhead, as estimates of adult escapement are lacking. Pink salmon have a fixed two-year life cycle with even and odd year brood lines reproductively isolated. Thus, we fit separate stock recruitment curves for even and odd year Pink Salmon. Adult Chinook, Pink, and Chum Salmon spawn during fall, and the juveniles outmigrate from the system during the spring of the following year (Burt 2003). Thus, to fit stock recruitment curves for these species, we considered adult escapement in year *t* and estimated fry outmigration in year *t*+1. Adult Coho Salmon spawn during the fall and most juvenile Coho Salmon rear in freshwater for one year and outmigrate as 1+ smolts, with only a minor portion of the Coho Salmon population emigrating as 2+ smolts (Burt 2003). Thus, to fit stock recruitments curves for Coho Salmon, we considered adult escapement in year *t* and only 1+ smolt outmigration in year *t*+2, i.e., 2+ smolts were omitted from the analysis. For Coho Salmon, the description in files obtained from DFO made it difficult to distinguish 1+ smolts from 2+ smolts prior to 1979, and therefore pre-1979 data were not considered (see details of datasets used to fit stock-recruitment curves in Table 7)[3]. We fit the stock-recruitment curves considering wild fish only.

Most model fitting algorithms assume that the random errors in the model are additive and normal. For example, the Ricker model with additive errors would be expressed as

$$R = Se^{a(1-\frac{S}{b})} + \epsilon$$

Fitting the model with additive errors assumes that the variability around the model is the same at all levels of the stock. It is often the case that the variability in recruitment increases with stock level. A Ricker model with a multiplicative error structure is written as

$$R = Se^{a(1-\frac{S}{b})}e^{\epsilon}$$

Fitting the model with different error structures can lead to substantially different parameter estimates. Quinn and Deriso (1999) suggest that the theory used to develop the Beverton-Holt and Ricker models suggests that the multiplicative error model should be the default choice. Therefore, effort was made to fit the models with multiplicative errors. However, we found convergence errors when attempting to fit models for Chinook Salmon, and therefore we implemented models with additive errors. In addition, it was not possible to fit the Beverton-Holt model for Chum Salmon due to convergence errors with both multiplicative and additive errors.

Following Ogle (2016), we fit the models through non-linear regression implemented with the nls() function in the Statistical Language R (R Core Team 2020) and functions provided in the FSA package (Ogle *et al.* 2021). For each species, we fit the three stock recruitment models, and ranked and selected the best models based on the Akaike Information Criterion (AIC) (Burnham and Anderson 2002), and the derived measure evidence ratio (Anderson 2008). The evidence ratio is a metric of relative

[3] We plan to re-examine this methodological detail in future years to confirm whether it may be appropriate to make additional assumptions to allow for inclusion of pre-1979 data; note that 2+ smolts only comprise a minor proportion of the estimated total Coho Salmon smolt outmigration (e.g., <1% in 2020; Section 3.1.2).

strength of evidence of a given model, with respect to the best model in the set; thus, if the evidence ratio for model *X* is 5, then the best model has five times the weight of evidence relative to model *X*.

Table 7. Summary of datasets used to fit stock-recruitment curves.

Species/Stock	Timing of Adult Spawning	Timing of Juvenile Outmigration	Dataset (Year *t*)
Chinook Salmon	Fall year *t*	Spring year *t*+1	1980, 1986, 1988-1991, 1995-2003, 2005, 2007-2011, 2013-2019
Coho Salmon	Fall year *t*	Spring year *t*+2	1979-1990, 1994-2002, 2004, 2006-2010, 2012-2018
Pink - Even Year	Fall year *t*	Spring year *t*+1	1974, 1976, 1978, 1980, 1984, 1986, 1988, 1990, 1996, 1998, 2000, 2008, 2010, 2014, 2016, 2018
Pink - Odd Year	Fall year *t*	Spring year *t*+1	1973, 1975, 1979, 1981, 1983, 1985, 1987, 1989, 1991, 1995, 1997, 1999, 2001, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019
Chum Salmon	Fall year *t*	Spring year *t*+1	1973-1976, 1978-1971, 1985, 1988, 1990-1991, 1995-2001, 2005, 2007-2011, 2013-2019

2.2. Water Quality

2.2.1. Water Chemistry

2.2.1.1. Quinsam River Water Chemistry Monitoring

One water quality site was established in the Quinsam River (QUN-WQ) in 2014 (Year 1) at 327433 E 5534757 N (UTM; Zone 10) and elevation 193 masl (Map 2). This site was selected based on guidance in the British Columbia Field Sampling Manual (Clark 2013) and the Ambient Fresh Water and Effluent Sampling Manual (RISC 2003), which require sites to be established in mid-stream locations that can be safely accessed and are located away from eddies where suspended particulate material can accumulate, potentially biasing results. QUN-WQ (Figure 3) is located ~950 m downstream of the confluence with the Iron River, and downstream of the Quinsam Coal Mine and the salmon carcass nutrient enhancement site. Sampling dates (*in situ* and laboratory samples) are provided in Table 8.

Water quality has been monitored during Year 1 through Year 7 at QUN-WQ, with monitoring scheduled to continue for the remainder of JHTMON-8. Water quality has been monitored six times on a monthly basis from May through October during each year. During all years, standard methods according to the procedures set out in the Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia (RISC 1997a) were employed to collect samples and measure *in situ* water quality parameters. Water chemistry variables were chosen based on provincial standards (Lewis *et al.* 2004).

The variables measured in Year 7 are presented in Table 9 (*in situ*) and Table 10 (laboratory). Laboratory method detection limits (MDL) for each analyte occasionally differed (Table 10) due to matrix effects in the sample, or variations in laboratory analytical instruments.

Table 8. Quinsam River water quality index site (QUN-WQ) sampling dates, Years 1 to 7.

Study Year	Sampling Dates
1	3-May-14; 18-Jun-14; 22-Jul-14; 19-Aug-14; 24-Sep-14; 04-Nov-14
2	12-May-15; 17-Jun-15; 23-Jul-15; 13-Aug-15; 16-Sep-15; 14-Oct-15
3	18-May-16, 15-Jun-16, 13-Jul-16; 17-Aug-16, 14-Sep-16; 12-Oct-16
4	10-May-17; 14-Jun-17; 12-Jul-17; 9-Aug-17; 13-Sep-17; 11-Oct-17
5	10-May-18; 05-Jun-18; 04-Jul-18; 09-Aug-18; 12-Sep-18; 05-Oct-18
6	13-May-19; 12-Jun-19; 11-Jul-19; 12-Aug-19; 12-Sep-19; 09-Oct-19
7	11-May-20; 08-Jun-20; 07-Jul-20; 10-Aug-20; 10-Sep-20; 08-Oct-20

Figure 3. Looking downstream to QUN-WQ on September 10, 2020.

Table 9. Water quality variables measured *in situ* and meters used in Year 7.

Parameter	Unit	Meter
Water temperature	°C	YSI Pro Plus, YSI 85
pH	pH units	YSI Pro Plus
Salinity	ppt	YSI Pro Plus, YSI 85
Conductivity	µS/cm	YSI Pro Plus, YSI 85
Specific conductivity	µS/cm	YSI Pro Plus, YSI 85
Oxidation reduction potential	mV	YSI Pro Plus
Dissolved oxygen	mg/L	YSI Pro Plus, YSI 85
Dissolved oxygen	% Saturation	YSI Pro Plus, YSI 85

Table 10. Variables analyzed in the laboratory by ALS Environmental and corresponding units and method detection limit (MDL) in Year 7.

Parameter	Unit	MDL
General Water Quality		
Specific conductivity	µS/cm	2
pH	pH	0.1
Total suspended solids	mg/L	1
Total dissolved solids	mg/L	10 to 13
Turbidity	NTU	0.1
Alkalinity, Total (as $CaCO_3$)	mg/L	1
Nutrients		
Ammonia (as N)	µg/L	5
Nitrate (as N)	µg/L	5
Nitrite (as N)	µg/L	1
Total phosphorus	µg/L	2
Orthophosphate	µg/L	1

2.2.1.2. Quality Assurance/Quality Control

In situ water quality meters were maintained and operated following manufacturer recommendations. Maintenance included calibration, cleaning, periodic replacement of components, and proper storage. Triplicate *in situ* readings were recorded from each meter at each site on each sampling date.

For samples collected for laboratory analysis, sampling procedures and assignment of detection limits were determined following the guidelines of the BC Field Sampling Manual (Clark 2013) and the

Ambient Fresh Water and Effluent Sampling Manual (RISC 2003). Duplicate samples were collected on each sampling date at the site.

In Year 7, one field blank and one trip blank were collected on May 11, 2020. Values for all parameters for both blanks were below the respective MDLs. Overall, for the JHTMON-8 sampling program on the Quinsam River, the total number of quality assurance/quality control (QA/QC) samples collected over seven years (24 out of 84 samples, or 29%) met or exceeded recommendations; the BC field sampling manual recommends that 20% to 30% of samples consist of QA/QC samples (Clark 2013), while the RISC (1997a) manual recommends a minimum of 10% of samples consist of QA/QC samples.

Samples for laboratory analysis were collected in clean 500 mL plastic bottles provided by a certified laboratory (ALS Environmental). Samples were packaged in clean coolers that were filled with ice packs and couriered to the laboratory in Burnaby within 24 to 48 hours of collection. Standard Chain of Custody procedure was strictly followed. ALS Environmental performed in-house quality control checks including analysis of replicate aliquots, measurement of standard reference materials, and method blanks. A summary of the QA/QC laboratory results is provided in Section 4 of Appendix A.

In Vancouver Island streams, concentrations of several variables (notably nutrients) are commonly less than, or near to, the MDL. When this occurs, there are several different methods to analyze these values. In this report, any values that were less than the MDL were assigned the MDL values and averaged with the results of the other replicates. In these cases, the "real" average is less than the average reported.

2.2.1.3. Comparison with Guidelines for the Protection of Aquatic Life

Water quality guidelines for the protection of aquatic life (WQG-AL) and typical ranges of water quality variables in BC waters that were considered for this report are provided in Appendix A. Any results for water chemistry variables that approximated or exceeded WQG-AL, or ranges typical for BC, are noted in Section 3.2 of the Results.

For most water quality variables measured in this study, there are provincial WQG-AL. For total phosphorus, there are no provincial WQG-AL; however, there are federal guidelines (CCME 2004). For the remaining variables without provincial WQG-AL (i.e., orthophosphate, alkalinity, and specific conductivity) there are no federal guidelines either.

2.2.2. Water and Air Temperature

2.2.2.1. Quinsam River Temperature Monitoring

Water and air temperature monitoring was completed in Year 7 for the Quinsam River. Water temperature data have now been collected at the water quality index site for the period May 2014 to October 2020 for the Quinsam River. Air temperature has also been measured near-continuously throughout this period.

Water temperature was recorded at intervals of 15 minutes using self-contained TidbiT v2 loggers (Onset, MA, USA). These TidbiT loggers had an operating range of -20°C to +70°C with an accuracy of ±0.2°C and a resolution of 0.02°C. Water temperature at the monitoring station was logged using duplicate TidbiT loggers installed on separate anchors. This redundancy is intended to prevent gaps in the data if one of the loggers malfunctions or is lost.

Air temperature was measured using one HOBO Air Temperature U23 Data Logger (range of -40°C to 70°C, accuracy of ±0.21°C) at the water quality index site (QUN-AT). The temperature logger recorded air temperature at a regular interval of 15 minutes. The logger was placed on a tree that was close (< 100 m) to the site.

2.2.2.2. Data Analysis

Water temperature data were analyzed as follows. First, erroneous data were identified and removed. Sources of erroneous data include occasional drops in water level which can expose the sensors to the atmosphere, and high flows which can move sediment and bury the sensors. Second, the records from duplicate loggers (when available) were averaged and records from different download dates were combined into a single time-series for the monitoring station. The time series for the station was then interpolated to a regular interval of 15 minutes, starting at the full hour.

Time series of water and air temperature data were plotted at 15-minute intervals; the hourly rates of change in water temperature were also plotted. Analysis of the water temperature data involved computing a range of summary statistics (Table 11) that were chosen based on the provincial WQG-AL (Oliver and Fidler 2001; Table 5 of Appendix A). The following statistics were computed: mean, minimum, and maximum water temperatures for each month of the record; hourly rate of change of temperature; days with mean daily temperature >18°C, >20°C, and <1°C; the length of the growing season, and; the accumulated degree days in the growing season. Statistics were based on the data collected at, or interpolated to, intervals of 15 minutes. Mean weekly maximum temperatures (MWMxT) were calculated and compared to optimum temperature ranges for different fish species and their life stages as outlined in the provincial WQG-AL (Oliver and Fidler 2001). Note that calculations of growing season length and accumulated degree days in the growing season have been updated from previous reports to use a threshold value of 7°C instead of 5°C to define the start of the growing season, and 7°C instead of 4°C to define the end (Table 11). This change is considered to provide a more accurate estimate of growing season length (5°C is more appropriate for streams with Bull Trout *Salvelinus confluentus*) and is consistent with the approach taken by provincial biologists for estimating growing season length on other Vancouver Island streams (MFLNRORD and DFO 2018).

Table 11. Parameters calculated based on water and air temperature data.

Parameter	Description	Method of Calculation
Monthly water- and air-temperature statistics	Mean, minimum, and maximum on a monthly basis	Calculated from temperatures observed at or interpolated to 15-min intervals
Rate of water temperature change	Hourly rate of change in water temperature	Calculated observed or interpolated to 15-min intervals. The hourly rate of change is set to the difference between temperature data points that are separated over one hour.
Degree days in growing season	The beginning of the growing season is defined as the beginning of the first week that mean stream temperatures exceed and remain above 7°C; the end of the growing season was defined as the last day of the first week that mean stream temperature dropped below 7°C (modified from Coleman and Fausch 2007).	Daily mean water temperatures were summed over this period (i.e., from the first day of the first week when weekly mean temperatures reached and remained above 7°C until the last day of the first week when weekly mean temperature dropped below 7°C).
Number of Days of Extreme Daily Temperature	Daily temperature extremes for all streams	Total number of days with daily mean water temperature >18°C, >20°C, and <1°C
MWMxT (Mean Weekly Maximum or Minimum Temperature)	Mean, minimum, and maximum on a running centered weekly (7 day) basis	Mean of the warmest daily maximum or coldest daily minimum water temperature based on hourly data for 7 consecutive days; e.g., if MWMxT = 15°C on August 1, 2018, this is the mean of the daily maximum water temperatures from July 29 to August 4, 2018; this is calculated for every day of the year.

2.3. Hydrology

The Water Survey of Canada measures discharge at multiple gauges on the Quinsam River (Map 2). Available discharge data collected since the start of the study were plotted to evaluate flow conditions at the following sites downstream of the diversion facility: 'Quinsam R. near Campbell R.' and 'Quinsam R. at Argonaut Bridge' sites (Table 12). To provide historical context, discharge was plotted alongside summary statistics (10th, 50th and 90th percentiles) for the periods of record. At the time of reporting, quality assured historical data were only available until the end of 2019.

In addition, several annual hydrological metrics were calculated using data for each gauge to quantify key flow characteristics that have potential to influence fish productivity (Table 13). The metrics quantify the occurrence of high flows during biologically sensitive periods of the year to support analysis to test $H_0 4$, which relates to floods (Section 1.5.5). For Pacific Salmon species (fall spawners), the maximum discharge during the incubation period was calculated based on the discharge measured between the start of incubation in fall the previous year, and the end of incubation during spring of the current year. Low flow metrics were also calculated to support future analysis to test whether low summer flows affect the abundance of juvenile salmonids that rear in freshwater through the summer

(Coho Salmon and steelhead). All metrics are based on a subset (Group 2) of the Indicators of Hydrologic Alteration (Richter *et al*. 1996) that were developed to quantify the magnitude and duration of hydrological extremes. Metrics were either calculated based on annual records of mean daily discharge (m^3/s) or using records for the spawning and incubation periods of specific fish species, based on fish periodicity information for the Quinsam River reported by Burt (2003; Quinsam River). Metrics were calculated using the Indicators of Hydrologic Alteration package developed for R (R Core Team 2019) by The Nature Conservancy. Metrics were calculated based on discharge data collected at the gauges at Argonaut Bridge (08HD021) and near the confluence with the Campbell River (08HD005).

Table 12. Hydrometric gauges maintained by Water Survey of Canada on the Quinsam River. See Map 2 for site locations.

Site Name	Site Code	Period of Record		Position Relative to Diversion
		Start	End	
Quinsam R. at Argonaut Bridge	08HD021	1993	Ongoing	Downstream
Quinsam R. below Lower Quinsam Lake	08HD027	1997	Ongoing	Downstream
Quinsam R. near Campbell R.	08HD005	1956	Ongoing	Downstream

Table 13. Hydrological metrics calculated for the Quinsam River.

Hydrological Metric	Data Period
Max. discharge during Chinook Salmon incubation	15 Oct - 30 Apr
Max. discharge during Coho Salmon incubation	15 Oct - 22 Apr
Max. discharge during steelhead incubation	15 Feb - 15 Jun
Max. discharge during Pink Salmon incubation	15 Sep - 08 Apr
1-day minimum discharge	Calendar year
7-day minimum discharge	Calendar year
30-day minimum discharge	Calendar year

2.4. Invertebrate Drift

2.4.1. Sample Collection

One invertebrate drift sampling site was established on the Quinsam River (Map 2, Figure 4), located close (<150 m) to the water quality index site. The site location was consistent among years; UTM coordinates (Zone 10) were: 327,361 E and 5,534,796 N. The site was located in riffle or run habitats (depending on flow), upstream of any obvious source of debris that could clog the nets or areas that seemed subject to frequent erosion. Invertebrate sampling was conducted monthly from May to October, with weekly sampling conducted during July in Year 7 (the month that is sampled weekly is rotated among study years to quantify the variance in monthly data). In total, sampling occurred on nine dates in the Quinsam River in Year 7 (Table 14).

Invertebrate drift sampling followed methods recommended in Hatfield *et al.* (2007) and Lewis *et al.* (2013). Upon arrival at site, local areas with velocities of approximately 0.2 to 0.4 m/s were identified using a model 2100 Swoffer meter with a 7.5 cm propeller and a 1.4 m top-set rod. This range of velocities is ideal for sampling invertebrate drift as velocities are low enough to prevent clogging of the nets. Due to flow conditions at the time of sampling, it was not always possible to deploy the nets in areas with velocities of 0.2 m/s to 0.4 m/s (as per Hatfield *et al.* 2007), and nets sampled higher or lower water velocities at times.

Five drift nets were deployed simultaneously across the channel (Figure 4). The mouth of each drift net was positioned perpendicular to the direction of stream flow, and nets were spaced apart to ensure that each individual net did not obstruct flow into an adjacent net. The drift net mouth dimensions were 0.3 × 0.3 m and the nets (250 µm mesh) extended 1 m behind the mouth. Nets were anchored such that there was no sediment disturbance upstream of the net before and during deployment. All nets were deployed so that the top edge of the net was above the water surface so that invertebrate drift in the water column and on the water surface could be sampled.

At the start of sampling, measurements were made of water depth in each net and the water velocity by each net at the midpoint of the water column that was being sampled. These measurements were repeated hourly so that the volume of water sampled with each net could be calculated. Any large debris (e.g., leaves) that entered the nets was periodically removed from the nets (after it had been washed of any invertebrates, which were returned to the nets). Nets were deployed for approximately four hours on each sample date (Table 14). Once the nets were removed, the contents of all five nets were transferred into sample jars (500 mL plastic jars with screw top lids) for processing as a single sample in Years 2–7. This is a method change from Year 1 (2014), when contents of each net were processed separately. Samples were preserved in the field with a 10% solution of formalin (formalin = 37–40% formaldehyde).

In Year 7, kick net sampling was also undertaken on September 10, 2020 at QUN-IV. The CABIN standardized sampling method was followed (MoE 2009), with a single drift net (described above) used as a kick net. This required one crew member to hold the net flush with the stream bed immediately downstream of a second crew member undertaking the sampling. Sampling proceeded upstream for a timed period of three minutes, covering a horizontal distance of approximately 10 m. During sampling, the sampler kicked the substrate to disturb it to a depth of 5–10 cm, while also turning over any large cobbles or small boulders to dislodge invertebrates. Once sampling was complete, the contents were sieved (250 µm mesh), transferred into sample jars, and preserved in the same manner as drift net samples.

Table 14. Invertebrate drift sample timing and sampling duration at the Quinsam River site (QUN-IV) during Year 7.

Sample Date	Start Time[1]	Finish Time[2]	Sampling Duration[3,4] (hh:mm)
11-May-2020	07:09	11:09	4:00
08-Jun-2020	06:41	10:41	4:00
07-Jul-2020	06:45	10:45	4:00
14-Jul-2020	06:35	10:35	4:00
21-Jul-2020	06:36	10:37	4:01
27-Jul-2020	07:01	11:01	4:00
10-Aug-2020	07:11	11:11	4:00
10-Sep-2020	08:08	12:08	4:00
08-Oct-2020	08:45	12:45	4:00

[1] When the first net was set

[2] When the last net was removed

[3] The duration between retrieving the first and last net

[4] For data analysis, start and finish times for individual nets were used to calculate the volume of water filtered for each net

Figure 4. View across the stream from river right towards QUN-IV, July 14, 2020.

2.4.2. Laboratory Processing

Samples were sent to Ms. Dolecki of Invertebrates Unlimited in Vancouver, BC for processing. Ms. Dolecki is a taxonomist with Level II (genus) certification for Group 2 (Ephemeroptera, Plecoptera, and Trichoptera (EPT)) and for Chironomidae from the North American Benthological Society.

The drift and kick net samples were first processed by removing the formalin (pouring it through a 250 µm sieve), followed by immediate picking and identification of the very large and rare taxa. Samples were split into subsamples if the number of invertebrates was over 1,000. The invertebrates were enumerated using a Leica stereo-microscope with 6 to 8 × magnification, with additional examination of crucial body parts undertaken at higher magnifications (up to 400 ×) using an Olympus inverted microscope where necessary. Individuals from all samples were identified to the highest taxonomic resolution possible and it was noted whether a taxon was aquatic, semi-aquatic, or terrestrial. Life stages were also recorded.

Digitizing software (Zoobbiom v. 1.3; Hopcroft 1991) was used to measure the length of a sub-sample of individuals. Length measurements were then used to calculate average biomass (mg dry weight) of each taxon using standard length–weight regressions. The regressions were developed using un-preserved individuals and therefore the estimates are unaffected by reduction in biomass that can occur due to preservation in alcohol and subsequent drying of tissues inside carapaces (the length measurements are unaffected by preservation). This method is considered more accurate than weighing the invertebrates because it is not influenced by loss of biomass caused by preservation or the presence of debris and does not require invertebrates to be dried. For abundant taxa, up to 25 randomly chosen individuals per taxon were digitized to address the variability in size structure of the group. For the rare taxa, all individuals in the taxon were measured. The damaged or partial specimens were excluded from the measurements. For pupae and emerging Chironomidae, up to 50 individuals were measured.

To provide QA/QC, all the samples were re-picked a second time to calculate the accuracy of picking. This assured that > 90% accuracy was attained, and the accuracy of the methods employed is expected to be over 95%.

2.4.3. Data Analysis

Variables were chosen and calculated as per Lewis *et al.* (2013), and all taxa (aquatic, semi-aquatic, and terrestrial) were considered. Density (# of individuals), total biomass (mg dry weight) and the sum of EPT (Ephemeroptera, Plecoptera, and Trichoptera) biomass (mg dry weight) of each sample were expressed as units per m^3 of water, where volume is the amount of water that was filtered through a single net during a set. Volume filtered by each net was calculated based on the duration that the nets were deployed and the average discharge measured at each net. EPT biomass was calculated because EPT taxa are expected to comprise an important part of salmonid diets in these systems. Calculation of EPT biomass was an additional task undertaken in Year 7 with the aim to calculate invertebrate metrics that are best suited to test H_05. As agreed with BC Hydro, the addition of this new task was offset by assigning less effort to analysis of invertebrate community composition, which is considered peripheral to testing H_05, which concerns food availability.

During Years 2–7, the analysis was undertaken for each combined sample that included the contents of all five nets. For Year 1 (when net samples were not physically combined), data for each net were combined into site-level samples prior to calculating biodiversity metrics (family richness, Simpson's diversity) so that results were directly comparable with the results for Year 2–7. Family richness and Simpson's diversity are both standard metrics used to quantify invertebrate biodiversity. Change in these metrics may indicate change in the quality of food available to rearing fish.

Family richness (i.e., the number of families present) was calculated for each sample as a metric of biodiversity. Simpson's diversity index (1-λ, Simpson 1949) was calculated from family level density data to provide a measure that reflects both richness and the relative distribution or 'evenness' of invertebrate communities (i.e., higher Simpson's diversity index values denote communities that have high family richness, with the total number of individuals also evenly distributed among families). The index value ranges between 0 (no diversity) and 1 (a hypothetical scenario of infinite diversity). A Simpson's diversity index closer to 1 is associated with greater diversity and, thus, potentially greater food quality for fish.

The Canadian Ecological Flow Index (CEFI) was calculated using family level data for aquatic taxa following Armanini *et al.* (2011). Taxa present in <5% of the samples were not excluded from the CEFI calculation (Armanini, pers. comm. 2013). Relative abundances of taxa at the site were calculated considering only aquatic taxa, and only aquatic taxa used to develop the CEFI were considered when calculating the index. The top five families contributing to biomass at the site on each date were also identified.

3. RESULTS

3.1. Fish Population Assessments

3.1.1. Quinsam River Salmon Escapement, 2019

Salmon escapement data for the Quinsam River are presented for 2019 (Year 6; Table 15), which are the most recent results available at the time of reporting. Summary statistics for the period of record are also provided in Table 15 to provide points of reference. Figure 5 presents salmon escapement data for the period of record.

Pink, Coho and Chinook salmon were the most abundant returning species in 2019, as well as historically (Table 15). Escapement of Chinook Salmon in the Quinsam River in 2019 (6,793) was above-average, although the values in the late 2010s were lower than the values observed in the late 1980s, early 1990s and early 2000s. Estimated escapement of Coho Salmon (11,671) in 2019 was approximately equal to the mean value (12,157) for the period of record (1953–2019); the values estimated during the last decade are generally higher than those observed between the late 1950s and late 1970s, but lower than those observed between the early 1980s and early 2000s. The estimated

Chum Salmon escapement (8) was particularly low[4]; it was the 2nd lowest count recorded in the 60-year dataset, while the count in 1993 (6) was the lowest count. Pink Salmon escapement in the Quinsam River in 2019 (571,555) was higher than the mean value (136,840) for the period of record (1953-2019). The estimated escapement of Sockeye Salmon in 2019 (2) was the lowest count recorded in the 60-year dataset; the 2nd lowest count was recorded in 2010 and 2012 (3 fish each year).

During the six years of available data for the JHTMON-8 study period, a notable result was the occurrence of a record high Pink Salmon escapement (1.42 million) in Year 1 (2014). Chinook Salmon escapement in the Quinsam River increased steadily over the first four years from 2,366 fish to 9,131 fish, and decreased in 2018 and 2019 to 6,774 and 6,793 fish, respectively. By contrast, Coho Salmon escapement decreased steadily over the first four years from 14,883 fish to 5,865 fish, and increased in 2018 and 2019 to 10,025 and 11,671 fish, respectively.

Table 15. 2019 salmon escapement data for the Quinsam river (DFO 2020).

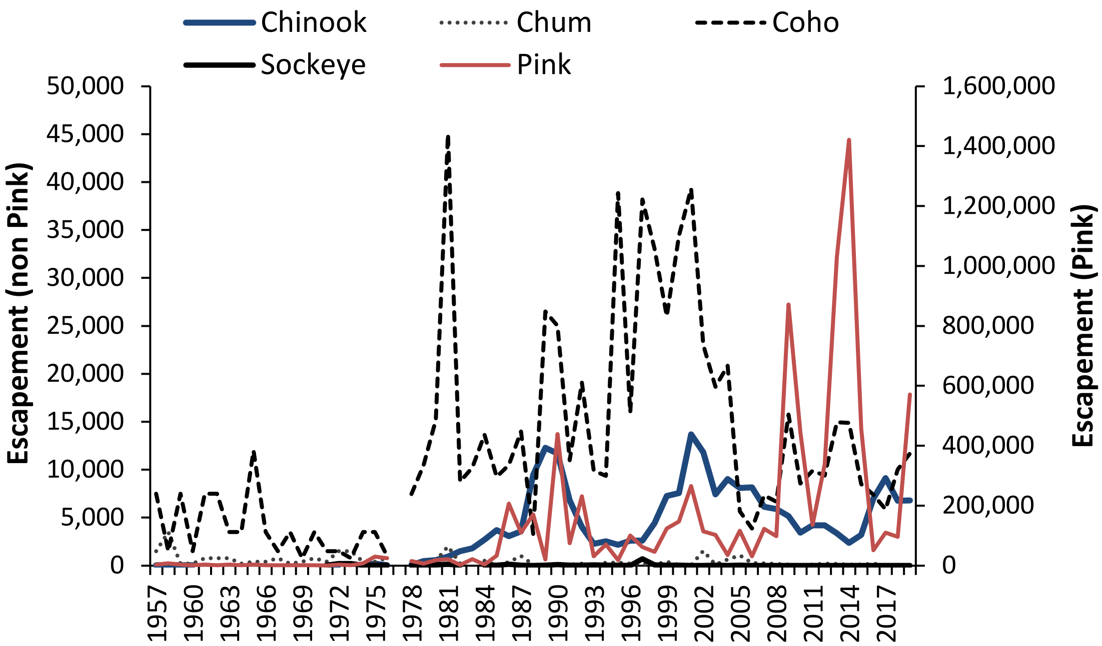
Statistic	Salmon Species				
	Chinook[1]	Chum	Coho[1]	Pink	Sockeye
2019 count	6,793	8	11,671	571,555	2
Mean (1957-2019)	4,320	472	12,157	136,840	52
Median (1957-2019)	3,431	255	9,310	31,995	23
10th percentile (1957-2019)	35	52	1,500	1,500	6
90th percentile (1957-2019)	9,395	1,458	31,077	442,989	128
Percent of years sampled (1957-2019)[2]	81	95	98	98	76

[1] Priority species for JHTMON-8

[2] "Percent of years sampled" is approximate; uncertainty in data recording means that a count of zero is not always distinguished from a record of "not measured"

[4] Note that the end of the Chum Salmon sampling period (December 1; Table 4) was ~2 weeks prior to the end of the defined migration period (Table 1) and therefore this value is expected to be an underestimate. Nonetheless, the sampling period spanned the majority of the migration period and the end date of sampling was within the range of dates monitored in previous years. Thus, it is appropriate to conclude that Chum Salmon returns to the Quinsam River were low in 2019 relative to returns in other years, although total escapement is expected to be greater than the reported value. Note that DFO records salmon escapement to the Campbell River (downstream) separately; Chum Salmon escapement to the Campbell River in 2019 was 3,000 fish (DFO 2020).

Figure 5. Salmon escapement for the Quinsam River (1957–2019; DFO 2020).



3.1.2. Quinsam River Hatchery Salmon Counting Fence Operations

Data collected at the salmon counting fence are summarized in Table 16. Following installation on March 8, the traps were monitored daily from March 9 to June 13.

The monitoring period provided good coverage of the Pink Salmon fry migration period in 2020, although lower numbers of fry were captured on the first two-days of sampling, suggesting that the migration period started slightly prior to March 9. The migration was largely complete by May 12 (only six Pink Salmon fry were captured after this date). Total estimated migration of Pink Salmon fry has been highly variable in the seven years of the monitoring program and was ~15 million in 2020 (Year 7) (Table 16). Estimates varied by an order of magnitude among years since 2014, ranging from a minimum of 1.5 million fry in 2017 to a maximum of 22 million fry in 2014.

Total outmigration estimates for the three JHTMON-8 priority species in the Quinsam River (Coho Salmon smolts, steelhead smolts, and Chinook Salmon fry) are presented for the JHTMON-8 period in Figure 6. To provide broader context, outmigration estimates of priority species are presented in Figure 7 for the full period of record (since the mid 1970s), based on a data compilation exercise undertaken in Year 5 (Abell *et al.* 2019). Annual values presented in Figure 7 are considered directly comparable, although there was some variability in sampling methods among years that contributes to variability in sampling error. Readers should consult the historical data review undertaken in Year 5 (Abell *et al.* 2019) and the review of capture efficiency estimates undertaken in Year 6 (Suzanne *et al.* 2020) for further details.

In Year 7 (2020), total estimated outmigration of colonized Coho Salmon (50,708) was the highest recorded during JHTMON-8. Total estimated outmigration of wild Coho Salmon (57,244) was also the highest of the seven years, with the second highest recorded in Year 5 (46,679). The total estimated outmigration of steelhead smolts (12,865; 869 fish captured) was the highest recorded during JHTMON-8, although it should be recognized that there is uncertainty regarding the accuracy of steelhead smolt outmigration estimates as capture efficiency is based on mark-recapture experiments undertaken with Coho Salmon, which may not be well-representative of steelhead smolt catchability (see Abell *et al*. 2019 for further discussion of sources of uncertainty). Estimated outmigration of wild Chinook Salmon (359,844) was the highest during the seven years of JHTMON-8, during which estimated Chinook Salmon outmigration has been highly variable. Chinook Salmon fry were noted to still be outmigrating on June 14 when the traps were removed, with 304 captured on the final day of sampling (June 13). As discussed in Section 2.1.2, colonized Chinook Salmon were not released into the upper Quinsam River watershed in 2020 due to COVID-19 pandemic restrictions; therefore, there is no total estimated outmigration of colonized Chinook Salmon for Year 7. Estimated outmigration of all priority species during JHTMON-8 has been within the range of historical estimates for the study, with the exception of wild Chinook Salmon in 2020 (Figure 7).

The survival of out-planted juvenile salmon was estimated by calculating the percentage of outmigrating juvenile colonized salmon that comprise the total number of fish out-planted (Figure 8). After a break of approximately 10 years, Chinook Salmon out-planting operations resumed in 2015, and therefore estimates of survival rate are available for 2015–2019 (Years 2–6 of JHTMON-8; no Chinook Salmon were out-planted in 2020). Estimated survival of colonized juvenile Chinook Salmon during JHTMON-8 was highest in 2019 and has varied between 65% and 80% during four of the five years, with a lower value (28%) estimated in 2016. Colonized juvenile Coho Salmon survival estimates are available for all seven years of monitoring, ranging between 13% and 32%, with survival lower than Chinook Salmon, at least partly reflecting that this Coho Salmon spend longer in freshwater. The survival estimate for Coho Salmon in 2020 was the highest during the seven years of JHTMON-8. Note that the estimates for Coho Salmon assume that fish outmigrate at age 1+, although some 2+ smolts were recorded at the fence[5].

[5] Estimated outmigration of 2+ Coho Salmon was 124 fish in 2020. Burt (2003) suggests that 2+ smolts represent fish that were trapped in off-channel habitats, preventing them from outmigrating the previous year.

Table 16. Summary of downstream migration data and total migration estimates from sampling at the Quinsam River Hatchery salmon counting fence, March 9 to June 13, 2020.

Species	Life Stage	Total Counts	Total Estimated Migration[1]	Peak Migration	Migration Period	Comments
Colonized Coho	Smolt	3,388	50,708	May 5 - 20	Mar 11 - Jun 13	Still migrating as of Jun 14
Wild Coho	Smolt	3,848	57,244	May 5 - 20	Mar 11 - Jun 13	Still migrating as of Jun 14
2 Year old Coho	Smolt	8	124	May 21	Apr 25 - May 21	
Coho	Fry	1,221	28,350	Apr 13 - 27	Mar 15 - Jun 13	Still migrating as of Jun 14
Steelhead	Smolt	869	12,865	May 10 - 22	Mar 21 - Jun 3	
Steelhead	Fingerling	129	1,961	May 11 - 25	Apr 26 - Jun 11	
Steelhead	Kelts	0	0	n/a	n/a	
Cutthroat	Fingerling	3	49	May 29 - 30	May 29 - Jun 11	
Cutthroat	Smolt	13	199	May 10 - 15	Apr 27 - Jun 13	Still migrating as of Jun 14
Cutthroat	Kelts	4	72	May 20	Mar 11 - May 11	
Trout Fry	Fry	1	25	Apr 1	Apr 1	
Chinook	Fry	22,958	359,844	May 15 - Jun 13	Mar 20 - Jun 13	Still migrating as of Jun 14
Colonized Chinook	Fry	0	0	No releases	No releases	No colonized Chinook were released due to COVID-19 restrictions
Chum	Fry	4,460	131,566	Apr 1 - 14	Mar 9 - May 18	
Sockeye	Fry	7	175	Mar 12 - 19	Mar 9 - 19	
Pink	Fry	501,679	14,930,120	Apr 11 - 18	Mar 9 - Jun 8	
Dolly Varden	Smolt	4	62	May 11	May 5 - 12	
Lamprey (2 species)	All	66	1,017	May 7 - 14	Apr 27 - Jun 13	
Sculpin	All	57	865	May 11 - 20	Apr 22 - May 29	

[1] Based on capture efficiency measured for Pink Salmon and Coho Salmon

"n/a" indicates no peak or migration period identified

Figure 6. Total estimated outmigration of priority species on the Quinsam River during Years 1–7 (2014–2020). Coho Salmon and steelhead were captured at the smolt stage and Chinook Salmon at the fry stage.

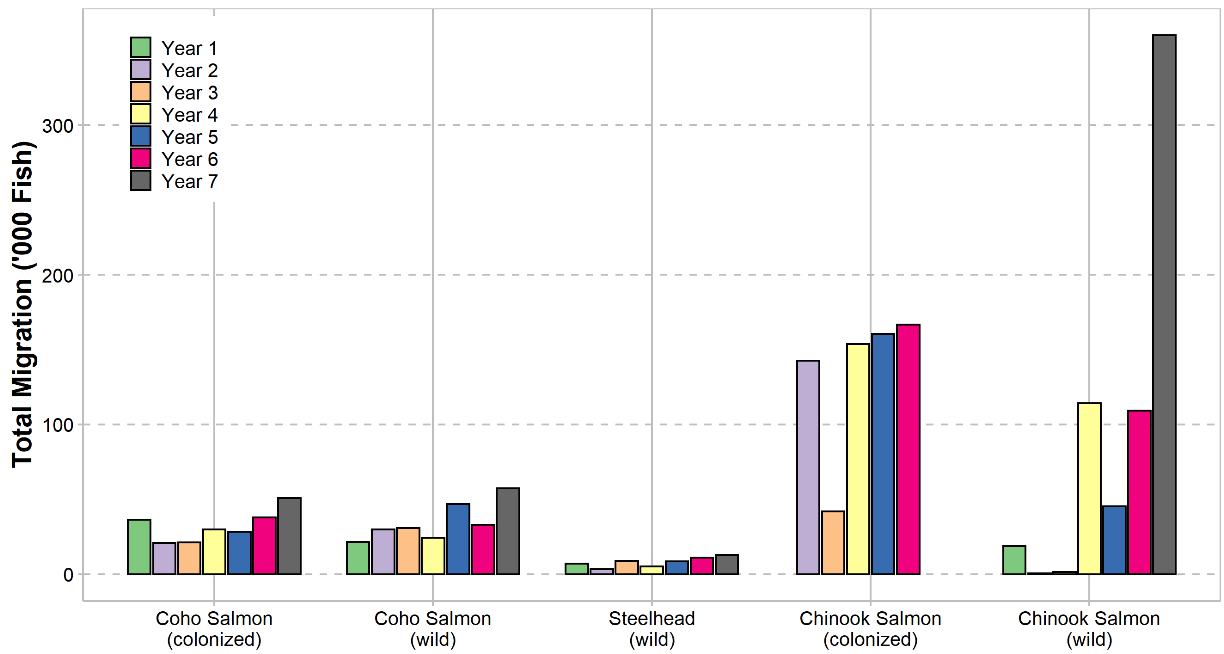


Figure 7. Estimated outmigration of priority species in the Quinsam River during 1979-2020, distinguished between colonized and wild fish. Coho Salmon and steelhead were captured at the smolt stage and Chinook Salmon at the fry stage (0+).

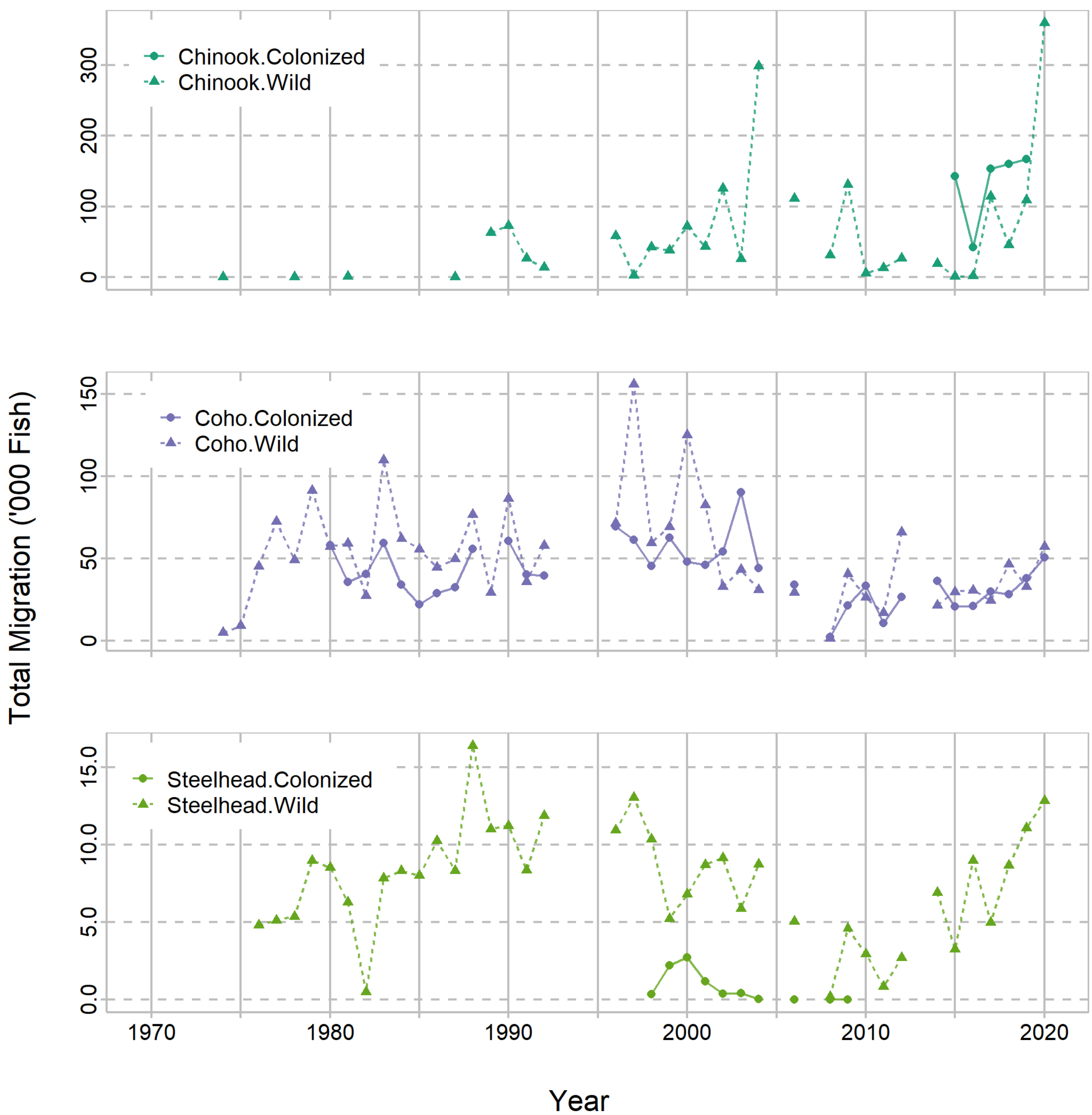
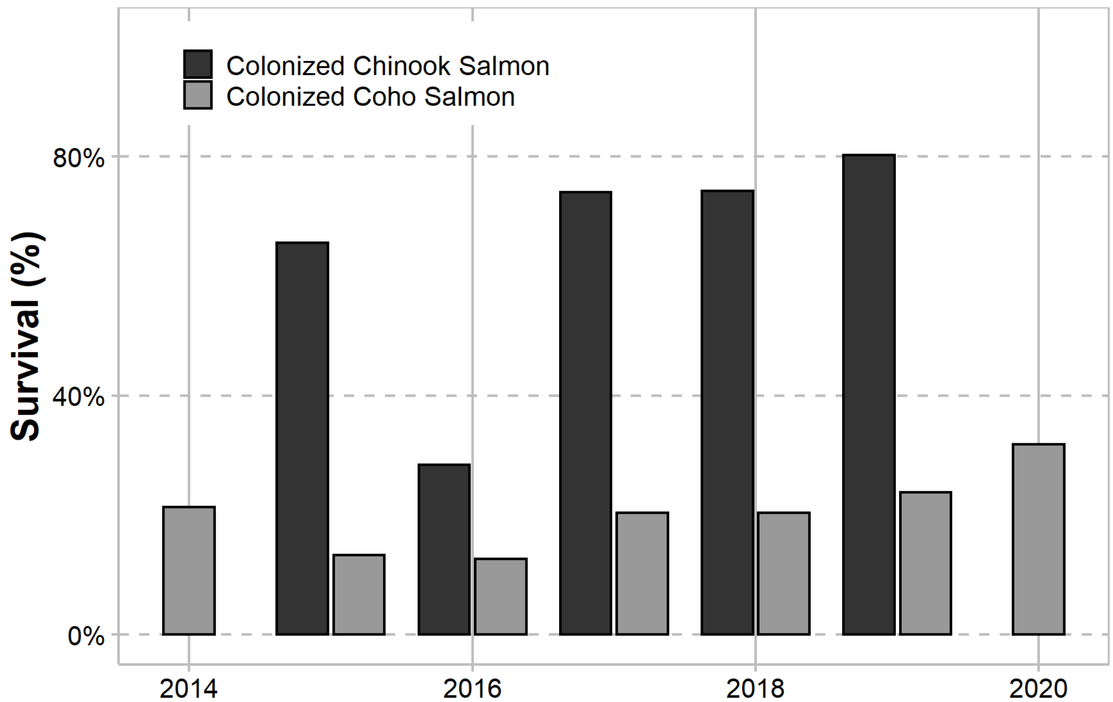


Figure 8. Estimated survival of out-planted salmon raised at the hatchery, based on the proportion of out-planted fish estimated to outmigrate at the salmon counting fence. Outmigrating Chinook Salmon were out-planted during spring (May) of the same year; outmigrating Coho Salmon were out-planted the previous year. No Chinook Salmon were out-planted in 2020.



3.1.3. Quinsam River Salmon Stock Recruitment

The stock recruitment data for the four species considered follow the general patterns for Pacific Salmon stock recruitment (Figure 9): 1) the relationship passes through the origin (i.e. when there is no parental stock there is no recruitment), 2) the number of recruits is not close to zero at higher levels of the stock (i.e., high levels of the stock never completely inhibit reproduction), 3) recruitment per spawner decreases with parental stock size (i.e., the number of recruits eventually reaches an asymptote or the relationship shows overcompensation), 4) recruitment exceeds parental stock over some range of the possible parental stocks (i.e., the abundance of recruits can exceed the abundance of associated spawners), 5) the number of recruits is highly variable, and in general as stock increases so does the variability in the number of recruits. The last pattern holds for Coho, Pink and Chum Salmon (Figure 9B, Figure 9C, Figure 9D, Figure 9E), but it does not hold for Chinook Salmon (Figure 9A). This may be why we were able to fit models with multiplicative errors for the three first species, whereas we had to fit models with additive errors for Chinook Salmon.

The highest values of observed recruitment of Chinook Salmon were observed at intermediate levels of the parental stock (Figure 9A). This may suggest that Chinook Salmon recruitment shows compensation, but there were only two observations of very high recruitment (> 200,000 recruits), and therefore the modelled relationships did not reflect compensation, i.e., there was no evidence of reduced recruitment at higher spawner abundance in Chinook Salmon. The three models fitted the data almost equally well (see similar values of log likelihood in Table 17). Thus, given that the density-independent model requires only one parameter, this was the most parsimonious model for Chinook Salmon. This may indicate that the stock has not reached levels high enough to produce density dependence.

The variability in the abundance of Coho Salmon recruits increased with parental stock size (Figure 9B). The empirical support for the density-dependent models was much higher than the support for the density-independent models (evidence ratio of density independent model: 25.8, Table 17). Between the density-dependent models, the Beverton-Holt had more empirical support than the Ricker model, although the difference in performance of those two models was small. Thus, both models may be valid descriptions of the average relationship between stock and recruitment of Coho Salmon. The close alignment of the two curves in Figure 9B indicates that the choice of either curve will have limited effect on the results, although this will be re-evaluated in Year 10 when additional data are available.

The number of Pink Salmon recruits relative to spawner abundance was highly variable at moderate to high stock sizes (even-year: Figure 9C and odd-year: Figure 9D). Most observations were recorded at low stock levels, and relatively few observations at high stock levels. The density-dependent models performed much better than the density-independent models (evidence ratio of density-independent model for even-year Pink Salmon: 491.85, evidence ratio of density-independent model for odd-year Pink Salmon: 62.41, Table 17). Some high values of recruits nonetheless corresponded to high levels of spawners (Figure 9). Of the two density-dependent models, the Beverton-Holt model fit the data better (see higher log likelihood values in Table 17), possibly because of the strong overcompensation (i.e., underestimates of recruitment at very high level of parental stock) estimated by the Ricker model.

The abundance of Chum Salmon recruits was highly variable at all values of stock size (Figure 9E). Most observations were recorded at relatively low stock sizes (stock < 500 fish). Recruitment observed at higher stock sizes was relatively low (<50,000 fish), which may indicate that the dynamics of this stock are compensatory – this may be the underlying reason why we were not able to fit a Beverton-Holt model to these data. Consequently, the Ricker model had more empirical support than the density-independent model (evidence ratio: 12.1, Table 17).

Figure 9. Stock recruitment relationships for A) Chinook Salmon, B) Coho Salmon, C) Pink Salmon Even Years, D) Pink Salmon Odd Years, and E) Chum Salmon in the Quinsam River.

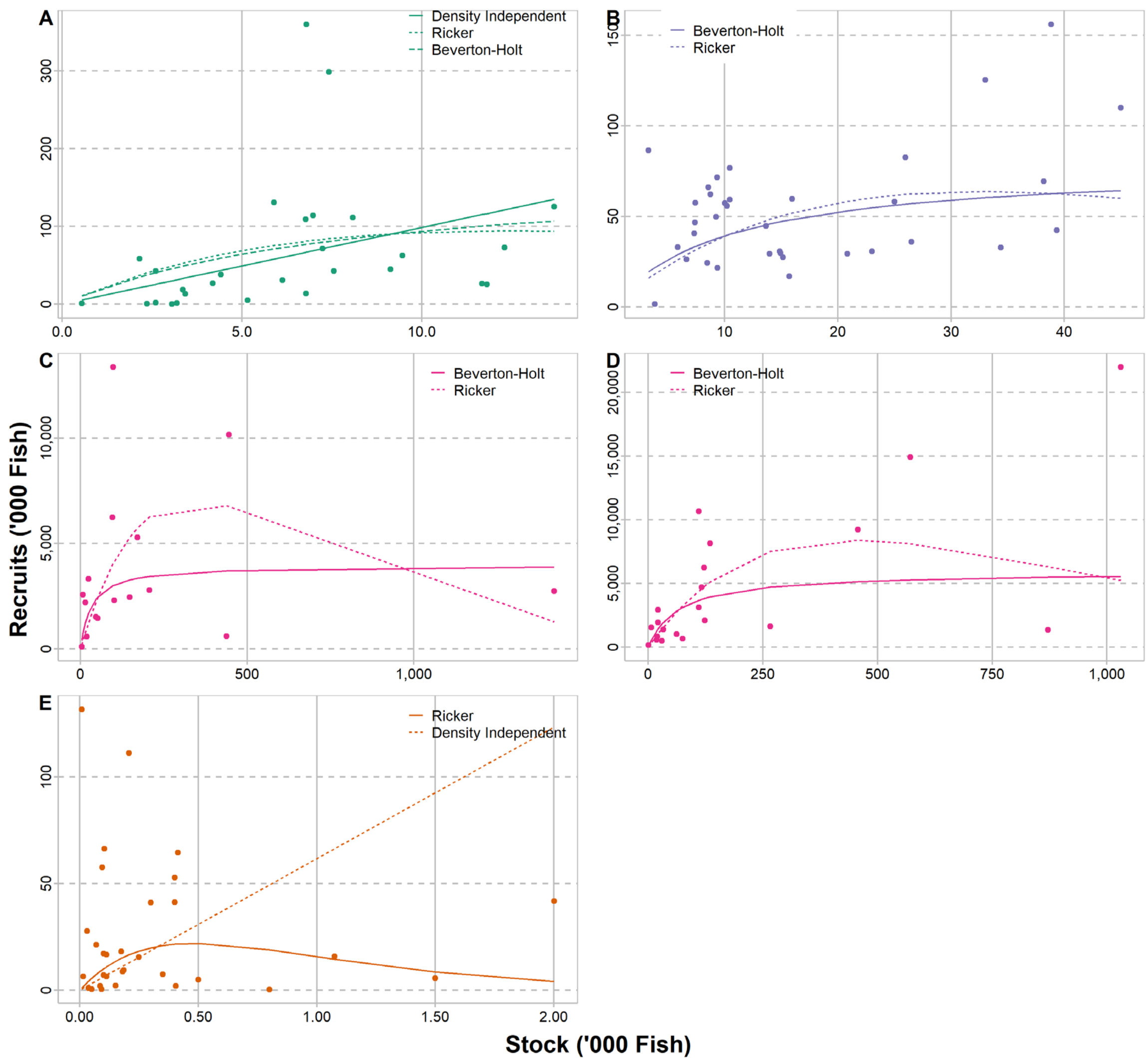


Table 17. Model selection statistics for stock-recruitment models for four Pacific Salmon species in the Quinsam River (ΔAIC: Change in Akaike Information Criterion). Models are ranked by ΔAIC scores. The model with the lowest ΔAIC is the best-performing model, based on this pre-defined evaluation criterion.

Species	Sample Size	Model Formulation	Parameters	LogLikelihood	ΔAIC	Evidence Ratio
Chinook	28	Density Independent	1	-355.9	0.00	1.00
		Ricker	2	-355.0	0.14	1.07
		Beverton-Holt	2	-355.2	0.57	1.33
Coho	35	Beverton-Holt	2	-37.8	0.00	1.00
		Ricker	2	-38.4	1.24	1.86
		Density Independent	1	-42.0	6.50	25.82
Pink Even Years	16	Beverton-Holt	2	-21.0	0.00	1.00
		Ricker	2	-22.9	3.69	6.33
		Density Independent	1	-28.2	12.40	491.85
Pink Odd Years	21	Beverton-Holt	2	-27.8	0.00	1.00
		Ricker	2	-29.2	2.79	4.03
		Density Independent	1	-32.9	8.27	62.41
Chum	31	Ricker	2	-62.2	0.00	1.00
		Density Independent	1	-65.7	4.99	12.10

3.2. Water Quality

3.2.1. QA/QC

All laboratory analyses in Year 7 were conducted within the recommended hold times (see Table 17 of Appendix A), with the exception of all pH values. All pH samples from QUN-WQ exceeded the recommended hold time of 0.25 hours, as occurred in all previous years and is inevitable given the sampling location. Both laboratory and field data for pH are presented in the following sections.

Clark (2013) and RISC (2003) recommend that results for duplicate samples should have relative percent difference or relative standard error values of 20% or less (provided that the concentrations are greater than five times higher than the MDL), otherwise it can indicate a potential issue with the sample. Contamination is suspected when the relative variability between duplicates exceeds 50% (Clark 2013).

In 2020, considering only parameters with concentrations five times higher than the MDL, one duplicate turbidity sample collected on August 10, 2020, had values with > 20% relative standard error (20.2%); however, no affect on data quality is anticipated. One field and one trip blank were collected in 2020. Values for all parameters were below the respective MDLs for both blanks. Values of pH were slightly higher in the field blank (5.42) than the travel blank (5.38).

3.2.2. Field Measurements

The Year 7 *in situ* and laboratory water chemistry results for the Quinsam River at QUN-WQ are summarized in Table 18 (general variables measured *in situ*), Table 19 (dissolved oxygen (DO) measured *in situ*), Table 20 (general variables measured at ALS laboratories), and Table 21 (low level nutrients measured at ALS laboratories). Combined results from Years 1 to 7 (2014 to 2020) of water quality monitoring are tabulated in Section 2 of Appendix A.

Alkalinity

Alkalinity (as $CaCO_3$) measured at ALS laboratories ranged from 24.6 mg/L (May) to 41.4 mg/L (October; Table 20) in 2020, similar to previous years. Alkalinity concentrations were consistently greater than 20 mg/L, indicating that the Quinsam River has low sensitivity to acidic inputs (RISC 1997b).

pH

pH values measured in the laboratory in Year 7 ranged from 7.46 to 7.76, while *in situ* pH ranged from 7.03 to 7.56 (Table 20 and Table 18, respectively). Natural fresh waters have a pH range from 4 to 10, BC lakes tend to have a pH ≥ 7.0, and coastal streams commonly have pH values of 5.5 to 6.5 (RISC 1997b). The pH measured *in situ* are expected to be more accurate than the laboratory pH, given that the pH measured in the laboratory samples exceeded the recommended hold time.

Specific Conductivity and Total Dissolved Solids

In situ specific conductivity (conductivity normalized to 25°C) measured in Year 7 ranged from 79.0 µS/cm (May) to 164.0 µS/cm (August; Table 18). It should be noted that during *in situ* sampling on September 10, 2020, the YSI meter was not functioning properly and was displaying unusually high values for multiple parameters (e.g., specific conductivity, DO); therefore, these values have been removed because they were considered anomalous. Laboratory values for conductivity in Year 7 ranged from 78.0 µS/cm (May) to 157.0 µS/cm (July; Table 20), similar to previous years. Coastal BC streams generally have specific conductivity of ~100 µS/cm (RISC 1997b). Most specific conductivity values in the Quinsam River were higher than typical levels in coastal streams. This may reflect the influence of primary productivity in the two lakes upstream of the monitoring site. Alternatively, high values of specific conductivity measured in the past have previously been linked with coal mining activities in the watershed (Redenbach 1990, cited in Burt 2003).

Total dissolved solids measured in the laboratory for the Quinsam River ranged from 54 mg/L (May) to 102 mg/L (July; Table 20) in Year 7.

Turbidity and Total Suspended Solids (TSS)

Turbidity in the Quinsam River at QUN-WQ was low in all seven monitoring years, indicating high water clarity (values in Year 7 ranged from 0.23 NTU to 0.98 NTU; Table 20). Similarly, TSS concentrations in Year 7 were low and consistent with previous years, with values generally ranging from below the MDL of 1.0 mg/L to slightly above this MDL (1.7 mg/L).

Dissolved Oxygen

Concentrations and saturation (%) of DO in the Quinsam River were highest in May 2020, when average concentrations were 11.50 mg/L. During June, July, August, and October 2020 sampling, DO measurements were lower and the average DO concentration did not meet the more conservative provincial WQG-AL (DO instantaneous minimum of 9 mg/L) for the protection of buried embryos/alevins (Table 19; MOE 1997). The measurement in June (average of 8.61 mg/L on June 8, 2020; Table 19) indicates that the 9 mg/L WQG-AL was not achieved during part of the incubation period for resident Rainbow Trout and steelhead, which spans from February 16 to June 15 (see Table 15 of Appendix A for periodicity information). The October measurement (average of 8.59 mg/L on October 8, 2020; Table 19) indicates that the 9 mg/L WQG-AL was not achieved during part of the incubation period for Pink Salmon, which spans from September 16 to April 7. DO concentrations below the most conservative provincial WQG-AL have routinely been measured in previous years (see Table 8 of Appendix A).

All samples met the WQG-AL for life stages other than buried embryo/alevin (DO instantaneous minimum of 5 mg/L). In BC, surface waters generally exhibit DO concentrations greater than 10 mg/L and are close to equilibrium with the atmosphere (i.e., ~100% saturation; RISC 1997b).

Total Gas Pressure (TGP)

Monitoring TGP was discontinued in Year 2 following evaluation of results in Year 1, and the limited potential of the Quinsam River Diversion facility to cause elevated TGP. Results from TGP monitoring in Year 1 are presented in Appendix A.

Nitrogen

Total ammonia concentrations in the Quinsam River at QUN-WQ were less than the detection limit of 5.0 μg N/L during five of the six sampling events in Year 7 (Table 21). During the October sampling event, total ammonia concentrations were detectable in both duplicates (average of 15.2 μg N/L). All measurements were well below the WQG-AL. Ammonia is usually present at low concentrations (<100 μg N/L) in waters not affected by waste discharges (Nordin and Pommen 2009).

Nitrite concentrations were below the detection limit of 1.0 μg N/L during sampling in Year 7 (Table 21). Nitrite is an unstable intermediate ion serving as an indicator of recent contamination from sewage and/or agricultural runoff; levels are typically <1.0 μg N/L (RISC 1997b).

Nitrate concentrations were low and ranged from 7.1 μg N/L (May) to 40.1 μg N/L (October) during Year 7, similar to previous years (Table 21). In oligotrophic lakes and streams, nitrate concentrations are usually lower than 100 μg N/L (Nordin and Pommen 2009).

Phosphorus

Orthophosphate concentrations were below the detection limit of 1.0 μg P/L during five of the six sampling events in Year 7 (Table 21). During the September sampling event, orthophosphate concentrations were detectable in both duplicates (average of 1.6 μg P/L). Low orthophosphate concentrations are typical of coastal BC streams, which generally have orthophosphate concentrations <1.0 μg P/L (Slaney and Ward 1993; Ashley and Slaney 1997).

Total phosphorus concentrations over the Year 7 sampling period were low, similar to previous years, ranging from below MDL (<2.0 μg/L) to 7.4 μg/L (Table 21).

Table 18. Quinsam River (QUN-WQ) general water quality variables measured *in situ* during Year 7 (2020).

Year	Date	Air Temperature °C				Water Temperature °C				Conductivity µS/cm				Specific Conductivity µS/cm				pH pH units			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2020	11-May	10	10	10	0	10.1	10.1	10.1	0.0	56.5	56.5	56.5	0.0	79.0	79.0	79.0	0.0	7.09	7.09	7.09	0.00
	08-Jun	9	9	9	0	12.5	12.5	12.5	0.0	97.6	97.5	97.6	0.1	128.0	128.0	128.0	0.1	7.04	7.03	7.05	0.01
	07-Jul	14	14	14	0	16.7	16.7	16.7	0.0	131.0	131.0	131.0	0.0	155.0	155.0	155.0	0.0	7.43	7.42	7.44	0.01
	10-Aug	16	16	16	0	18.8	18.8	18.8	0.0	145.0	145.0	145.0	0.0	164.0	164.0	164.0	0.1	7.55	7.55	7.56	0.01
	10-Sep	26	26	26	0	17.8	17.8	17.8	0.0	-	-	-	-	-	-	-	-	7.27	7.27	7.27	0.00
	08-Oct	13	13	13	0	14.8	14.8	14.8	0.0	114.0	114.0	114.0	0.0	143.0	143.0	143.0	0.1	7.44	7.44	7.44	0.00

[1] Average of three replicates (n=3) on each date unless otherwise indicated.

Black dashes (-) indicate no data were collected.

Red dashes (-) indicate values were removed because they were considered anomalous.

Table 19. Quinsam River (QUN-WQ) dissolved gases measured *in situ* during Year 7 (2020).

Year	Date	Oxygen Dissolved %				Oxygen Dissolved mg/L			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2020	11-May	102.0	102.0	103.0	0.3	11.50	11.50	11.60	0.02
	08-Jun	81.1	79.4	83.5	2.1	8.61	8.45	8.86	0.22
	07-Jul	86.0	85.9	86.1	0.1	8.36	8.35	8.37	0.01
	10-Aug	88.2	88.0	88.4	0.2	8.22	8.20	8.23	0.02
	10-Sep	-	-	-	-	-	-	-	-
	08-Oct	85.6	85.0	86.4	0.7	8.59	8.52	8.65	0.07

[1] Average of three replicates (n=3) on each date unless otherwise indicated.

Blue shading indicates that the more conservative provincial guideline (DO instantaneous minimum of 9.0 mg/L) for the protection of aquatic life was not met.

Red dashes (-) indicate values were removed because they were considered anomalous.

Table 20. Quinsam River (QUN-WQ) general water quality variables measured at ALS laboratories during Year 7 (2020).

Year	Date	Alkalinity, Total (as $CaCO_3$) mg/L				Conductivity µS/cm				Total Dissolved Solids mg/L				Total Suspended Solids mg/L				Turbidity NTU				pH pH units			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2020	11-May	24.8	24.6	25.0	0.3	78.5	78.0	78.9	0.6	57	54	59	4	<1	<1	<1	0.0	0.58	0.56	0.59	0.02	7.47	7.46	7.48	0.01
	08-Jun	33.4	33.1	33.7	0.4	124.0	124.0	124.0	0.0	82	81	83	1	<1	<1	<1	0.0	0.46	0.46	0.46	0.00	7.63	7.62	7.63	0.01
	07-Jul	39.6	39.5	39.7	0.1	157.0	157.0	157.0	0.0	96	90	102	8	<1.1	<1	1.1	0.1	0.51	0.47	0.55	0.06	7.59	7.58	7.59	0.01
	10-Aug	38.6	38.6	38.6	0.0	152.0	152.0	152.0	0.0	85	79	91	8	<1.4	<1	1.7	0.5	0.89	0.80	0.98	0.13	7.76	7.76	7.76	0.00
	10-Sep	39.1	39.1	39.1	0.0	146.0	145.0	146.0	1.0	91	90	92	1	<1	<1	<1	0.0	0.43	0.39	0.47	0.06	7.73	7.71	7.75	0.03
	08-Oct	41.0	40.5	41.4	0.6	143.0	143.0	143.0	0.0	96	95	96	1	<1	<1	<1	0.0	0.25	0.23	0.26	0.02	7.74	7.74	7.74	0.00

[1] Average of two duplicates (n=2) on each date unless otherwise indicated.

Parameters that have a concentration below the detection limit are assumed to have a concentration equal to the detection limit for calculation purposes.

Table 21. Quinsam River (QUN-WQ) nutrient concentrations measured at ALS laboratories during Year 7 (2020).

Year	Date	Ammonia, Total (as N) µg/L				Dissolved Orthophosphate (as P) µg/L				Nitrate (as N) µg/L				Nitrite (as N) µg/L				Total Phosphorus (P) µg/L			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2020	11-May	<5	<5	<5	0	<1	<1	<1	0	7.3	7.1	7.4	0.2	<1	<1	<1	0	<2.1	<2	2.2	0.1
	08-Jun	<5	<5	<5	0	<1	<1	<1	0	11.7	11.5	11.9	0.3	<1	<1	<1	0	7.2	7.0	7.4	0.3
	07-Jul	<5	<5	<5	0	<1	<1	<1	0	15.1	15.0	15.2	0.1	<1	<1	<1	0	<2.4	<2	2.8	0.6
	10-Aug	<5	<5	<5	0	<1	<1	<1	0	17.7	17.4	18.0	0.4	<1	<1	<1	0	5	4.8	5.2	0.3
	10-Sep	<5	<5	<5	0	1.6	1.1	2.1	1	17.0	16.5	17.4	0.6	<1	<1	<1	0	<2	<2	<2	0
	08-Oct	15.2	8.7	21.7	9.2	<1	<1	<1	0	39.8	39.4	40.1	0.5	<1	<1	<1	0	4.0	3.6	4.3	0.5

[1] Average of two duplicates (n=2) on each date unless otherwise indicated.

Parameters that have a concentration below the detection limit are assumed to have a concentration equal to the detection limit for calculation purposes.

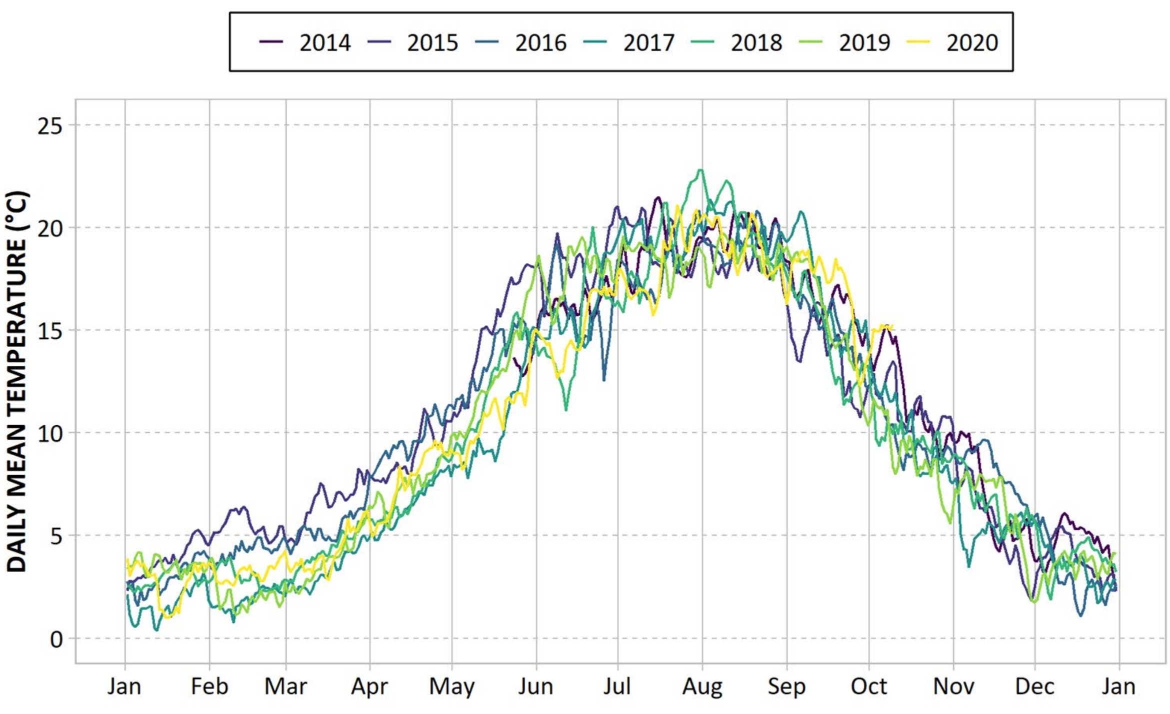
3.2.3. Water and Air Temperature Monitoring

Summary of Water Temperature Records

Figure 10 shows the daily average water temperatures at QUN-WQ from May 2014 to October 2020. In 2020 (January to September), monthly average water temperatures ranged between 2.7°C (January) and 18.8°C (August; Table 11 of Appendix A).

The water temperature records for the Quinsam River show occurrences of warm water temperatures from a fisheries biology perspective, with Year 7 data consistent with previous years. In 2020, there were 51 days (18% of record) with daily mean temperatures above 18°C, and 16 days (6% of record) with daily mean temperatures above 20°C. Over the period of record between 2014 and 2019, there were 52 to 77 days per year (14% to 21%) with daily mean temperatures above 18°C, and 0 to 30 days per year (0% to 8%) with daily mean temperatures above 20°C (Table 12 of Appendix A). There was one day in Year 7 (2020) with mean water temperature <1ºC; the only other year this occurred was in 2017 (7 days).

Figure 10. Daily mean water temperatures in the Quinsam River (QUN-WQ) between May 2014 and October 2020.



Rates of Change

Statistics relating to rates of change of water temperature at QUN-WQ are summarized in Appendix A. For the period of record, the hourly rates of temperature change at QUN-WQ were between -0.2°C/hr and +0.2°C/hr for at least 90% of the time (based on the 5th and 95th percentiles) and were between -0.3°C/hr and +0.4°C/hr for at least 98% of the time (based on the 1st and 99th percentiles).

For the period of record, the maximum rate of temperature increase was +1.2°C/hr, and the maximum rate of temperature decrease was -1.9°C/hr (Table 13 of Appendix A). Both these maximum values occurred prior to Year 7 (Figure 1 of Appendix A). Rates of temperature change with magnitudes >1°C/hr occurred for 0.019% of the records. Based on our experience on other streams in BC, it is normal for hourly rates of water temperature change to exceed ±1°C for a small percentage of data points.

Growing Season and Accumulated Thermal Units

The length of the growing season and accumulated thermal units (or degree days) are important indicators of the productivity of aquatic systems. As explained in Table 11, the growing season was assumed to begin when the weekly average water temperature exceeded and remained above 7°C, and to end when the weekly average temperature dropped below 7°C. As described in Section 2.2.2.2, growing season temperature thresholds for the start and end of the season were revised in Year 7 and data for previous years were updated to reflect this change.

The growing season at QUN-WQ was determined for 2015 to 2019 (Years 2 to 6), which are the study years for which complete annual records exist (Table 14 of Appendix A). The most recent growing season for which data are available was 2019 (Year 6), for which the growing season commenced on April 11th, ended on October 27th, covering a period of 200 days, and accumulating 2,961 degree days. This was shorter than the growing season length calculated for Year 2 (232 days), Year 3 (240 days) and Year 5 (206 days), but longer than for Year 4 (197 days). Growing season statistics for the 2020 growing season will be presented in the Year 8 Annual Report when all 2020 data are available.

Mean Weekly Maximum Water Temperatures

Fish species of primary interest for JHTMON-8 in the Quinsam River are steelhead, Coho Salmon and Chinook Salmon, although Pink Salmon are also particularly important to fishery managers. Steelhead and Coho Salmon are present both upstream and downstream of QUN-WQ, although falls and cascades downstream of Lower Quinsam Lake are complete barriers to Chinook Salmon and Pink Salmon (Burt 2003). Thus, results for the latter two species should be interpreted with caution.

The MWMxT data for 2014 through 2020 are compared to optimum temperature ranges for Chinook Salmon, Coho Salmon, Pink Salmon, and steelhead in Figure 11, Figure 12, Figure 13, and Figure 14, respectively. A precise synthesis of MWMxT data is presented in Table 15 of Appendix A.

Specifically, for each life stage, Table 15 of Appendix A shows the percentage of MWMxT data that are above, within, and below the optimum ranges for fish life stages during baseline monitoring. The percentages of MWMxT data above and below the optimum ranges by more than 1°C are also shown. Comparisons to the provincial WQG-AL are not made when records are ≤50% complete for the period of interest (Table 15 of Appendix A). In addition, if the water temperature records are only slightly >50% complete for a particular species/life stage, comparisons to the provincial WQG-AL should be interpreted with caution. In Year 7, data were downloaded on October 8, 2020, prior to the end of the rearing period for stream rearing species or life stages.

Considering all years and all species/life stages, MWMxT in the Quinsam River exceeded optimum ranges by more than 1°C for an average 17.2% of the time, and were below optimum ranges by more than 1ºC for an average of 28.3% of the time (Table 15 of Appendix A).

For Chinook Salmon (Figure 11), temperatures were within optimum ranges during the migration stage for all years (2014 to 2019). Temperatures for spawning were mostly within the optimum range (57.4% to 100% of the time) with instances where ranges were exceeded by more than 1ºC only occurring in 2014, 2015 and 2019. Temperatures during incubation were cooler than the optimum range at times during all years, particularly in 2016, when 52.3% of values exceeded the lower bound by more than 1ºC. Water temperatures were outside the optimum range during most of the Chinook Salmon rearing period (temperatures were within the optimum range for 8.6% to 36.5% of the time). In Year 7 (2020), 28.5% of values were below the optimum rearing range and 23.4% of values above the optimum rearing range.

For Coho Salmon (Figure 12), temperatures were typically below the upper bound of the optimum ranges for migration, spawning, and incubation stages (except migration in 2014 and 2019, where 6.5% and 0.9% of the temperatures, respectively, were > 1°C higher than the upper bound). Water temperatures during the rearing period were highly variable, with the majority of values outside the optimum range (both above and below) for all years. In Year 7 (2020), water temperatures during the Coho Salmon rearing period were below the lower bound (35.9%) more often than above the upper bound (33.8%) of the optimum temperature range, although the record is only 77% complete as the data were downloaded on October 8, 2020.

For Pink Salmon (Figure 13), the analysis indicates that for all years except Year 2 (2015), the majority of MWMxT values were above the upper bound for migration and spawning, with some years exceeding the upper bound by more than 1ºC for the majority of the time (e.g., up to 83.3% of the spawning period in 2014). In Year 7 (2020), MWMxT values were above the upper bound by more than 1 ºC for migration (82.4%) and spawning (100%) for a higher percentage of time than previous years, although both of these periods were not fully completed when the data were downloaded on October 8, 2020. During the Pink Salmon incubation period, water temperatures were within optimum ranges for the majority of time, except 2016 when 42.6% of values were within the optimum range.

For steelhead (Figure 14), MWMxT were rarely (0% to 22.3% of the records) within the optimum ranges for any life stage. Most notably, water temperatures during the spawning stage between 2015 and 2020 were below the optimum range by more than 1°C for 75.0% to 100% of the time. In 2020, water temperatures were within the optimum bounds for 0% of the spawning stage, 14.9% of the incubation stage, and 9.6% of the rearing stage (incomplete at the time of data retrieval).

Note that the WQG-AL temperature ranges for steelhead life stages are based on those for Rainbow Trout (Oliver and Fidler 2001) and are not specific to fish with an anadromous life history (i.e., steelhead). Data specific to steelhead (Carter 2005 and references therein) indicate that steelhead are adapted to tolerate MWMxT considerably lower than the optimum ranges presented in Figure 14 and Table 15 of Appendix A during spawning and incubation, although survival is likely to be affected by temperatures that exceed these ranges. For example, Carter (2005) cites WDOE (2002), which reports that the low end of the range of preferred spawning temperatures for steelhead is 4.4°C, rather than the MWMxT value of 10.0°C reported in Table 15 of Appendix A for Rainbow Trout. Thus, although the alternative values cited above may not be fully representative of steelhead populations on Vancouver Island, the occurrence of MWMxT in the Quinsam River that are below 10.0°C do not necessarily indicate poor conditions for spawning and incubation life stages of steelhead.

Figure 11. Mean weekly maximum temperatures (MWMxT) in the Quinsam River from 2014 to 2020 compared to optimum temperature ranges for Chinook Salmon. Periodicity information is from Burt (2003).

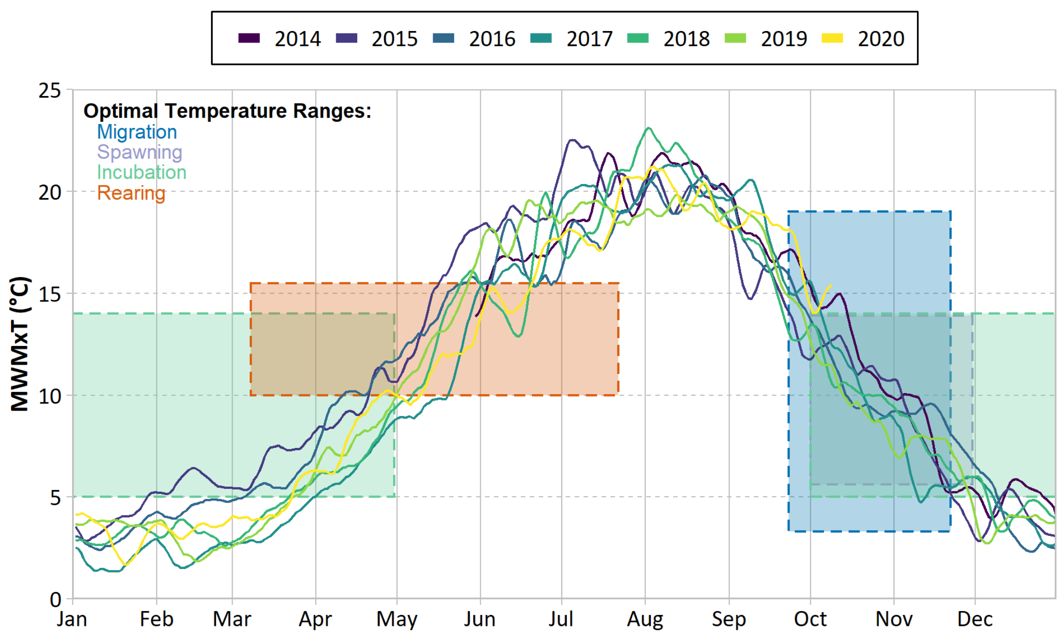


Figure 12. Mean weekly maximum temperatures (MWMxT) in the Quinsam River from 2014 to 2020 compared to optimum temperature ranges for Coho Salmon. Periodicity information is from Burt (2003).

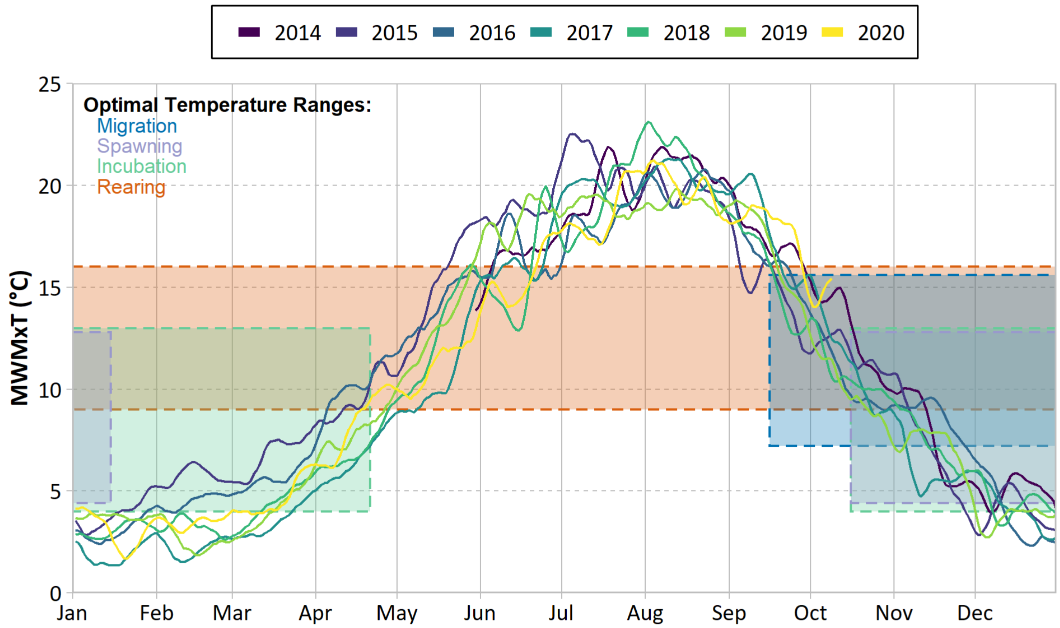


Figure 13. Mean weekly maximum temperatures (MWMxT) in the Quinsam River from 2014 to 2020 compared to optimum temperature ranges for Pink Salmon. Periodicity information is from Burt (2003).

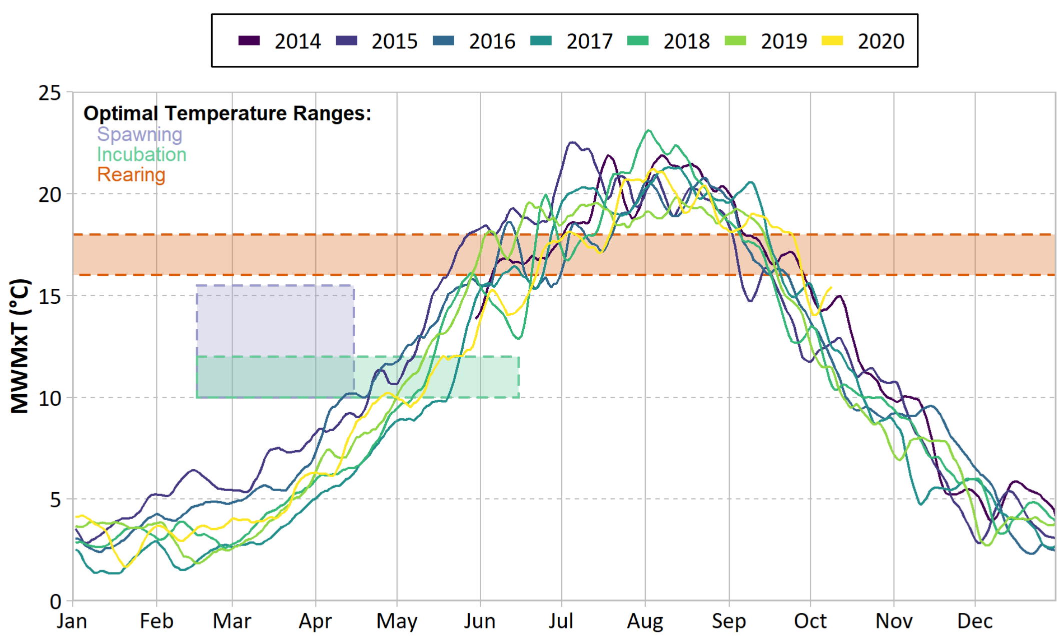
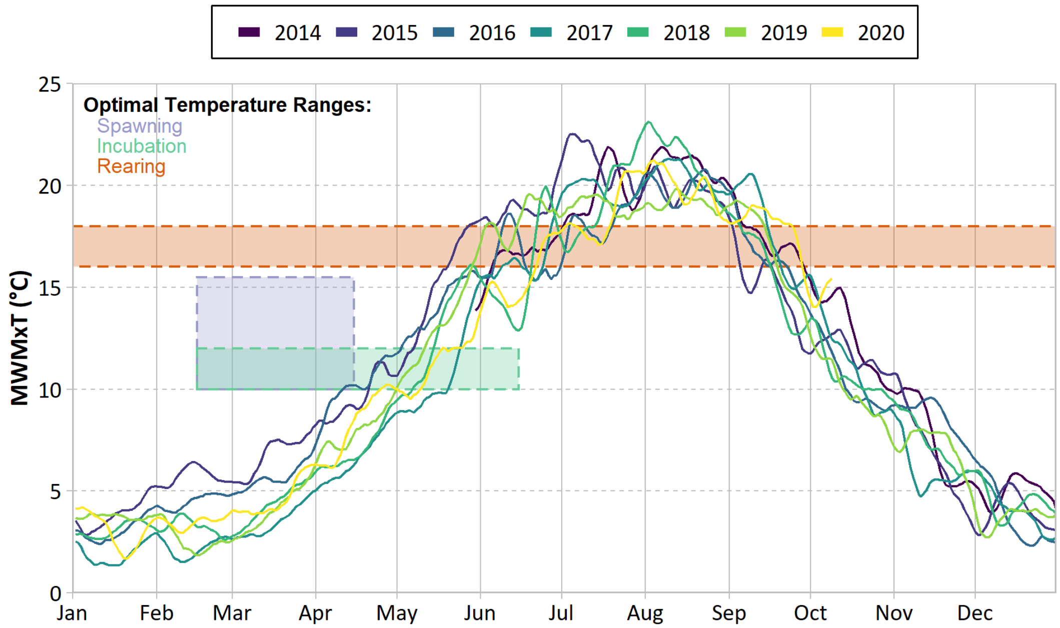


Figure 14. Mean weekly maximum temperatures (MWMxT) in the Quinsam River from 2014 to 2020 compared to optimum temperature ranges for steelhead. Periodicity information is from Burt (2003).



Air Temperature

Air temperature data are provided in Section 3 of Appendix A.

Figure 2 of Appendix A shows the daily average air temperature for the period of record from May 2014 to October 2020. The monthly average, minimum, and maximum air temperatures are shown in Table 16 of Appendix A. The mean monthly air temperature ranged from -2.2°C to 18.8°C during the period of record. The lowest air temperature measured during the monitoring period was -12.5ºC measured in February 2019, while the highest air temperature was 33.3°C in July 2018. The maximum monthly mean air temperature (18.8°C) was in July 2015. Mean monthly air temperatures during summer 2020 were generally lower than previous years of JHTMON-8; e.g., the mean monthly air temperature during July 2020 (16.5ºC) was lower than five of the previous years, while the mean monthly air temperature during August 2020 (15.9ºC) was lower than all previous years.

Air and water temperatures were highly correlated (Figure 3 of Appendix A). Daily mean water temperatures typically exceeded daily mean air temperatures, which likely partly reflected the influence of warming in lakes upstream.

3.3. Hydrology

Quality assured data collected by the Water Survey of Canada were available until the end of 2019 (Year 6). Hydrographs for 2014–2019 at sites on the Quinsam River are presented in Figure 15 and

Figure 16; hydrological metrics (Indicators of Hydrologic Alteration) for these years are presented in Table 22.

Flow measured in 2019 was within the range of previous years. For all years, discharge was low during the summer period, with minimum mean daily discharge of <1.0 m^3/s measured in the mainstem, downstream of the diversion facility (when it was not operating). It is also notable that maximum discharge was particularly high during the incubation periods for Pacific salmon species that emerged in 2015 and 2017, reflecting floods during December 2014 and November 2016.

Figure 15. Discharge measured on the Quinsam River upstream of Campbell River (Map 2) during 2014–2019.

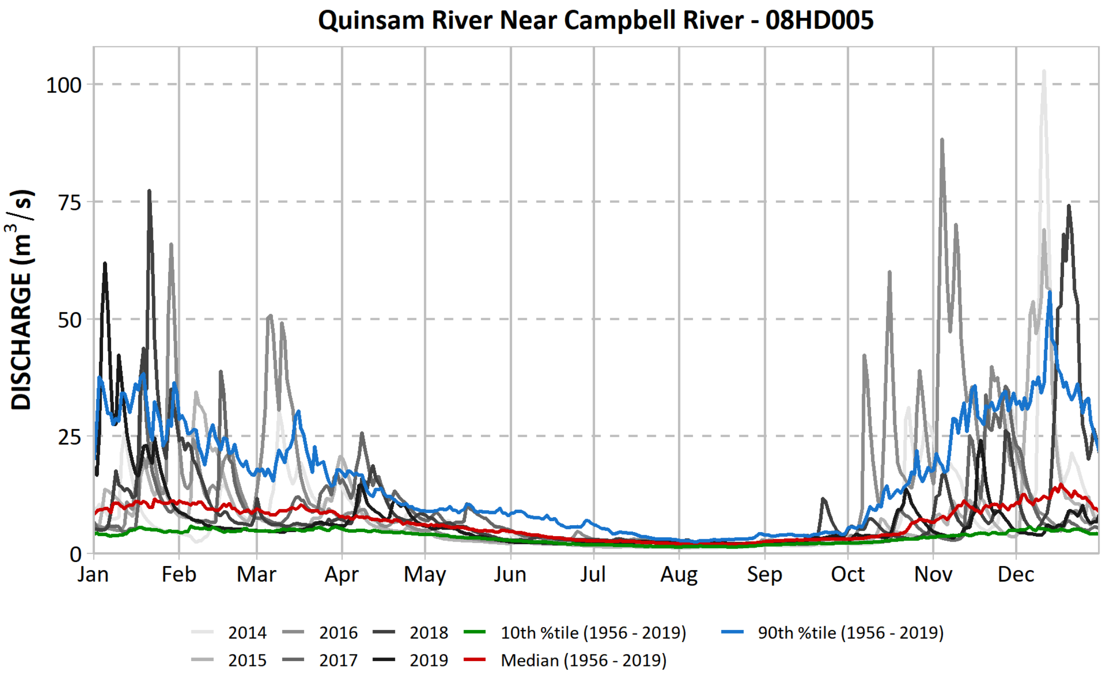


Figure 16. Discharge measured on the Quinsam River at Argonaut Bridge (Map 2) during 2014–2019.

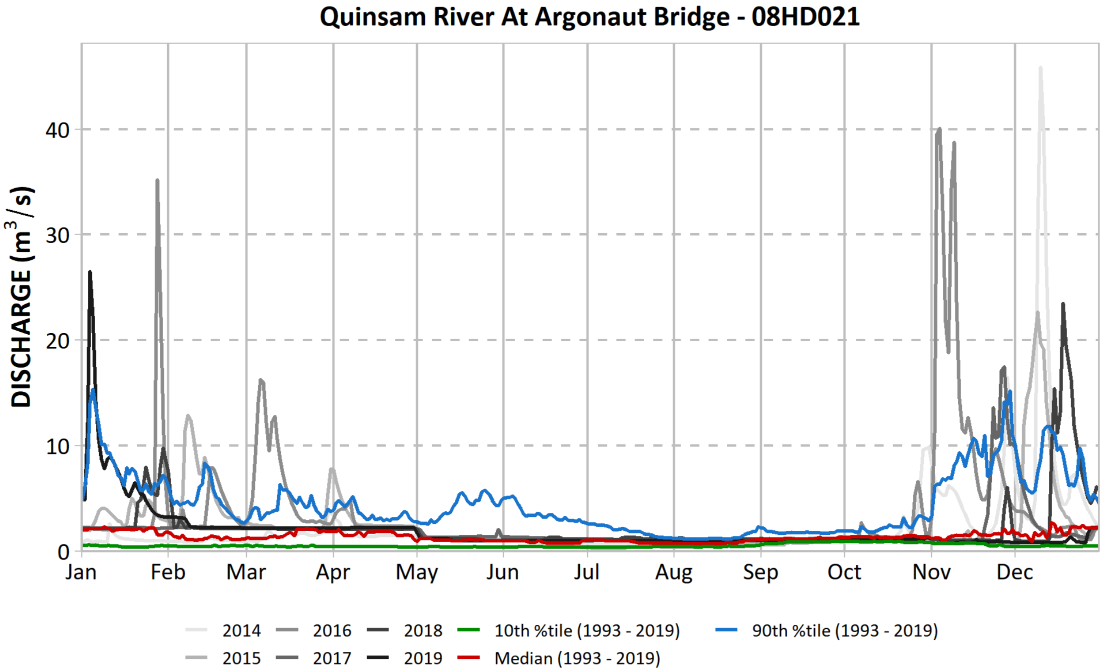


Table 22. Hydrological metrics calculated on the Quinsam River for 2014–2019. See Map 2 for hydrometric gauge locations.

Gauge	Year	Hydrological Metric (m³/s)						
		Minimum Mean Discharge (m³/s)			Maximum Discharge During Spawning and Incubation Periods[1]			
		1-Day Min.	3-Day Min.	30-Day Min.	Coho Salmon	Steelhead	Chinook Salmon	Pink Salmon
08HD021	2014	0.442	0.448	0.565	3.63	3.63	3.63	3.63
	2015	0.265	0.270	0.328	45.9	7.91	45.9	45.9
	2016	0.987	0.994	1.03	35.2	16.3	35.2	35.2
	2017	0.717	0.718	0.952	40.1	2.31	40.1	40.1
	2018	0.907	0.917	1.07	17.5	2.13	17.5	17.5
	2019	0.811	0.812	0.842	26.5	2.25	26.5	26.5
08HD005	2014	1.15	1.16	1.30	30.4	30.4	30.4	30.4
	2015	1.23	1.24	1.32	103	20.9	103	103
	2016	1.99	2.00	2.16	69.1	50.8	69.1	69.1
	2017	1.97	1.98	2.01	88.4	38.9	88.4	88.4
	2018	2.06	2.06	2.14	77.5	18.7	77.5	77.5
	2019	1.91	1.93	2.06	74.2	14.6	74.2	74.2

[1]For fall spawners, this metric was calculated based on the discharge between the start of spawning the previous year and fry emergence during the current year.

3.4. Invertebrate Drift

3.4.1. Quinsam River Invertebrate Drift

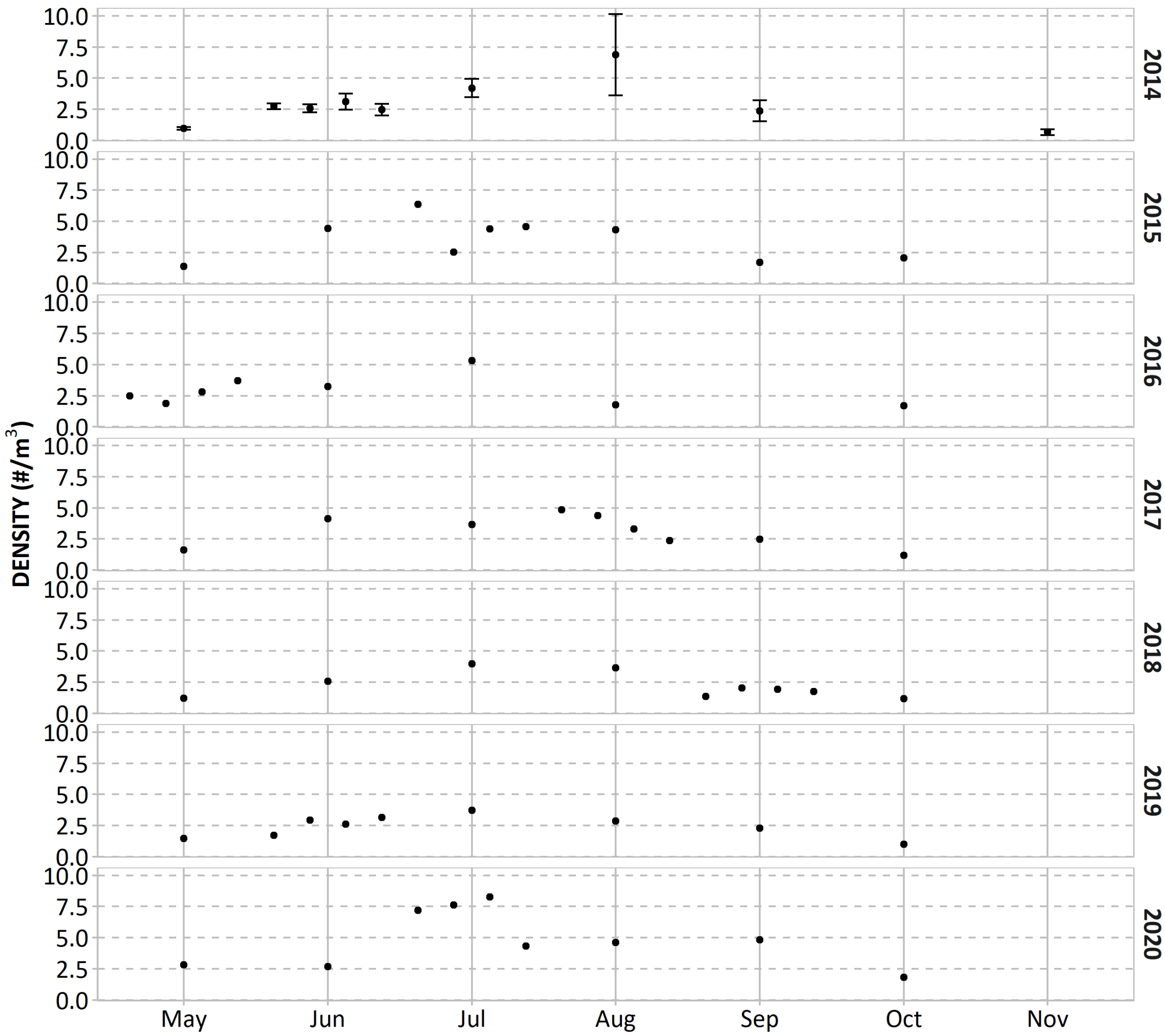
3.4.1.1. Overview

Results relating to invertebrate drift density (individuals/m^3) and biomass (mg/m^3) are provided in subsequent sections for the Quinsam River to provide indicators that could potentially be used to analyze drivers of changes in fish abundance to test H_05. Supplementary invertebrate drift results relating to Simpson's family-level diversity index (1-λ), richness (# families), CEFI are provided in Appendix B. Standard deviation values are provided for Year 1 (2014) data only, which is the only year when samples from all five drift nets were analyzed separately. All values except for the CEFI (for which only aquatic taxa are considered) were calculated based on results for all taxa (aquatic, semi-aquatic, and terrestrial).

3.4.1.2. Density

Invertebrate drift density in the Quinsam River was variable among sampling dates in Year 7 (Figure 17). Density reached a peak of 8.26 individuals/m^3 in July 2020, with lower values observed earlier and later in the growing season (e.g., 2.66 individuals/m^3 in June; 1.80 individuals/m^3 in October; Figure 17). Density measured at weekly intervals during July ranged from 4.32 - 8.26 individuals/m^3 (Figure 17). In Year 7, mean density ranged from 1.80 – 8.26 individuals/m^3, which is higher than the range of values observed in previous years (0.65 – 6.88 individuals/m^3; Figure 17).

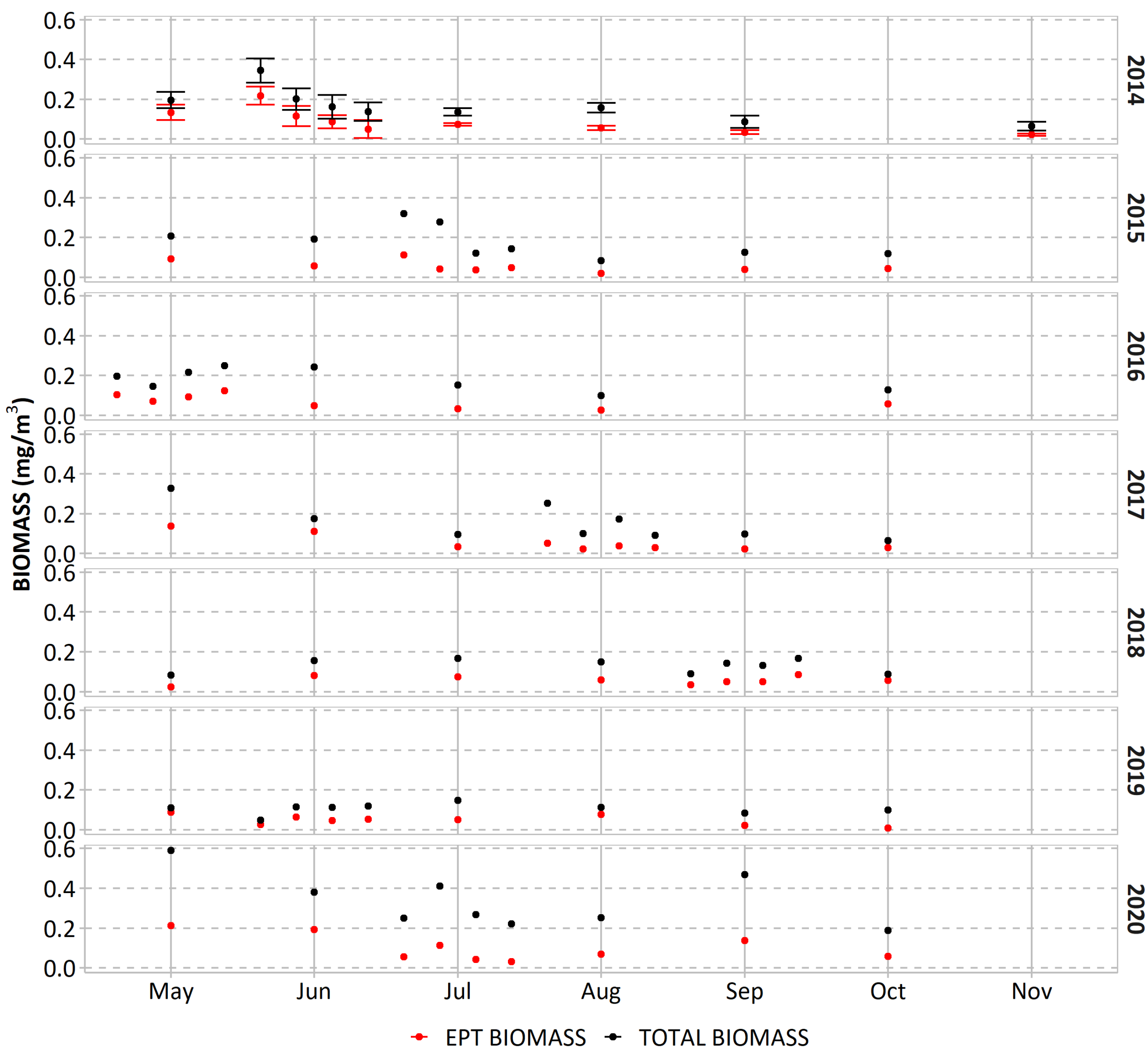
Figure 17. Drift invertebrate density (all taxa) in the Quinsam River, 2014 – 2020. Standard deviation (vertical bars) is provided for Year 1 (2014) only, which is the only year when samples from all five drift nets were analyzed separately.



3.4.1.3. Biomass

Total invertebrate drift biomass in the Quinsam River ranged from 0.19 – 0.59 mg/m^3 in Year 7, which is higher than observed in previous years (0.05 – 0.34 mg/m^3; Figure 18). Total biomass was variable throughout Year 7, with the annual maximum value of 0.59 mg/m^3 observed in May 2020, which was higher than maxima observed in previous years of JHTMON-8 (Figure 18). EPT biomass was also variable across sampling dates in Year 7 and there seemed to generally be a higher proportion of non-EPT taxa that contributed to total biomass in comparison to previous years (Figure 18).

Figure 18. Total drift invertebrate biomass (all taxa) and EPT biomass in the Quinsam River throughout 2014 – 2020. Standard deviation (vertical bars) is provided for Year 1 (2014) only, which is the only year when samples from all five drift nets were analyzed separately.



3.4.1.4. Top Five Families Contributing to Biomass

A summary of the top five families contributing to biomass of the invertebrate drift community in Year 7 is provided in Table 23. Note that, in some instances, a taxonomic level higher than family is listed (e.g., Ephemeroptera), as this was the lowest taxonomic level enumerated.

The invertebrate community was dominated (in terms of biomass) by true flies (most notably Chironomidae and Simuliidae) and mayflies (notably Baetidae). True fly families were the most dominant in Year 7, as these were the most dominant family on six of nine sampling dates and ranked second within the top five families contributing to biomass on two other sampling dates. Mayflies were also consistently present in the top five, with one or more mayfly families present on eight of nine sampling dates. The contribution to biomass of individual true fly families ranged from 3.7% to 33.6%, while individual mayfly families ranged from 9.0% to 15.0%.

Other taxa sometimes present in the top five included Caddisflies (Limnephilidae, Philopotamidae, and Hydropsychidae), true bugs (Gerridae), mites (Trombidiidae), beetles (Chrysomelidae and Staphylinidae), spiders (Araneae), bees (Apidae), bark lice (Psocodea), and butterflies/moths (Lepidoptera). It is notable that biomass was relatively evenly distributed among the dominant families in the May 2020 sample, which had the highest biomass measured to date (Section 3.4.1.3). This indicates that this high value reflected generally high biomass of multiple taxa present on that date, as opposed to an unusually high biomass of a single taxon, e.g., as might occur if the sampling period coincided with a period of unusually high emergence of a taxon (i.e., a hatch).

A summary of the top five families contributing to biomass across all JHTMON-8 years in the Quinsam River is provided in Table 24. These results show consistencies in the top five families across years, with Baetidae comprising the top family in five of seven years and present in all seven years along with two other families (Chironomidae and Simuliidae). In all years, these three families comprised 31.4–49.5% of the biomass. Four of the five dominant families in Year 7 were true flies, consistent with the observation described above that non-EPT taxa made a relatively high contribution to invertebrate biomass in Year 7. Ephemeroptera, Trichoptera, and Plecotera have been shown to be important invertebrate taxa for juvenile salmonids (Johnson and Ringler 1980, Rader 1997). Ephemeroptera and Trichoptera were, for the most part, prevalent in the top five families during each sampling date in Year 7 (2020) as well as across years; Plecoptera were only present in the top five families in 2015.

Table 23. Top five families contributing to invertebrate drift biomass (all taxa) in the Quinsam River in Year 7. Names in parentheses represent taxa higher than families in instances where family level classifications were unavailable.

QUN-IV	11-May-20	QUN-IV	8-Jun-20	QUN-IV	7-Jul-20	QUN-IV	14-Jul-20
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass
Limnephilidae	14.2	(Ephemeroptera)	15.0	Chironomidae	33.6	Chironomidae	24.1
Baetidae	11.4	Chironomidae	11.7	Apidae	15.4	Sciaridae	9.3
Trombidiidae	9.9	Limnephilidae	11.4	(Ephemeroptera)	10.0	Baetidae	7.7
Staphylinidae	9.3	Dolichopodidae	8.1	Simuliidae	9.6	(Ephemeroptera)	7.1
Bibionidae	8.1	Simuliidae	7.9	Baetidae	7.8	(Trichoptera)	7.1
Sum	53.0	Sum	54.1	Sum	76.4	Sum	55.3

Key	
True Flies	Bees
Mayflies	Barklice
Caddisflies	
True Bugs	
Butterflies/Moths	
Spiders	
Beetles	
Mites	

QUN-IV	21-Jul-20	QUN-IV	27-Jul-20	QUN-IV	10-Aug-20	QUN-IV	10-Sep-20	QUN-IV	8-Oct-20
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass
Chironomidae	29.3	Empididae	22.0	(Araneae1)	20.8	Simuliidae	16.8	Simuliidae	13.1
Sciaridae	21.4	Gerridae	16.2	Chironomidae	15.6	Empididae	15.7	(Ephemeroptera)	12.8
Baetidae	12.3	Chironomidae	12.5	Baetidae	10.8	Baetidae	14.3	(Araneae1)	11.4
Simuliidae	7.3	Sciaridae	10.7	Philopotamidae	7.9	Hydropsychidae	10.9	Baetidae	9.0
Chrysomelidae	5.8	(Psocodea)	6.0	Simuliidae	3.7	(Lepidoptera)	6.9	Chironomidae	9.0
Sum	76.0	Sum	67.4	Sum	58.8	Sum	64.6	Sum	55.4

Table 24. Annual top five families contributing to invertebrate drift biomass (all taxa) in the Quinsam River throughout Years 1 to 7. Names in parentheses represent taxa higher than families in instances where family level classifications were unavailable.

QUN-IV	2014	QUN-IV	2015	QUN-IV	2016	QUN-IV	2017
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass
Baetidae	20.2	Chironomidae	14.4	Baetidae	15.9	Baetidae	18.0
Limnephilidae	15.8	Simuliidae	13.2	Chironomidae	15.3	Chironomidae	12.0
Chironomidae	9.5	Baetidae	11.5	Simuliidae	12.0	Simuliidae	9.4
Simuliidae	7.5	Chrysomeloidea	6.7	Limnephilidae	5.8	Empididae	8.6
(Ephemeroptera)	5.8	(Plecoptera)	4.2	Cicadellidae	3.5	Bibionidae	5.7
Sum	58.8	Sum	50.0	Sum	52.5	Sum	53.8

QUN-IV	2018	QUN-IV	2019	QUN-IV	2020	Key
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	True Flies
						Mayflies
Baetidae	21.3	Baetidae	28.3	Chironomidae	14.8	Caddisflies
Simuliidae	12.6	Simuliidae	12.8	Baetidae	9.8	True Bugs
Chironomidae	12.1	Chironomidae	8.4	Simuliidae	6.8	Stoneflies
Hydropsychidae	6.0	Torrenticolidae	7.8	Sciaridae	6.0	Spiders
(Araneae)	3.8	Heptageniidae	3.1	Empididae	5.5	Beetles
Sum	55.9	Sum	60.4	Sum	43.0	Mites

3.4.2. Comparison of Kick Net and Drift Net Sampling Methods

Invertebrates collected using kick net sampling were almost exclusively aquatic taxa (99.6–100%) in the Quinsam River whereas drift sampling captured 49.8–79.3% aquatic invertebrates (based on biomass; Table 25). The kick net method involves holding the collection net completely under the stream surface for three minutes, so the greater dominance of aquatic taxa is expected. Drift nets are installed with the top of the net above the stream surface, so that any invertebrates suspended on the surface are collected, in addition to submerged invertebrates. These invertebrates are more likely to have entered the stream from terrestrial or semi-aquatic (riparian) habitats.

The contribution of individual families to invertebrate biomass differed between the two sampling methods (Table 26). In the Quinsam River, two groups (true flies and mayflies) accounted for most of the biomass in drift net samples and most of the top five families comprised these taxa on all dates, whereas a wider range of families were present during kick sampling, including Hydropsychidae (caddisflies), Gomphidae (dragonflies), Astacidae (crayfish), and Lumbricidae (earthworms). Overall, the taxa present in the kick net samples were more diverse within and among sampling dates than taxa present in drift net samples.

Table 25. Contribution of invertebrate taxa to total biomass by habitat type on the Quinsam River. Kick net data were not collected in 2014 and 2016.

Sample Date	Collection Method	Relative Contribution to Biomass (%)		
		Aquatic Taxa	Semi-Aquatic Taxa	Terrestrial Taxa
16-Sep-2015	Driftnet	75.0	19.2	5.8
	Kicknet	100.0	0.0	0.0
13-Sep-2017	Driftnet	64.5	15.7	19.8
	Kicknet	100.0	0.0	0.0
12-Sep-2018	Driftnet	64.2	24.9	10.9
	Kicknet	100.0	0.0	0.0
12-Sep-2019	Driftnet	79.3	2.3	18.4
	Kicknet	99.6	0.4	0.0
10-Sep-2020	Driftnet	49.8	28.2	22.0
	Kicknet	100.0	0.0	0.0

Table 26. **Top five families contributing to invertebrate biomass collected using drift nets and a kick net in the Quinsam River. Names in parentheses represent taxa higher than families in instances where family level classifications were unavailable.**

Date	Driftnet		Kicknet	
	Family	% of Biomass	Family	% of Biomass
16-Sep-2015	Simuliidae	39.0	Hydropsychidae	16.5
	Chironomidae	15.5	Tipulidae	14.5
	(Ephemeroptera)	13.7	(Trichoptera)	13.7
	Ameletidae	6.3	Chironomidae	7.3
	Sperchontidae	4.7	Lumbriculidae	5.9
13-Sep-2017	Chironomidae	25.4	Astacidae	26.5
	Simuliidae	17.5	Naididae	11.8
	Baetidae	11.3	Gomphidae	10.8
	Curculionidae	8.6	Elmidae	9.0
	Aphididae	6.2	Chironomidae	6.0
12-Sep-2018	Baetidae	21.1	Heptageniidae	33.6
	Psychodidae	20.7	Perlidae	17.9
	Simuliidae	17.9	Hydropsychidae	13.0
	Chironomidae	7.9	Tipulidae	8.8
	(Plecoptera)	7.5	Baetidae	7.9
12-Sep-2019	Chironomidae	22.0	Hydropsychidae	21.2
	Baetidae	19.5	Tipulidae	13.6
	Simuliidae	14.3	Lumbricidae	11.9
	Coccinellidae	8.1	Heptageniidae	11.3
	Aphididae	7.4	Chironomidae	10.3
10-Sep-2020	Simuliidae	16.8	Lumbriculidae	51.9
	Empididae	15.7	Tipulidae	14.4
	Baetidae	14.3	Heptageniidae	5.5
	Hydropsychidae	10.9	Leptophlebiidae	5.1
	(Lepidoptera)	6.9	Chironomidae	4.2

Key
True Bugs
Aquatic Worms
Mites
True Flies
Mayflies
Caddisflies
Crustaceans
Dragonflies
Stoneflies
Beetles
Earthworms
Butterflies/Moths

4. SUMMARY

4.1. JHTMON-8 Status

JHTMON-8 is ongoing and analysis to test the management hypotheses and address the management questions will be undertaken in Year 10 when data collection is complete. For each hypothesis, this section summarizes of the status of data collection to date and describes key results.

4.2. H_01: Annual population abundance does not vary with time (i.e., years) over the course of the Monitor

This hypothesis focuses on juvenile fish (BC Hydro 2018a). The JHTMON-8 results, and historical data compiled so far show considerable inter-annual variability in juvenile fish abundance, suggesting that this hypothesis will be rejected in Year 10. For example, Figure 7 shows that juvenile abundance of JHTMON-8 priority species has varied by at least a factor of four for juvenile Chinook Salmon, Coho Salmon and steelhead throughout the period of record. For the JHTMON-8 period to date (2014–2020), variability in annual outmigration data provided by DFO has been greatest for wild Chinook Salmon (~600 to ~360,000 fry) and lower for wild Coho Salmon (~22,000 to ~57,000 smolts) and steelhead (~3,000 to ~13,000 smolts) (Figure 6). A key result from Year 7 was the particularly high abundance of outmigrating juvenile Chinook Salmon recorded at the Quinsam Hatchery fence (~360,000), which was over three times higher than the maximum value previously recorded during JHTMON-8 (Figure 6), and the highest value recorded overall in the period of record (Figure 7). The abundance of spawners that correspond to this cohort (~6,793 in 2019) was moderate relative to the period of record (Figure 5), therefore suggesting that egg to fry survival of wild Chinook Salmon was unusually high for the cohort that outmigrated in Year 7.

4.3. H_02: Annual population abundance is not correlated with annual habitat availability as measured by Weighted Usable Area (WUA)

WUA (in m^2) provides an index of habitat availability calculated using relationships developed between flow and the area of different habitats, accounting for differences in habitat suitability across different flows (Lewis *et al.* 2004). In Year 5, we quantified WUA for different life stages of JHTMON-8 priority species (Abell *et al.* 2019). Results from Year 5 showed that variability in annual average spawning habitat WUA was similar among the three Pacific salmon species, with maximum differences among years of approximately 100% (i.e., approximately two-fold differences). Annual average WUA for steelhead life stages varied throughout the dataset, with variability highest for steelhead spawning WUA. Flow-habitat relationships have not been previously developed for Pacific salmon rearing habitat. This issue is only potentially applicable to Coho Salmon because the other two species spend limited time rearing in the river (Burt 2003). Accordingly, we plan to use steelhead fry rearing habitat WUA estimates as a proxy for juvenile Coho Salmon rearing habitat.

4.4. H_03: Annual population abundance is not correlated with water quality

H_03 focuses on juvenile fish. Year 7 water quality results were generally consistent with results for Year 1 through Year 6. Results from JHTMON-8 to date show that the Quinsam River is typical of streams in coastal BC watersheds with low nutrient concentrations (oligotrophic), near-neutral pH, and low turbidity during baseflow. Results show that measurements of some water quality variables were, at times, outside of the biologically optimum ranges for fish species present in the watershed. Specifically, water temperatures were recorded in the Quinsam River that exceeded WQG-AL temperature ranges for suitable salmonid rearing conditions. For example, MWMxT measured in Year 7 exceeded the upper limit of the optimum temperature ranges for the rearing life stage of all fish species (Section 3.2.3). The duration and magnitude of exceedances of the upper limit of the optimum temperature range for the rearing life stage were generally consistent with results from Years 1 to 6 (Table 15 of Appendix A). As observed in previous years, concentrations of DO less than the provincial WQG-AL for the protection of buried embryos/alevins (DO instantaneous minimum of 9 mg/L) were recorded in Year 7 during reported incubation periods (Burt 2003) for resident Rainbow Trout and steelhead. Measurements in Year 7 also indicated that DO concentrations were below the WQG-AL range for part of the Pink Salmon incubation period (Table 19). The DO concentrations measured in June, July, August, and October during Year 7 were only marginally (<10%) less than the WQG-AL (e.g., average value of 8.45 mg/L); this small difference limits the potential for the low DO concentrations to be a biological concern, although the potential for low DO concentrations to limit fish production will be considered in more detail during the final analysis in Year 10.

4.5. H_04: Annual population abundance is not correlated with the occurrence of flood events

As part of JHTMON-8, data collected by the Water Survey of Canada have been collated and analyzed to quantify hydrologic variability in the Quinsam River. Data collected for the first six years of JHTMON-8 show that the largest flood event occurred in December 2014, when flow at the mouth of the Quinsam River briefly peaked at just over 100 m^3/s (Figure 15). Particularly high flows also occurred in November 2016, when flow at the mouth of the Quinsam River reached approximately 85 m^3/s (Figure 15). For all years, discharge was low during the summer low-flow period, with minimum mean daily discharge of <1.0 m^3/s measured in the Quinsam River during each year in the summer (when the diversion facility was not operating).

4.6. H_05: Annual population abundance is not correlated with food availability as measured by aquatic invertebrate sampling

Invertebrate drift data have now been collected for seven growing seasons for the Quinsam River. There are no clear differences in invertebrate drift biomass among years, although data indicate that invertebrate drift biomass was higher in 2020 (Year 7) than in previous years, with a higher contribution to total biomass from non-EPT taxa in Year 7 than in previous years (Figure 18). Otherwise, invertebrate drift biomass generally tends to decline during the growing season, with highest values occurring at the beginning of the growing season (Figure 18).

These seasonal trends have potential implications for juvenile salmonid productivity, because invertebrates typically form the bulk of the diet of salmonids in rivers (Quinn 2005) and a change in invertebrate community structure can affect food quality (i.e., a decrease in the biomass of taxa preferred by salmonids), which could theoretically affect juvenile growth and abundance.

4.7. H_06: Annual smolt abundance is not correlated with the number of adult returns (Quinsam River)

We propose to test this hypothesis by constructing stock (spawner)-recruitment relationships to quantify the relationship between the abundance of adult fish and the subsequent recruitment of juvenile fish each year. This hypothesis will therefore be tested using juvenile and adult fish abundance data. This analysis will use the juvenile abundance data collected at the Quinsam Hatchery salmon counting fence and the adult escapement data collected by DFO. Compilation of the historical juvenile abundance dataset for the Quinsam River in Year 5 (Abell *et al.* 2019) provides the potential to substantially increase the duration of the dataset that can be analyzed to test this hypothesis, thereby increasing statistical power.

In Year 7, we started to develop and explore stock-recruitment relationships for priority species, thereby providing a valuable advancement of the study. Initial stock-recruitment relationships were consistent with general patterns expected for Pacific Salmon stock recruitment (Figure 9). For most species, there was some evidence that the abundance of recruits reached an asymptote ("plateau"), or the relationship showed overcompensation at high spawner abundance. However, this was not clearly the case for Chinook Salmon, for which there is lowest spawner abundance of the four species analyzed.

5. FUTURE TASKS

This section provides an overview of the planned approach to test each hypothesis, including how work undertaken in previous years will be used in the analysis. Additional tasks proposed for the remaining years of JHTMON-8 are summarized in Section 5.7 below.

5.1. H_01: Annual population abundance does not vary with time (i.e., years) over the course of the Monitor

In Year 10, variability in juvenile fish abundance will be analyzed by reviewing time series graphs and calculating summary statistics (e.g., standard deviation and percentile values). Where feasible, stock-recruitment relationships will be constructed and analyzed to isolate variability in juvenile fish abundance that is due to variability in freshwater survival, from variability due to fluctuations in the abundance of adult fish – this task was initiated in Year 7 and is discussed further in Section 4.7 in relation to H_06. Analysis in Year 10 will draw on work undertaken in Year 5 (Abell *et al.* 2019) to compile, digitize, and analyze juvenile fish outmigration data collected at the Quinsam Hatchery fence prior to JHTMON-8 (since the 1970s; Figure 7), which will substantially increase the statistical power of analysis to quantify variability in juvenile fish abundance in the Quinsam River. Further, analysis in Year 10 will draw on the outcomes of a review of capture efficiency estimates completed in Year 6

(Suzanne *et al*. 2020), which examined how to reduce uncertainty associated with the results of juvenile mark-recapture experiments conducted at the Quinsam Hatchery salmon counting fence.

5.2. *$H_0$2*: Annual population abundance is not correlated with annual habitat availability as measured by Weighted Usable Area (WUA)

The WUA analysis will be updated in Year 10 and used to test *$H_0$2*. We propose to test this hypothesis separately for each of the JHTMON-8 priority species. For Chinook Salmon and Coho Salmon, we propose to construct stock-recruitment relationships (discussed further in Section 4.7 below) and then test whether variability in WUA explains variability in the stock-recruitment relationships, which would indicate that variability in WUA affects juvenile fish recruitment (indicating that *$H_0$2* can be rejected). For these two species, the flow-habitat relationships that have been previously developed relate to spawning (not rearing) habitat. For Chinook Salmon, this is reasonable because this species only spends up to a few months rearing in the Quinsam River (Burt 2003). Coho Salmon typically rear in freshwater for 1–2 years in the Quinsam River (Burt 2003) and therefore we will consider whether it is feasible to also analyze whether variability in rearing habitat WUA affects juvenile Coho abundance.

At this time, we propose to use steelhead fry rearing habitat WUA estimates as a proxy for juvenile Coho Salmon rearing habitat, since both prefer habitats with low water velocity; however, we plan to examine this assumption further in Year 10 (e.g., by comparing the HSI curve used to calculate steelhead fry habitat with curves developed elsewhere for juvenile Coho Salmon). In addition to these two priority salmon species, we also propose to test *$H_0$2* using the same approach for Pink Salmon, which is a species of interest in the Quinsam River watershed. For steelhead, *$H_0$2* will be tested in relation to spawning habitat, as well as rearing habitat for two life stages (fry and parr). We do not expect to construct stock-recruitment relationships for steelhead because adult steelhead abundance is not monitored in the Quinsam River; instead, we plan to complete the analysis using total steelhead smolt outmigration as the dependent variable.

5.3. *$H_0$3*: Annual population abundance is not correlated with water quality

Analyses to test *$H_0$3* will be undertaken separately for individual species and water quality variables. The analyses will initially focus on the ten-year period of the monitoring program, although there are opportunities to use water temperature data collected by other parties to extend the time period over which the potential effects of water temperature are considered, as identified during a review conducted in Year 2 (Dinn *et al*. 2016). The analysis will initially involve evaluating scatter-plots, time series graphs, and correlation metrics to examine whether there is a link between variability in water quality variables and juvenile fish abundance. In Year 4, an initial screening analysis of the water quality variables showed that alkalinity (or specific conductivity), DO, and water temperature are expected to be the most suitable predictor variables to include in statistical models to quantify the effect of water quality on juvenile fish abundance (Sharron *et al*. 2018), although all variables that are monitored as part of JHTMON-8 will nonetheless be considered. The Year 4 screening analysis generally showed that inter-annual variability in many of the water quality variables was low, which may limit the power of the final analysis to quantify effects of water quality (if present) on fish abundance. As an alternate line of evidence, it will therefore also be important to continue to evaluate water quality results in the context of WQG-AL to make inferences about the potential for water quality to limit juvenile fish abundance in the Quinsam River.

5.4. $H_0 4$: Annual population abundance is not correlated with the occurrence of flood events

This hypothesis will be tested by quantifying high flow metrics separately for each watershed based on discharge measured at gauges maintained by the Water Survey of Canada. Relationships between the occurrence of floods and juvenile fish abundance will then be analyzed. Further, we propose to extend the analysis to consider hydrologic variability more widely (discussed in Section 1.5.5). Analysis will be completed using a subset of Indicators of Hydrologic Alteration (Richter *et al.* 1996), which were identified in Year 3. Candidate metrics include measures of both high and low flows to provide an opportunity to extend the analysis to consider hydrologic variability more widely, reflecting that the occurrence of low summer flows can be a significant limiting factor for juvenile salmonid productivity (e.g., Grantham *et al.* 2012), in addition to the occurrence of floods. We plan to consider additional metrics in future years, e.g., that quantify the duration of high flows. Following the collation of a historical dataset collected at the Quinsam Hatchery fence, we also plan to extend the analysis of $H_0 4$ to consider years prior to JHTMON-8, substantially increasing statistical power.

5.5. $H_0 5$: Annual population abundance is not correlated with food availability as measured by aquatic invertebrate sampling

Relationships between invertebrate drift and fish abundance will be examined in Year 10. To test $H_0 5$, we plan to examine whether variability in invertebrate drift biomass explains variability in species-specific spawner recruitment curves for JHTMON-8 priority species. If robust spawner recruitment curves cannot be established (due to weak or no relationships between adult and juvenile fish), then we plan to use juvenile fish abundance as the dependent variable in the analysis. $H_0 5$ would be rejected if invertebrate biomass is shown to be a statistically significant predictor of juvenile fish abundance, although it will be necessary to then evaluate the effect size to infer biological significance. We plan to use both total invertebrate biomass and EPT invertebrate biomass (first quantified in Year 7) as key predictor variables. Furthermore, we plan to trial invertebrate density as a secondary measure of food abundance; however, consistent with the TOR (BC Hydro 2018a), we expect to use invertebrate biomass as the main measure of food availability because it is a direct measure of the energy available for fish to consume.

If strong relationships are detected between fish abundance and invertebrate biomass/density, then we may conduct inferential statistical analysis (modelling) of invertebrate diversity metrics (family richness and Simpson's diversity index) to provide greater insight. As discussed in Section 1.5.6, salmonids can preferentially forage on certain taxa and therefore it is plausible that changes to invertebrate community composition could affect food quality by changing foraging opportunities.

However, a clear link between invertebrate diversity and fish productivity is not well-established in the literature and therefore, at this stage, the main purpose of evaluating invertebrate community composition and diversity is to provide a more general understanding of the invertebrate food available to rearing fish.

Variability in invertebrate drift biomass among years is generally low (Figure 18); therefore, as for some water quality metrics (discussed above in Section 4.4), this may limit the statistical power of the analysis conducted in Year 10; i.e., without a clear gradient in invertebrate drift biomass among years, it will be challenging to quantify how variability in this metric affects annual estimates of juvenile fish abundance. Therefore, as an alternate line of evidence, it will be useful to also compare invertebrate drift biomass in the Quinsam River with benchmarks such as measurements collected at other streams to inform conclusions about whether a lack of invertebrate drift biomass is expected to limit juvenile fish abundance in the Quinsam River. As with water quality, the study is currently premised on the assumption that invertebrate drift measured at a single index site is representative of conditions experienced by fish in the wider watershed.

5.6. H_06: Annual smolt abundance is not correlated with the number of adult returns (Quinsam River)

Updated stock-recruitment relationships will be used in Year 10 to test H_06, i.e., to confirm whether the abundance of outmigrating juveniles is correlated with the abundance of corresponding prior adult returns. Stock-recruitment relationships can then be used in the analysis to test the remaining hypotheses, i.e., to quantify whether variability in the environmental factors can explain variability in the stock-recruitment relationships (assuming such relationships are present; Lawson *et al.* 2004). Such consideration of the potential influence of adult returns on juvenile fish abundance is important to avoid misleading inferences about the role of environmental factors in driving population fluctuations (Walters and Ludwig 1981). When the Year 10 data are available, we will review the best approach for the assessment of the role of environmental factors, noting that it could be carried out in different ways, e.g., by modelling the residuals from the most parsimonious stock-recruitment using predictor variables based on the covariates of interest, or by incorporating such covariates directly into the stock recruitment models. The latter approach can be readily implemented using the Ricker formulation of the stock recruitment curve, e.g., as undertaken by Malick *et al.* (2017) who incorporated the effects of marine currents on the productivity of Pacific Salmon stocks. Further evaluation will be necessary to confirm how hatchery-raised fish will be considered in the analysis – note that stock-recruitment curves were only developed for juvenile fish that incubated in the wild.

At a minimum, we propose to test H_06 separately for Chinook Salmon, Coho Salmon and Pink Salmon. Quantitative analysis is not proposed to test H_06 for steelhead because adult abundance is not monitored on the Quinsam River. Instead, we propose to adopt a qualitative approach to assess steelhead by evaluating historical data and information relevant to BC watersheds more widely (e.g., Lill 2002) to consider whether estimated steelhead smolt production indicates that the

Quinsam River is "fully seeded" for this species, which would indicate that additional adult returns would not affect smolt production.

5.7. Additional Tasks for Year 8 (2021) and Subsequent Years

Each year, we have undertaken additional analysis tasks to streamline final hypothesis testing in Year 10, consistent with an evaluation of the study design undertaken during Year 1 (Abell *et al.* 2015). Additional tasks proposed for the remaining years of JHTMON-8 are summarized in Table 27.

Table 27. Additional tasks undertaken in Year 7 and planned for the remainder of JHTMON-8.

Year Number (Year)	Task	Hypothesis
7 (2020)	• Updated JHTMON-8 outmigration estimates based on the outcomes of our review • Constructed and reviewed initial spawner-recruitment relationships (to be used in Year 10)	$H_0$1, $H_0$6
8 (2021)	Complete initial hypothesis testing for one hypothesis ($H_0$3) to demonstrate proof of concept for proposed analysis approach	$H_0$3
9 (2022)	Prepare predictor variables for final analysis, including WUA estimates	All
10 (2023)	Complete final analysis to test hypotheses and address management questions	All

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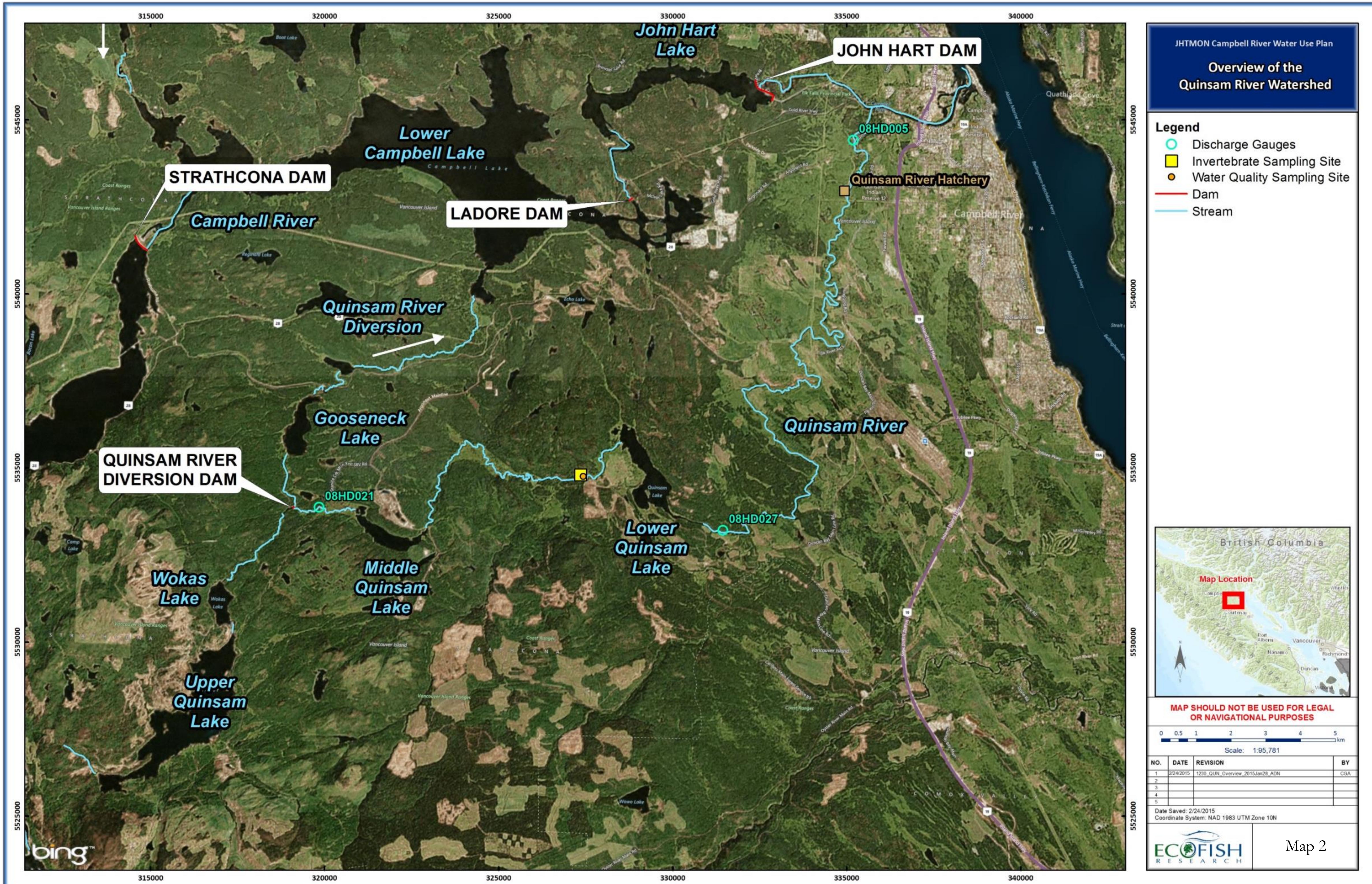
PROJECT MAPS



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APPENDICES

Appendix A. Water Quality and Water Temperature Guidelines, Typical Parameter Values, Previous Results, and Quality Control Results Summary

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1. WATER QUALITY AND WATER TEMPERATURE GUIDELINES AND TYPICAL PARAMETER VALUES

Table 1. Water quality guidelines for the protection of aquatic life in British Columbia for conductivity, pH, alkalinity, and nutrients.

Parameter	Unit	BC Guideline for the Protection of Aquatic Life[1]	Guideline Reference
Specific Conductivity	µS/cm	No provincial or federal guidelines	n/a
pH	pH units	When baseline values are between 6.5 and 9 there is no restriction on changes within this range (lethal effects observed below 4.5 and above 9.5)	MOE (1991)
Alkalinity	mg/L	No provincial or federal guidelines. However, waterbodies with <10 mg/L are highly sensitive to acidic inputs, 10 to 20 mg/L are moderately sensitive to acidic inputs, > 20 mg/L have a low sensitivity to acidic inputs	n/a
Total Ammonia (N)	µg/L	Dependent on pH and temperature, too numerous to present, lowest maximum allowable concentration of 680 µg/L occurs at a pH of 9 and water temperature of 8ºC, lowest maximum average 30 day concentration of 102 µg/L occurs at a pH of 9 and water temperature of 20ºC	Nordin and Pommen (2009)
Nitrite (N)	µg/L	The lowest maximum allowable concentration occurs when chloride is ≤ 2 mg/L; instantaneous maximum allowable concentration is 60 µg/L and a maximum 30 day average of 20 µg/L is allowed when chloride is ≤ 2 mg/L	Nordin and Pommen (2009)
Nitrate (N)	µg/L	The 30 day average concentration to protect freshwater aquatic life is 3,000 µg/L[2] and the maximum concentration is 32.8 mg/L	Nordin and Pommen (2009)
Orthophosphate	µg/L	No provincial or federal guidelines	n/a
Total Phosphorus (P)	µg/L	Trigger ranges that would signify a change in the trophic classification: <4 µg/L: ultra-oligotrophic, 4-10 µg/L: oligotrophic, 10-20 µg/L: mesotrophic, 20-35 µg/L: meso-eutrophic, 35-100 µg/L: eutrophic, > 100 µg/L: hyper-eutrophic	CCME (2004)

[1] Guideline for total phosphorus is a federal guideline; provincial guidelines do not exist

[2] The 30-d average (chronic) concentration is based on 5 weekly samples collected within a 30-day period

Table 2. Total suspended sediments and turbidity guidelines for the protection of aquatic life in British Columbia.

Period	British Columbia[1] Suspended Sediment and Turbidity Guidelines for the Protection of Aquatic Life	
	Total Suspended Sediments (mg/L)	**Turbidity (NTU)**
Clear Flow Period (< 25 mg/L or < 8 NTU)	"Induced suspended sediment concentrations should not exceed background levels by more than 25 mg/L during any 24-hour period (hourly sampling preferred). For sediment inputs that last between 24 hours and 30 days (daily sampling preferred), the average suspended sediment concentration should not exceed background by more than 5 mg/L."	"Induced turbidity should not exceed background levels by more than 8 NTU during any 24-hour period (hourly sampling preferred). For sediment inputs that last between 24 hours and 30 days (daily sampling preferred) the mean turbidity should not exceed background by more than 2 NTU."
Turbid Flow Period (≥ 25 mg/L or ≥ 8 NTU)	"Induced suspended sediment concentrations should not exceed background levels by more than 10 mg/L at any time when background levels are between 25 and 100 mg/L. When background exceeds 100 mg/L, suspended sediments should not be increased by more than 10% of the measured background level at any one time."	"Induced turbidity should not exceed background levels by more than 5 NTU at any time when background turbidity is between 8 and 50 NTU. When background exceeds 50 NTU, turbidity should not be increased by more than 10% of the measured background level at any one time."

[1] Reproduced from Singleton (2001)

Table 3. Dissolved oxygen guidelines for the protection of aquatic life in British Columbia.

BC Guidelines for the Protection of Aquatic Life (MOE 2019)			
	Life Stages Other Than Buried Embryo/Alevin	**Buried Embryo/Alevin**[1]	**Buried Embryo/Alevin**[1]
Dissolved Oxygen Concentration	Water column mg/L O_2	Water column mg/L O_2	Interstitial Water mg/L O_2
Instantaneous minimum[2]	5	9	6
30-day mean[3]	8	11	8

[1] For the buried embryo / alevin life stages these are in-stream concentrations from spawning to the point of yolk sac absorption or 30 days post-hatch for fish; the water column concentrations recommended to achieve interstitial dissolved oxygen values when the latter are unavailable. Interstitial oxygen measurements would supersede water column measurements in comparing to criteria.

[2] The instantaneous minimum level is to be maintained at all times.

[3] The mean is based on at least five approximately evenly spaced samples. If a diurnal cycle exists in the water body, measurements should be taken when oxygen levels are lowest (usually early morning).

Table 4. Total gas pressure guidelines for the protection of aquatic life in British Columbia.

Water Depth	**Water Use**	**Maximum Allowable ΔP (Excess Gas Pressure) for the Protection of Aquatic Life in BC**[1]
> 1 m	Freshwater	76 mm Hg regardless of pO_2 levels
< 1 m	Shallow Water/Hatchery Environments	24 mm Hg is the most conservative form (assuming water column depth = 0 m)[2]
All depths	Background Levels Higher than BC WQG	No increase in ΔP or %TGP

[1] Adapted from Fidler and Miller (1994) and BC WQG Summary Report (MOE 2019).

[2] Derived from equation: $\Delta P_{\text{initiation of swim bladder overinflation}} = 73.89 * \text{water depth (m)} + 0.15 * pO_2$, where pO_2 = 157 mm Hg (i.e., sea level, normoxic condition) (Fidler and Miller 1994).

Table 5. Water temperature guidelines for the protection of freshwater aquatic life (Oliver and Fidler 2001).

Category	Guideline[1]
All Streams	the rate of temperature change in natural water bodies not to exceed 1°C/hr
	temperature metrics to be described by the mean weekly maximum temperature (MWMxT)
Streams with Known Fish Presence	mean weekly maximum water temperatures should not exceed ±1°C beyond the optimum temperature range for each life history phase of the most sensitive salmonid species present[1]
Streams with Bull Trout or Dolly Varden	maximum daily temperature is 15°C
	maximum incubation temperature is 10°C
	minimum incubation temperature is 2°C
	maximum spawning temperature is 10°C
Streams with Unknown Fish Presence	salmonid rearing temperatures not to exceed MWMxT of 18°C
	maximum daily temperature not to exceed 19°C
	maximum temperature for salmonid incubation from June until August not to exceed 12°C

[1] The guidelines state that "the natural temperature cycle characteristic of the site should not be altered in amplitude or frequency by human activities". Accordingly, it is implied that when conditions are naturally outside of guidelines, human activities should not increase the magnitude and/or frequency to which conditions are outside of guidelines.

Table 6. Typical values for water quality parameters in British Columbia waters.

Parameter	Unit	Typical range in BC streams and rivers	Reference
Specific Conductivity	µS/cm	The typical value in coastal British Columbia streams is 100 µS/cm	RISC (1998)
pH	pH units	Natural fresh waters have a pH range from 4 to 10, lakes tend to have a pH ≥ 7.0 and coastal streams commonly have pH values of 5.5 to 6.5	RISC (1998)
Alkalinity	mg/L	Natural waters almost always have concentrations less than 500 mg/L, with waters in coastal BC typically ranging from 0 to 10 mg/L; waters in interior BC can have values greater than 100 mg/L	RISC (1998)
Total Suspended Solids	mg/L	In British Columbia natural concentrations of suspended solids vary extensively from waterbody to waterbody and can have large variation within a day and among seasons	Singleton (1985) in Caux *et al.* (1997)
Turbidity	NTU	In British Columbia natural concentrations of suspended solids vary extensively from waterbody to waterbody and can have large variation within a day and among seasons	Singleton (1985) in Caux *et al.* (1997)
Dissolved Oxygen	mg/L	In BC surface waters are generally well aerated and have DO concentrations > 10 mg/L	MOE (1997)
Dissolved Oxygen	% saturation	In BC surface waters are generally well aerated and have DO concentrations close to equilibrium with the atmosphere (i.e., close to 100% saturation)	MOE (1997)
ΔP (Total Gas Pressure - Barometric Pressure)	mm Hg	In British Columbia, dissolved gas supersaturation is a natural feature of many waters with ΔP commonly being between 50 – 80 mm Hg. (We often see values between -10 and 60)	Fidler and Miller (1994)
Total Ammonia (N)	µg/L	<100 µg/L for waters not affected by waste discharges	Nordin and Pommen (2009)
Nitrite (N)	µg/L	Due to its unstable nature, nitrite concentrations are very low, typically present in surface waters at concentrations of <1 µg/L	RISC (1998)
Nitrate (N)	µg/L	In oligotrophic lakes and streams, nitrate concentrations are expected to be <100 µg/L; in most streams and lakes not impacted by anthropogenic activities, nitrate is typically <900 µg/L.	Nordin and Pommen (2009)
Orthophosphate (P)	µg/L	Coastal BC streams have concentrations <1 µg/L	Slaney and Ward (1993); Ashley and Slaney (1997)
Total Phosphorus (P)	µg/L	Oligotrophic water bodies have total phosphorus concentrations that are between 4 to 10 µg/L while concentrations are typically between 10 to 20 µg/L in mesotrophic water bodies.	CCME (2004)

2. 2014 TO 2020 WATER QUALITY IN THE QUINSAM RIVER

Table 7. Quinsam River (QUN-WQ) general water quality variables measured *in situ* during Years 1 to 7 (2014 to 2020).

Year	Date	Air Temperature °C				Conductivity µS/cm				Specific Conductivity µS/cm				Water Temperature °C				pH pH units			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	23-May	-	-	-	-	73.3	73.3	73.3	0.0	95.6	95.6	95.6	0.0	12.8	12.8	12.8	0.0	7.38	7.38	7.39	0.01
	18-Jun	14	14	14	0	121.5	121.5	121.6	0.1	143.1	143.1	143.1	0.0	17.1	17.1	17.1	0.0	7.58	7.57	7.58	0.01
	22-Jul	16	16	16	0	127.5	127.5	127.5	0.0	148.1	148.1	148.1	0.0	17.7	17.7	17.7	0.0	7.36	7.36	7.36	0.00
	19-Aug	19	19	19	0	138.2	138.1	138.3	0.1	152.3	152.2	152.4	0.1	20.2	20.2	20.2	0.0	7.38	7.36	7.43	0.04
	24-Sep	14	14	14	0	91.2	91.2	91.3	0.1	109.9	109.9	109.9	0.0	16.1	16.1	16.1	0.0	7.30	7.23	7.36	0.07
	04-Nov	7	7	7	0	48.9	48.9	48.9	0.0	69.4	69.4	69.4	0.0	9.6	9.6	9.6	0.0	7.01	7.01	7.02	0.01
2015	12-May	14	14	14	0	114.6	114.6	114.6	0.0	144.4	144.4	144.5	0.1	14.2	14.2	14.2	0.0	7.68	7.68	7.68	0.00
	17-Jun	15	15	15	0	121.9	121.9	121.9	0.0	98.1	14.0	140.2	72.8	18.2	18.2	18.2	0.0	7.71	7.71	7.71	0.00
	23-Jul	17	17	17	0	161.6	161.6	161.7	0.1	190.7	190.7	190.7	0.0	17.0	17.0	17.0	0.0	7.49	7.49	7.49	0.00
	13-Aug	17	17	17	0	173.2	173.1	173.2	0.1	197.7	197.6	197.7	0.1	18.5	18.5	18.5	0.0	7.41	7.40	7.41	0.01
	16-Sep	12	12	12	0	147.1	147.1	147.1	0.0	185.7	185.7	185.7	0.0	14.1	14.1	14.1	0.0	7.50	7.50	7.50	0.00
	14-Oct	11	11	11	0	92.9	92.9	92.9	0.0	131.9	131.8	131.9	0.1	9.5	9.5	9.6	0.1	7.52	7.50	7.54	0.02
2016	18-May	12	12	12	0	119.1	119.1	119.2	0.1	150.1	150.0	150.2	0.1	14.7	14.7	14.7	0.0	7.18	7.16	7.20	0.02
	15-Jun	9	9	9	0	112.1	112.0	112.1	0.1	143.5	143.4	143.6	0.1	14.0	14.0	14.0	0.0	6.86	6.86	6.87	0.01
	13-Jul	15	15	15	0	125.5	125.4	125.6	0.1	154.2	154.1	154.4	0.2	15.7	15.7	15.7	0.0	10.52	10.46	10.59	0.07
	17-Aug	19	19	19	0	139.4	139.4	139.4	0.0	157.4	157.4	157.4	0.0	19.3	19.3	19.3	0.0	7.25	7.24	7.25	0.01
	14-Sep	12	12	12	0	138.5	138.5	138.5	0.0	172.6	172.6	172.7	0.1	15.1	15.1	15.1	0.0	7.40	7.39	7.40	0.01
	12-Oct	5	5	5	0	115.2	114.9	115.5	0.3	175.9	175.5	176.1	0.3	7.7	7.7	7.7	0.0	15.86	15.86	15.86	0.00
2017	10-May	7	7	7	0	73.3	73.3	73.3	0.0	105.7	105.7	105.8	0.1	8.9	8.9	8.9	0.0	7.58	7.58	7.58	0.00
	14-Jun	9	9	9	0	99.3	99.3	99.3	0.0	124.1	124.1	124.1	0.0	15.0	15.0	15.0	0.0	7.47	7.46	7.47	0.01
	12-Jul	17	17	17	0	140.4	140.4	140.4	0.0	158.2	158.2	158.2	0.0	19.4	19.4	19.4	0.0	7.08	7.05	7.10	0.03
	09-Aug	13	13	13	0	149.8	149.8	149.8	0.0	162.7	162.6	162.7	0.1	21.1	21.1	21.1	0.0	7.17	7.17	7.17	0.00
	13-Sep	8	8	8	0	137.6	137.6	137.6	0.0	166.8	166.8	166.9	0.1	16.2	16.2	16.2	0.0	7.21	7.20	7.22	0.01
	11-Oct	2	2	2	0	128.9	128.8	128.9	0.1	178.0	178.0	178.1	0.1	11.2	11.2	11.2	0.0	7.21	7.17	7.24	0.04
2018	10-May	9	9	9	0	66.7	66.6	66.8	0.1	95.9	95.8	96.0	0.1	9.7	9.7	9.7	0.0	6.02	5.92	6.11	0.10
	05-Jun	8	8	8	0	118.5	118.5	118.5	0.0	153.4	153.3	153.4	0.1	13.6	13.6	13.6	0.0	6.58	6.57	6.58	0.01
	04-Jul	12	12	12	0	116.1	116.1	116.1	0.0	139.0	139.0	139.0	0.0	16.8	16.8	16.8	0.0	7.59	7.59	7.59	0.00
	09-Aug	14	14	14	0	129.9	129.8	129.9	0.1	137.4	137.3	137.4	0.1	22.1	22.1	22.1	0.0	7.05	7.04	7.06	0.01
	12-Sep	10	10	10	0	91.0	91.0	91.0	0.0	112.8	112.8	112.8	0.0	15.3	15.3	15.3	0.0	7.69	7.69	7.70	0.01
	05-Oct	5	5	5	0	79.3	79.3	79.4	0.1	112.5	112.4	112.6	0.1	9.5	9.5	9.5	0.0	-	-	-	-

[1] Average of three replicates (n=3) on each date unless otherwise indicated. A single data listed under Avg. indicates n=1.

Black dashes (-) indicate that no data were collected.

Red dashes (-) indicate that values were removed because they were considered anomalous.

Table 7. Continued (2 of 2).

Year	Date	Air Temperature °C				Conductivity µS/cm				Specific Conductivity µS/cm				Water Temperature °C				pH pH units			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2019	13-May	8	8	8	0	84.4	84.4	84.4	0.0	115.3	115.2	115.3	0.1	11.0	11.0	11.0	0.0	6.50	6.50	6.50	0.00
	12-Jun	19	19	19	0	128.0	128.0	128.0	0.0	146.6	146.5	146.6	0.1	18.4	18.4	18.4	0.0	7.60	7.59	7.60	0.01
	11-Jul	15	15	15	0	98.8	98.8	98.9	0.1	113.8	113.8	113.8	0.0	18.4	18.4	18.4	0.0	7.15	7.13	7.17	0.02
	12-Aug	14	14	14	0	82.8	82.8	82.8	0.0	94.6	94.6	94.6	0.0	18.8	18.8	18.8	0.0	7.42	7.41	7.42	0.01
	12-Sep	13	13	13	0	66.3	66.3	66.3	0.0	78.2	78.2	78.2	0.0	17.0	17.0	17.0	0.0	7.56	7.55	7.56	0.01
	09-Oct	5	5	5	0	91.8	91.7	91.8	0.1	135.7	135.7	135.7	0.0	8.1	8.1	8.1	0.0	7.33	7.33	7.33	0.00
2020	11-May	10	10	10	0	56.5	56.5	56.5	0.0	79.0	79.0	79.0	0.0	10.1	10.1	10.1	0.0	7.09	7.09	7.09	0.00
	08-Jun	9	9	9	0	97.6	97.5	97.6	0.1	128.0	128.0	128.0	0.1	12.5	12.5	12.5	0.0	7.04	7.03	7.05	0.01
	07-Jul	14	14	14	0	131.0	131.0	131.0	0.0	155.0	155.0	155.0	0.0	16.7	16.7	16.7	0.0	7.43	7.42	7.44	0.01
	10-Aug	16	16	16	0	145.0	145.0	145.0	0.0	164.0	164.0	164.0	0.1	18.8	18.8	18.8	0.0	7.55	7.55	7.56	0.01
	10-Sep	26	26	26	0	-	-	-	-	-	-	-	-	17.8	17.8	17.8	0.0	7.27	7.27	7.27	0.00
	08-Oct	13	13	13	0	114.0	114.0	114.0	0.0	143.0	143.0	143.0	0.1	14.8	14.8	14.8	0.0	7.44	7.44	7.44	0.00

[1] Average of three replicates (n=3) on each date unless otherwise indicated. A single data listed under Avg. indicates n=1.

Black dashes (-) indicate that no data were collected.

Red dashes (-) indicate that values were removed because they were considered anomalous.

Table 8. Quinsam River (QUN-WQ) dissolved gases measured *in situ* during Years 1 to 7 (2014 to 2020).

Year	Date	Barometric Pressure mm Hg				Oxygen Dissolved %				Oxygen Dissolved mg/L				TGP %				TGP mm Hg				ΔP mm Hg			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	23-May	744	743	745	1	101.8	101.4	102.6	0.7	10.74	10.69	10.82	0.07	100	100	100	0	744	744	745	1	0	0	1	1
	18-Jun	748	748	749	1	91.3	90.9	91.9	0.5	8.84	8.80	8.87	0.04	101	101	101	0	755	753	757	2	7	5	8	2
	22-Jul	747	747	748	1	95.8	95.8	95.9	0.1	9.13	9.12	9.13	0.01	101	101	101	0	753	753	753	0	6	5	6	1
	19-Aug	745	744	745	1	77.9	77.7	78.3	0.3	7.01	6.99	7.03	0.02	99	99	99	0	735	735	735	0	-10	-10	-9	1
	24-Sep	753	752	753	1	91.7	90.1	92.7	1.4	8.78	8.53	8.91	0.21	98	98	98	0	739	739	740	1	-13	-14	-13	1
	04-Nov	761	761	762	1	88.5	88.4	88.5	0.1	9.95	9.94	9.96	0.01	99	99	99	0	755	755	755	0	-6	-7	-6	1
2015	12-May	741	741	741	0	96.2	96.2	96.3	0.1	9.89	9.88	9.89	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	17-Jun	-	-	-	-	83.7	83.6	83.9	0.2	7.90	7.89	7.91	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	23-Jul	744	744	744	0	84.2	84.1	84.4	0.2	8.14	8.13	8.14	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	13-Aug	746	746	746	0	84.2	84.1	84.4	0.2	7.89	7.88	7.91	0.02	-	-	-	-	-	-	-	-	-	-	-	-
	16-Sep	743	743	743	0	78.1	77.8	78.5	0.4	8.03	8.00	8.05	0.03	-	-	-	-	-	-	-	-	-	-	-	-
	14-Oct	754	754	754	0	87.0	86.8	87.3	0.3	9.88	9.87	9.89	0.01	-	-	-	-	-	-	-	-	-	-	-	-
2016	18-May	747	747	747	0	81.9	81.7	82.0	0.2	8.30	8.30	8.30	0.00	-	-	-	-	-	-	-	-	-	-	-	-
	15-Jun	744	744	744	0	80.0	79.9	80.2	0.2	8.23	8.22	8.24	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	13-Jul	757	757	757	0	79.4	79.3	79.5	0.1	7.89	7.87	7.92	0.03	-	-	-	-	-	-	-	-	-	-	-	-
	17-Aug	749	749	749	0	84.4	84.1	84.6	0.3	7.77	7.75	7.79	0.02	-	-	-	-	-	-	-	-	-	-	-	-
	14-Sep	747	747	747	0	81.0	80.9	81.2	0.2	8.16	8.15	8.17	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	12-Oct	747	747	747	0	98.0	97.6	98.5	0.5	11.70	11.63	11.75	0.06	-	-	-	-	-	-	-	-	-	-	-	-
2017	10-May	742	742	742	0	76.9	76.6	77.3	0.4	8.94	8.92	8.96	0.02	-	-	-	-	-	-	-	-	-	-	-	-
	14-Jun	752	752	752	0	89.6	89.5	89.7	0.1	9.03	9.01	9.05	0.02	-	-	-	-	-	-	-	-	-	-	-	-
	12-Jul	749	749	749	0	87.1	87.0	87.1	0.1	8.02	8.01	8.03	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	09-Aug	748	748	748	0	80.0	79.5	80.3	0.5	7.13	7.13	7.13	0.00	-	-	-	-	-	-	-	-	-	-	-	-
	13-Sep	749	749	749	0	83.7	83.5	83.8	0.2	8.21	8.20	8.22	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	11-Oct	751	751	751	0	91.6	91.6	91.7	0.1	10.05	10.04	10.06	0.01	-	-	-	-	-	-	-	-	-	-	-	-
2018	10-May	748	748	748	0	96.5	95.8	97.0	0.6	10.99	10.97	11.02	0.03	-	-	-	-	-	-	-	-	-	-	-	-
	05-Jun	744	743	744	0	85.3	85.2	85.4	0.1	8.86	8.85	8.87	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	04-Jul	753	753	753	0	82.4	82.2	82.6	0.2	7.99	7.97	8.02	0.03	-	-	-	-	-	-	-	-	-	-	-	-
	09-Aug	-	-	-	-	90.7	90.0	91.9	1.0	8.25	7.85	8.87	0.55	-	-	-	-	-	-	-	-	-	-	-	-
	12-Sep	744	744	744	0	93.8	92.1	95.7	1.8	9.41	9.24	9.62	0.19	-	-	-	-	-	-	-	-	-	-	-	-
	05-Oct	-	-	-	-	84.8	84.1	85.9	1.0	9.75	9.65	9.80	0.08	-	-	-	-	-	-	-	-	-	-	-	-

[1] Average of three replicates (n=3) on each date unless otherwise indicated. A single data listed under Avg. indicates n=1.

Blue shading indicates that the more conservative provincial guideline (DO instantaneous minimum of 9 mg/L) for the protection of buried embryo/alevin has not been achieved. Note that the guideline for life stages other than buried embryo/alevin is met (DO instantaneous minimum of 5 mg/L).

Black dashes (-) indicate that no data were collected.

Red dashes (-) indicate that values were removed because they were considered anomalous.

Table 8. Continued (2 of 2).

Year	Date	Barometric Pressure mm Hg				Oxygen Dissolved %				Oxygen Dissolved mg/L				TGP %				TGP mm Hg				ΔP mm Hg			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2019	13-May	-	-	-	-	90.4	90.4	90.4	0.0	9.95	9.95	9.96	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	12-Jun	746	746	746	0.1	90.9	90.9	91.0	0.1	8.54	8.53	8.55	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	11-Jul	754	754	754	0.1	89.8	89.4	90.0	0.3	8.43	8.40	8.45	0.03	-	-	-	-	-	-	-	-	-	-	-	-
	12-Aug	754	754	754	0.1	91.9	91.8	92.0	0.1	8.58	8.57	8.59	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	12-Sep	753	753	753	0.0	89.4	89.1	89.7	0.3	8.63	8.62	8.65	0.02	-	-	-	-	-	-	-	-	-	-	-	-
	09-Oct	756	756	756	0.0	98.4	98.3	98.5	0.1	11.64	11.64	11.65	0.01	-	-	-	-	-	-	-	-	-	-	-	-
2020	11-May	739	739	739	0.1	102.0	102.0	103.0	0.3	11.50	11.50	11.60	0.02	-	-	-	-	-	-	-	-	-	-	-	-
	08-Jun	748	748	748	0.1	81.1	79.4	83.5	2.1	8.61	8.45	8.86	0.22	-	-	-	-	-	-	-	-	-	-	-	-
	07-Jul	752	752	752	0.1	86.0	85.9	86.1	0.1	8.36	8.35	8.37	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	10-Aug	-	-	-	-	88.2	88.0	88.4	0.2	8.22	8.20	8.23	0.02	-	-	-	-	-	-	-	-	-	-	-	-
	10-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	08-Oct	-	-	-	-	85.6	85.0	86.4	0.7	8.59	8.52	8.65	0.07	-	-	-	-	-	-	-	-	-	-	-	-

[1] Average of three replicates (n=3) on each date unless otherwise indicated. A single data listed under Avg. indicates n=1.

Blue shading indicates that the more conservative provincial guideline (DO instantaneous minimum of 9 mg/L) for the protection of buried embryo/alevin has not been achieved. Note that the guideline for life stages other than buried embryo/alevin is met (DO instantaneous minimum of 5 mg/L).

Black dashes (-) indicate that no data were collected.

Red dashes (-) indicate that values were removed because they were considered anomalous.

Table 9. Quinsam River (QUN-WQ) general water quality variables measured at ALS laboratories during Years 1 to 7 (2014 to 2020).

Year	Date	Alkalinity, Total (as $CaCO_3$) mg/L				Conductivity µS/cm				Total Dissolved Solids mg/L				Total Suspended Solids mg/L				Turbidity NTU				pH pH units			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	23-May	31.7	31.5	31.8	0.2	94.8	94.1	95.4	0.9	69	68	70	1	<1	<1	<1	0.0	0.59	0.52	0.65	0.09	7.77	7.77	7.77	0.00
	18-Jun	41.0	40.8	41.1	0.2	139.5	139.0	140.0	0.7	96	96	96	0	<1	<1	<1	0.0	0.42	0.40	0.44	0.03	7.87	7.87	7.87	0.00
	22-Jul	42.4	42.4	42.4	0.0	140.0	139.0	141.0	1.4	103	101	105	3	<1	<1	<1	0.0	0.46	0.44	0.47	0.02	7.73	7.65	7.81	0.11
	19-Aug	42.1	41.9	42.3	0.3	156.0	146.0	166.0	14.1	96	95	96	1	<1	<1	<1	0.0	0.70	0.47	0.93	0.33	7.81	7.57	8.05	0.34
	24-Sep	35.0	35.0	35.0	0.0	109.0	109.0	109.0	0.0	71	67	74	5	<1	<1	<1	0.0	0.56	0.50	0.62	0.08	7.55	7.52	7.58	0.04
	04-Nov	23.7	23.5	23.8	0.2	71.3	70.7	71.8	0.8	59	53	64	8	<1	<1	<1	0.0	0.74	0.71	0.77	0.04	7.61	7.59	7.63	0.03
2015	12-May	40.8	40.6	41.0	0.3	143.0	143.0	143.0	0.0	91	89	93	3	<1	<1	<1	0.0	0.38	0.37	0.39	0.01	7.79	7.78	7.80	0.01
	17-Jun	43.9	43.8	43.9	0.1	157.0	157.0	157.0	0.0	97	94	100	4	<1	<1	<1	0.0	0.41	0.40	0.42	0.01	7.91	7.90	7.92	0.01
	23-Jul	52.9	51.7	54.0	1.6	206.0	206.0	206.0	0.0	120	120	120	0	<1	<1	<1	0.0	0.49	0.49	0.49	0.00	8.00	7.99	8.01	0.01
	13-Aug	48.8	48.0	49.6	1.1	175.0	173.0	177.0	2.8	124	120	127	5	<1	<1	<1	0.0	0.36	0.30	0.42	0.08	7.78	7.70	7.85	0.11
	16-Sep	46.2	46.0	46.3	0.2	178.0	177.0	179.0	1.4	145	116	173	40	<1	<1	<1	0.0	0.40	0.38	0.42	0.03	7.94	7.94	7.94	0.00
	14-Oct	34.0	33.9	34.1	0.1	130.0	129.0	131.0	1.4	94	92	96	3	<1	<1	1.6	0.4	0.47	0.40	0.53	0.09	7.55	7.52	7.58	0.04
2016	18-May	35.4	35.1	35.6	0.4	131.5	131.0	132.0	0.7	85	85	85	0	<1	<1	<1	0.0	0.49	0.38	0.59	0.15	7.83	7.80	7.86	0.04
	15-Jun	34.3	33.9	34.7	0.6	130.5	130.0	131.0	0.7	87	86	88	1	<1	<1	<1	0.0	0.45	0.44	0.46	0.01	7.78	7.77	7.78	0.01
	13-Jul	36.6	36.5	36.7	0.1	110.0	109.0	111.0	1.4	70	67	72	4	<1	<1	1.5	0.4	1.17	1.14	1.19	0.04	7.68	7.67	7.68	0.01
	17-Aug	35.5	35.4	35.5	0.1	137.5	137.0	138.0	0.7	87	86	88	1	<1	<1	1.1	0.1	0.46	0.44	0.47	0.02	7.51	7.50	7.51	0.01
	14-Sep	35.3	35.1	35.4	0.2	139.0	139.0	139.0	0.0	84	83	84	1	<1	<1	<1	0.0	0.46	0.45	0.46	0.01	7.71	7.70	7.72	0.01
	12-Oct	30.6	30.4	30.8	0.3	118.5	114.0	123.0	6.4	83	81	84	2	<1	<1	<1	0.0	0.72	0.72	0.72	0.00	7.70	7.69	7.71	0.01
2017	10-May	32.4	32.2	32.6	0.3	105.5	104.0	107.0	2.1	90	72	107	25	2.1	1.7	2.4	0.5	0.59	0.55	0.62	0.05	7.71	7.69	7.72	0.02
	14-Jun	41.1	41.1	41.1	0.0	145.5	145.0	146.0	0.7	99	95	102	5	<1	<1	<1	0.0	0.54	0.53	0.54	0.01	7.94	7.93	7.94	0.01
	12-Jul	44.3	43.5	45.0	1.1	148.0	147.0	149.0	1.4	93	92	94	1	1.4	1.3	1.4	0.1	0.57	0.53	0.61	0.06	7.91	7.89	7.93	0.03
	09-Aug	43.8	43.7	43.9	0.1	161.0	160.0	162.0	1.4	102	101	103	1	<1	<1	<1	0.0	0.61	0.54	0.68	0.10	7.80	7.79	7.80	0.01
	13-Sep	43.2	42.7	43.7	0.7	162.0	162.0	162.0	0.0	103	98	107	6	<1	<1	<1	0.0	0.46	0.44	0.47	0.02	7.91	7.91	7.91	0.00
	11-Oct	45.4	45.1	45.6	0.4	169.0	169.0	169.0	0.0	127	125	128	2	<1	<1	<1	0.0	0.41	0.41	0.41	0.00	7.63	7.62	7.63	0.01
2018	10-May	27.8	27.8	27.8	0.0	93.2	92.7	93.6	0.6	70	69	70	1	<1	<1	<1	0.0	0.46	0.43	0.48	0.04	7.59	7.57	7.60	0.02
	05-Jun	41.3	40.9	41.7	0.6	149.5	149.0	150.0	0.7	97	96	98	1	1.4	1.1	1.6	0.4	0.48	0.45	0.50	0.04	7.85	7.84	7.85	0.01
	04-Jul	38.7	38.4	39.0	0.4	132.5	132.0	133.0	0.7	93	87	98	8	1.4	1.3	1.5	0.1	0.58	0.54	0.62	0.06	7.78	7.76	7.79	0.02
	09-Aug	41.2	41.1	41.2	0.1	132.0	132.0	132.0	0.0	88	88	88	0	<1	<1	1.1	0.1	0.64	0.52	0.75	0.16	7.84	7.84	7.84	0.00
	12-Sep	37.0	36.8	37.1	0.2	110.0	110.0	110.0	0.0	78	73	82	6	<3	<3	<3	0.0	0.38	0.32	0.43	0.08	7.81	7.80	7.82	0.01
	05-Oct	31.0	30.9	31.0	0.1	105.5	104.0	107.0	2.1	78	77	78	1	<1	<1	1.3	0.2	0.44	0.43	0.44	0.01	7.65	7.61	7.68	0.05

[1] Average of two replicates (n=2) on each date unless otherwise indicated. A single data listed under Avg. indicates n=1.

Parameters that have a concentration below the detection limit are assumed to have a concentration equal to the detection limit for calculation purposes.

Table 9. Continued (2of 2).

Year	Date	Alkalinity, Total (as $CaCO_3$) mg/L				Conductivity µS/cm				Total Dissolved Solids mg/L				Total Suspended Solids mg/L				Turbidity NTU				pH pH units			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2019	13-May	35.8	35.6	36.0	0.3	119.5	118.0	121.0	2.1	71	66	76	7	<1.2	<1.0	1.3	0.2	0.35	0.33	0.36	0.02	7.65	7.65	7.65	0.00
	12-Jun	41.5	41.5	41.5	0.0	142.0	142.0	142.0	0.0	96	94	97	2	<1.1	<1.0	1.2	0.1	0.36	0.34	0.38	0.03	7.88	7.87	7.88	0.01
	11-Jul	35.0	35.0	35.0	0.0	103.0	103.0	103.0	0.0	75	74	76	1	1.4	1.2	1.5	0.2	0.48	0.45	0.51	0.04	7.75	7.73	7.76	0.02
	12-Aug	33.7	33.4	34.0	0.4	83.6	83.4	83.8	0.3	56	56	56	0	<3	<3	<3	0.0	0.43	0.41	0.45	0.03	7.64	7.62	7.66	0.03
	12-Sep	31.2	31.1	31.2	0.1	78.2	77.9	78.5	0.4	62	61	62	1	<3	<3	<3	0.0	0.41	0.33	0.49	0.11	7.57	7.56	7.58	0.01
	09-Oct	39.2	39.1	39.3	0.1	132.0	132.0	132.0	0.0	79	77	81	3	<1	<1	<1	0.0	0.32	0.29	0.34	0.04	7.73	7.73	7.73	0.00
2020	11-May	24.8	24.6	25.0	0.3	78.5	78.0	78.9	0.6	57	54	59	4	<1	<1	<1	0.0	0.58	0.56	0.59	0.02	7.47	7.46	7.48	0.01
	08-Jun	33.4	33.1	33.7	0.4	124.0	124.0	124.0	0.0	82	81	83	1	<1	<1	<1	0.0	0.46	0.46	0.46	0.00	7.63	7.62	7.63	0.01
	07-Jul	39.6	39.5	39.7	0.1	157.0	157.0	157.0	0.0	96	90	102	8	<1.1	<1	1.1	0.1	0.51	0.47	0.55	0.06	7.59	7.58	7.59	0.01
	10-Aug	38.6	38.6	38.6	0.0	152.0	152.0	152.0	0.0	85	79	91	8	<1.4	<1	1.7	0.5	0.89	0.80	0.98	0.13	7.76	7.76	7.76	0.00
	10-Sep	39.1	39.1	39.1	0.0	146.0	145.0	146.0	1.0	91	90	92	1	<1	<1	<1	0.0	0.43	0.39	0.47	0.06	7.73	7.71	7.75	0.03
	08-Oct	41.0	40.5	41.4	0.6	143.0	143.0	143.0	0.0	96	95	96	1	<1	<1	<1	0.0	0.25	0.23	0.26	0.02	7.74	7.74	7.74	0.00

[1] Average of two replicates (n=2) on each date unless otherwise indicated. A single data listed under Avg. indicates n=1.

Parameters that have a concentration below the detection limit are assumed to have a concentration equal to the detection limit for calculation purposes.

Table 10. Quinsam River (QUN-WQ) low level nutrients measured at ALS laboratories during Years 1 to 7 (2014 to 2020).

Year	Date	Ammonia, Total (as N) µg/L				Dissolved Orthophosphate (as P) µg/L				Nitrate (as N) µg/L				Nitrite (as N) µg/L				Total Phosphorus (P) µg/L			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	23-May	<5	<5	<5	0	<1	<1	<1	0	14	14	14	0	<1	<1	<1	0	4	4	4	0
	18-Jun	<5	<5	<5	0	<1	<1	<1	0	30	29	30	1	<1	<1	<1	0	3	3	3	0
	22-Jul	<5	<5	<5	0	<1	<1	<1	0	32	31	32	0	<1	<1	<1	0	3	3	3	0
	19-Aug	<5	<5	5	0	<1	<1	<1	0	17	17	17	0	<1	<1	<1	0	5	5	5	0
	24-Sep	<5	<5	<5	0	<1	<1	<1	0	21	21	22	1	<1	<1	<1	0	4	4	5	0
	04-Nov	5	5	5	0	<1	<1	<1	0	25	24	25	1	<1	<1	<1	0	4	3	4	1
2015	12-May	<5	<5	<5	0	<1	<1	<1	0	23	23	23	0	<1	<1	<1	0	3	3	3	1
	17-Jun	<5	<5	<5	0	<1	<1	<1	0	24	24	24	0	<1	<1	<1	0	<2	<2	<2	0
	23-Jul	<5	<5	<5	0	<1	<1	<1	0	30	29	31	1	<1	<1	<1	0	<2	<2	2	0
	13-Aug	<5	<5	<5	0	<1	<1	<1	0	41	41	41	0	<1	<1	<1	0	<2	<2	<2	0
	16-Sep	<5	<5	<5	0	<1	<1	<1	0	14	14	14	0	<1	<1	<1	0	<2	<2	2	0
	14-Oct	9	9	9	0	<1	<1	<1	0	36	36	36	0	<1	<1	<1	0	5	4	5	0
2016	18-May	<5	<5	<5	0	<1	<1	<1	0	16	16	16	0	<1	<1	<1	0	3	3	4	1
	15-Jun	<5	<5	<5	0	1	1	2	0	15	14	16	1	<1	<1	<1	0	3	3	4	1
	13-Jul	<5	<5	<5	0	<1	<1	<1	0	17	16	17	1	<1	<1	<1	0	5	4	5	0
	17-Aug	<5	<5	<5	0	<1	<1	<1	0	24	24	24	0	<1	<1	<1	0	4	3	5	1
	14-Sep	<5	<5	<5	0	<1	<1	<1	0	18	18	19	0	<1	<1	<1	0	3	3	3	0
	12-Oct	10	9	10	0	<1	<1	<1	0	39	39	39	0	<1	<1	<1	0	5	5	6	0
2017	10-May	<5	<5	<5	0	<1	<1	<1	0	14	13	14	1	<1	<1	<1	0	<2	<2	<2	0
	14-Jun	<5	<5	<5	0	<1	<1	<1	0	18	18	18	0	<1	<1	<1	0	<2	<2	<2	0
	12-Jul	<5	<5	<5	0	<1	<1	<1	0	20	20	21	0	<1	<1	<1	0	3	2	3	1
	09-Aug	<5	<5	<5	0	<1	<1	<1	0	18	18	19	1	<1	<1	<1	0	2	2	3	0
	13-Sep	<5	<5	<5	0	<1	<1	<1	0	12	12	13	0	<1	<1	<1	0	<2	<2	2	0
	11-Oct	24	23	25	1	<1	<1	<1	0	47	47	48	1	<1	<1	<1	0	4	4	4	0
2018	10-May	<5	<5	<5	0	<1	<1	<1	0	9.6	8.5	10.6	1.5	<1	<1	<1	0	2.7	2.6	2.7	0.1
	05-Jun	<5	<5	5.4	0.3	<1	<1	<1	0	16.6	16.2	16.9	0.5	<1	<1	<1	0	3.1	2.9	3.3	0.3
	04-Jul	<5	<5	<5	0	<1	<1	<1	0	13.5	13.1	13.9	0.6	<1	<1	<1	0	5.5	4.9	6.0	0.8
	09-Aug	<5	<5	<5	0	<1	<1	<1	0	21.6	21.5	21.6	0.1	<1	<1	<1	0	3.9	3.7	4.0	0.2
	12-Sep	<5	<5	<5	0	<1	<1	<1	0	30.4	30.2	30.5	0.2	<1	<1	<1	0	3.3	3.1	3.5	0.3
	05-Oct	16.8	16.7	16.9	0.1	<1	<1	<1	0	21.6	21.3	21.8	0.4	<1	<1	<1	0	4.7	4.2	5.2	0.7

[1] Average of two duplicates (n=2) on each date unless otherwise indicated.

Parameters that have a concentration below the detection limit are assumed to have a concentration equal to the detection limit for calculation purposes.

Table 10. Continued (2 of 2).

Year	Date	Ammonia, Total (as N) µg/L				Dissolved Orthophosphate (as P) µg/L				Nitrate (as N) µg/L				Nitrite (as N) µg/L				Total Phosphorus (P) µg/L			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2019	13-May	<5	<5	<5	0	<1	<1	<1	0	10.2	10.2	10.2	0.0	<1	<1	<1	0	<2.3	<2	2.5	0.4
	12-Jun	<5.1	<5	5.2	0.1	<1	<1	<1	0	21.3	20.8	21.8	0.7	<1	<1	<1	0	3.3	3.0	3.6	0.4
	11-Jul	<5	<5	<5	0	<1	<1	<1	0	17.9	17.3	18.5	0.8	<1	<1	<1	0	4.8	4.7	4.9	0.1
	12-Aug	<11.9	<5.0	18.7	9.7	<1	<1	<1	0	19.1	18.8	19.4	0.4	<1	<1	<1	0	<2.1	<2	2.1	0.1
	12-Sep	<5	<5	<5	0	<1	<1	<1	0	14.2	14.1	14.3	0.1	<1	<1	<1	0	3.5	3.3	3.6	0.2
	09-Oct	5.7	5.5	5.8	0.2	<1	<1	<1	0	27.1	26.1	28.1	1.4	1.5	1.5	1.5	0	4.4	4.3	4.4	0.1
2020	11-May	<5	<5	<5	0	<1	<1	<1	0	7.3	7.1	7.4	0.2	<1	<1	<1	0	<2.1	<2	2.2	0.1
	08-Jun	<5	<5	<5	0	<1	<1	<1	0	11.7	11.5	11.9	0.3	<1	<1	<1	0	7.2	7.0	7.4	0.3
	07-Jul	<5	<5	<5	0	<1	<1	<1	0	15.1	15.0	15.2	0.1	<1	<1	<1	0	<2.4	<2	2.8	0.6
	10-Aug	<5	<5	<5	0	<1	<1	<1	0	17.7	17.4	18.0	0.4	<1	<1	<1	0	5.0	4.8	5.2	0.3
	10-Sep	<5	<5	<5	0	1.6	1.1	2.1	1	17.0	16.5	17.4	0.6	<1	<1	<1	0	<2	<2	<2	0
	08-Oct	15.2	8.7	21.7	9.2	<1	<1	<1	0	39.8	39.4	40.1	0.5	<1	<1	<1	0	4.0	3.6	4.3	0.5

[1] Average of two duplicates (n=2) on each date unless otherwise indicated.

Parameters that have a concentration below the detection limit are assumed to have a concentration equal to the detection limit for calculation purposes.

3. 2014 TO 2020 WATER AND AIR TEMPERATURE IN THE QUINSAM RIVER

3.1. Water Temperature

Table 11. Monthly water temperature in the Quinsam River (QUN-WQ) from 2014 to 2020. Statistics were not calculated for months with fewer than 3 weeks of observations.

Month	2014[1, 2, 3]				2015[1, 3]				2016[1, 3]				2017[1, 3]				2018[1, 3]				2019[1, 3]				2020[1, 3, 4]			
	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD
Jan	n/a	n/a	n/a	n/a	3.8	2.0	5.6	0.8	3.0	1.3	4.7	0.8	1.7	0.2	3.4	0.8	2.9	2.0	3.8	0.4	3.5	2.6	4.3	0.4	2.7	0.0	4.5	1.0
Feb	n/a	n/a	n/a	n/a	5.5	4.1	6.5	0.6	4.3	3.1	5.3	0.5	1.9	0.5	2.9	0.5	2.9	1.9	4.1	0.5	2.0	0.7	4.1	0.7	3.2	2.2	4.5	0.5
Mar	n/a	n/a	n/a	n/a	6.6	4.0	8.9	1.1	5.5	3.3	9.2	1.0	3.4	1.9	5.4	0.9	4.4	2.5	6.4	0.9	3.8	1.5	7.5	1.3	4.3	2.2	6.7	1.1
Apr	n/a	n/a	n/a	n/a	9.0	6.6	12.7	1.3	9.8	6.8	12.4	1.2	6.6	4.1	9.3	1.2	7.0	5.0	9.9	1.2	7.5	4.7	11.3	1.2	7.8	4.5	10.6	1.6
May	n/a	n/a	n/a	n/a	15.1	9.6	18.5	2.5	13.7	10.1	16.2	1.5	10.5	7.1	16.5	2.4	12.6	8.3	16.9	2.4	13.0	8.3	18.7	2.5	11.1	7.1	15.5	1.9
Jun	16.3	14.4	18.9	0.8	18.3	15.0	22.9	1.4	16.1	11.9	19.8	1.7	16.0	13.6	20.2	1.8	15.3	10.1	20.6	2.5	17.8	14.5	20.0	1.2	15.3	11.5	18.6	1.7
Jul	18.9	16.5	22.7	1.4	19.3	15.9	23.0	1.6	18.2	15.5	21.3	1.3	19.3	17.6	20.9	0.8	19.4	14.9	23.6	2.2	18.6	15.9	20.2	0.7	18.4	15.0	21.7	1.8
Aug	19.8	17.5	22.2	1.0	18.3	15.9	21.2	1.1	19.3	17.7	21.3	0.9	19.9	18.0	21.8	0.9	20.1	17.3	23.1	1.5	18.7	16.3	20.3	0.8	18.8	15.6	21.3	1.2
Sep	16.3	13.9	18.6	1.1	13.8	10.2	17.1	1.8	15.1	11.8	18.1	1.4	16.8	13.3	21.1	2.3	14.6	10.8	18.6	2.1	15.5	9.8	19.2	2.6	16.9	11.3	19.3	2.1
Oct	11.8	8.3	15.5	2.1	11.3	9.3	13.7	1.1	9.6	7.4	13.1	1.2	10.0	7.1	13.9	1.8	9.7	8.2	12.8	0.8	8.8	5.2	11.8	1.7	-	-	-	-
Nov	6.6	3.6	10.3	2.2	5.4	1.7	10.1	2.1	8.0	5.6	9.8	1.2	5.4	3.1	8.1	0.8	6.6	4.5	9.1	1.2	6.4	1.4	8.3	1.9	-	-	-	-
Dec	4.5	2.1	6.2	1.0	3.8	2.0	5.6	1.0	2.9	0.9	6.1	1.2	3.4	1.5	5.7	0.9	3.8	1.7	5.7	0.8	3.5	1.7	4.7	0.6	-	-	-	-

[1] "Avg", "Min", "Max" and "SD" denote the monthly average, minimum, maximum and standard deviation of water temperatures.

[2] "n/a" indicates that TidbiTs were not installed.

[3] Blue and orange shadings highlight minimum and maximum temperatures respectively for years with complete data.

[4] "-" indicates that TidbiT data has not yet been collected.

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Table 12. Summary of the frequency of exceedances of mean daily water temperature extremes (T_{water}>18°C, T_{water}>20°C, and T_{water}<1°C) in the Quinsam River at QUN-WQ from 2014 to 2020.

Year	Record Length (days)	Days T_{water} < 1°C	Days T_{water} > 18°C	Days T_{water} > 20°C
2014	222	0	54	20
2015	365	0	69	16
2016	366	0	52	14
2017	365	7	77	25
2018	365	0	55	30
2019	365	0	75	0
2020	281	1	51	16

Table 13. Statistics for the hourly rates of change in water temperature at QUN-WQ in the Quinsam River, 2014 to 2020. The frequency of rates of change exceeding a magnitude of 1°C/hr is also shown.

Station	Start of Record	End of Record	Number of Datapoints	Occurrence of rates > 1°C/hr		Max -ve	Percentile				Max +ve
				Number	% of record		1st	5th	95th	99th	
QUN-WQ	23-May-14	8-Oct-20	223,684	42	0.019	-1.9	-0.3	-0.2	0.2	0.4	1.2

Figure 1. Hourly rate of change in 15-minute water temperature in the Quinsam River (QUN-WQ) from 2014 to 2020. Red dots indicate rates with magnitudes exceeding ±1°C/hr.

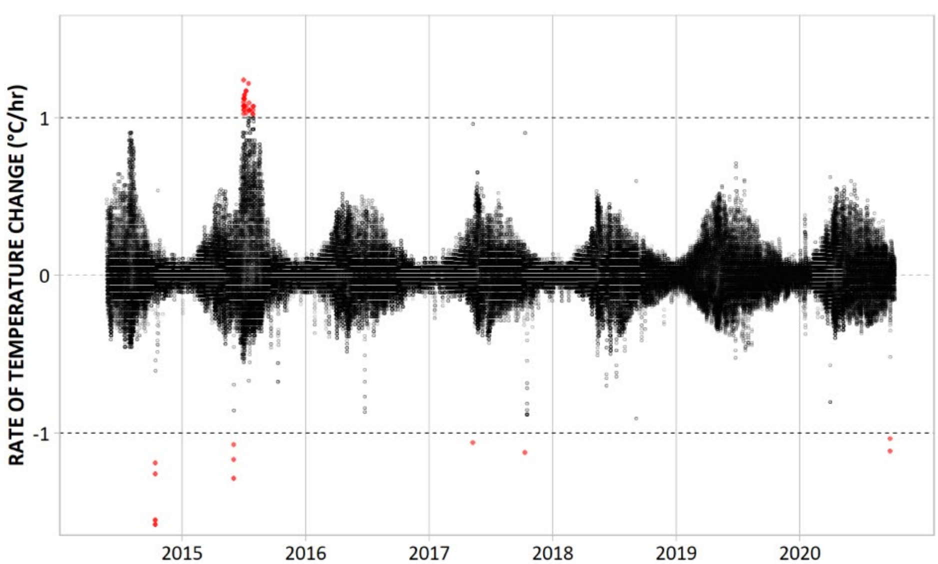


Table 14. Growing season timing and growing degree days at QUN-WQ in the Quinsam River (2014 to 2020).

Year	Number of Days with Valid Data	Growing Season[1]				
		Start Date	End Date	Length (days)	Gap (days)	Degree Days[2]
2014[2]	-	-	-	-	-	-
2015	365	23-Mar-15	09-Nov-15	232	0	3,344
2016	366	29-Mar-16	23-Nov-16	240	0	3,324
2017	365	19-Apr-17	01-Nov-17	197	0	2,926
2018	365	18-Apr-18	09-Nov-18	206	0	2,978
2019	365	11-Apr-19	27-Oct-19	200	0	2,961
2020[3]	-	-	-	-	-	-

[1] Growing season calculations were revised in Year 7 using a threshold of 7°C to define the start and end of the growing season.

[2] Growing season could not be estimated because a complete dataset over the course of the growing season is not available.

[3] Growing season will be reported once the dataset covers a complete growing season.

Table 15. Mean weekly maximum temperatures (MWMxT) in the Quinsam River from 2014 to 2020 compared to optimum temperature ranges for fish species present. Periodicity information is from Burt (2003).

Species	Life Stage: Periodicity	Life Stage: Optimum Temperature Range (°C)	Life Stage: Duration (days)	Year	Percent Complete (%)	MWMT (°C): Min	MWMT (°C): Max	% of MWMT: Below Lower Bound by >1°C	% of MWMT: Below Lower Bound	% of MWMT: Between Bounds	% of MWMT: Above Upper Bound	% of MWMT: Above Upper Bound by >1°C
Chinook Salmon	Migration (Sep. 23 to Nov. 22)	3.3-19.0	61	2014	100%	5.2	16.5	0.0	0.0	100.0	0.0	0.0
				2015	100%	4.4	12.9	0.0	0.0	100.0	0.0	0.0
				2016	100%	7.3	14.4	0.0	0.0	100.0	0.0	0.0
				2017	100%	4.7	15.6	0.0	0.0	100.0	0.0	0.0
				2018	100%	5.8	13.5	0.0	0.0	100.0	0.0	0.0
				2019	100%	6.9	14.8	0.0	0.0	100.0	0.0	0.0
				2020	25%	-	-	-	-	-	-	-
	Spawning (Oct. 01 to Nov. 30)	5.6-13.9	61	2014	100%	4.7	15.0	0.0	26.2	57.4	16.4	3.3
				2015	100%	2.8	12.9	16.4	23.0	77.0	0.0	0.0
				2016	100%	6.0	12.6	0.0	0.0	100.0	0.0	0.0
				2017	100%	4.7	14.0	0.0	26.2	72.1	1.6	0.0
				2018	100%	5.6	12.4	0.0	1.6	98.4	0.0	0.0
				2019	100%	4.0	12.3	3.3	6.6	93.4	0.0	0.0
				2020	11%	-	-	-	-	-	-	-
	Incubation (Oct. 01 to Apr. 30)[1]	5.0-14.0	242	2014	100%	2.8	11.6	9.6	21.3	78.7	0.0	0.0
				2015	100%	2.4	12.6	25.8	49.0	51.0	0.0	0.0
				2016	100%	1.3	9.6	52.3	57.4	42.6	0.0	0.0
				2017	100%	2.6	10.2	41.6	54.3	45.7	0.0	0.0
				2018	100%	1.8	10.7	42.6	54.8	45.2	0.0	0.0
				2019	100%	1.7	12.3	38.5	53.1	46.9	0.0	0.0
				2020	3%	-	-	-	-	-	-	-
	Rearing (Mar. 08 to Jul. 22)	10.0-15.5	137	2014	42%	13.9	21.9	0.0	0.0	8.6	91.4	86.2
				2015	100%	6.6	22.5	22.6	29.2	19.0	51.8	48.2
				2016	100%	5.4	19.3	17.5	21.9	36.5	41.6	26.3
				2017	100%	2.8	20.3	42.3	50.4	12.4	37.2	23.4
				2018	100%	4.0	21.1	34.3	40.9	27.0	32.1	26.3
				2019	100%	3.5	19.6	33.6	36.5	19.7	43.8	41.6
				2020	100%	3.9	20.7	28.5	39.4	35.0	25.5	23.4
Coho Salmon	Migration (Sep. 16 to Dec. 31)	7.2-15.6	61	2014	100%	3.1	17.1	44.9	45.8	44.9	9.3	6.5
				2015	100%	2.8	14.9	43.9	48.6	51.4	0.0	0.0
				2016	100%	2.2	16.2	30.8	36.4	60.7	2.8	0.0
				2017	100%	2.6	16.0	55.1	56.1	41.1	2.8	0.0
				2018	100%	3.3	14.4	40.2	48.6	51.4	0.0	0.0
				2019	100%	2.7	16.8	33.6	41.1	56.1	2.8	0.9
				2020	21%	-	-	-	-	-	-	-
	Spawning (Oct. 16 to Jan. 15)	4.4-12.8	39	2014	100%	2.8	11.6	10.9	28.3	71.7	0.0	0.0
				2015	100%	2.4	11.5	33.7	47.8	52.2	0.0	0.0
				2016	100%	1.3	9.6	41.3	44.6	55.4	0.0	0.0
				2017	100%	2.6	10.2	29.3	43.5	56.5	0.0	0.0
				2018	100%	3.3	10.0	3.3	38.0	62.0	0.0	0.0
				2019	100%	2.5	9.7	12.0	51.1	48.9	0.0	0.0
				2020	0%	-	-	-	-	-	-	-
	Incubation (Oct. 16 to Apr. 21)[2]	4.0-13.0	197	2014	100%	3.1	11.6	0.0	6.5	93.5	0.0	0.0
				2015	100%	2.8	11.5	5.2	31.2	68.8	0.0	0.0
				2016	100%	2.2	9.6	27.3	32.5	67.5	0.0	0.0
				2017	100%	2.6	10.2	14.3	20.8	79.2	0.0	0.0
				2018	100%	3.3	10.0	0.0	16.9	83.1	0.0	0.0
				2019	100%	1.7	9.8	10.1	43.4	56.6	0.0	0.0
				2020	0%	-	-	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2014	60%	3.1	21.9	23.2	24.1	23.2	52.7	38.6
				2015	100%	2.8	22.5	38.4	42.7	26.3	31.0	28.5
				2016	100%	2.2	20.8	36.1	38.5	35.2	26.2	21.0
				2017	100%	1.3	21.3	47.1	53.7	19.7	26.6	23.0
				2018	100%	2.6	23.1	45.2	47.9	27.1	24.9	22.5
				2019	100%	1.8	19.8	45.2	51.0	18.1	31.0	29.0
				2020	77%	1.7	21.2	35.9	37.7	27.0	35.2	33.8

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001)

Orange shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001)

[1]The start of incubation (previously mid-Oct) was amended in Year 7 to align with the start of spawning, as based on Burt (2003), which states that "Spawning takes place from the beginning of October…"

[2]The end of incubation was previously reported incorrectly as Dec 31 and was updated in Year 7 to April 21

Table 15. Continued (2 of 2).

Species	Life Stage: Periodicity	Life Stage: Optimum Temperature Range (°C)	Life Stage: Duration (days)	Year	Percent Complete (%)	MWMT (°C): Min	MWMT (°C): Max	% of MWMT: Below Lower Bound by >1°C	% of MWMT: Below Lower Bound	% of MWMT: Between Bounds	% of MWMT: Above Upper Bound	% of MWMT: Above Upper Bound by >1°C
Pink Salmon	Migration (Aug. 01 to Oct. 15)	7.2-15.6	53	2014	100%	11.8	21.9	0.0	0.0	26.3	73.7	67.1
				2015	100%	11.0	20.9	0.0	0.0	50.0	50.0	40.8
				2016	100%	9.3	20.8	0.0	0.0	35.5	64.5	48.7
				2017	100%	10.5	21.3	0.0	0.0	35.5	64.5	59.2
				2018	100%	10.1	22.6	0.0	0.0	42.1	57.9	53.9
				2019	100%	9.5	19.8	0.0	0.0	35.5	64.5	61.8
				2020	89%	14.0	21.2	0.0	0.0	16.2	83.8	82.4
	Spawning (Sep. 16 to Oct. 15)	7.2-12.8	61	2014	100%	11.8	17.1	0.0	0.0	10.0	90.0	83.3
				2015	100%	11.0	14.9	0.0	0.0	70.0	30.0	16.7
				2016	100%	9.3	16.2	0.0	0.0	50.0	50.0	33.3
				2017	100%	10.5	16.0	0.0	0.0	40.0	60.0	53.3
				2018	100%	10.1	14.4	0.0	0.0	63.3	36.7	6.7
				2019	100%	9.5	16.8	0.0	0.0	53.3	46.7	40.0
				2020	73%	14.0	18.4	0.0	0.0	0.0	100.0	100.0
	Incubation (Sep. 16 to Apr. 07)	4.0-13.0	168	2014	100%	2.8	17.1	1.5	9.3	77.5	13.2	12.3
				2015	100%	2.4	14.9	9.8	24.9	72.2	2.9	2.0
				2016	100%	1.3	16.2	43.6	50.5	42.6	6.9	4.4
				2017	100%	2.6	16.0	16.7	40.2	51.0	8.8	7.4
				2018	100%	1.8	14.4	13.2	41.2	54.4	4.4	0.5
				2019	100%	1.7	16.8	9.3	40.0	53.2	6.8	5.9
				2020	11%	-	-	-	-	-	-	-
Rainbow/ Steelhead Trout	Spawning (Feb. 16 to Apr. 15)	10.0-15.5	91	2014	0%	-	-	-	-	-	-	-
				2015	100%	5.3	9.4	86.4	100.0	0.0	0.0	0.0
				2016	100%	4.8	10.2	75.0	85.0	15.0	0.0	0.0
				2017	100%	2.4	6.9	100.0	100.0	0.0	0.0	0.0
				2018	100%	2.6	7.0	100.0	100.0	0.0	0.0	0.0
				2019	100%	2.1	8.3	100.0	100.0	0.0	0.0	0.0
				2020	100%	3.5	8.9	100.0	100.0	0.0	0.0	0.0
	Incubation (Feb. 16 to Jun. 15)	10.0-12.0	137	2014	18%	-	-	-	-	-	-	-
				2015	100%	5.3	19.3	42.5	50.0	14.2	35.8	34.2
				2016	100%	4.8	18.6	37.2	42.1	17.4	40.5	33.9
				2017	100%	2.4	16.4	65.0	74.2	4.2	21.7	20.0
				2018	100%	2.6	16.1	55.8	63.3	6.7	30.0	26.7
				2019	100%	2.1	19.6	55.0	58.3	9.2	32.5	29.2
				2020	100%	3.5	15.3	49.6	62.0	14.9	23.1	14.9
	Rearing (Jan. 01 to Dec. 31)	16.0-18.0	365	2014	60%	3.1	21.9	45.0	47.3	22.3	30.5	23.2
				2015	100%	2.8	22.5	65.8	69.0	4.4	26.6	18.4
				2016	100%	2.2	20.8	64.8	73.8	10.4	15.8	10.9
				2017	100%	1.3	21.3	66.3	73.4	4.4	22.2	20.3
				2018	100%	2.6	23.1	71.5	75.1	8.2	16.7	13.4
				2019	100%	1.8	19.8	67.7	69.0	4.9	26.0	12.9
				2020	77%	1.7	21.2	60.9	64.8	9.6	25.6	13.9

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001)
Orange shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001)

3.2. Air Temperature

Figure 2. Air temperature at the Quinsam River (QUN-AT) between May 2014 and October 2020.

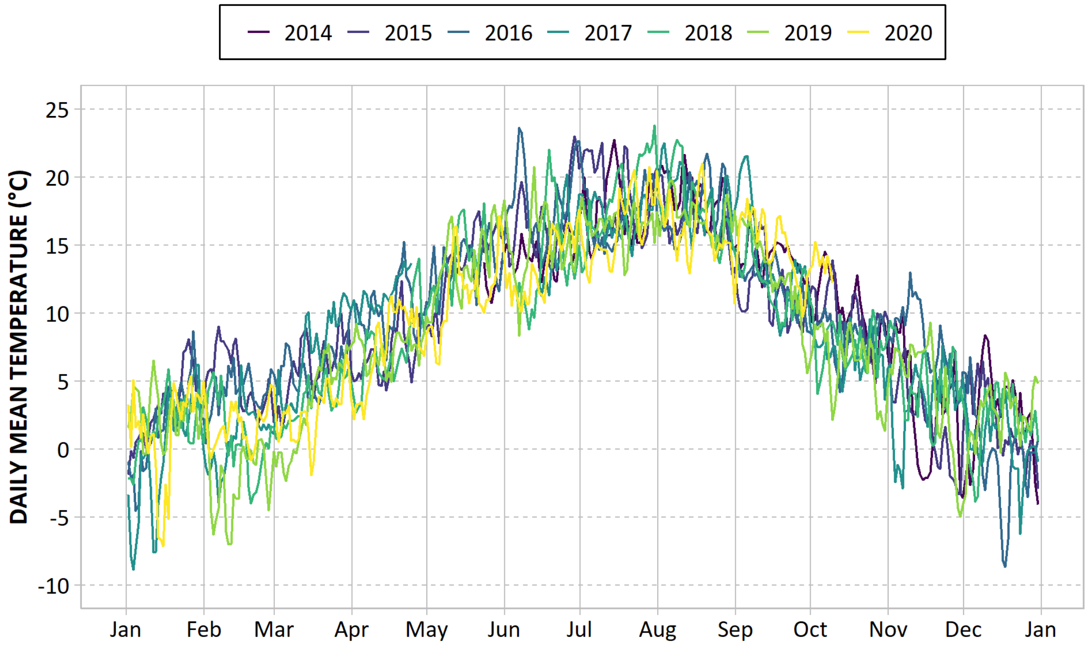


Table 16. Monthly air temperature statistics at the Quinsam River (QUN-AT) from 2014 to 2020. Statistics were not calculated for months with fewer than 3 weeks of observations.

Month	2014[1, 2, 3]				2015[1, 3]				2016[1, 3]				2017[1, 3]				2018[1, 3]				2019[1, 3]				2020[1, 3, 4]			
	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD
Jan	n/a	n/a	n/a	n/a	3.0	-4.0	9.1	2.6	1.8	-7.0	9.3	3.2	-0.4	-11.5	8.2	4.5	1.7	-5.4	7.3	2.3	2.6	-2.5	8.7	2.3	1.3	-11.6	8.2	3.8
Feb	n/a	n/a	n/a	n/a	5.1	-1.4	10.0	2.8	4.3	-1.2	9.9	2.1	0.9	-6.9	8.5	2.6	0.9	-9.1	8.4	3.3	-2.2	-12.5	6.3	3.7	1.7	-4.5	7.6	2.4
Mar	n/a	n/a	n/a	n/a	6.1	-1.8	13.8	3.2	6.1	-0.9	18.6	3.2	7.1	-0.9	14.9	3.4	3.6	-2.4	12.8	3.3	3.4	-7.7	20.1	5.5	2.7	-7.2	14.5	3.8
Apr	n/a	n/a	n/a	n/a	7.1	0.0	19.7	3.7	10.2	1.8	23.7	3.8	11.4	4.8	18.3	2.1	7.3	-2.3	24.2	4.7	7.4	-0.5	18.4	4.0	7.8	-1.9	19.9	4.9
May	n/a	n/a	n/a	n/a	13.7	1.6	25.5	4.7	13.9	4.0	23.9	4.3	-	-	-	-	14.0	4.0	26.7	5.1	13.9	1.4	27.2	5.4	11.7	0.3	25.9	4.9
Jun	14.4	5.9	23.0	3.4	16.9	6.9	31.7	4.8	18.3	9.3	31.0	4.0	-	-	-	-	14.1	2.2	32.6	5.0	15.0	3.2	29.0	4.6	13.6	4.3	24.3	3.8
Jul	17.9	9.2	30.9	4.3	18.8	9.4	30.6	4.9	17.1	9.7	27.1	3.4	17.0	7.2	27.4	4.1	18.5	6.0	33.3	5.6	16.4	6.3	25.9	3.4	16.5	7.0	30.4	4.6
Aug	18.6	10.1	29.5	4.2	16.9	8.8	27.3	3.9	17.6	10.0	29.4	4.2	18.4	7.8	32.0	5.0	17.9	7.3	31.2	5.2	17.0	7.8	27.9	4.0	15.9	5.3	28.5	4.4
Sep	14.2	5.8	25.3	3.8	11.5	3.4	23.4	3.4	11.9	3.7	20.2	2.9	14.0	2.4	31.0	5.4	12.1	3.0	24.6	3.7	12.8	0.2	24.0	4.2	15.0	6.8	27.4	4.2
Oct	10.1	1.9	17.3	2.7	9.8	2.8	18.4	2.7	8.3	0.5	11.7	1.9	6.9	-0.3	16.6	3.3	7.5	-0.1	16.0	3.5	6.3	-2.2	13.7	3.6	-	-	-	-
Nov	3.1	-6.6	11.9	4.4	1.9	-6.8	9.2	3.3	7.8	1.5	14.5	2.7	3.6	-7.1	11.6	3.1	4.8	-2.2	11.6	3.0	4.3	-8.4	11.0	4.4	-	-	-	-
Dec	2.4	-6.3	10.0	3.5	1.9	-4.8	8.4	2.8	-0.7	-10.9	8.6	3.5	0.3	-8.5	6.6	2.4	1.8	-6.8	8.4	2.7	2.7	-7.0	7.3	2.4	-	-	-	-

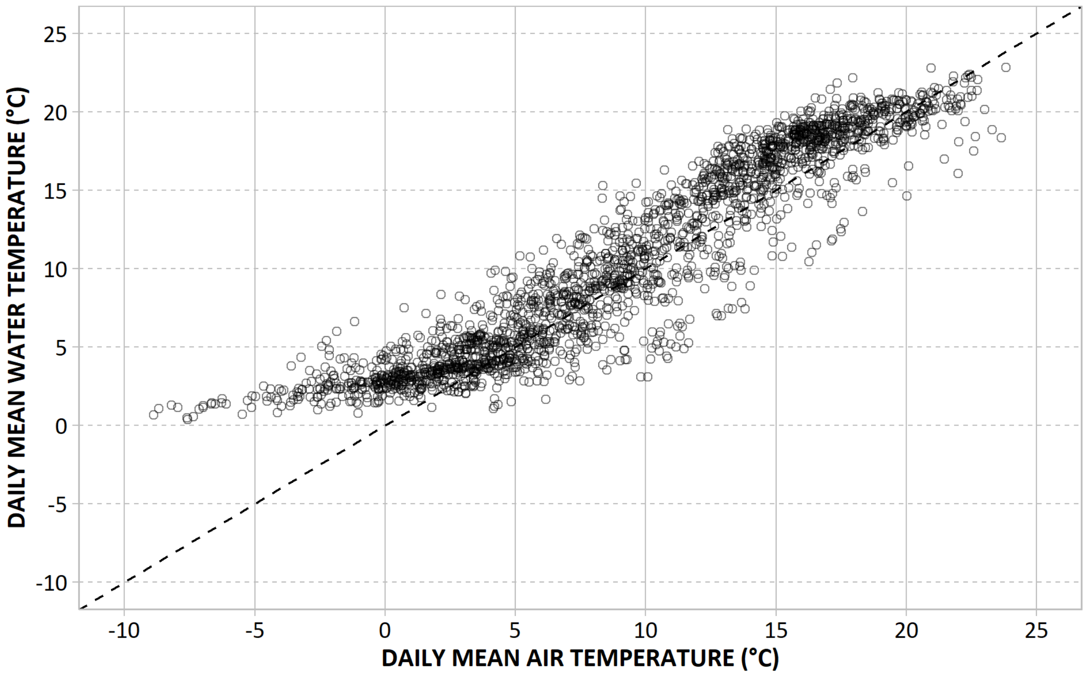
[1] "Avg", "Min", "Max" and "SD" denote the monthly average, minimum, maximum and standard deviation of air temperatures.

[2] "n/a" indicates that TidbiTs were not installed.

[3] Blue and orange shadings highlight minimum and maximum temperatures respectively for years with complete data.

[4] "-" indicates that TidbiT data has not yet been collected.

Figure 3. Relationship between daily average water and air temperature in the Quinsam River (QUN-AT) between May 2014 and October 2020. Dashed line denotes 1:1 line.



4. QUALITY CONTROL/QUALITY ASSURANCE

Table 17. Hold time exceedances for water samples analyzed by ALS laboratories recorded during 2014 to 2020.

Description[1]	Sampling Date	Recommended Hold Time (days)	Actual Hold Time (days)
Anions and Nutrients			
Nitrite in Water by Ion Chromatography	19-Aug-14	3	8
Nitrate in Water by IC (Low Level)	10-May-18	3	5

[1]All samples for all sites and sample dates exceeded the recommended hold time for pH of 0.25 hours

Table 18. Results of field blank and trip blanks for water samples analysed by ALS laboratories, 2014 to 2020.

Year	Date	Type of Sample	Alkalinity, Total (as $CaCO_3$) mg/L	Ammonia, Total (as N) µg/L	Conductivity µS/cm	Orthophosphate (as P) µg/L	Nitrate (as N) µg/L	Nitrite (as N) µg/L	Total Dissolved Solids mg/L	Total Phosphorus (P) µg/L	Total Suspended Solids mg/L	Turbidity NTU	pH pH units
2014	23-May	Field Blank	<2.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.60
		Trip Blank	<2.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.64
	18-Jun	Field Blank	<2.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.47
		Trip Blank	<2.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.45
	22-Jul	Field Blank	<2.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.69
		Trip Blank	<2.0	2.71	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.76
	19-Aug	Field Blank	<2.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.91
		Trip Blank	<2.0	38.7	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	6.17
	24-Sep	Field Blank	<2.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.45
		Trip Blank	<2.0	55.1	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.41
	04-Nov	Field Blank	<2.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.70
		Trip Blank	<2.0	99.5	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.75
2015	12-May	Field Blank	<2.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.84
		Trip Blank	<2.0	11.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.80
	17-Jun	Field Blank	<2.0	<5.0	3.2	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	6.22
		Trip Blank	<2.0	58.5	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.91
2016	18-May	Field Blank	<2.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.62
		Trip Blank	<2.0	5.90	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.58
2018	10-May	Field Blank	<1.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.53
		Trip Blank	<1.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.3
2019	13-May	Field Blank	<1.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.41
		Trip Blank	<1.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.38
2020	11-May	Field Blank	<1.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.42
		Trip Blank	<1.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.38

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Appendix B. Supplementary Results of Analysis of Invertebrate Drift Data

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1. QUINSAM RIVER INVERTEBRATE DRIFT RESULTS (SUMMARY TABLE)

Table 1. Quinsam River invertebrate drift density, biomass, Simpson's diversity index (family level), richness and Canadian Ecological Flow Index (CEFI). Each drift net was analyzed separately in 2014 for density, biomass and CEFI, while nets were combined into one sample per site for biodiversity metrics (family richness, Simpson's diversity) and for all metrics in subsequent years. Thus, standard deviation (SD) and coefficient of variation (CV) are provided for Year 1 (2014) only.

All Taxa (Aquatic, Semi-Aquatic, and Terrestrial)													
Year	Date	# of Replicates	Density (#/m^3)[1]			Biomass (mg/m^3)[1]			CEFI Index†[1]			Simpson's Diversity Index (1-λ)[2]	Richness (# of Families)[2]
			Value	S.D.	C.V.	Value	S.D.	C.V.	Value	S.D.	C.V.	Value	Value
2014	23-May	5	0.96	0.12	12.6	0.20	0.04	21.2	0.38	0.01	2.9	0.84	66
	04-Jun	5	2.73	0.22	8.1	0.34	0.06	17.5	0.36	0.02	4.5	0.78	66
	12-Jun	5	2.57	0.31	12.0	0.20	0.05	26.9	0.36	0.01	2.4	0.74	65
	18-Jun	5	3.11	0.65	20.9	0.16	0.06	36.8	0.36	0.01	1.6	0.76	63
	27-Jun	5	2.48	0.46	18.7	0.14	0.05	33.2	0.35	0.01	2.1	0.81	70
	22-Jul	5	4.19	0.73	17.5	0.14	0.02	14.1	0.36	0.00	0.6	0.82	60
	19-Aug	5	6.88	3.27	47.5	0.16	0.02	15.7	0.35	0.01	1.9	0.66	59
	24-Sep	5	2.36	0.85	35.9	0.09	0.03	35.6	0.32	0.01	3.4	0.81	52
	04-Nov	5	0.65	0.22	33.3	0.07	0.02	33.5	0.33	0.01	1.6	0.92	80
2015	12-May	1	1.38	-	-	0.21	-	-	0.35	-	-	0.78	52
	17-Jun	1	4.41	-	-	0.19	-	-	0.34	-	-	0.65	50
	09-Jul	1	6.38	-	-	0.32	-	-	0.34	-	-	0.74	61
	16-Jul	1	2.52	-	-	0.28	-	-	0.35	-	-	0.81	73
	23-Jul	1	4.38	-	-	0.12	-	-	0.33	-	-	0.76	53
	29-Jul	1	4.57	-	-	0.14	-	-	0.34	-	-	0.64	39
	13-Aug	1	4.34	-	-	0.08	-	-	0.31	-	-	0.78	42
	16-Sep	1	1.71	-	-	0.12	-	-	0.35	-	-	0.79	33
	14-Oct	1	2.06	-	-	0.12	-	-	0.34	-	-	0.87	50
2016	04-May	1	2.49	-	-	0.20	-	-	0.36	-	-	0.78	38
	11-May	1	1.87	-	-	0.15	-	-	0.36	-	-	0.79	43
	18-May	1	2.82	-	-	0.22	-	-	0.35	-	-	0.78	48
	25-May	1	3.72	-	-	0.25	-	-	0.34	-	-	0.82	59
	15-Jun	1	3.25	-	-	0.24	-	-	0.33	-	-	0.82	40
	13-Jul	1	5.33	-	-	0.15	-	-	0.31	-	-	0.66	41
	17-Aug	1	1.76	-	-	0.10	-	-	0.33	-	-	0.77	53
	12-Oct	1	1.71	-	-	0.13	-	-	0.35	-	-	0.92	53
2017	10-May	1	1.63	-	-	0.33	-	-	0.36	-	-	0.85	44
	14-Jun	1	4.13	-	-	0.18	-	-	0.37	-	-	0.71	28
	12-Jul	1	3.66	-	-	0.10	-	-	0.35	-	-	0.76	39
	09-Aug	1	4.84	-	-	0.25	-	-	0.34	-	-	0.75	46
	16-Aug	1	4.37	-	-	0.10	-	-	0.34	-	-	0.68	33
	23-Aug	1	3.29	-	-	0.17	-	-	0.33	-	-	0.81	40
	31-Aug	1	2.38	-	-	0.09	-	-	0.35	-	-	0.77	45
	13-Sep	1	2.46	-	-	0.10	-	-	0.34	-	-	0.80	31
	11-Oct	1	1.18	-	-	0.06	-	-	0.34	-	-	0.83	30
2018	10-May	1	1.21	-	-	0.08	-	-	0.35	-	-	0.74	32
	05-Jun	1	2.58	-	-	0.16	-	-	0.32	-	-	0.69	35
	04-Jul	1	3.97	-	-	0.17	-	-	0.34	-	-	0.78	40
	09-Aug	1	3.67	-	-	0.15	-	-	0.34	-	-	0.85	47
	04-Sep	1	1.35	-	-	0.09	-	-	0.36	-	-	0.84	46
	12-Sep	1	2.04	-	-	0.14	-	-	0.37	-	-	0.84	35
	21-Sep	1	1.94	-	-	0.13	-	-	0.33	-	-	0.91	28
	26-Sep	1	1.76	-	-	0.17	-	-	0.36	-	-	0.90	56
	05-Oct	1	1.19	-	-	0.09	-	-	0.35	-	-	0.89	47

† Calculation considers only aquatic taxa

[1] Replicates were averaged where applicable prior to calculating metric

[2] Net data were combined into a single sample for the site prior to calculating metric

Table 1. Continued (2 of 2).

Year	Date	# of Replicates	All Taxa (Aquatic, Semi-Aquatic, and Terrestrial) Density ($\#/m^3$)[1]			Biomass (mg/m^3)[1]			CEFI Index[†1]			Simpson's Diversity Index (1-λ)[2]	Richness (# of Families)[2]
			Value	S.D.	C.V.	Value	S.D.	C.V.	Value	S.D.	C.V.	Value	Value
2019	13-May	1	1.47	-	-	0.11	-	-	0.40	-	-	0.55	28
	06-Jun	1	1.70	-	-	0.05	-	-	0.34	-	-	0.87	48
	12-Jun	1	2.92	-	-	0.12	-	-	0.35	-	-	0.81	33
	20-Jun	1	2.61	-	-	0.11	-	-	0.34	-	-	0.86	39
	27-Jun	1	3.15	-	-	0.12	-	-	0.33	-	-	0.86	40
	11-Jul	1	3.74	-	-	0.15	-	-	0.34	-	-	0.88	36
	12-Aug	1	2.87	-	-	0.11	-	-	0.34	-	-	0.77	23
	12-Sep	1	2.27	-	-	0.08	-	-	0.34	-	-	0.79	31
	09-Oct	1	1.00	-	-	0.10	-	-	0.38	-	-	0.63	35
2020	11-May	1	2.83	-	-	0.59	-	-	0.35	-	-	0.83	40
	08-Jun	1	2.66	-	-	0.38	-	-	0.34	-	-	0.77	40
	07-Jul	1	7.21	-	-	0.25	-	-	0.33	-	-	0.64	27
	14-Jul	1	7.63	-	-	0.41	-	-	0.34	-	-	0.74	38
	21-Jul	1	8.26	-	-	0.27	-	-	0.34	-	-	0.65	28
	27-Jul	1	4.32	-	-	0.22	-	-	0.34	-	-	0.80	34
	10-Aug	1	4.60	-	-	0.25	-	-	0.35	-	-	0.68	36
	10-Sep	1	4.84	-	-	0.47	-	-	0.34	-	-	0.82	37
	08-Oct	1	1.80	-	-	0.19	-	-	0.35	-	-	0.80	32

† Calculation considers only aquatic taxa

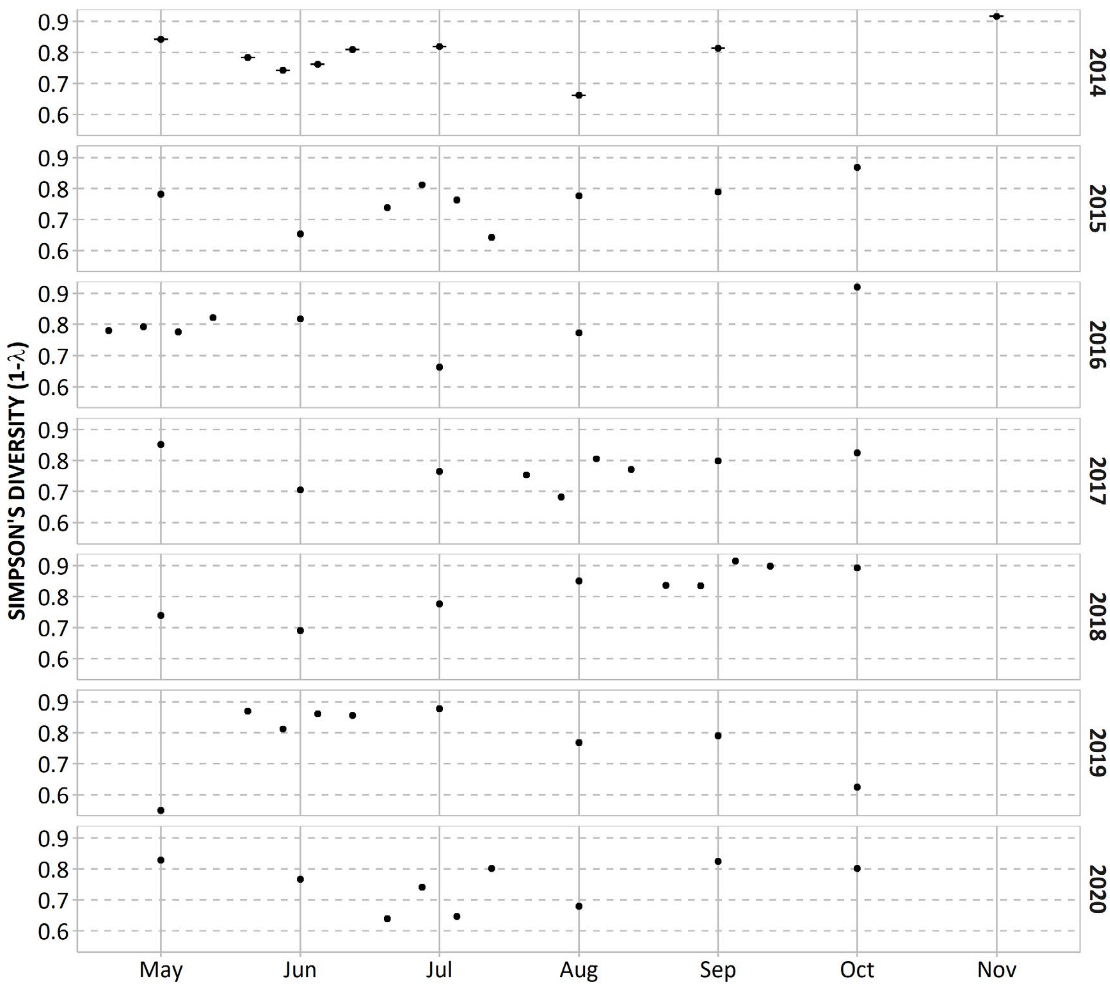
1 Replicates were averaged where applicable prior to calculating metric

2 Net data were combined into a single sample for the site prior to calculating metric

2. SIMPSON'S FAMILY LEVEL DIVERSITY (1-Λ)

Simpson's family level diversity values ranged from 0.64 – 0.83 in Year 7, which was within the range observed in previous years (0.55 – 0.92; Table 1; Figure 1). Simpson's family level diversity was variable throughout Year 7, with the highest value observed on May 11, 2020 and the lowest value observed on July 7, 2020.

Figure 1. Drift invertebrate Simpson's Diversity (all taxa) in the Quinsam River throughout 2014 - 2020. Standard deviation (SD) is provided for Year 1 (2014) only, which is the only year when samples from all five drift nets were analyzed separately.



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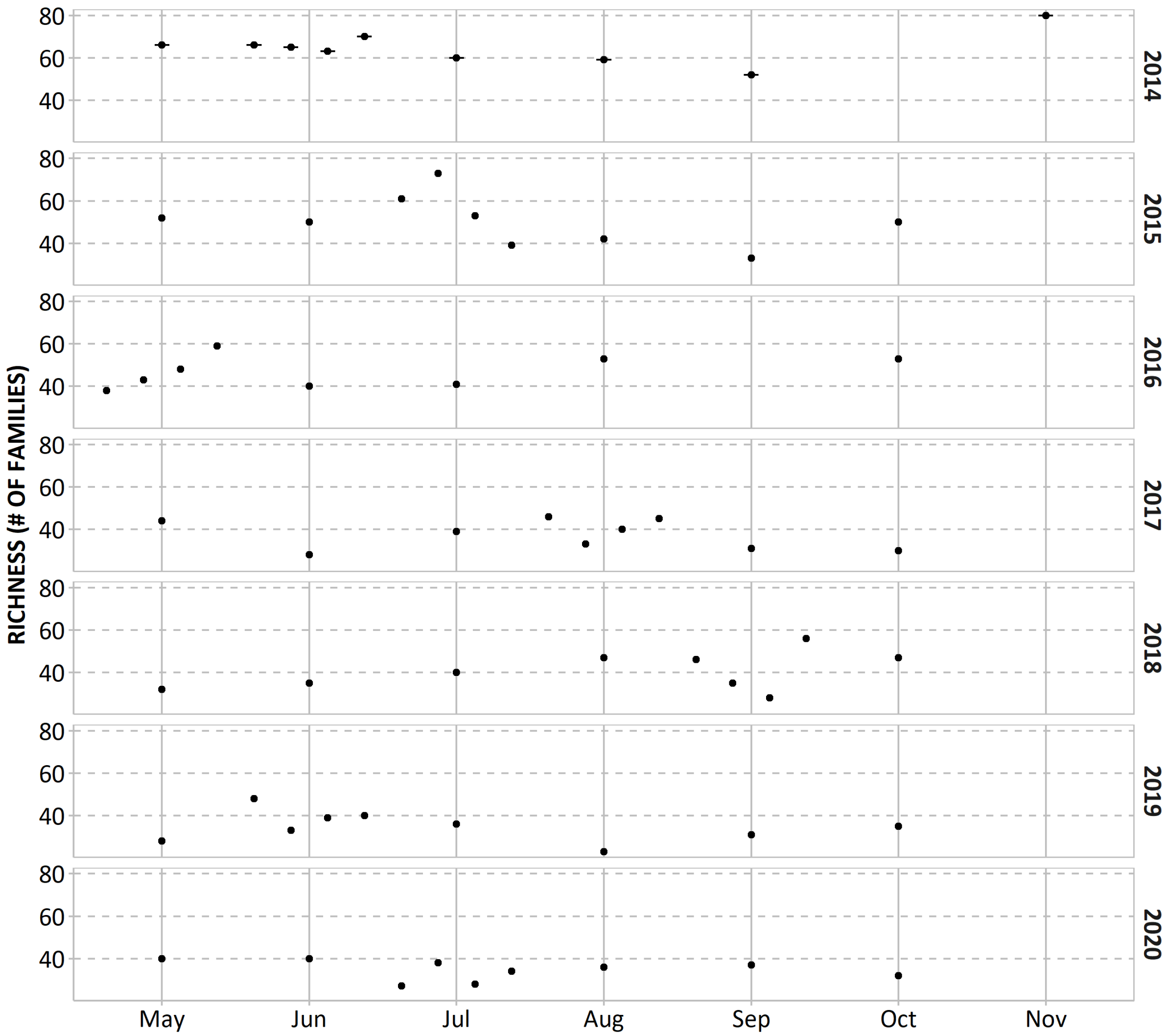
3. RICHNESS (# OF FAMILIES)

Family richness measured in Year 7 ranged from 27 – 40 families across sampling dates (Table 1, Figure 2). There was no clear seasonal pattern, with the lowest value observed on July 7, 2020 and the highest value observed on May 11 and June 8, 2020.

Similar to Year 6, average family richness in Year 7 was lower than previous years sampled during the JHTMON-8 monitoring period (Figure 2).

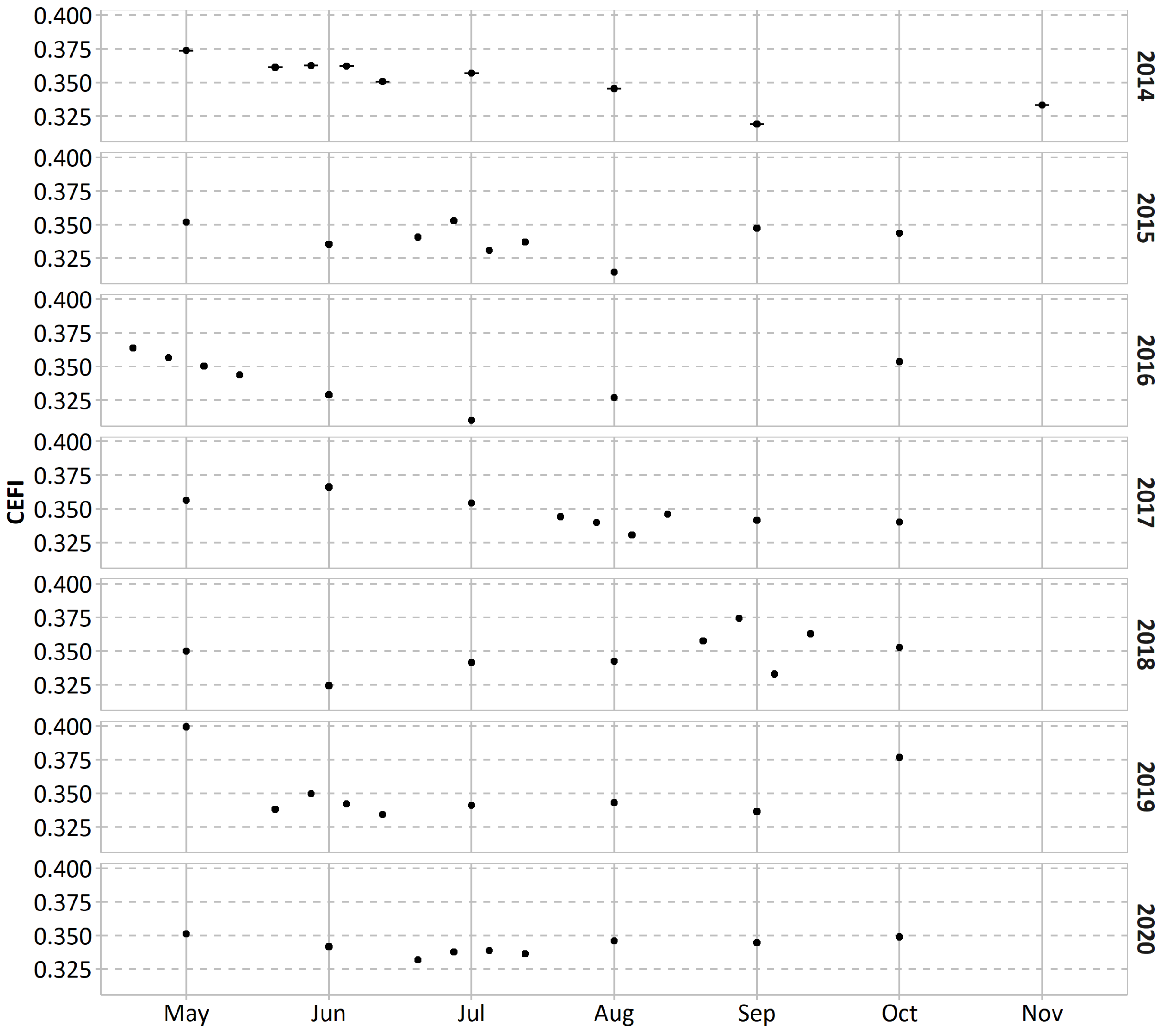
Figure 2. Drift invertebrate family richness (all taxa) in the Quinsam River throughout 2014 – 2020. Standard deviation (SD) is provided for Year 1 (2014) only, which is the only year when samples from all five drift nets were analyzed separately.



4. CANADIAN ECOLOGICAL FLOW INDEX

The CEFI results for Year 7 are in the range 0.33 – 0.35, which are above the 0.25 threshold of low CEFI values (Armanini *et al.* 2011). In Year 7, the lowest CEFI value occurred in July while the maximum value was observed in May, August, and October (Table 1; Figure 3). These results showed no clear seasonal patterns throughout Year 7.

Figure 3. CEFI values for drift invertebrates (aquatic taxa) in the Quinsam River throughout 2014 - 2020. Standard deviation (SD) values are provided for Year 1 (2014) only, which is the only year when samples from all five drift nets were analyzed separately.



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