Campbell River Project Water Use Plan

Quinsam River Smolt and Spawner Abundance Assessment

Implementation Year 9

Reference: JHTMON-8

Year 9 Annual Monitoring Report

Study Period: April 1, 2022 to March 31, 2023

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

October 18, 2023

JHTMON-8: Quinsam River Smolt and Spawner Abundance Assessment

Year 9 Annual Monitoring Report




Prepared for:

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Title page photographs – top left: looking downstream on the Quinsam River (August 11, 2022); top right: drift nets deployed in the Quinsam River (May 16, 2022); bottom left: retrieving drift nets in the Quinsam River (August 11, 2022); bottom right: looking upstream on the Quinsam River (June 06, 2022)

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EXECUTIVE SUMMARY

Background and Objectives

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 regarding 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 factors limit 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 nine years of data collection (Table i) have now been completed. In Year 10 (2023), 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_0$3*);
- Floods (*$H_0$4*);
- Food abundance (*$H_0$5*); or
- The abundance of returning adult fish (*$H_0$6*).

Species of primary interest are Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*) and steelhead (*O. mykiss*), although the study involves compiling adult escapement and juvenile abundance data for additional Pacific salmon species.

Juvenile Fish Abundance (*$H_0$1*)

Annual outmigration abundance data provided by DFO for Years 1–9 vary the most for wild Chinook Salmon (~600 to ~360,000 fry) and less so 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 9 was the particularly high abundance of outmigrating juvenile Chinook Salmon recorded at the Quinsam Hatchery fence (~222,000), which was the third highest value recorded during the nine years of JHTMON-8, and the fourth highest value recorded overall in the period of record (Figure 6, Figure 7). Historical data compiled to date show considerable inter-annual variability in juvenile fish abundance, with the abundance of each of the three JHTMON-8 priority species varying by at least a factor of four throughout the period of record (Figure 7).

Habitat Availability (*$H_0$2*)

To initiate analysis to test *$H_0$2* (habitat availability), we initially quantified the Weighted Usable Area (WUA; in m^2) for different life stages of priority species in Year 5. Further analysis to test $H_0$4 was not completed in Year 9, but analysis to test this hypothesis will be updated in Year 10 by updating the habitat time series using the latest flow data.

Water Quality (*$H_0$3*)

Water quality data (relevant to *$H_0$3*) collected at an index site 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. Measurements of some water quality variables were, at times, outside of the biological optimum ranges for fish species present in the watershed (Figure 10 to Figure 13). Specifically, the mean weekly maximum water temperature values observed in Year 9 exceeded the upper limit of the optimum temperature ranges by >1°C at times for the rearing life stage of juvenile Coho Salmon (27% of the period; maximum exceedance of 8.1°C), Chinook Salmon (18% of the period; maximum exceedance of 4.7°C), and steelhead/Rainbow Trout (17% of the period; maximum exceedance of 6.1°C). Mean weekly maximum water temperatures that were >1°C cooler than optimum temperature ranges were also observed in 2022, most notably in relation to the rearing periods for each of the three priority species. These exceedances were generally consistent with results from Years 1 to 8 (Table 15 of Appendix A) although it was notable that water temperatures in spring and early summer 2022 were unusually cool, whereas water temperatures in late summer and early fall 2022 were unusually warm.

Furthermore, as in previous years, concentrations of dissolved oxygen lower than the provincial guideline for the protection of buried embryos/alevins were recorded at the start of the Pink Salmon incubation period in Year 9; however, these values were only slightly less than the guideline (~0.61 mg/L below the guideline minimum at the start of the incubation period) and were expected to have increased (i.e., conditions improved) as water temperatures cooled later in the fall.

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 potential 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 water quality measurements generally exhibit low variability through time, with measurements of variables such as nutrient concentrations close to method detection limits.

Floods (H_04)

Preliminary analysis was undertaken in Year 8 to provide initial insights into potential links between hydrologic variability and juvenile fish abundance. Analysis involved analyzing relationships between hydrological metrics and either the shape of stock-recruitment curves (Pacific salmon species), or smolt abundance (steelhead). The analysis provided insight regarding H_04 (effect of floods), but also provided proof of concept for analysis of the effects of environmental variables in general that will be completed during Year 10. Further analysis to test H_04 was not completed in Year 9 but analysis to test this hypothesis will be updated in Year 10.

Food Availability (H_05)

Food availability for juvenile salmonids was quantified using drift net sampling undertaken nine times throughout the growing season. Additional insight was provided based on kick net sampling completed once in fall. Invertebrate drift biomass in the Quinsam River is often highest in the spring, although seasonal trends are not pronounced each year. Total invertebrate biomass in Year 9 (0.06 – 0.55 mg/m^3) was within the range of previous years (0.05 – 0.59 mg/m^3) (Figure 15). In Year 10, we will examine the relationship between invertebrate biomass (i.e., fish food) and juvenile fish abundance to test H_05, although we plan to trial invertebrate density as a secondary measure of food abundance. Interannual variability in invertebrate biomass has so far been generally low, despite seasonal patterns (Figure 15).

Adult Escapement (H_06)

Pacific salmon escapement data collected by DFO have been compiled and analyzed each year to test H_06 (adult returns). In Year 9 (2022), data were available for the period to 2021 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 2021 (5,789) was above-average (4,395), whereas estimated escapement of Coho Salmon in 2021 (10,428) was lower than the mean value (12,166) for previous years in the period of record (1957 – 2020; Table 12, Figure 5). Pink Salmon escapement in the Quinsam River in 2021 (599,302) was higher than the mean value for the dataset (142,819; Table 12). The estimated Chum Salmon escapement in 2021 (5) was particularly low as it was the lowest count recorded in the 62-year dataset (Figure 5). The Chum Salmon estimate is likely biased low as the sampling period does not usually capture the full duration of the migration period, as was the case in 2021.

Table ii. Status of JHTMON-8 objectives, management questions and hypotheses after Year 9.

<table>
<tr><th>Study Objective</th><th>Management Questions</th><th>Management Hypotheses</th><th>Year 9 (2022/2023) Status</th></tr>
<tr><td rowspan="4">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.</td><td rowspan="4">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?</td><td>$H_0$1: Annual population abundance does not vary with time (i.e., years) over the course of the Monitor</td><td>-Juvenile fish have been sampled annually at the Quinsam River Hatchery salmon counting fence to derive total outmigration estimates
-Inter-annual variability has been observed in the abundance of priority species so we expect to reject this hypothesis in Year 10</td></tr>
<tr><td>$H_0$2: Annual population abundance is not correlated with annual habitat availability as measured by Weighted Usable Area (WUA)</td><td>-In Year 5, we used existing flow-habitat relationships to estimate WUA of habitat for priority species for 1975-2017
-Additional work relating to this hypothesis was not undertaken in Year 9; relationships will be updated in Year 10 for the final analysis to test this hypothesis</td></tr>
<tr><td>$H_0$3: Annual population abundance is not correlated with water quality</td><td>-Water quality has been measured each year through the growing season at a single index site
-Water quality is generally within guidelines to support healthy salmonid populations, although there are some exceptions
-Analysis will be undertaken to test this hypothesis in Year 10. Low variability in independent variables is expected to limit the statistical power of this analysis; comparisons with water quality guidelines will be an important line of evidence</td></tr>
<tr><td>$H_0$4: Annual population abundance is not correlated with the occurrence of flood events</td><td>-Further analysis to test $H_0$4 was not completed in Year 9 but analysis to test this hypothesis will be updated in Year 10, when flow data collected by the Water Survey of Canada will be analyzed to calculate flow metrics to use as predictor variables in statistical models</td></tr>
</table>

Study Objective	Management Questions	Management Hypotheses	Year 9 (2022/2023) Status
		$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 -Seasonal patterns have been observed although they are inconsistent among years -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 watersheds 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 -Initial stock-recruitment curves have been developed, which will be updated to test this hypothesis in Year 10

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1. INTRODUCTION

1.1. Background

Water use planning is intended provide a balance between 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, several 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 field work and analysis undertaken in Year 9 of JHTMON-8, which commenced on April 1, 2022. 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 mean annual discharge near the mouth of 8.5 m^3/s. The river has high fisheries values, supporting a range 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 2022). 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).

The Quinsam River Diversion generally does not operate during the summer months (July through September; Figure 1) because there is usually insufficient flow to operate the facility and also meet minimum instream flow requirements in the Quinsam River (Table 3). In most months, diversion during the assumed post-WUP period was lower than during the pre-WUP period (Figure 1)[1]. Analysis of differences in flow in the mainstem Quinsam River between pre- and post-WUP periods will be completed in Year 10.

[1] Although the WUP is dated 2012 (BC Hydro 2012), the post-WUP period was provisionally assumed to start in 2005, which is the year when flow management consistent with the WUP started, as identified during discussions with BC Hydro when completing JHTMON-4 (Perrin *et al.* 2017). For the final analysis in Year 10, we propose to apply this assumption regarding the timing of changes to water management, unless advised otherwise by BC Hydro.

Overview of the Quinsam River watershed

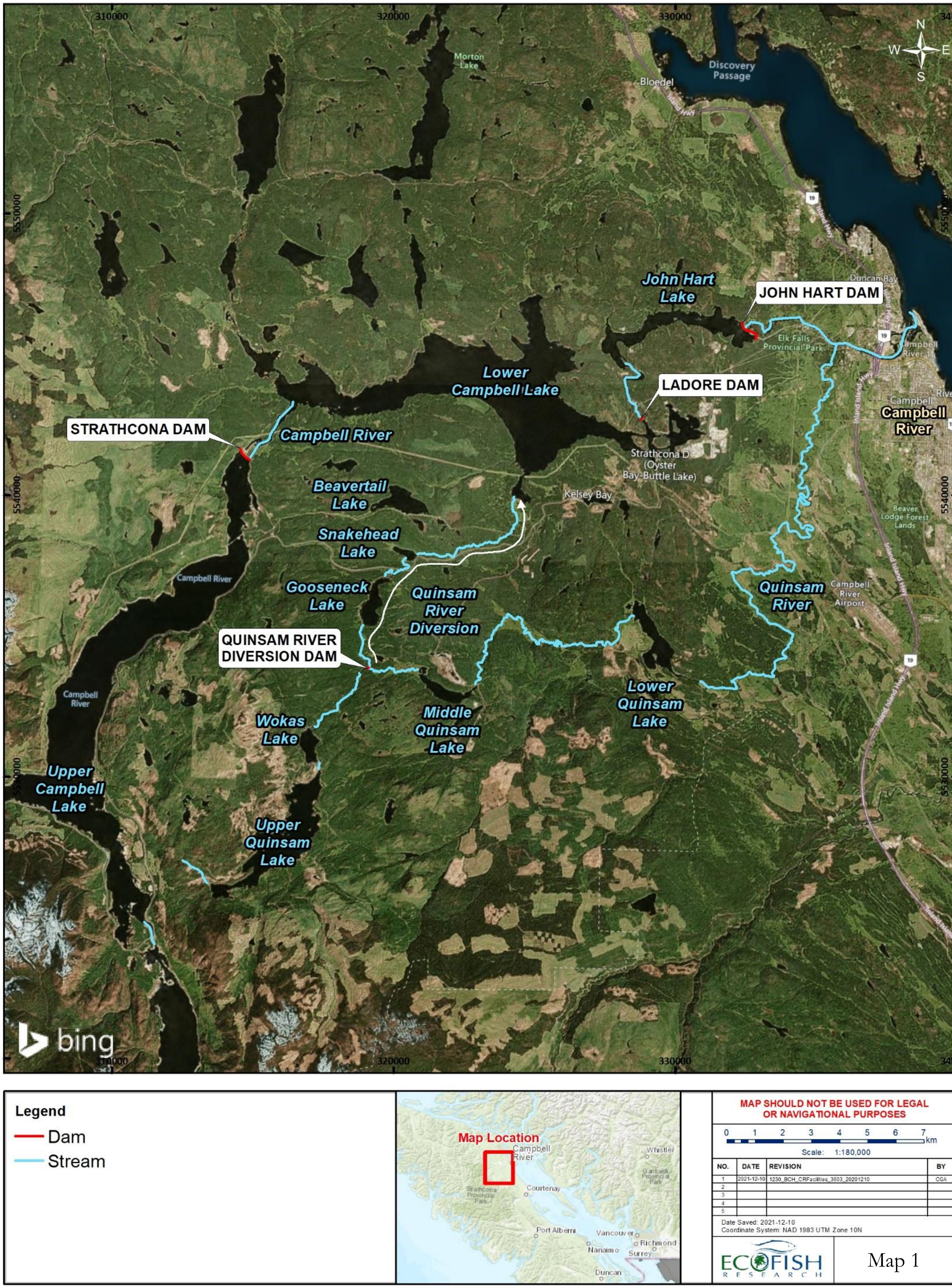

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Table 1. Periodicity of important fish species in the Quinsam River system (from BC Hydro files for Campbell River Water Use Plan, dated 2001).

Species	Life History Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook Salmon	Adult migration												
	Spawning										P	P	
	Incubation[1]												
	Emergence begins												
	Rearing												
	Juvenile migration				F	S							
Chum Salmon	Adult migration												
	Spawning											PP	
	Incubation												
	Emergence begins												
	Juvenile migration			F									
Coho Salmon	Adult migration												
	Spawning											PPP	
	Incubation												
	Emergence begins												
	Rearing												
	Juvenile migration			F	S								
Pink Salmon	Adult migration												
	Spawning									P			
	Incubation												
	Emergence begins												
	Juvenile migration			F									
Rainbow Trout	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Sockeye Salmon	Adult migration												
	Spawning												
	Incubation												
	Emergence begins												
	Rearing												
	Juvenile migration			F									
Steelhead (winter run; summer-run steelhead not present)	Adult migration												
	Spawning			PP									
	Incubation												
	Emergence begins												
	Rearing												
	Juvenile migration				S								

Critical times

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

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

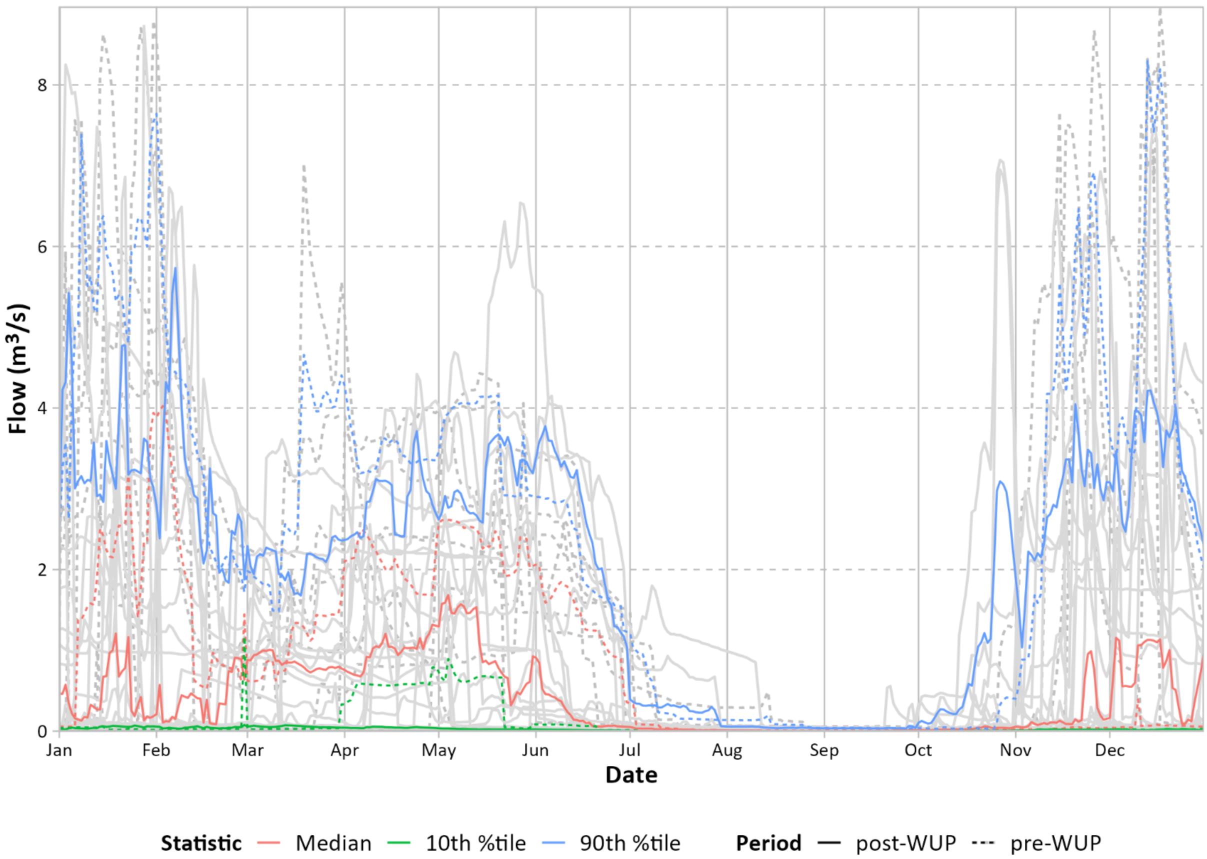
Table 2. Quinsam River maximum permitted down ramping rates (BC Hydro 2012).

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

Figure 1. **Discharge measured at the Quinsam River Diversion near Campbell River (Map 2) during 1997–2022. The assumed pre-WUP period spans 1997 to 2004 and the assumed post-WUP period spans 2005 to 2022 (see main text for rationale for selecting these periods).**



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 considered that involved flow diversion.

1.4. Management Questions and Hypotheses

The JHTMON-8 monitoring program aims to address the following three management questions, in relation 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_01: Annual population abundance does not vary with time (i.e., years) over the course of the Monitor.

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

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

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

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

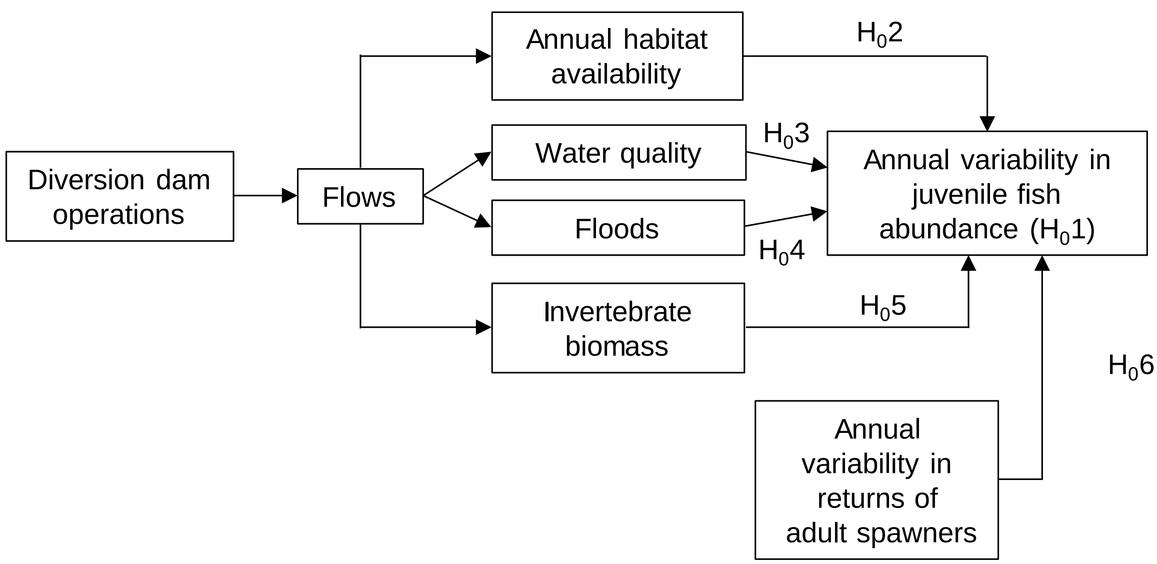
H_06: Annual smolt abundance is not correlated with the number of adult returns.

The basis of JHTMON-8 is outlined conceptually in Figure 2. The monitoring program is designed to first establish whether there is variability among-years in fish abundance (H_01). 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_02); water quality (H_03); an accumulated flood risk index during the spawning and incubation periods (H_04), or; invertebrate abundance (food availability; H_05).

The study will also investigate whether annual variability in juvenile fish abundance is affected by annual variability in salmon spawner escapement (*H_06*), 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 were developed[2]. 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 2. Effect-pathway diagram showing context for the six hypotheses that the JHTMON-8 monitoring program sets out to address.



[2] 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.

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 approach allows the study to integrate established work programs and 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 collected by operating a salmon counting fence at Quinsam River Hatchery to enumerate downstream juvenile migration of a range of species in the spring. In addition to these juvenile abundance datasets, adult escapement data obtained by Fisheries and Oceans Canada (DFO) for a range of Pacific salmon species during monitoring in the fall 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 $H_0 1$: '*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 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 $H_0 6$ '*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). In Year 5, historical data collected at the Quinsam River Hatchery salmon counting fence since the 1970s were collated, increasing the duration of the dataset available for this analysis. In Year 7 (2020), we developed initial stock (spawner)-recruitment relationships to describe relationships between adult spawner abundance and associated smolt abundance (Suzanne *et al.* 2021b). These relationships will be further 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 expect to 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 ($H_0 2$), water quality ($H_0 3$), floods ($H_0 4$) and food availability (*$H_0$5*). In Year 8, we conducted an analysis to provide a proof of concept for the general approach that will be performed in Year 10 to test the study hypotheses.

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 undertaken by D. Burt and Associates to inform WUP development [3], 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_0$2*: *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_0$2*, 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_0$3*: '*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.

[3] Note that, contrary to the revised terms of reference (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 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).

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 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 $H_0 4$: '*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 that evaluation, we quantified the maximum daily mean discharge each year that occurs during the spawning and incubation periods of key species. In Year 8, we undertook preliminary analysis of the effect of high flows during the spawning and incubation period (Suzanne *et al.* 2022), recognizing that these life stages have been shown to be particularly sensitive to the effects of high flows (e.g., Cattanéo *et al.* 2002). We also extended the analysis to consider hydrological variability more generally by analyzing the potential effect of low flows in the summer, recognizing that such flow conditions can limit the abundance of juvenile fish species that rear in freshwater throughout the summer, e.g., Coho Salmon (Matthews and Olson 1980).

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 $H_0 5$ *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 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 evaluation 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. Furthermore, 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 to sampling invertebrate drift, a single kick net sample is collected in September. Kick net sampling targets benthic invertebrates and is therefore less representative of the total abundance of food available to non benthivorous fish such as juvenile salmonids. However, kick net sampling based on the Canadian Aquatic Biomonitoring Network (CABIN) protocol (Environment Canada 2012) has been widely used to characterize stream invertebrate communities throughout Canada, and therefore supplementary data collected using CABIN protocols can be readily compared with benchmarks to assess how the benthic invertebrate community in the Quinsam River compares with streams elsewhere, including reference sites. As an additional task in Year 9, we conducted a review of CABIN documentation that had been updated since the start of the study (e.g., Somers *et al.* 2021) to further develop the proposed methods to analyze benthic invertebrate data collected in JHTMON-8. Outcomes of this additional task are described in Section 3.3.2 and summarized in Section 4.6.

In Year 10, we plan to use benthic invertebrate data collected using the CABIN method to evaluate the wider ecological integrity of the Quinsam River, based on comparisons with Environment Canada's CABIN database of Vancouver Island reference sites (Somers *et al.* 2021).

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. These estimates are collected as part of wider salmon stock assessment work and provide important data to support JHTMON-8. The results of summer and fall 2021 surveys were finalized during Year 9 (2022). Escapement estimates were obtained directly from DFO (Haines, pers. comm. 2023) and are reported here alongside results from previous years. Data for the Quinsam River will support analysis in Year 10 to examine relationships between abundance of adult spawning fish and corresponding counts of juvenile fish in successive years.

Methods used in the 2021 surveys are summarized in Table 4 for the Quinsam River, based on information provided in the nuSEDS database (DFO 2022). 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 assigned by DFO are reported in Table 4, with further general details about survey types provided in Table 5.

Table 4. Methods used for 2021 salmon spawner escapement counts on the Quinsam River (DFO 2022). See Table 5 for descriptions of estimate classification types assigned by DFO.

	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	20-Aug	3-Aug	17-Aug	19-Jul	3-Aug
Date of last inspection	19-Nov	19-Nov	19-Nov	1-Nov	19-Nov
Estimation method	Mark/Recap. and Actual counts	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 2022).

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 river occurs either soon after emergence or a few months later. Those Chinook Salmon that rear for a full summer and winter are believed to do so in the estuary (Burt 2003). The life history strategies adopted by steelhead, Cutthroat Trout, and Coho Salmon are more variable, and the timing of emigration from the river varies from the first spring to three years after emergence.

In Year 9, sampling was undertaken from March 14 to July 3, 2022. 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. 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 14 to May 4, 2022. 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 from 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 five releases were undertaken on March 25, March 31, April 7, April 14, and April 21; a total of 21,164 fish were released (3,995-4,649 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 17 (302 fish) and May 26 (422 fish), with a total of 724 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). Further details about how capture efficiency estimates are derived and applied are provided in Appendix A to the Year 6 Annual Report (Suzanne *et al.* 2021a).

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 and colonized Chinook Salmon were recorded in 2022.

Quinsam River Hatchery staff have out-planted juvenile salmon during each year of JHTMON-8, in addition to previous years (Table 6). In 2021, approximately 34,575 Coho Salmon fry were released in the Upper Quinsam Lake. Chinook Salmon fry were released in Lower Quinsam Lake in 2015 for the first time in 10 years. Since then, approximately 200,000 fry have been released annually (including in 2022 on May 5–6), although only ~150,000 were released in 2016 and no Chinook Salmon fry were released in 2020 due to COVID-19 restrictions (Table 6).

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

Species	Life Stage	Waterbody	Year of Release	Number Released[1]
Coho Salmon	Fry	Upper Quinsam River	2021	34,575 [2, 3]
			2020	139,570
			2019	181,524
			2018	159,336
			2017	139,570
			2016	146,547
			2015	167,030
			2014	157,661
Chinook Salmon	Fry	Lower Quinsam Lake	2022	221,955 [3]
			2021	224,130
			2020	0
			2019	207,736
			2018	215,952
			2017	207,319
			2016	147,549
			2015	217,603

[1] Coho Salmon are released in spring between early April to early June. Chinook Salmon are released in spring, typically in May

[2] The colonized Coho Salmon release number is low due to accidental mortality in incubation

[3] These data are provisional; confirmation has been requested from DFO

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 327,433 E and 553,4757 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.

Water quality has been monitored during Year 1 through Year 9 at QUN-WQ, with monitoring scheduled to continue for the remainder of JHTMON-8. Each year, water quality has been monitored six times on a monthly basis from May through October, with water quality sampled *in situ* using a YSI Pro Plus meter and by collecting samples for laboratory analysis by ALS Environmental (Table 7). 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) have been 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 9 (2022) are presented in Table 8 (*in situ*) and Table 9 (laboratory). Laboratory method detection limits (MDL) for each analyte occasionally differed among sampling dates (Table 9) due to matrix effects in the sample, or variations in laboratory analytical instruments.

Table 7. Quinsam River water quality index site (QUN-WQ) sampling dates, Years 1 to 9.

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
8	13-May-21; 10-Jun-21; 08-Jul-21; 16-Aug-21; 16-Sep-21; 07-Oct-21
9	16-May-22; 15-Jun-22; 06-Jul-22; 11-Aug-22; 15-Sep-22; 17-Oct-22

Figure 3. Looking downstream to QUN-WQ on May 16, 2022.

Table 8. Water quality variables measured *in situ* in Year 9.

Parameter	Unit
Water temperature	ºC
pH	pH units
Salinity	ppt
Conductivity	µS/cm
Specific conductivity	µS/cm
Oxidation reduction potential	mV
Dissolved oxygen	mg/L
Dissolved oxygen	% Saturation

Table 9. Variables analyzed in the laboratory by ALS Environmental and corresponding units and method detection limit (MDL) in Year 9.

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 20
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 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.

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 Year 9 (2022), one field blank and one trip blank were collected on May 16, 2022. 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 nine years (28 out of 136 total samples, or 21%) met or exceeded recommendations; i.e., the BC field sampling manual recommends that 20% to 30% of samples consist of QA/QC samples (Clark 2013), whereas the RISC (1997a) manual recommends a minimum of 10% of samples consist of QA/QC samples.

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 3.2.2 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 9 (2022) for the Quinsam River. Water temperature data have now been collected at the Quinsam River water quality index site and processed for the period May 2014 to October 2022. 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 that 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 10) that were chosen based on the provincial WQG-AL (Oliver and Fidler 2001; Table 5 of Appendix A), based on the data collected at, or interpolated to, intervals of 15 minutes. 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.

The growing season metrics were not species-specific, although the water temperature threshold of 7°C that was applied in the calculation (Table 10) was selected based on considering the fish community in the Quinsam River. The 7°C threshold has been applied by provincial biologists to characterize the active rearing period for fish in other rivers on Vancouver Island (e.g., McCulloch 2017), although other thresholds may be more appropriate for fish communities elsewhere with different thermal tolerance (Coleman and Fausch 2007). Thus, the growing season metrics characterize annual variability in the extent to which water temperatures are sufficiently high to support growth of species such as Rainbow Trout and juvenile Coho Salmon, with the assumption that fish growth is positively correlated with the length of the growing season and the accumulated degree days. In isolation of other factors (e.g., variability in nutrients), these metrics are also assumed to be positively correlated with gross primary productivity of aquatic plants (e.g., periphyton) that support invertebrate communities that provide prey for juvenile fish.

The thresholds of >18°C, >20°C, and <1°C were selected as thresholds of temperatures that indicate potential for adverse effects to the fish community generally. The threshold of <1°C was selected as an indicator of the potential for changes to habitat caused by ice formation, whereas the thresholds of >18°C and >20°C were selected as indicators of water temperatures that approach (but not necessarily exceed) the upper thermal tolerances for salmonids in streams, e.g., based on thresholds summarized in Oliver and Fidler (2001). To provide further information about how water temperatures related to species specific optima, 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).

Table 10. 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. Invertebrate Drift

2.3.1. 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 has been 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 June in Year 9 (the month that is sampled weekly is rotated among study years to quantify the variance of monthly data). In total, sampling occurred on nine dates in the Quinsam River in Year 9 (2022) (Table 11).

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 m/s 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. 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 11). 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 2–9. This detail differed from Year 1 (2014), when contents of each net were processed separately. Samples were preserved in the field with a 10% solution of formalin (37–40% formaldehyde).

Consistent with most previous years, kick net sampling was also undertaken during September in Year 9 at QUN-IV, with sampling completed on September 15, 2022. The CABIN standardized sampling method was followed (Environment Canada 2012), 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 11. Invertebrate drift sample timing and sampling duration at the Quinsam River site (QUN-IV) during Year 9.

Sample Date	Start Time[1]	Finish Time[2]	Sampling Duration[3,4] (hh:mm)
16-May-2022	07:16	11:19	4:03
06-Jun-2022	07:06	11:17	4:11
15-Jun-2022	07:27	11:39	4:12
21-Jun-2022	07:30	11:30	4:00
28-Jun-2022	07:29	11:34	4:05
06-Jul-2022	06:51	10:56	4:05
11-Aug-2022	07:16	11:18	4:02
15-Sep-2022	08:06	12:09	4:03
17-Oct-2022	08:37	12:43	4:06

[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 of invertebrate sampling drift nets across the stream from river right towards QUN-IV, July 06, 2022.

2.3.2. 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 Society of Freshwater Science (previously 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%.

2.3.3. 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 volume of water, whereby volume is the amount (m^3) 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, the net dimensions, 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 the Quinsam River. Calculation of EPT biomass was an additional task initiated in Year 7 with the aim to calculate invertebrate metrics that are best suited to test H_05. As agreed with BC Hydro,

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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 2–9, 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 Years 2–9. 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). As per the direction of David Armanini (Armanini, pers. comm. 2013), taxa present in <5% of the samples were not excluded from the CEFI calculation. 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.

2.3.4. Review of CABIN Models

As an additional task in Year 9, we conducted a review of CABIN reference model documentation to select a model that includes suitable reference sites to compare to the Quinsam River watershed. The purpose of this task was to inform how the kick net data will be analyzed in Year 10 to make inferences about the status of the benthic invertebrate community that provides a food source for fish.

3. RESULTS

3.1. Fish Population Assessments

3.1.1. Quinsam River Salmon Escapement, 2021

Salmon escapement data for the Quinsam River are presented for 2021 (Year 8; Table 12), which are the most recent results available at the time of reporting. Summary statistics for the period of record are also provided in Table 12 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 2021, as well as historically (Table 12). Escapement of Chinook Salmon in the Quinsam River in 2021 (5,789) was above-average (4,395); Chinook Salmon escapement during the JHTMON-8 period has generally been higher than during the preceding decade, although these values were lower than the values observed in the late 1980s and early 1990s. Estimated escapement of Coho Salmon (10,428) in 2021 was lower than the mean value (12,166) for the period of record (1957–2020); 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 (5) was particularly low[4]; it was the lowest count recorded in the 62 years for which there are counts, with the count in 1993 (6) the 2nd lowest count. Pink Salmon escapement in the Quinsam River in 2021 (599,302) was higher than the mean value (142,819) for the period of record (1957–2020). The estimated escapement of Sockeye Salmon in 2021 (24) was lower than the mean value (51). The annual escapement values estimated during the last two decades (range from 2 to 25) are generally lower than those observed between 1970–2000 (range from 6 to 691; few data are available prior to 1970).

During the eight 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). Escapement of Chinook Salmon (a priority species) in the Quinsam River increased steadily over the first four years from 2,366 fish to 9,131 fish, decreased in 2018 and 2019 to 6,774 and 6,793 fish, respectively, increased in 2020 to 8,236 fish, and decreased in 2021 to 5,789 fish. By contrast, escapement of Coho Salmon (also a priority species) decreased steadily over the first four years from 14,883 fish to 5,865 fish and increased in subsequent years to 10,428 fish in 2021.

Table 12. 2021 salmon escapement data for the Quinsam River (DFO 2022).

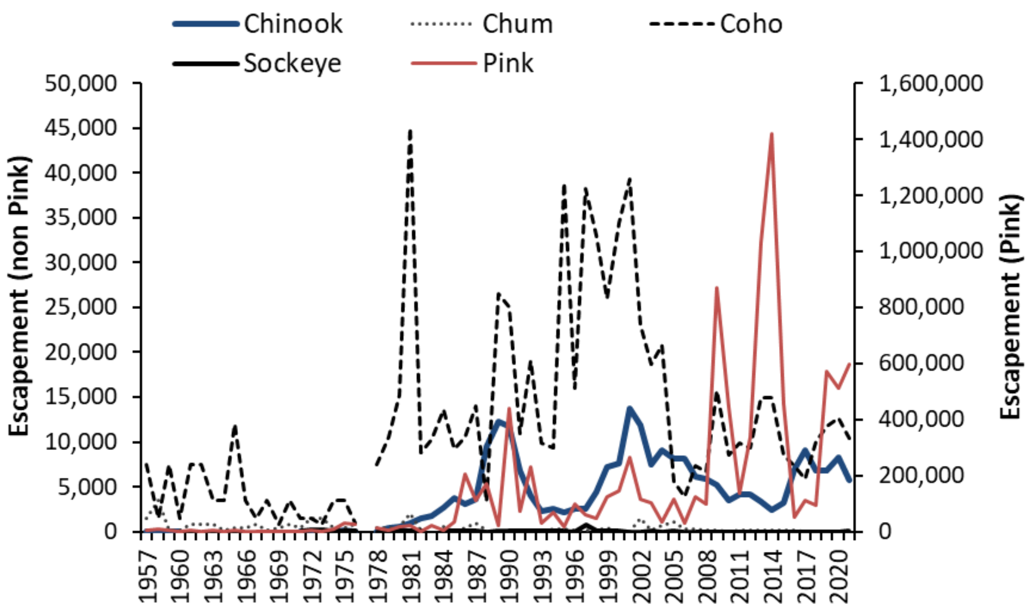
Statistic	Chinook[1]	Chum	Coho[1]	Pink	Sockeye
2021 count	5,789	5	10,428	599,302	24
Mean (1957-2020)	4,395	465	12,166	142,819	51
Median (1957-2020)	3,502	249	9,357	32,600	21
10th percentile (1957-2020)	40	40	1,500	1,500	6
90th percentile (1957-2020)	9,362	1,415	30,423	452,272	125
Proportion of years sampled (%) (1957-2020)[2]	81	95	98	98	77

[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 (November 19; Table 4) was ~4 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 2021 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 2021 was 2,000 fish (DFO 2022).

Figure 5. Salmon escapement for the Quinsam River (1957–2021; DFO 2022). Note the separate y-axis for Pink Salmon.



3.1.2. Quinsam River Hatchery Salmon Counting Fence Operations

Data collected at the salmon counting fence are summarized in Table 13. Following installation on March 13, the traps were monitored daily from March 14 to July 3.

The monitoring period provided good coverage of the **Pink Salmon fry migration period in 2022**, although a low number (137) of fry was captured on the first day of sampling, suggesting that the migration period started slightly prior to March 14. Similarly, a low number (5) of fry was captured on the last day of sampling (July 3), indicating that the end of the migration period extended into early July. Total estimated migration of Pink Salmon fry has been highly variable in the nine years of the monitoring program and was the highest recorded in JHTMON-8 to date in Year 9, with ~23 million estimated in 2022 (Year 9) (Table 13). Estimates varied by an order of magnitude among years since 2014, with a minimum of 1.5 million outmigrating fry estimated in 2017.

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 historical data compilation 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.* 2021a) for further details.

In Year 9 (2022), total estimated outmigration of colonized **Coho Salmon** (20,471) was the lowest recorded during JHTMON-8. Coho Salmon fry were still outmigrating on July 3 when the traps were removed, with five wild Coho Salmon fry captured on the final day of sampling. Total estimated outmigration of wild Coho Salmon 1+ smolts (26,239) in 2022 was also low, with the highest value recorded in Year 7 (57,244). One wild Coho Salmon 2+ smolt (i.e., corresponding to a total estimate of 10 fish) was recorded outmigrating on June 26.

The total estimated outmigration of **steelhead smolts** (3,599; 345 fish captured) in 2022 was relatively low (~25% of the highest estimate during the study period, recorded in Year 7), although 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** in 2022 (222,142) was the third highest value recorded during the nine years of JHTMON-8, during which estimated Chinook Salmon outmigration has been highly variable. Chinook Salmon fry were noted to still be outmigrating on July 3 when the traps were removed, with 110 wild Chinook Salmon fry captured on the final day of sampling. Estimated outmigration of colonized Chinook Salmon (152,484) in 2022 was the 5th highest value recorded during the nine years of JHTMON-8. 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, which is the highest value recorded in the dataset (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, as shown in Figure 8, which also shows estimated survival for years prior to the start of JHTMON-8, based on an additional task completed in Year 5 of JHTMON-8 (Abell *et al.* 2019). After a break of approximately 10 years, Chinook Salmon out-planting operations resumed in 2015, and therefore estimates of survival rate are available since 2015 except for 2020 when no Chinook Salmon were out-planted. Estimated survival of colonized juvenile Chinook Salmon during JHTMON-8 was 69% in 2022 and has varied between 65% and 84% during six of the seven years, with a lower value (28%) estimated in 2016. Colonized juvenile Coho Salmon survival estimates are available for eight years of JHTMON-8, ranging between 13% and 81%, with survival generally lower than for Chinook Salmon, at least partly reflecting that Coho Salmon spend longer in freshwater. The survival estimate for Coho Salmon in 2022 (81%) was the highest during the eight years for which estimates are available for JHTMON-8; however, the number of out-planted Coho Salmon in 2021 was substantially lower (34,575) than previous years (over ~140,000) due to accidental mortality in incubation (Table 6). Note that the estimates for Coho Salmon assume that fish outmigrate at age 1+ (one 2+ smolt was observed at the fence in 2022[5]). Thus, the Coho Salmon survival estimate in 2022 (for example), is based on dividing the estimated smolt outmigration in 2022 by the number of hatchery fry released in 2021.

Table 13. Summary of downstream migration data and total migration estimates from sampling at the Quinsam River Hatchery salmon counting fence, March 14 to July 3, 2022.

Species	Life Stage	Total Counts	Total Estimated Migration[1]	Peak Migration	Migration Period[2]
Colonized Coho	Smolt	1,958	20,471	19-May-22	04 May-03 Jul
Wild Coho	Smolt	2,358	26,239	20-May-22	05 Apr-26 Jun
2 Year old Coho	Smolt	1	35	06-May-22	06 May-06 May
Coho	Fry	7,185	235,317	19-Apr-22	15 Mar-03 Jul
Steelhead	Smolt	345	3,599	24-May-22	05 May-19 Jun
Steelhead	Fingerling	3	60	19-May-22	09 Apr-19 May
Steelhead	Kelts	5	49	16-May-22	14 May-26 May
Cutthroat	Fingerling	24	302	21-Jun-22	22 Mar-03 Jul
Cutthroat	Smolt	56	633	02-Jun-22	01 May-26 Jun
Cutthroat	Kelts	8	78	23-May-22	16 May-25 Jun
Trout Fry	Fry	1	10	13-Jun-22	13 Jun-13 Jun
Chinook	Fry	19,172	222,142	04-Jun-22	07 Apr-03 Jul
Colonized Chinook	Fry	14,679	152,484	07-Jun-22	06 May-03 Jul
Chum	Fry	205	7,154	16-Apr-22	28 Mar-19 Jun
Sockeye	Fry	0	0	n/a	n/a
Pink	Fry	568,222	23,153,204	19-Apr-22	14 Mar-25 Jun
Dolly Varden	Smolt	1	10	30-May-22	30 May-30 May
Lamprey (2 species)	all	248	2,897	24-May-22	22 Mar-03 Jul
Sculpin	all	243	3,869	04-Jun-22	16 Mar-03 Jul

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

[2] Low numbers of Chinook Salmon and Coho Salmon were still outmigrating on the final day of sampling

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

[5] Burt (2003) suggests that 2+ smolts (observed in some years) represent fish that were trapped in off-channel habitats, preventing them from outmigrating the previous year.

Figure 6. Total estimated outmigration of priority species on the Quinsam River during Years 1–9 (2014–2022). Coho Salmon and steelhead were captured at the smolt stage and Chinook Salmon at the fry stage.

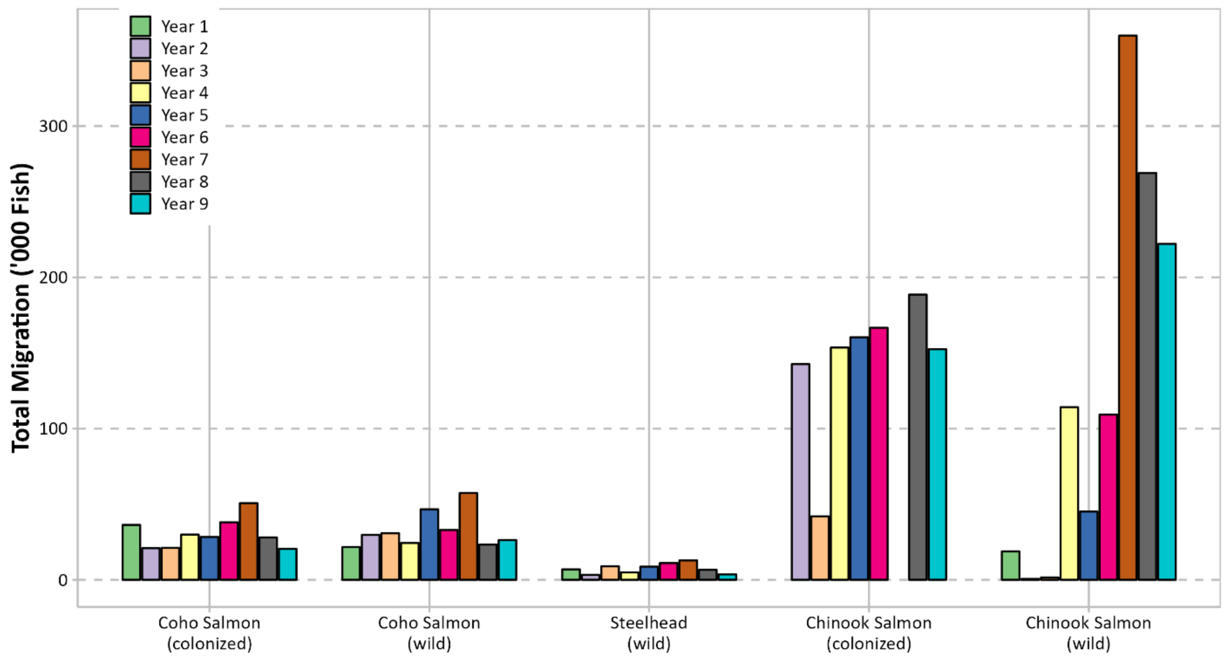


Figure 7. Estimated outmigration of priority species in the Quinsam River during 1979-2022, distinguished between colonized and wild fish. Coho Salmon and steelhead were captured at the smolt stage and Chinook Salmon at the fry stage (0+).

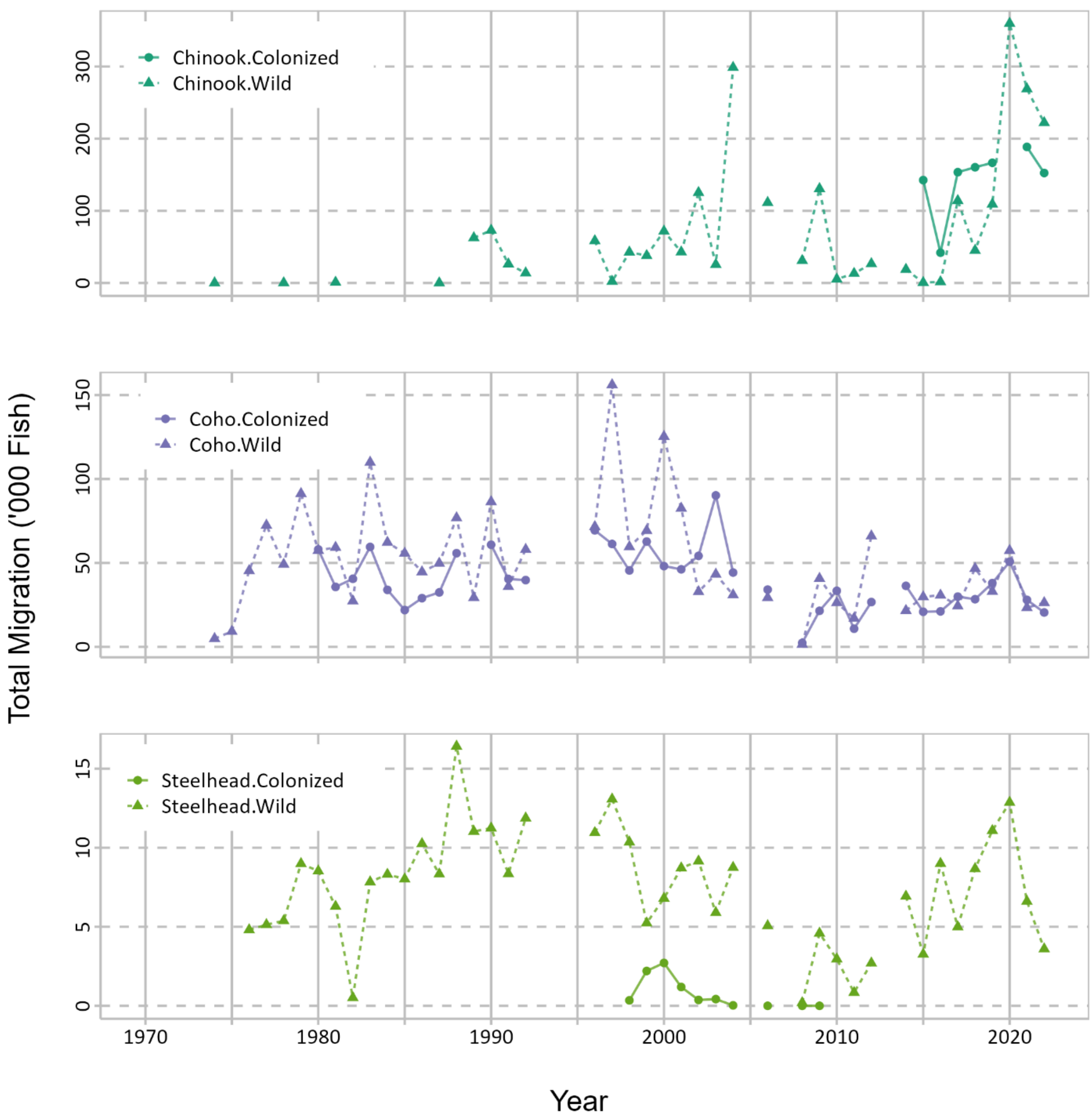
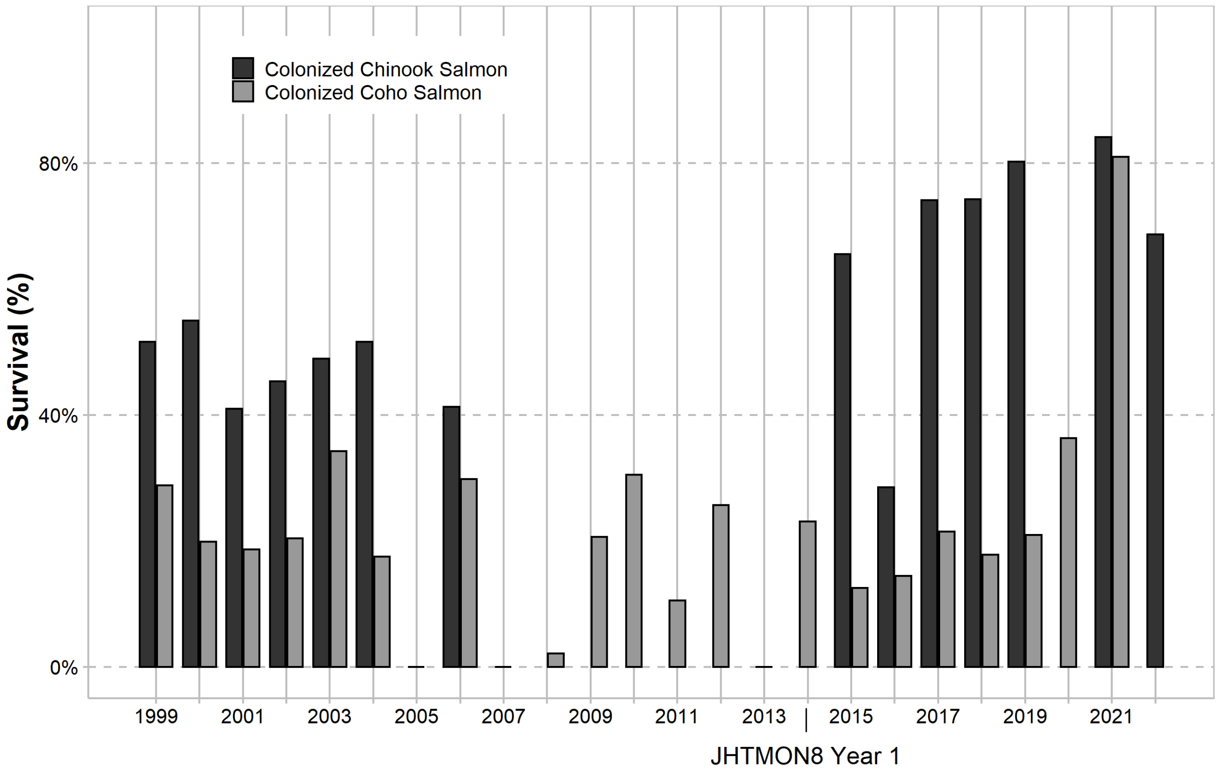


Figure 8. Estimated survival of out-planted salmon raised at the hatchery, based on the proportion of out-planted fish estimated to outmigrate at the salmon counting fence. Estimates correspond to the year of release; Chinook Salmon outmigrate during the year of release, whereas Coho Salmon are assumed to outmigrate during the year following release.



3.2. Water Quality

3.2.1. QA/QC

All laboratory analyses were conducted within the recommended hold times (see Table 17 of Appendix A), with the exception of turbidity analysis of the sample collected on September 15, 2022, and all pH values. The hold time for the turbidity sample was four days, thus exceeding the recommended hold time of three days. The turbidity measurements collected on September 15, 2022 (0.32–0.36 NTU) are within historical ranges, the magnitude of the hold time exceedance is minor, and the samples were well preserved (immediately placed on ice and kept cool); therefore, no substantive effect on data quality is anticipated.

All pH measurements from QUN-WQ that corresponded to laboratory analysis 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 2022, considering only parameters with concentrations five times higher than the MDL, the relative standard error threshold of 20% was exceeded for duplicate turbidity (lab, NTU) measurements corresponding to samples collected on July 6, 2022 and October 17, 2022 (relative standard error of 74.9% and 27.4%, respectively). Duplicate total dissolved solids measurements corresponding to samples collected on July 6, 2022 (relative standard error of 26.1%) also exceeded the relative standard error threshold of 20%. It is unlikely that the high variability in the turbidity and total dissolved solids measurements for this set of duplicates was due to contamination of the sample since values for other parameters measured in the same samples do not show high variability. The turbidity and total dissolved solids measurements in all two sets of duplicate samples were relatively low and are within historical ranges; accordingly, the high variability for these duplicates does not affect our ability to test the applicable hypothesis ($H_0 3$).

One field and one trip blank were collected in 2022. Values for all parameters were below the respective MDLs for both blanks, indicating that contamination was avoided during sampling. Values of pH were slightly lower in the trip blank (5.24) than the field blank (5.25), with the difference in values within the range observed in previous years (Table 18 of Appendix A).

3.2.2. Field Measurements

3.2.2.1. Summary

A summary of Year 9 (2022) water quality results for the Quinsam River (QUN-WQ) is presented in Table 14, which compares the ranges of values for water quality variables for Year 9 with ranges for previous years (Years 1 to 8) and to typical ranges in BC waterbodies. Dissolved oxygen (DO) is the only parameter for which measurements exceeded WQG-AL, as discussed in further detail below.

The Year 9 laboratory and *in situ* water chemistry results for the Quinsam River at QUN-WQ are summarized in Table 15 (general variables measured at ALS laboratories), Table 16 (general variables measured *in situ*), Table 17 (DO measured *in situ*), and Table 18 (low level nutrients measured at ALS laboratories). Combined results from Years 1 to 9 (2014 to 2022) of water quality monitoring are tabulated in Section 2 of Appendix A.

Table 14. Summary of Year 9 (2022) water quality measurements in the Quinsam River (QUN-WQ), compared to Years 1-8 (2014–2021) values and typical ranges in BC waterbodies.

Water Quality Variable	Units	Year 9 Range	Years 1–8 Range	Typical Range for BC Waters	Comments
Alkalinity (as $CaCO_3$)	mg/L	30.4 to 49.1	23.5 to 54.0	Natural waters almost always have concentrations less than 500 mg/L; waters in coastal BC typically range from 0 to 10 mg/L and waters in interior BC can have values greater than 100 mg/L (RISC 1997a).	Alkalinity is consistently > 20 mg/L, indicating low sensitivity to acidic inputs. Values are elevated relative to coastal BC streams generally, likely reflecting the influence of upstream lakes.
pH	pH units	6.43 to 7.88	5.92 to 8.05	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 1997a).	pH is typical of BC waters.
Specific conductivity	μS/cm	93.4 to 159.0	69.4 to 236.0	~100 μS/cm for coastal BC streams (RISC 1997a).	Specific conductivity is higher than typical coastal BC streams; possible influence of two upstream lakes.
Turbidity	NTU	0.27 to 1.23	0.23 to 1.19	In BC natural concentrations of suspended solids vary extensively from waterbody to waterbody and can have large variation within a day and among seasons (Singleton 1985).	Turbidity is low, indicating high water clarity.
Total suspended solids	mg/L	<1.0 to 1.3	<1.0 to 2.4	In BC natural concentrations of suspended solids vary extensively from waterbody to waterbody and can have large variation within a day and among seasons (Singleton 1985).	TSS is low, indicating high water clarity.
Dissolved oxygen	mg/L	7.68 to 12.20	6.99 to 11.75	In BC surface waters are generally well aerated and have DO concentrations >10 mg/L (BC MOE 1997).	DO (mg/L) below the most conservative provincial guideline (DO instantaneous minimum of 9 mg/L) for the protection of buried embryos/alevins has routinely been measured but, based on considering the timing of incubation, is expected to have low potential to affect fish.
	% saturation	84.2 to 110.0	76.6 to 103.0	In BC surface waters are generally well aerated and have DO concentrations close to equilibrium with the atmosphere (i.e., close to 100% saturation) (BC MOE 1997).	DO (%) is consistently close to 100% saturation, indicating generally well-oxygenated waters.
Total Ammonia (as N)	μg/L	<5 to 10.5	<5 to 24.5	<100 μg/L for waters not affected by waste discharges (Nordin and Pommen 2009).	Ammonia is low, and well below the WQG-AL.
Orthophosphate (as P)	μg/L	<1 to 1.3	<1 to 2.1	Coastal BC streams typically have concentrations <1 μg/L (Slaney and Ward 1993; Ashley and Slaney 1997).	Orthophosphate is low, and typical of coastal BC streams.
Nitrate (as N)	μg/L	7.2 to 30.2	6.9 to 47.8	In oligotrophic (low productivity) 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).	Nitrate is low, indicative of an oligotrophic river.
Nitrite (as N)	μg/L	<1 to 1.5	<1 to 1.5	Due to its unstable nature, nitrite concentrations are very low, typically present in surface waters at concentrations of <1 μg/L (RISC 1997b).	Nitrite is very low, and typical of surface waters.
Total phosphorus (P)	μg/L	2.6 to 5.7	<2 to 7.4	Oligotrophic (low productivity) waterbodies 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. Total phosphorus can vary seasonally and with turbidity and TSS (CCME 2004).	Total phosphorus is low, indicative of an oligotrophic river.

3.2.2.2. Dissolved Oxygen

Concentrations of DO in the Quinsam River were highest in May and June 2022 (when water temperatures were coolest; Table 17), when average DO concentrations were 12.10 mg/L and 11.80 mg/L, respectively. During July, August, and September 2022 sampling, 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 17; BC MOE 1997). The measurement in September (average of 8.39 mg/L on September 15, 2022; Table 17) 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 (i.e., incubation is assumed to start the day after sampling was undertaken; see Table 15 of Appendix A for periodicity information). July and August do not coincide with the incubation periods of fish species in the river (Table 1) and therefore the lower DO concentrations measured in those months are not expected to have caused adverse effects to fish, recognizing that all values were above the long-term chronic and instantaneous minimum guideline values that apply to free-swimming life stages of fish (BC MOE 1997). DO concentrations below the most conservative provincial WQG-AL have routinely been measured in previous years (see Table 8 of Appendix A). Measurements of DO in October were not collected due to meter calibration issues in the field.

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).

Table 15. Quinsam River (QUN-WQ) general water quality variables measured at ALS laboratories during Year 9 (2022).

Year	Date	Alkalinity, Total (as $CaCO_3$) mg/L				Specific 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
2022	16-May	30.5	30.4	30.5	0.1	93.9	93.4	94.4	0.7	65	62	68	4	<1.2	<1	1	0.2	0.28	0.27	0.28	0.01	7.50	7.49	7.51	0.01
	15-Jun	36.7	34.1	39.3	3.7	119.0	118.0	119.0	1.0	78	75	81	4	<1	<1	<1	0.0	0.34	0.33	0.34	0.01	7.53	7.52	7.53	0.01
	06-Jul	35.6	35.6	35.6	0.0	115.0	114.0	116.0	1.0	92	80	104	17	<1	<1	<1	0.0	0.90	0.56	1.23	0.47	7.67	7.66	7.67	0.01
	11-Aug	49.0	48.9	49.1	0.1	156.0	155.0	157.0	1.0	109	106	111	4	<1	<1	<1	0.0	0.63	0.55	0.70	0.11	7.72	7.70	7.74	0.03
	15-Sep	45.2	44.8	45.5	0.5	155.0	154.0	155.0	1.0	94	93	94	1	<1.2	<1	1	0.2	0.34	0.32	0.36	0.03	7.87	7.86	7.88	0.01
	17-Oct	43.5	42.7	44.2	1.1	154.0	154.0	154.0	0.0	96	90	102	8	<1	<1	<1	0.0	0.48	0.41	0.54	0.09	7.82	7.81	7.83	0.01

[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 16. Quinsam River (QUN-WQ) general water quality variables measured *in situ* during Year 9 (2022).

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
2022	16-May	9	9	9	0	62.3	62.3	62.3	0.0	93.7	93.7	93.8	0.1	7.4	7.4	7.5	0.1	7.10	7.07	7.13	0.03
	15-Jun	-	-	-	-	84.4	84.4	84.4	0.0	113.0	113.0	113.0	0.0	11.8	11.8	11.8	0.0	7.26	7.26	7.26	0.00
	06-Jul	17	17	17	0	90.4	90.4	90.5	0.1	114.0	114.0	114.0	0.1	14.3	14.3	14.3	0.0	6.61	6.43	6.76	0.17
	11-Aug	-	-	-	-	149.0	149.0	149.0	0.0	159.0	158.0	159.0	0.6	21.6	21.6	21.6	0.0	7.32	7.26	7.37	0.06
	15-Sep	19	19	19	0	134.0	134.0	134.0	0.0	156.0	156.0	156.0	0.0	17.8	17.8	17.8	0.0	7.55	7.52	7.59	0.04
	17-Oct	14	14	14	0	114.0	114.0	114.0	0.0	149.0	149.0	149.0	0.1	12.7	12.7	12.7	0.0	7.50	7.48	7.52	0.02

[1] Average of three replicates (n=3) on each date unless otherwise indicated.
Black dashes (-) indicate that no data were collected.

Table 17. Quinsam River (QUN-WQ) *in situ* dissolved oxygen measurements during Year 9 (2022).

Year	Date	Oxygen Dissolved %				Oxygen Dissolved mg/L			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2022	16-May	101.0	101.0	101.0	0.5	12.10	12.10	12.20	0.06
	15-Jun	110.0	110.0	110.0	0.0	11.80	11.80	11.80	0.00
	06-Jul	84.8	84.2	85.6	0.7	8.69	8.63	8.77	0.07
	11-Aug	88.5	87.6	90.0	1.3	7.83	7.68	8.00	0.16
	15-Sep	88.9	85.1	92.7	3.8	8.39	7.93	8.84	0.46
	17-Oct	-	-	-	-	-	-	-	-

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

Table 18. Quinsam River (QUN-WQ) nutrient concentrations measured at ALS laboratories during Year 9 (2022).

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
2022	16-May	<5	<5	<5	0	<1	<1	<1	0	7.3	7.2	7.3	0.1	<1	<1	<1	0	4.6	4.5	4.7	0.1
	15-Jun	<5.1	<5	5.2	0.1	<1	<1	<1	0	10.3	10.1	10.4	0.2	<1	<1	<1	0	3.3	3.1	3.4	0.2
	06-Jul	<5	<5	<5	0	<1	<1	<1	0	10.3	10.2	10.3	0.1	<1	<1	<1	0	5.2	4.6	5.7	0.8
	11-Aug	<5	<5	<5	0	<1	<1	<1	0	16.1	15.9	16.2	0.2	<1.3	<1	1.5	0.4	2.9	2.6	3.2	0.4
	15-Sep	<7.8	<5	10.5	3.9	1.3	1.3	1.3	0	10.4	8.9	11.9	2.1	<1	<1	<1	0	3.9	3.7	4.1	0.3
	17-Oct	<5	<5	<5	0	<1	<1	<1	0	28.0	25.8	30.2	3.1	<1	<1	<1	0	3.7	3.7	3.7	0.0

[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.

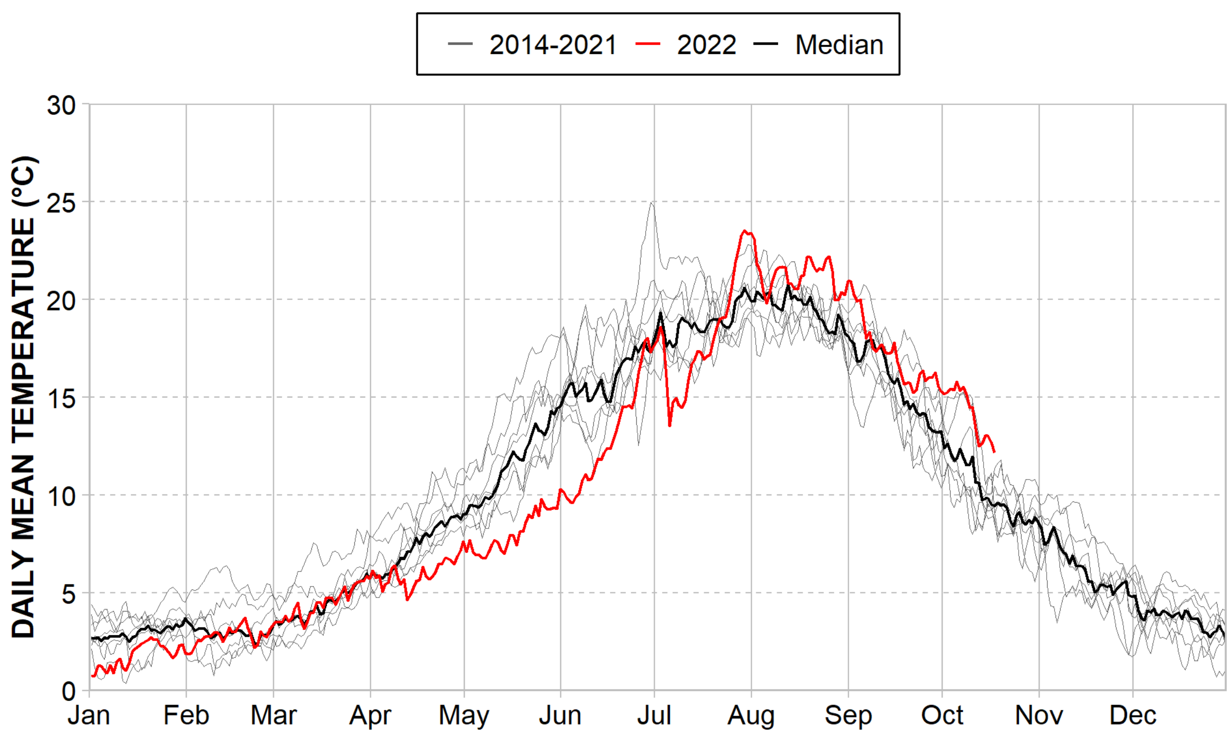
3.2.3. Water and Air Temperature Monitoring

3.2.3.1. Summary of Water Temperature Records

Figure 9 shows the daily average water temperatures at QUN-WQ from May 2014 to October 2022. In 2022 (January to September), monthly average water temperatures ranged between 1.8°C (January) and 21.2°C (August; Table 11 of Appendix A). Water temperature measurements in Year 9 (2022) were unusually cool in spring and unusually warm in late August, relative to previous years (Figure 9). The maximum instantaneous water temperature measurement was 24.5°C, recorded on July 30, 2022.

The water temperature records for the Quinsam River show occurrences of warm water temperatures from a fisheries biology perspective. In 2022, there were 52 days (18% of record) with daily mean temperatures above 18°C, and 38 days (13% of record) with daily mean temperatures above 20°C (Table 12 of Appendix A). Over the period of record between 2014 and 2022, there were 51 to 77 days per year (14% to 21%) with daily mean temperatures above 18°C, and 0 to 47 days per year (0% to 13%) with daily mean temperatures above 20°C. 2022 had the 2nd highest number of days with daily mean temperatures above 20°C for the period of record. Based on available data to October 17, there were four days in 2022 with mean water temperature <1°C, which is within the historical range of 0 to 7 days (Table 12 of Appendix A).

Figure 9. Mean daily water temperature (°C) for the Quinsam River (QUN-WQ) between May 2014 and October 2022. The grey lines represent individual years, the red line represents 2022, and the black line represents the median daily water temperatures for the period.



3.2.3.2. Rates of Change

Statistics relating to rates of change of water temperature at QUN-WQ are summarized in Table 13 of 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 90% of the time (based on the 5th and 95th percentiles) and were between -0.3°C/hr and +0.4°C/hr for 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 9 (2022) (Figure 1 of Appendix A). Rates of temperature change with magnitudes >1°C/hr occurred for 0.016% of the records. Based on our experience on other streams in BC, it is common for hourly rates of water temperature change to occasionally exceed ±1°C.

3.2.3.3. 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 because they characterize the period when temperatures are sufficiently warm to support net primary productivity in areas with sufficient sunlight. As explained in Table 10, 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.

The growing season at QUN-WQ was determined for 2015 to 2021 (Years 2 to 8), 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 2021 (Year 8), for which the growing season commenced on April 12th, ended on November 8th, covering a period of 212 days, and accumulating 3,068 degree days. The growing season length in Year 8 was within the range of values for previous years, which ranged from 197 days (Year 4) to 240 days (Year 3). Growing season statistics for the 2022 growing season will be presented in the Year 10 Annual Report when all 2022 data are available.

3.2.3.4. Mean Weekly Maximum Water Temperatures (MWMxT)

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 2022 are compared to optimum temperature ranges for Chinook Salmon, Coho Salmon, Pink Salmon, and steelhead in Figure 10, Figure 11, Figure 12, and Figure 13, respectively. A detailed 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 9 (2022), data were downloaded on October 17, 2022, prior to the end of the rearing period for stream rearing species or life stages.

For **Chinook Salmon** (Figure 10), temperatures were within optimum ranges during the **migration** stage for all years (2014 to 2021). Temperatures for **spawning** were mostly within the optimum range (50.8% to 100% of the time, depending on the year) with instances when ranges were exceeded by more than 1ºC for both lower and upper bounds of optimum ranges only occurring in 2014, 2015, 2019, and 2020 (Table 15 of Appendix A). Temperatures during Chinook Salmon **incubation** were cooler than the optimum range at times during all years, particularly in 2016, when 48.6% of values exceeded the lower bound by more than 1ºC (Table 15 of Appendix A). Water temperatures were outside the optimum range during most of the Chinook Salmon rearing period (temperatures were within the optimum range for 12.4% to 36.5% of the time; Table 15 of Appendix A). In Year 9 (2022), 54.7% of values were below the optimum rearing range and 21.2% of values above the optimum rearing range (Table 15 of Appendix A).

For **Coho Salmon** (Figure 11), temperatures were typically below the upper bound of the optimum ranges for **migration, spawning, and incubation** stages. Water temperatures during the rearing period were highly variable, with most values outside the optimum range (both higher and lower) for all years. In Year 9 (2022), water temperatures during the Coho Salmon rearing period were below the lower bound (47.9%) more often than above the upper bound (34.3%) of the optimum temperature range, although the record is only 78% complete as the data were downloaded on October 17, 2022 (Table 15 of Appendix A).

For **Pink Salmon** (Figure 12), 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 100% of the spawning period in 2022 (Table 15 of Appendix A), corresponding to unusually high water temperatures in late summer and early fall 2022 (Figure 9) when Vancouver Island experienced drought conditions). In Year 9 (2022), MWMxT values were above the upper bound by more than 1ºC for migration (66.2%) and spawning (100%) for a higher percentage of time than most previous years (Table 15 of Appendix A). During the Pink Salmon **incubation** period, water temperatures were within optimum ranges for the majority of time during every year, except 2016 when 42.6% of values were within the optimum range (Table 15 of Appendix A).

For **steelhead** (Figure 13), MWMxT were rarely (0% to 22.3% of the records) within the optimum ranges for **any life stage** (Table 15 of Appendix A). Most notably, water temperatures during the spawning period between 2015 and 2022 were below the optimum range by more than 1°C for 75.0% to 100% of the time (Table 15 of Appendix A). In 2022, water temperatures were never recorded within the optimum bounds during the spawning period, whereas water temperatures were within the optimum bounds for 15.8% of the incubation period, and 11.9% of the rearing period (incomplete at the time of data retrieval; Table 15 of Appendix A).

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 13 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 of steelhead.

Figure 10. Mean weekly maximum temperatures (MWMxT) in the Quinsam River from 2014 to 2022 compared to optimum temperature ranges for Chinook Salmon. Periodicity information is from Burt (2003).

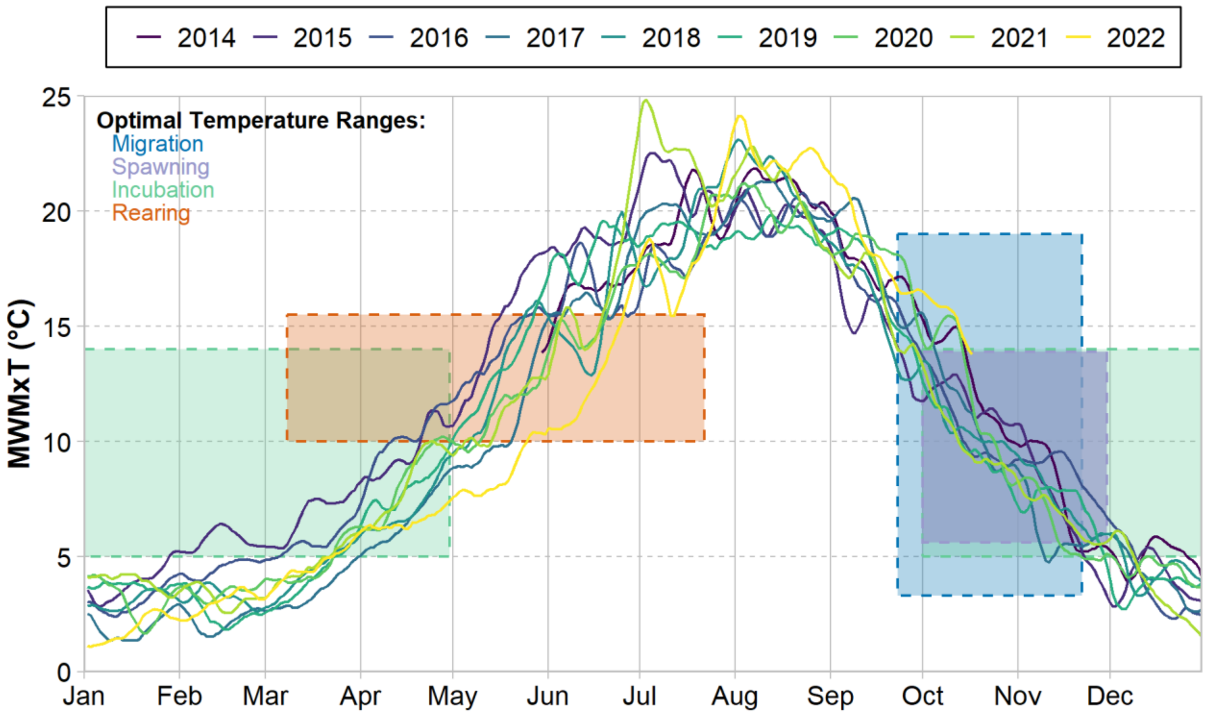


Figure 11. Mean weekly maximum temperatures (MWMxT) in the Quinsam River from 2014 to 2022 compared to optimum temperature ranges for Coho Salmon. Periodicity information is from Burt (2003).

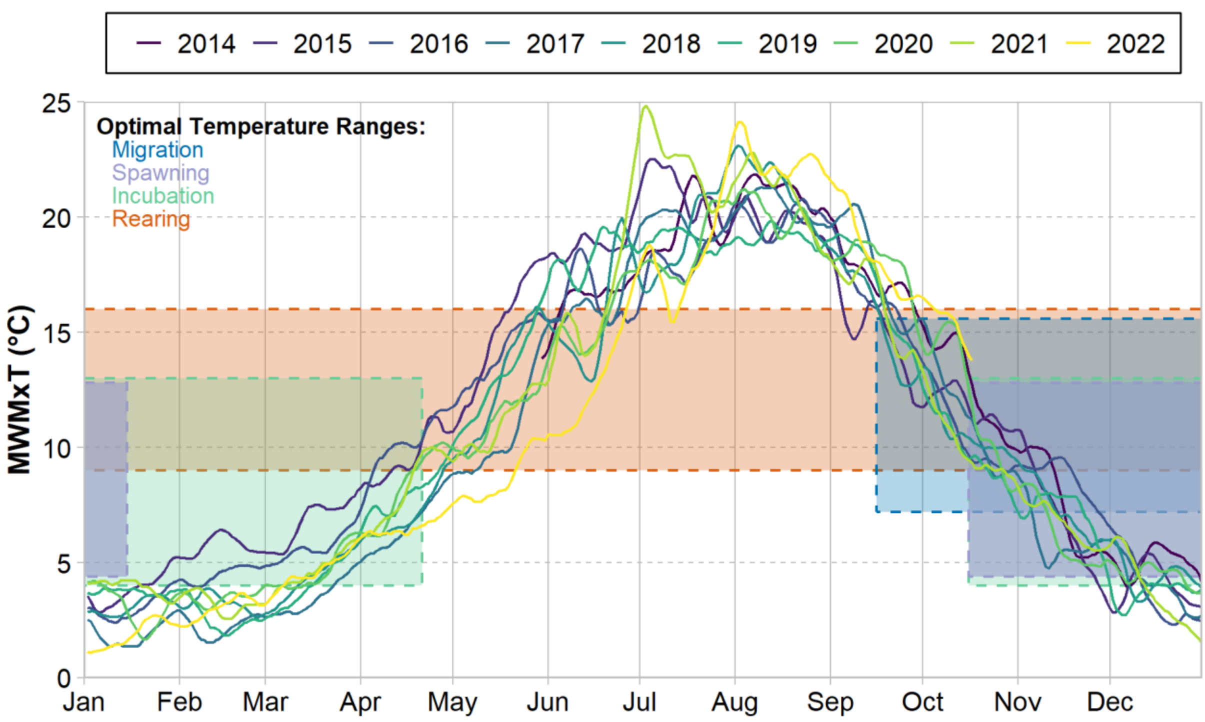


Figure 12. Mean weekly maximum temperatures (MWMxT) in the Quinsam River from 2014 to 2022 compared to optimum temperature ranges for Pink Salmon. Periodicity information is from Burt (2003).

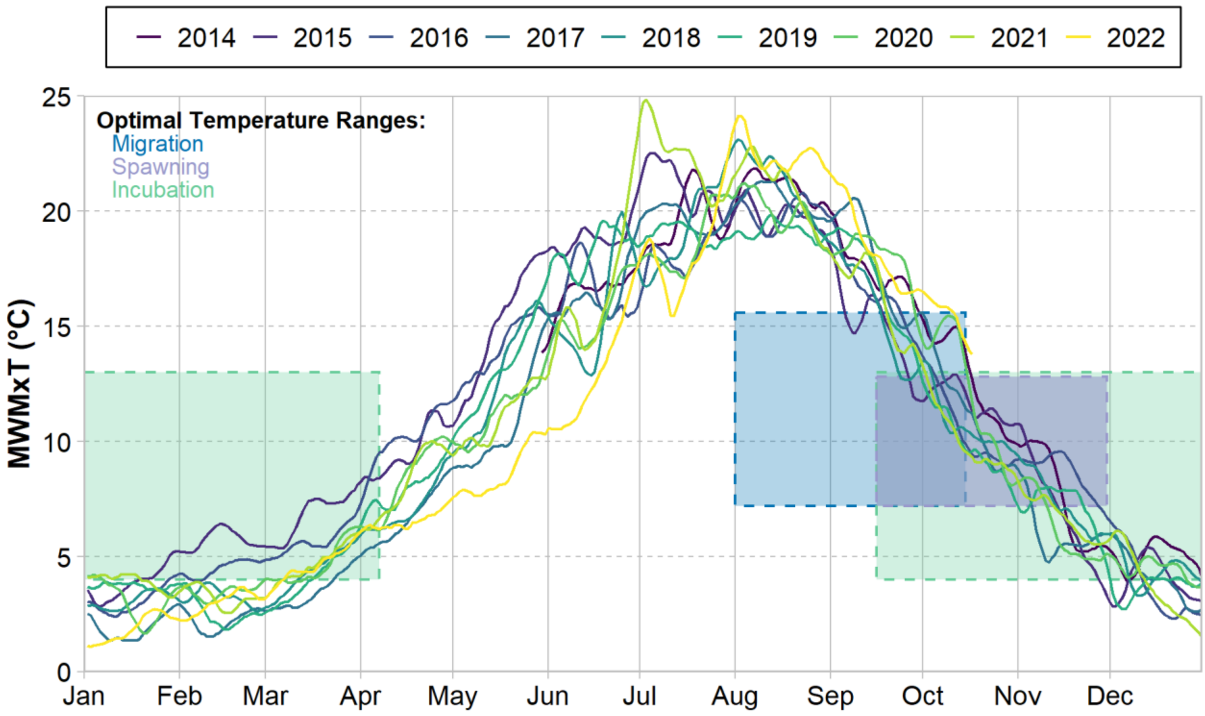
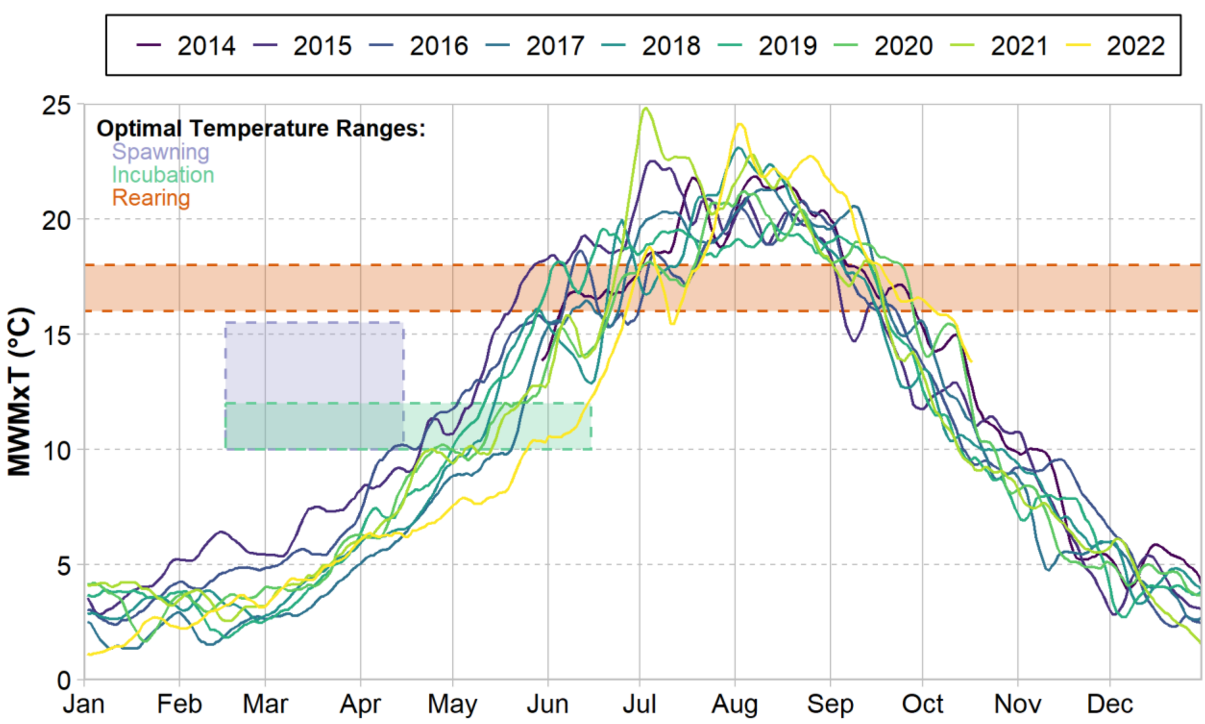


Figure 13. Mean weekly maximum temperatures (MWMxT) in the Quinsam River from 2014 to 2022 compared to optimum temperature ranges for steelhead. Periodicity information is from Burt (2003).



3.2.3.5. 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 2022. The monthly average, minimum, and maximum air temperatures are shown in Table 16 of Appendix A. The mean monthly air temperature ranged from 0.1°C to 18.8°C during the period of record. The lowest air temperature measured during the monitoring period was -15.6ºC measured in December 2021, while the highest air temperature was 36.4°C in June 2021. The maximum monthly mean air temperature (18.8°C) was in July 2015 and August 2022. Mean monthly air temperatures during summer 2022 were generally higher than previous years of JHTMON-8.

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 and heat storage in lakes upstream.

3.3. Invertebrate Drift

3.3.1. Quinsam River Invertebrate Drift

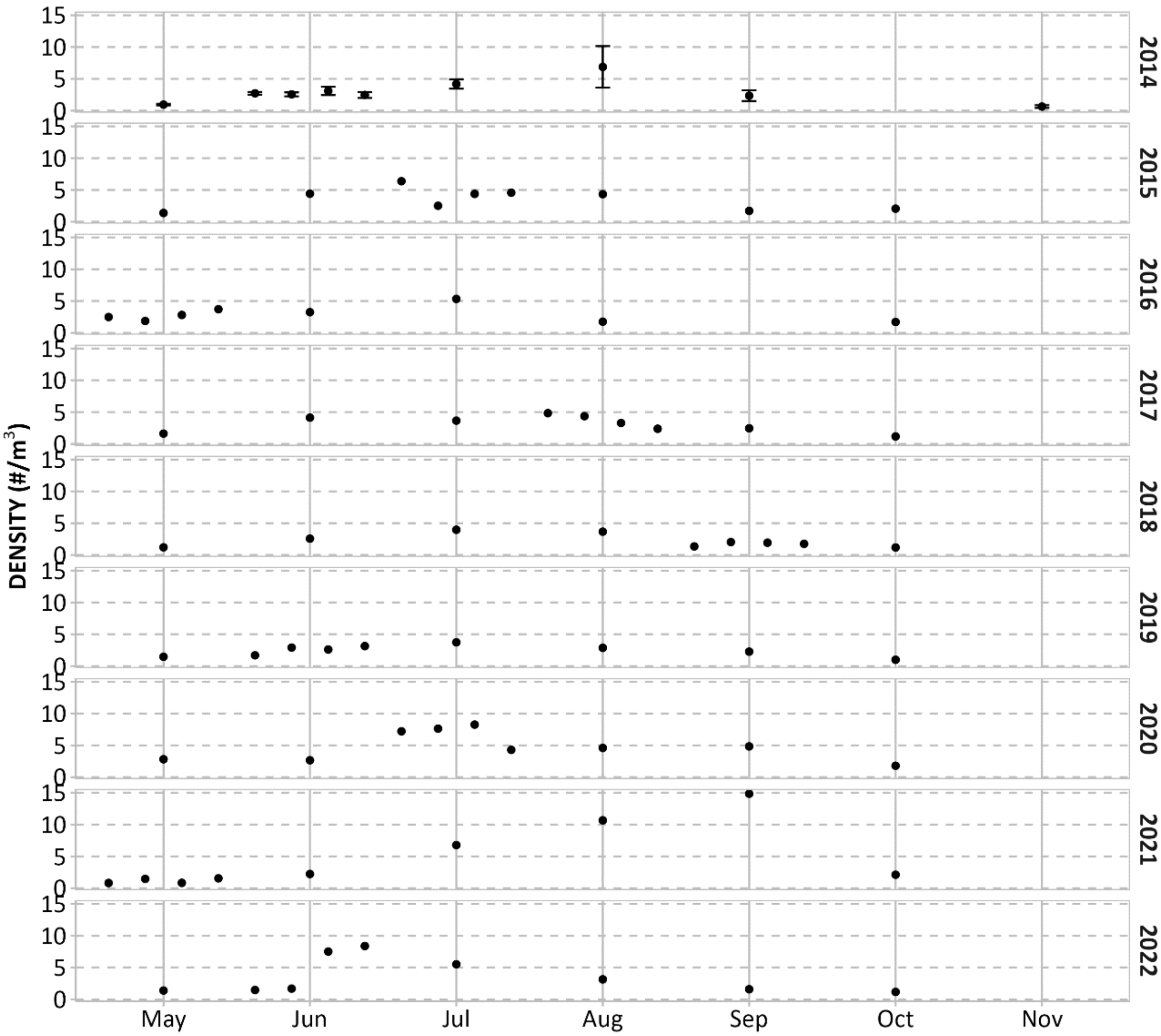
3.3.1.1. Overview

Results relating to invertebrate drift density (individuals/m^3) and biomass (mg/m^3) are provided in sections below to provide indicators of food abundance for juvenile fish that could potentially be used to test H_05. Supplementary invertebrate drift results relating to Simpson's family-level diversity index (1-λ), richness (# families), and 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).

3.3.1.2. Density

Invertebrate drift density in the Quinsam River varied among sampling dates in Year 9 (2022) (Figure 14). Over the sampling period, density generally increased to reach a peak of 8.38 individuals/m^3 on June 28, 2022, before declining to the lowest density value of 1.17 individuals/m^3 on October 17, 2022 (Figure 14). Density measured at weekly intervals during June ranged from 1.47 – 8.38 individuals/m^3 (Figure 14). In Year 9, density ranged from 1.17 – 8.38 individuals/m^3, which is within the range of values observed in previous years (0.65 – 14.85 individuals/m^3; Figure 14).

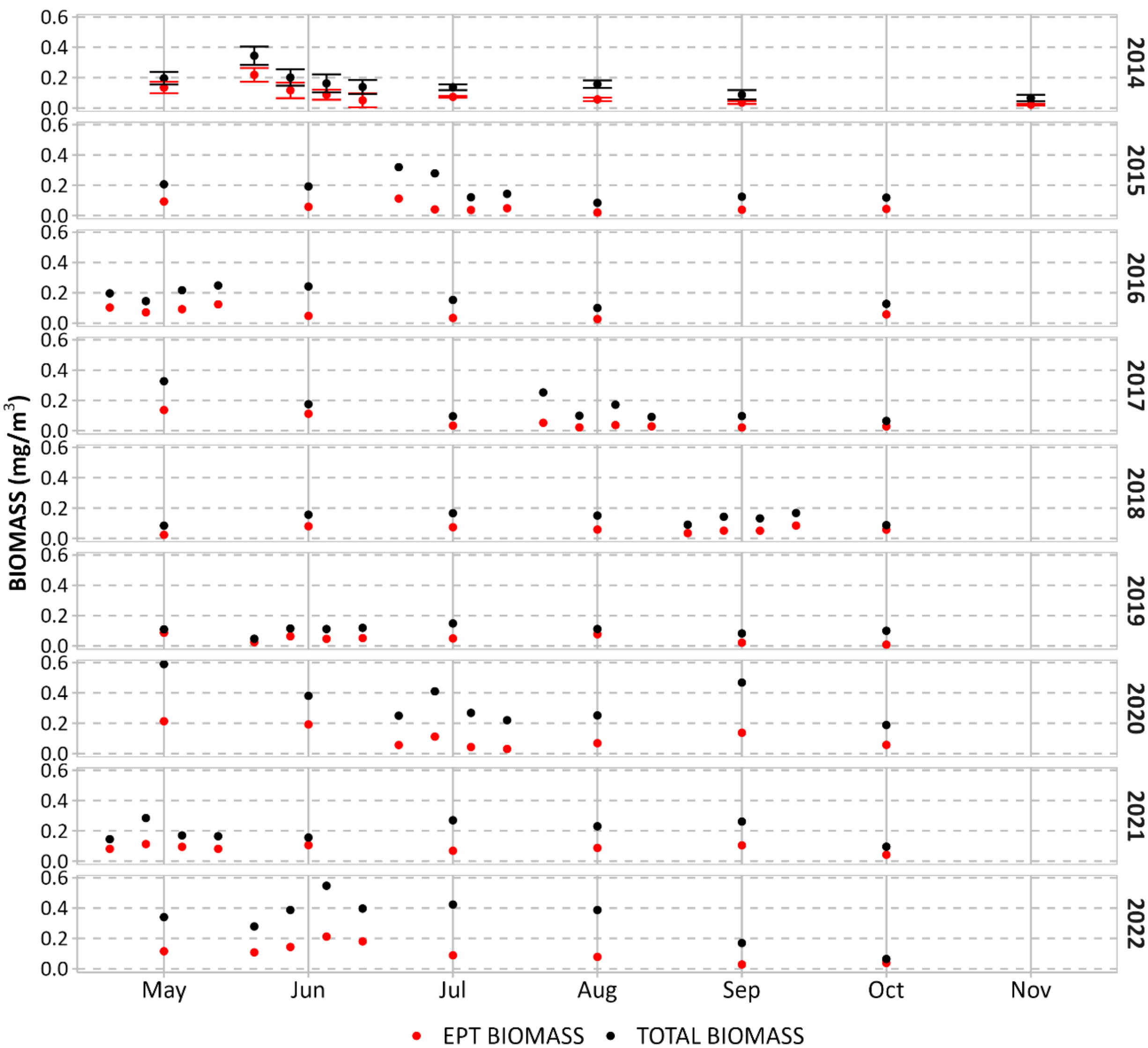
Figure 14. Drift invertebrate density (all taxa) in the Quinsam River, 2014 – 2022. Standard deviations (vertical bars) are provided for Year 1 (2014) only, which is the only year when samples from all five drift nets were analyzed separately.



3.3.1.3. Biomass

Total invertebrate drift biomass in the Quinsam River ranged from 0.06 – 0.55 mg/m^3 in Year 9 (2022), which is within the range observed in previous years (0.05 – 0.59 mg/m^3; Figure 15). Total biomass was variable throughout Year 9, with the annual maximum value of 0.55 mg/m^3 observed on June 21, 2022, which was greater than the maximum value in seven of the preceding eight years (a greater value of 0.59 mg/m^3 was observed in Year 7; Figure 15). EPT biomass was also variable in Year 9 and contributed to a moderate portion of the total biomass on most sampling dates, although the relative proportion of EPT taxa was generally higher in spring (May and June) than in the summer (July and August) (Figure 15).

Figure 15. Total drift invertebrate biomass (all taxa) and EPT biomass in the Quinsam River throughout 2014 – 2022. Standard deviations (vertical bars) are provided for Year 1 (2014) only, which is the only year when samples from all five drift nets were analyzed separately.



3.3.1.4. Top Five Families Contributing to Biomass

A summary of the top five families contributing to biomass of the invertebrate drift community in Year 9 (2022) is provided in Table 19. 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 mayflies (notably Baetidae) and true flies (most notably Chironomidae and Simuliidae) in Year 9. Mayflies were present in the top five families on seven of the nine sampling dates and were the most dominant family on three of the nine sampling dates. True flies were also consistently present in the top five, with one or more true fly families present on all nine sampling dates. The contribution to biomass of individual mayfly families ranged from 7.3% to 26.6%, while individual true fly families ranged from 4.9% to 22.2% across all nine sampling dates.

Other taxa sometimes present in the top five included caddisflies (Limnephilidae, Hydropsychidae), beetles (Cantharidae, Hydrophilidae), arachnids (Araneae, Opiliones), horsehair worms (Nematomorpha), aquatic worms (Lumbriculidae), crustaceans (Ostracoda), true bugs (Aphididae, Gerridae), and ants (Formicidae).

A summary of the top five families contributing to biomass across all JHTMON-8 monitoring years in the Quinsam River is provided in Table 20. These results show similarities in the top five families across years, with Baetidae comprising the top family in six of nine years and present in all nine years, as were two other families (Chironomidae and Simuliidae). In all years, these three families comprised 31.4–49.5% of the biomass (35.6% in Year 9).

Ephemeroptera, Trichoptera, and Plecoptera can be particularly important invertebrate prey for juvenile salmonids in streams (Johnson and Ringler 1980; Rader 1997). Ephemeroptera taxa were present in the top five families during seven of nine sampling dates in Year 9 (2022) and across all years. Trichoptera were present in the top five families during three sampling dates in Year 9 (2022) and were present in the top five families overall in 2014, 2016, 2018, and 2021. Plecoptera were not present in the top five families during any sampling date in Year 9 (2022) and were only present in the top five families overall in 2015.

Table 19. Top five families contributing to invertebrate drift biomass (all taxa) in the Quinsam River in Year 9 (2022). Names in parentheses represent taxa higher than families in instances where family level classifications were unavailable.

QUN-IV	16-May-22	QUN-IV	6-Jun-22	QUN-IV	15-Jun-22	QUN-IV	21-Jun-22
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass
Cantharidae	16.6	Baetidae	26.0	(Ephemeroptera)	20.7	Chironomidae	22.2
Limnephilidae	13.0	Simuliidae	19.3	Simuliidae	17.0	Simuliidae	15.9
Gerridae	11.9	Chironomidae	11.6	Baetidae	13.9	(Ephemeroptera)	15.1
Baetidae	11.8	Cantharidae	11.6	(Araneae1)	8.2	Baetidae	15.0
Simuliidae	7.6	(Nematomorpha)	11.1	Chironomidae	7.7	Lumbriculidae	8.0
Sum	60.8	Sum	79.5	Sum	67.4	Sum	76.3

Key	
True Flies	Horsehair Worm
Mayflies	Crustacean
Caddisflies	Aquatic Worm
Beetles	Ants
True Bugs	
Arachnids	

QUN-IV	28-Jun-22	QUN-IV	6-Jul-22	QUN-IV	11-Aug-22	QUN-IV	15-Sep-22	QUN-IV	17-Oct-22
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass
(Trichoptera)	22.9	Chironomidae	18.0	Aphididae	32.1	Gerridae	25.2	Heptageniidae	26.6
Chironomidae	20.4	Ceratopogonidae	12.6	(Opiliones)	23.3	Chironomidae	10.8	Baetidae	12.8
(Ephemeroptera)	10.7	Baetidae	10.6	Hydropsychidae	10.2	Hydrophilidae	8.0	Simuliidae	12.7
Baetidae	7.4	Tipulidae	8.1	Chironomidae	5.9	Formicidae	6.2	Chironomidae	7.3
(Ostracoda)	5.4	Aphididae	7.7	Simuliidae	5.5	Tipulidae	4.9	Leptophlebiidae	7.3
Sum	66.8	Sum	57.0	Sum	77.0	Sum	55.0	Sum	66.7

Table 20. Top five families contributing to invertebrate drift biomass (all taxa) in the Quinsam River each year throughout Years 1 to 9. 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	Key	
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	True Flies	Mites
								Mayflies	Crustacean
Baetidae	20.2	Chironomidae	14.4	Baetidae	15.9	Baetidae	18.0	Caddisflies	
Limnephilidae	15.8	Simuliidae	13.2	Chironomidae	15.3	Chironomidae	12.0	True Bugs	
Chironomidae	9.5	Baetidae	11.5	Simuliidae	12.0	Simuliidae	9.4	Stoneflies	
Simuliidae	7.5	Chrysomeloidea	6.7	Limnephilidae	5.8	Empididae	8.6	Arachnida	
(Ephemeroptera)	5.8	(Plecoptera)	4.2	Cicadellidae	3.5	Bibionidae	5.7	Beetles	
Sum	58.8	Sum	50.0	Sum	52.5	Sum	53.8		

QUN-IV	2018	QUN-IV	2019	QUN-IV	2020	QUN-IV	2021	QUN-IV	2022
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass
Baetidae	21.3	Baetidae	28.3	Chironomidae	14.8	Baetidae	21.3	Chironomidae	13.5
Simuliidae	12.6	Simuliidae	12.8	Baetidae	9.8	Chironomidae	12.9	Baetidae	11.8
Chironomidae	12.1	Chironomidae	8.4	Simuliidae	6.8	Simuliidae	9.1	Simuliidae	10.2
Hydropsychidae	6.0	Torrenticolidae	7.8	Sciaridae	6.0	(Ostracoda)	5.6	(Ephemeroptera)	8.0
(Araneae)	3.8	Heptageniidae	3.1	Empididae	5.5	(Trichoptera)	4.9	Aphididae	6.5
Sum	55.9	Sum	60.4	Sum	43.0	Sum	53.7	Sum	50.1

3.3.2. Comparison of Kick Net and Drift Net Sampling Methods

As a proportion of total biomass, invertebrates collected using kick net sampling in the Quinsam River in Year 9 (2022) were exclusively aquatic taxa (100%), whereas drift net sampling captured a mixture of aquatic (76.6%), semi-aquatic (8.1%), and terrestrial (15.3%) taxa for samples collected on the same date and location (Table 21). These results were generally consistent with all years: in general, kick net sampling has almost exclusively captured aquatic taxa (99.6–100%), whereas drift sampling has captured 49.8–79.3% aquatic invertebrates (based on biomass; Table 21). 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 at the surface are more likely to have entered the stream from terrestrial or riparian habitats.

Consistent with the differences described above, the contribution of individual families to invertebrate biomass differed between the two sampling methods (Table 22). In the Quinsam River, two groups (true flies and mayflies) accounted for the majority of biomass in drift net samples in most sampling years. 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. Both sampling methods are appropriate for sampling streams and the methods are expected to provide suitable data to support the study; however, this comparison of methods demonstrates that neither method provides data that fully reflect the diversity of potential prey items available to juvenile fish, thus supporting an approach of considering both datasets in combination.

Table 21. Contribution of invertebrate taxa to total biomass by habitat type on the Quinsam River. Kick net data were not collected in 2014 and 2016.

Stream	Sample Date	Collection Method	Relative Contribution to Biomass (%)		
			Aquatic Taxa	Semi-Aquatic Taxa	Terrestrial Taxa
Quinsam River	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
	16-Sep-2021	Driftnet	61.5	35.6	2.9
		Kicknet	99.6	0.4	0.0
	15-Sep-2022	Driftnet	76.6	8.1	15.3
		Kicknet	100.0	0.0	0.0

Table 22. Top five families contributing to invertebrate biomass collected using drift nets and a kick net in the Quinsam River on the same date. Names in parentheses represent taxa higher than families in instances where family level classifications were unavailable. Key includes habitat types the collected invertebrate taxa are associated with.

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
16-Sep-2021	(Trichoptera)	30.4	Astacidae	53.3
	(Ostracoda)	23.3	Leptophlebiidae	20.0
	Chironomidae	11.1	Lumbriculidae	7.4
	Baetidae	8.2	Elmidae	3.6
	Lumbriculidae	5.3	Chironomidae	3.5
15-Sep-2022	Gerridae	25.2	Heptageniidae	37.3
	Chironomidae	10.8	Lumbriculidae	14.2
	Hydrophilidae	8.0	Elmidae	9.3
	Formicidae	6.2	Chironomidae	5.3
	Tipulidae	4.9	Philopotamidae	4.4

Key	Habitat Type
True Bugs	Terrestrial
Aquatic Worms	Aquatic
Mites	Aquatic
True Flies	Aquatic, Semi-Aquatic, Terrestrial
Mayflies	Aquatic, Semi-Aquatic
Caddisflies	Aquatic, Semi-Aquatic
Crustaceans	Aquatic
Dragonflies	Aquatic
Stoneflies	Aquatic, Semi-Aquatic
Beetles	Aquatic, Semi-Aquatic, Terrestrial
Earthworms	Aquatic
Butterflies/Moths	Semi-Aquatic, Terrestrial
Ants	Terrestrial

3.3.3. Review of CABIN Models

Our review of CABIN reference models indicated that reference sites included in the Vancouver Island Updated Model 2021 (Somers *et al.* 2021) were the most suitable sites to compare with the Quinsam River watershed. These reference sites were identified as the most suitable sites because they are exclusively located on Vancouver Island and the period when reference sites were sampled (2001 to 2019) overlaps with the JHTMON-8 monitoring period. Accordingly, in Year 10 we propose to compare invertebrate community metrics calculated using JHTMON-8 kick net sampling data with corresponding values for these reference sites to evaluate the status of the benthic invertebrate community that provides a food source for rearing fish such as juvenile Coho Salmon.

4. SUMMARY

4.1. JHTMON-8 Status

JHTMON-8 is ongoing and analyses 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. Hypotheses are described in full in Section 1.4 and paraphrased in the subheadings below.

4.2. $H_0 1$: Juvenile Fish Abundance Does Not Vary in Time

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 (2014–2022), 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).

Similar to the two previous years, the abundance of outmigrating juvenile Chinook Salmon recorded at the Quinsam River Hatchery fence in Year 9 (2022) (~222,000) was high relative to other years as it was the third highest value recorded during the nine years of JHTMON-8 (Figure 6), and the fourth highest value recorded overall in the period of record (Figure 7). The abundance of spawners that correspond to this cohort (~5,789 in 2021) 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 9.

4.3. $H_0 2$: Juvenile Fish Abundance is Not Correlated with Habitat Availability

Annual habitat availability can be expressed based on WUA (in m^2), which provides an index of habitat availability calculated using relationships between flow and habitat area, accounting for differences in habitat suitability across different flows (Lewis *et al.* 2004). Analysis of WUA was initiated in Year 5 (Abell *et al.* 2019) and will be updated in Year 10, as discussed further in Section 5.2.

4.4. $H_0 3$: Juvenile Fish Abundance is Not Correlated with Water Quality

Year 9 (2022) water quality results were generally consistent with results for Year 1 through Year 8 and show that water quality in the Quinsam 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 biologically optimum ranges for fish species present in the watershed, as discussed below.

Water temperatures were recorded in the Quinsam River that exceeded WQG-AL temperature ranges for suitable salmonid rearing conditions. For example, mean weekly maximum temperatures measured in Year 9 exceeded the upper limit of the optimum temperature ranges by >1°C for the rearing life stage of juvenile Coho Salmon (27% of the period; maximum exceedance of 8.1°C), Chinook Salmon (18% of the period; maximum exceedance of 4.7°C), and steelhead/Rainbow Trout (17% of the period; maximum exceedance of 6.1°C) (Section 3.2.3), and the number of days with water temperature >20°C (38 days out of 289 days with data) in Year 9 was higher than all but one (2021) of the previous years of the study (range: 0–47 days). In addition, MWMxT in the Quinsam River were below optimum ranges by more than 1ºC for an average of 29.8% of the time for the JHTMON-8 monitoring period to date (2014–2022), and water temperatures in spring and early summer 2022 were unusually cool, although water temperatures in late summer and early fall were unusually warm (Figure 9) (Table 15 in Appendix A). Based on our experience of monitoring streams elsewhere in BC, the frequency and magnitude of biologically sub-optimally warm or cool temperatures are typical of coastal systems in southern BC, including those with productive fisheries. However, interannual variability in water temperatures could potentially affect juvenile fish productivity, and this potential influence will be considered using quantitative analysis in Year 10 (Section 5.3).

As in previous years, concentrations of DO were occasionally lower than the provincial WQG-AL for the protection of buried embryos/alevins (DO instantaneous minimum of 9 mg/L) during periods when water temperature was highest and therefore oxygen solubility is reduced. However, the timing of the low DO measurements generally did not overlap with fish incubation periods, with the exception of the minimum average DO concentration measured in September (8.39 mg/L on September 15, 2022; Table 17), which was immediately prior to the assumed start of the Pink Salmon incubation period. This measurement was only slightly (~7%) less than the WQG-AL, which limits the potential for the low DO concentrations to be a biological concern.

The potential for water quality variables including water temperature and DO concentrations to limit fish production will be considered in more detail during the final analysis in Year 10, as discussed in Section 5.3.

4.5. $H_0 4$: Juvenile Fish Abundance is Not Correlated with the Occurrence of Flood Events

Multiple gauges maintained by the Water Survey of Canada provide data to characterize hydrologic variability in the Quinsam River. Preliminary analyses undertaken in Year 8 (2021) provided initial insight into potential links between hydrologic variability and juvenile fish abundance. Further analysis to test H_04 was not completed in Year 9 but analysis to test this hypothesis will be updated in Year 10, as discussed further in Section 5.4.

4.6. H_05: Juvenile Fish Abundance is Not Correlated with Food Availability

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.

Invertebrate drift data have now been collected for nine growing seasons for the Quinsam River. There are no clear differences in invertebrate drift biomass among years, with Year 9 (2022) biomass within the range of previous years (Figure 15). Otherwise, invertebrate drift biomass has generally tended to decline towards the end of the growing season, although this trend is not pronounced each sampling year (Figure 15).

4.7. *H06*: Annual Smolt Abundance is Not Correlated with the Number of Adult Returns

Analysis to test this hypothesis was initiated in Year 7, when we developed initial stock (spawner)-recruitment relationships for priority species to quantify the relationship between the abundance of adult spawners and the subsequent recruitment of juvenile fish each year (Suzanne *et al.* 2021b). To increase statistical power, the analysis drew on historical juvenile abundance data collected since the 1970s that were compiled as part of an additional task completed during Year 5 (Abell *et al.* 2019). Stock-recruitment curves will be further updated in Year 10 to formally test H_06 (Section 5.6).

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 in Year 10.

5.1. H_01: Juvenile Fish Abundance Does Not Vary in Time

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. 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 River 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. Furthermore, analysis in Year 10 will draw on the outcomes of a review of capture efficiency estimates completed in Year 6 (Suzanne *et al.* 2021a), which examined how to reduce uncertainty associated with the results of juvenile mark-recapture experiments conducted at the Quinsam River Hatchery salmon counting fence.

5.2. <u>*$H_0$2*: Juvenile Fish Abundance is Not Correlated with Habitat Availability</u>

The WUA analysis initiated in Year 5 (Abell *et al.* 2019) will be updated in Year 10 and used to test *$H_0$2*. We propose to test this hypothesis separately for each of the JHTMON-8 priority species. For Chinook Salmon and Coho Salmon, we propose to construct stock-recruitment relationships (discussed further in Section 4.7) and then test whether variability in WUA explains variability in the stock-recruitment relationships, which would indicate that variability in WUA affects juvenile fish recruitment (indicating that *$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 steelhead fry and juvenile Coho Salmon 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. <u>*$H_0$3*: Juvenile Fish Abundance is Not Correlated with Water Quality</u>

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 final analysis in Year 10 will initially involve summarizing all water quality data collected during JHTMON-8. Water quality data will then be screened against thresholds in WQG-AL and supporting literature (e.g., Oliver and Fidler 2001) to evaluate whether measurements exceed or approach values that indicate the potential for adverse effects to juvenile salmonids. Based on this screening task, metrics that warrant further evaluation will be selected for statistical modelling. Specifically, such metrics will be used as predictor variables to examine whether they account for variability in stock-recruitment relationships, consistent with the approach described above for WUA in relation to *$H_0$2*.

To date, monitoring has indicated that water quality in the Quinsam River is broadly suitable for aquatic life in relation to most variables considered. Therefore, it is anticipated that only a small number of water quality variables will be selected for statistical modelling. Results to date show that maximum water temperatures in the summer can exceed optimum ranges for priority fish species (Section 4.4) and therefore metrics such as the number of days with water temperature >20°C are examples of biologically relevant variables to analyze further in Year 10. Measurements of other variables such as total ammonia and pH so far indicate suitable water quality for juvenile salmonids and, as identified in an initial screening analysis in Year 4 (Sharron *et al.* 2018), such variables generally exhibit low inter-annual variability, which limits the suitability of such predictor variables in statistical models.

Thus, $H_0 3$ will be examined with multiple lines of evidence (comparisons with WQG-AL and statistical modelling) to make inferences about the potential for water quality to limit juvenile fish recruitment in the Quinsam River, with appropriate consideration of biological relevance and significance, e.g., based on assessing effect sizes in the context of background variability.

5.4. $H_0 4$: Juvenile Fish Abundance is Not Correlated with the Occurrence of Flood Events

This hypothesis will be tested by extending the analysis undertaken in Year 8 (Suzanne *et al.* 2022) to further analyze the potential effects of high flow metrics on juvenile fish recruitment. Furthermore, 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. Following the collation of a historical dataset collected at the Quinsam River 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. $H_0 5$: Juvenile Fish Abundance is Not Correlated with Food Availability

Relationships between fish abundance and invertebrate drift will be examined in Year 10. To test $H_0 5$, we plan to examine whether (and if so, what amount of) variability in invertebrate drift biomass explains variability in species-specific spawner recruitment curves or juvenile fish abundance (e.g., steelhead) for JHTMON-8 priority species. $H_0 5$ will be assessed based on the magnitude of the effect size to infer biological significance. We plan to use both total invertebrate biomass and EPT invertebrate biomass as key predictor variables. Furthermore, we plan to trial invertebrate density as a secondary measure of food abundance; however, consistent with the terms of reference (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 15); 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 and benthic invertebrate biomass (based on kick net sampling) for 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.

Based on an additional review task completed in Year 9 (Section 3.3.3), our proposed analysis approach for Year 10 is to select reference sites that were used to develop the Vancouver Island Updated Model 2021 (Somers *et al.* 2021) and export corresponding benthic invertebrate taxonomy data from the CABIN database. Invertebrate community metrics for the reference sites will then be compared with values calculated using the JHTMON-8 data. One caveat to this proposed analysis is that biomass data are not recorded in the CABIN database and therefore other community metrics, such as density, richness, and diversity, will be compared. This proposed analysis step will help to evaluate the status of benthic invertebrate communities in the Quinsam River watershed. However, this analysis will only indirectly provide information about the food base available to rearing fish and therefore this analysis will be considered to provide a secondary line of evidence to test $H_0 5$.

5.6. $H_0 6$: Annual Smolt Abundance is Not Correlated with the Number of Adult Returns

Updated stock-recruitment relationships will be used in Year 10 to test $H_0 6$, 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).

Development of stock-recruitment relationships will extend the work initiated in Year 7 (Suzanne *et al.* 2021a), as summarized in Section 4.7. At a minimum, we propose to test $H_0 6$ separately for Chinook Salmon, Coho Salmon, and Pink Salmon. Quantitative analyses are not proposed to test $H_0 6$ 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.

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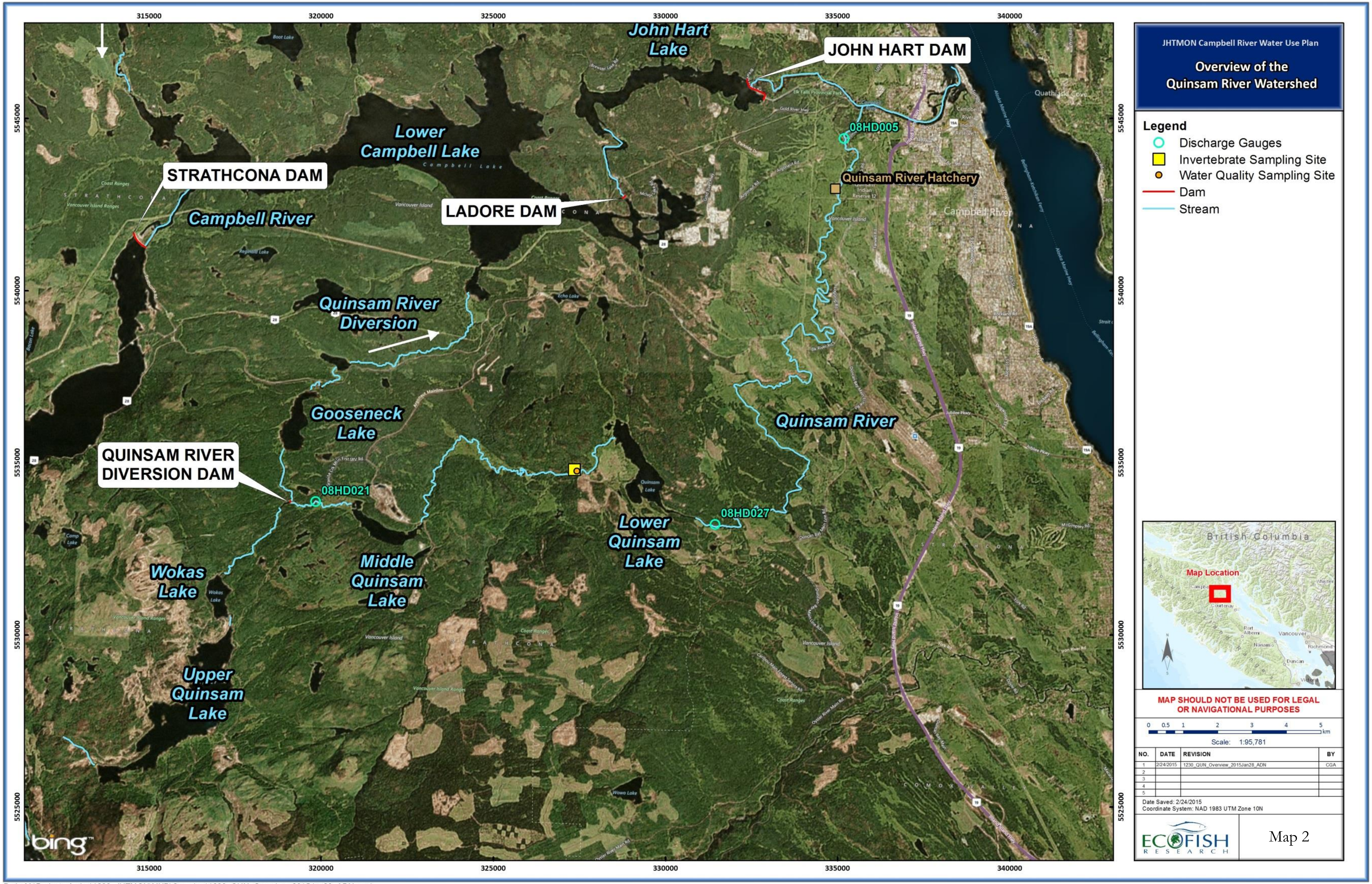
PROJECT MAP



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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).	BC ENV (2021b)
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: ultra-oligotrophic, 4-10 oligotrophic, 10-20 mesotrophic, 20-35 meso-eutrophic, 35-100 eutrophic, >100 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 (2021)

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

BC Guidelines for the Protection of Aquatic Life (BC ENV 2021a)			
	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 waterbody, 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 (BC ENV 2021a).

[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 British Columbia	Reference
Specific Conductivity	μS/cm	The typical value in coastal BC 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; waters in coastal BC typically range 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 BC 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 BC ENV (2021c)
Turbidity	NTU	In BC 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 BC ENV (2021c)
Dissolved Oxygen	mg/L	In BC surface waters are generally well aerated and have DO concentrations > 10 mg/L.	BC MOE (1997)
	% 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).	BC MOE (1997)
ΔP (Total Gas Pressure - Barometric Pressure)	mm Hg	In BC, dissolved gas supersaturation is a natural feature of many waters with ΔP commonly being between 50 – 80 mm Hg.	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 low productivity 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 typically have concentrations <1 μg/L.	Slaney and Ward (1993); Ashley and Slaney (1997)
Total Phosphorus (P)	μg/L	Oligotrophic (low productivity) 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. Total phosphorus can vary seasonally and with turbidity and total suspended solids.	CCME (2004)

2. 2014 TO 2022 WATER QUALITY IN THE QUINSAM RIVER

Table 7. Quinsam River (QUN-WQ) general water quality variables measured *in situ* during Years 1 to 9 (2014 to 2022).

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.

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
2021	13-May	10	10	10	0	80.4	80.3	80.4	0.1	120.0	120.0	120.0	0.1	8.6	8.6	8.6	0.0	6.89	6.86	6.92	0.03
	10-Jun	12	12	12	0	138.0	138.0	138.0	0.0	184.0	184.0	184.0	0.0	12.3	12.3	12.3	0.0	7.12	7.09	7.14	0.03
	08-Jul	20	20	20	0	218.0	218.0	218.0	0.0	235.0	235.0	235.0	0.1	21.3	21.3	21.3	0.0	7.29	7.29	7.30	0.01
	16-Aug	20	20	20	0	169.0	169.0	169.0	0.0	186.0	186.0	187.0	0.1	20.4	20.4	20.4	0.0	7.58	7.57	7.59	0.01
	16-Sep	7	7	7	0	154.0	154.0	154.0	0.0	196.0	196.0	196.0	0.0	13.9	13.9	13.9	0.0	7.32	7.31	7.32	0.01
	07-Oct	6	6	6	0	103.0	103.0	103.0	0.0	145.0	145.0	145.0	0.0	9.8	9.8	9.8	0.0	7.54	7.53	7.55	0.01
2022	16-May	9	9	9	0	62.3	62.3	62.3	0.0	93.7	93.7	93.8	0.1	7.4	7.4	7.5	0.1	7.10	7.07	7.13	0.03
	15-Jun	-	-	-	-	84.4	84.4	84.4	0.0	113.0	113.0	113.0	0.0	11.8	11.8	11.8	0.0	7.26	7.26	7.26	0.00
	06-Jul	17	17	17	0	90.4	90.4	90.5	0.1	114.0	114.0	114.0	0.1	14.3	14.3	14.3	0.0	6.61	6.43	6.76	0.17
	11-Aug	-	-	-	-	149.0	149.0	149.0	0.0	159.0	158.0	159.0	0.6	21.6	21.6	21.6	0.0	7.32	7.26	7.37	0.06
	15-Sep	19	19	19	0	134.0	134.0	134.0	0.0	156.0	156.0	156.0	0.0	17.8	17.8	17.8	0.0	7.55	7.52	7.59	0.04
	17-Oct	14	14	14	0	114.0	114.0	114.0	0.0	149.0	149.0	149.0	0.1	12.7	12.7	12.7	0.0	7.50	7.48	7.52	0.02

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

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

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

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Table 8. Quinsam River (QUN-WQ) dissolved gases measured *in situ* during Years 1 to 9 (2014 to 2022).

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.

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.

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	-	-	-	-	-	-	-	-	-	-	-	-
2021	13-May	751	751	751	0.0	90.4	90.3	90.4	0.1	10.60	10.50	10.60	0.01	-	-	-	-	-	-	-	-	-	-	-	-
	10-Jun	747	747	747	0.1	83.4	82.7	83.7	0.6	8.93	8.89	9.01	0.07	-	-	-	-	-	-	-	-	-	-	-	-
	08-Jul	745	745	745	0.0	89.8	89.7	89.9	0.1	7.94	7.94	7.94	0.00	-	-	-	-	-	-	-	-	-	-	-	-
	16-Aug	742	742	742	0.1	95.6	93.6	96.8	1.7	8.63	8.54	8.75	0.11	-	-	-	-	-	-	-	-	-	-	-	-
	16-Sep	749	749	749	0.1	94.5	94.1	94.7	0.3	9.74	9.70	9.76	0.03	-	-	-	-	-	-	-	-	-	-	-	-
	07-Oct	749	749	749	0.0	95.1	95.0	95.2	0.1	10.80	10.80	10.80	0.01	-	-	-	-	-	-	-	-	-	-	-	-
2022	16-May	746	746	746	0.1	101.0	101.0	101.0	0.5	12.10	12.10	12.20	0.06	-	-	-	-	-	-	-	-	-	-	-	-
	15-Jun	-	-	-	-	110.0	110.0	110.0	0.0	11.80	11.80	11.80	0.00	-	-	-	-	-	-	-	-	-	-	-	-
	06-Jul	743	743	743	0.1	84.8	84.2	85.6	0.7	8.69	8.63	8.77	0.07	-	-	-	-	-	-	-	-	-	-	-	-
	11-Aug	747	747	747	0.1	88.5	87.6	90.0	1.3	7.83	7.68	8.00	0.16	-	-	-	-	-	-	-	-	-	-	-	-
	15-Sep	746	746	746	0	88.9	85.1	92.7	3.8	8.39	7.93	8.84	0.46	-	-	-	-	-	-	-	-	-	-	-	-
	17-Oct	748	748	748	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[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.

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Table 9. Quinsam River (QUN-WQ) general water quality variables measured at ALS laboratories during Years 1 to 9 (2014 to 2022).

Year	Date	Alkalinity, Total (as $CaCO_3$) mg/L				Specific 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 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 9. Continued (2 of 2).

Year	Date	Alkalinity, Total (as $CaCO_3$) mg/L				Specific 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	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	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
2021	13-May	32.6	32.2	33.0	0.6	123.0	123.0	123.0	0.0	79	76	81	4	<1	<1	<1	0.0	0.28	0.26	0.29	0.02	7.78	7.77	7.79	0.01
	10-Jun	41.8	41.8	41.8	0.0	184.0	184.0	184.0	0.0	127	116	138	16	<1	<1	<1	0.0	0.45	0.42	0.47	0.04	7.84	7.83	7.84	0.01
	08-Jul	50.5	50.4	50.5	0.1	236.0	236.0	236.0	0.0	143	142	143	1	<1	<1	<1	0.0	0.49	0.46	0.51	0.04	7.84	7.82	7.85	0.02
	16-Aug	47.1	47.0	47.2	0.1	201.0	201.0	201.0	0.0	124	124	124	0	<1.1	<1	1.2	0.1	0.36	0.35	0.37	0.01	7.88	7.87	7.88	0.01
	16-Sep	45.5	45.0	45.9	0.6	198.0	197.0	198.0	1.0	135	134	136	1	<1	<1	<1	0.0	0.27	0.26	0.27	0.01	7.88	7.85	7.91	0.04
	07-Oct	46.6	40.2	53.0	9.1	149.0	146.0	152.0	4.0	94	93	95	1	<1	<1	<1	0.0	0.25	0.23	0.26	0.02	7.89	7.81	7.97	0.11
2022	16-May	30.5	30.4	30.5	0.1	93.9	93.4	94.4	0.7	65	62	68	4	<1.2	<1	1	0.2	0.28	0.27	0.28	0.01	7.50	7.49	7.51	0.01
	15-Jun	36.7	34.1	39.3	3.7	119.0	118.0	119.0	1.0	78	75	81	4	<1	<1	<1	0.0	0.34	0.33	0.34	0.01	7.53	7.52	7.53	0.01
	06-Jul	35.6	35.6	35.6	0.0	115.0	114.0	116.0	1.0	92	80	104	17	<1	<1	<1	0.0	0.90	0.56	1.23	0.47	7.67	7.66	7.67	0.01
	11-Aug	49.0	48.9	49.1	0.1	156.0	155.0	157.0	1.0	109	106	111	4	<1	<1	<1	0.0	0.63	0.55	0.70	0.11	7.72	7.70	7.74	0.03
	15-Sep	45.2	44.8	45.5	0.5	155.0	154.0	155.0	1.0	94	93	94	1	<1.2	<1	1	0.2	0.34	0.32	0.36	0.03	7.87	7.86	7.88	0.01
	17-Oct	43.5	42.7	44.2	1.1	154.0	154.0	154.0	0.0	96	90	102	8	<1	<1	<1	0.0	0.48	0.41	0.54	0.09	7.82	7.81	7.83	0.01

[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. Quinsam River (QUN-WQ) low level nutrients measured at ALS laboratories during Years 1 to 9 (2014 to 2022).

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	0.4	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	<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	0.7	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
2021	13-May	<5	<5	<5	0	<1	<1	<1	0	8.2	6.9	9.4	1.8	<1	<1	<1	0	2.6	2.5	2.6	0.1
	10-Jun	<5	<5	<5	0	<1.3	<1	1.6	0.4	37.6	37.1	38.0	0.6	<1	<1	<1	0	6.0	5.6	6.3	0.5
	08-Jul	<7.8	<5	10.6	4.0	<1	<1	<1	0	15.7	15.6	15.8	0.1	<1	<1	<1	0	<2.3	<2	2.5	0.4
	16-Aug	<5	<5	<5	0	<1	<1	<1	0	15.1	14.4	15.7	0.9	<1	<1	<1	0	4.4	4.2	4.5	0.2
	16-Sep	<5	<5	<5	0	<1.2	<1	1.3	0.2	13.0	13.0	13.0	0.0	<1	<1	<1	0	3.4	3.2	3.5	0.2
	07-Oct	<5	<5	<5	0	<1.3	<1	1.6	0.4	18.2	18.1	18.3	0.1	<1	<1	<1	0	3.4	3.4	3.4	0.0
2022	16-May	<5	<5	<5	0	<1	<1	<1	0	7.3	7.2	7.3	0.1	<1	<1	<1	0	4.6	4.5	4.7	0.1
	15-Jun	<5.1	<5	5.2	0.1	<1	<1	<1	0	10.3	10.1	10.4	0.2	<1	<1	<1	0	3.3	3.1	3.4	0.2
	06-Jul	<5	<5	<5	0	<1	<1	<1	0	10.3	10.2	10.3	0.1	<1	<1	<1	0	5.2	4.6	5.7	0.8
	11-Aug	<5	<5	<5	0	<1	<1	<1	0	16.1	15.9	16.2	0.2	<1.3	<1	1.5	0.4	2.9	2.6	3.2	0.4
	15-Sep	<7.8	<5	10.5	3.9	1.3	1.3	1.3	0	10.4	8.9	11.9	2.1	<1	<1	<1	0	3.9	3.7	4.1	0.3
	17-Oct	<5	<5	<5	0	<1	<1	<1	0	28.0	25.8	30.2	3.1	<1	<1	<1	0	3.7	3.7	3.7	0.0

[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 2022 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 2022. 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]			
	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
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
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
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
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
Jun	16.3	14.4	18.8	0.7	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
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
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
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
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
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
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

Month	2019[1,3]				2020[1,3]				2021[1,3]				2022[1,3,4]			
	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD
Jan	3.5	2.6	4.3	0.4	2.7	0.0	4.5	1.0	3.6	2.1	4.7	0.5	1.8	0.3	2.8	0.6
Feb	2.0	0.7	4.1	0.7	3.2	2.2	4.5	0.5	2.8	1.3	4.1	0.6	2.8	1.6	4.1	0.5
Mar	3.8	1.5	7.5	1.3	4.3	2.2	6.7	1.1	4.4	2.8	6.6	0.8	4.5	2.6	6.5	0.8
Apr	7.5	4.7	11.3	1.2	7.8	4.5	10.6	1.6	7.6	4.8	10.5	1.4	6.0	3.8	8.4	0.8
May	13.0	8.3	18.7	2.5	11.1	7.1	15.5	1.9	10.6	7.4	14.3	1.5	8.1	5.9	11.4	1.2
Jun	17.8	14.5	20.0	1.2	15.3	11.5	18.6	1.7	17.1	12.4	26.1	3.7	13.1	8.9	19.0	2.7
Jul	18.6	15.9	20.2	0.7	18.4	15.0	21.7	1.8	21.2	18.2	24.8	1.2	18.2	12.3	24.5	2.9
Aug	18.7	16.3	20.3	0.8	18.8	15.6	21.3	1.2	20.0	15.9	23.5	1.7	21.2	18.9	24.2	0.9
Sep	15.5	9.8	19.2	2.6	16.9	11.3	19.3	2.1	15.2	10.4	18.7	2.2	17.2	14.6	22.0	1.6
Oct	8.8	5.2	11.8	1.7	10.8	5.7	15.5	3.0	9.1	6.3	11.8	1.2	-	-	-	-
Nov	6.4	1.4	8.3	1.9	5.3	3.0	8.6	1.2	6.2	4.6	8.3	0.9	-	-	-	-
Dec	3.5	1.7	4.7	0.6	4.0	2.6	5.4	0.7	2.8	0.3	6.6	1.5	-	-	-	-

[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 have not yet been collected.

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 2022.

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	366	1	51	16
2021	365	4	69	47
2022[1]	289	4	52	38

[1]Tidbit sensors were retrieved October 17, 2022, therefore total days T_{water} < 1°C will be updated in 2023.

Table 13. Statistics for the hourly rates of change in water temperature at QUN-WQ in the Quinsam River, 2014 to 2022. The frequency of rates of change exceeding 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	17-Oct-22	294,629	47	0.016	-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 2022. Red dots indicate rates with magnitudes exceeding ±1°C/hr.**

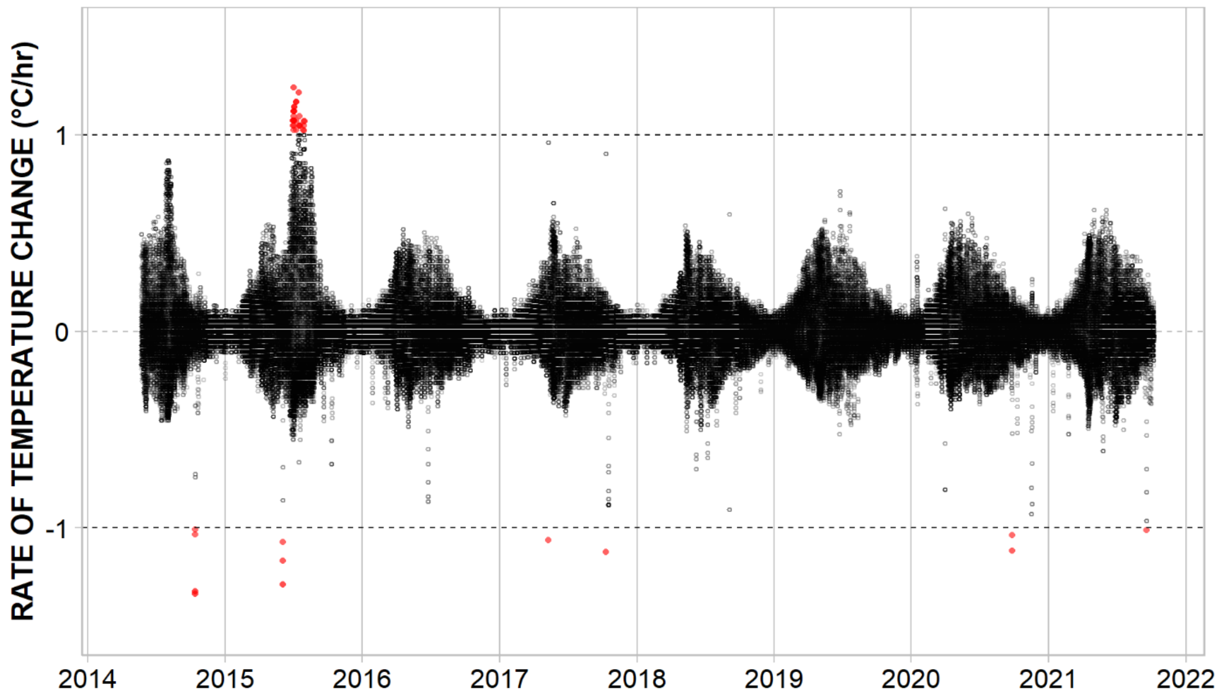


Table 14. **Growing season timing and growing degree days at QUN-WQ in the Quinsam River (2014 to 2022).**

Year	Number of days with valid data	Growing Season[1]				
		Start Date	End Date	Length (days)	Gap (days)	Degree days[2]
2014[2]	-	-	12-Nov-2014	-	-	-
2015	365	23-Mar-2015	09-Nov-2015	232	0	3,344
2016	366	29-Mar-2016	23-Nov-2016	240	0	3,324
2017	365	19-Apr-2017	01-Nov-2017	197	0	2,926
2018	365	18-Apr-2018	09-Nov-2018	206	0	2,978
2019	365	11-Apr-2019	27-Oct-2019	200	0	2,961
2020	366	09-Apr-2020	05-Nov-2020	211	0	3,018
2021	365	12-Apr-2021	08-Nov-2021	212	0	3,068
2022[3]	289	28-Apr-2022	-	-	-	-

[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 data set 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 2022 compared to optimum temperature ranges for fish species present. Periodicity information is from Burt (2003).

Species	Life Stage			Year	Percent Complete[2] (%)	MWMT (°C)		% of MWMT				
	Periodicity[1]	Optimum Temperature Range (°C)	Duration (days)			Min	Max	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	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%	6.2	14.3	0.0	0.0	100.0	0.0	0.0
				2020	100%	4.9	16.0	0.0	0.0	100.0	0.0	0.0
				2021	100%	5.5	14.3	0.0	0.0	100.0	0.0	0.0
				2022	34%	-	-	-	-	-	-	-
	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%	2.8	11.5	8.2	11.5	88.5	0.0	0.0
				2020	100%	4.4	15.4	1.6	34.4	50.8	14.8	11.5
				2021	100%	5.5	11.7	0.0	8.2	91.8	0.0	0.0
				2022	21%	-	-	-	-	-	-	-
	Incubation (Oct. 01 to Apr. 30)	5.0-14.0	242	2014	100%	2.8	15.0	9.0	19.8	75.5	4.7	0.0
				2015	100%	2.4	12.9	23.9	45.5	54.5	0.0	0.0
				2016	100%	1.3	12.6	48.6	53.3	46.7	0.0	0.0
				2017	100%	2.6	14.0	38.7	50.5	49.5	0.0	0.0
				2018	100%	1.8	12.4	39.6	50.9	49.1	0.0	0.0
				2019	100%	1.7	11.5	38.5	53.1	46.9	0.0	0.0
				2020	100%	2.5	15.4	25.0	54.2	41.5	4.2	2.8
				2021	100%	1.1	11.7	39.6	49.1	50.9	0.0	0.0
				2022	6%	-	-	-	-	-	-	-
	Rearing (Mar. 08 to Jul. 22)	10.0-15.5	137	2014	42%	-	-	-	-	-	-	-
				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%	4.0	20.7	26.3	37.2	35.0	27.7	25.5
				2021	100%	4.1	24.8	27.7	42.3	27.0	30.7	25.5
				2022	100%	4.3	20.2	51.8	54.7	24.1	21.2	17.5
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	100%	3.7	18.2	50.5	52.3	40.2	7.5	6.5
				2021	100%	1.1	15.2	43.0	49.5	50.5	0.0	0.0
				2022	26%	-	-	-	-	-	-	-
	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	100%	3.7	10.4	0.0	33.7	66.3	0.0	0.0
				2021	100%	1.1	9.3	38.0	43.5	56.5	0.0	0.0
				2022	0%	-	-	-	-	-	-	-
	Incubation (Oct. 16 to Apr. 21)	4.0-13.0	197	2014	100%	2.8	11.6	1.6	10.1	89.9	0.0	0.0
				2015	100%	2.4	11.5	10.6	27.0	73.0	0.0	0.0
				2016	100%	1.3	9.6	47.3	54.8	45.2	0.0	0.0
				2017	100%	2.6	10.2	18.1	43.6	56.4	0.0	0.0
				2018	100%	1.8	10.0	14.4	44.7	55.3	0.0	0.0
				2019	100%	1.7	10.1	10.1	43.4	56.6	0.0	0.0
				2020	100%	2.5	10.4	4.8	28.2	71.8	0.0	0.0
				2021	100%	1.1	9.3	29.3	44.7	55.3	0.0	0.0
				2022	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	100%	1.7	21.2	42.9	47.5	25.4	27.0	26.0
				2021	100%	1.1	24.8	45.2	47.7	27.4	24.9	23.8
				2022	78%	1.2	24.1	45.5	47.9	17.8	34.3	27.3

[1]Periodicity dates were revised since Year 7 for Coho and Chinook salmon inbutation and Chinook salmon spawning, therefore values are likely to differ from those previously reported.
[2]A dash (-) indicates that the MWMT data were not included because available data cover less than 50% during the period of record for each life stage.
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 mor ethan 1°C (Oliver and Fidler 2001).

Table 15. Continued (2 of 2).

Species	Life Stage			Year	Percent Complete[2] (%)	MWMT (°C)		% of MWMT				
	Periodicity[1]	Optimum Temperature Range (°C)	Duration (days)			Min	Max	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	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	100%	10.3	21.1	0.0	0.0	28.9	71.1	69.7
				2021	100%	9.1	22.8	0.0	0.0	39.5	60.5	57.9
				2022	97%	13.8	23.4	0.0	0.0	8.1	91.9	66.2
	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	100%	10.3	18.2	0.0	0.0	16.7	83.3	80.0
				2021	100%	9.1	15.2	0.0	0.0	56.7	43.3	33.3
				2022	93%	13.8	17.3	0.0	0.0	0.0	100.0	96.4
	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	100%	2.5	18.2	4.4	26.0	61.8	12.3	11.8
				2021	100%	1.1	15.2	27.0	41.2	52.9	5.9	2.9
				2022	14%	-	-	-	-	-	-	-
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	9.2	95.0	100.0	0.0	0.0	0.0
				2021	100%	2.9	9.3	98.3	100.0	0.0	0.0	0.0
				2022	100%	3.1	6.5	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	15.5	47.1	59.5	14.9	25.6	17.4
				2021	100%	2.9	15.8	48.3	65.0	11.7	23.3	15.0
				2022	100%	3.1	13.2	75.8	79.2	15.8	5.0	1.7
	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	100%	1.7	21.2	69.1	73.0	7.4	19.7	10.7
				2021	100%	1.1	24.8	72.3	75.1	4.9	20.0	17.3
				2022	78%	1.2	24.1	61.5	65.7	11.9	22.4	17.1

[1]Periodicity dates were revised since Year 7 for Coho and Chinook salmon inbutation and Chinook salmon spawning, therefore values are likely to differ from those previously reported.
[2]A dash (-) indicates that the MWMT data were not included because available data cover less than 50% during the period of record for each life stage.
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 mor ethan 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 2022.

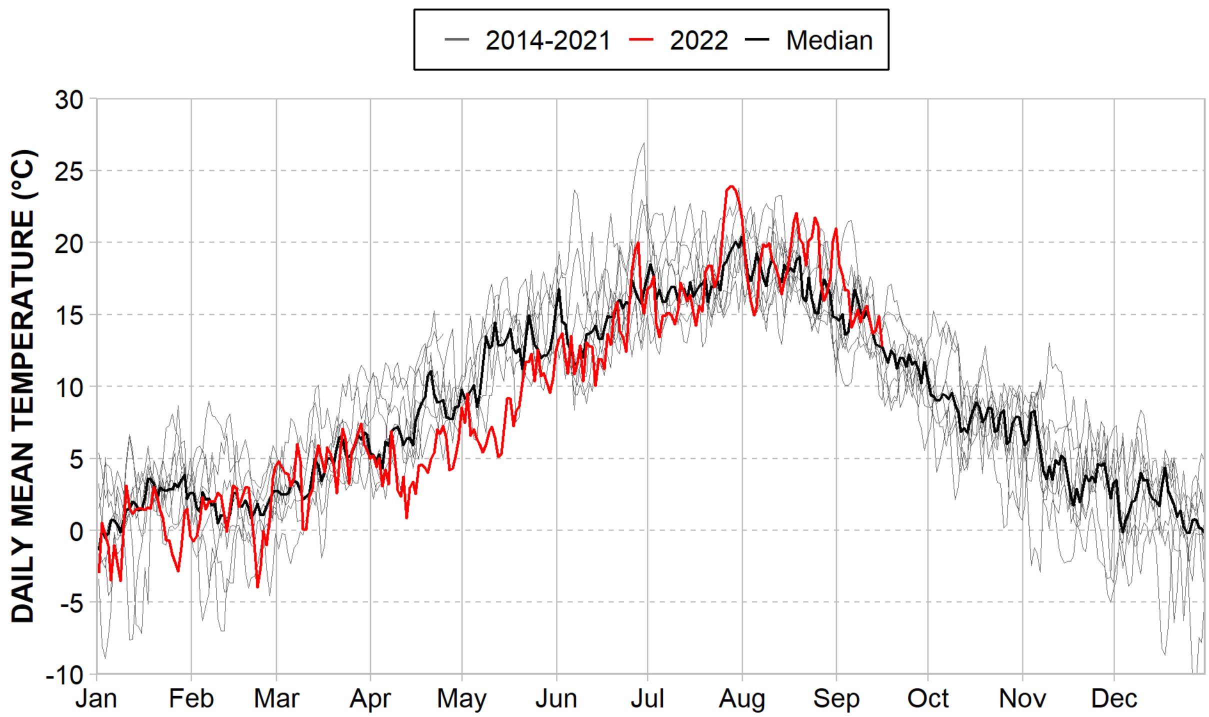


Table 16. Monthly air temperature statistics at the Quinsam River (QUN-AT) from 2014 to 2022. Statistics were not calculated for months with fewer than 3 weeks of observations.

Month	2014[1,2,3]				2015[1,3]				2016[1,3]				2017[1,3]				2018[1,3]			
	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
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
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
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
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	n/a	n/a	n/a	n/a	14.0	4.0	26.7	5.1
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	n/a	n/a	n/a	n/a	14.1	2.2	32.6	5.0
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
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
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
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
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
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

Month	2019[1,3]				2020[1,3]				2021[1,3]				2022[1,3,4]			
	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD
Jan	2.6	-2.5	8.7	2.3	1.3	-11.6	8.2	3.8	2.6	-3.8	7.9	2.3	0.1	-7.8	5.4	2.2
Feb	-2.2	-12.5	6.3	3.7	1.7	-4.5	7.6	2.4	0.5	-7.7	7.5	2.8	1.2	-8.9	9.2	2.9
Mar	3.4	-7.7	20.1	5.5	2.7	-7.2	14.5	3.8	3.6	-3.4	11.6	3.2	4.6	-4.6	14.1	3.2
Apr	7.4	-0.5	18.4	4.0	7.8	-1.9	19.9	4.9	7.7	-3.1	23.7	5.7	4.7	-2.1	13.5	3.4
May	13.9	1.4	27.2	5.4	11.7	0.3	25.9	4.9	10.9	1.3	23.2	4.6	8.6	-0.1	20.1	4.1
Jun	15.0	3.2	29.0	4.6	13.6	4.3	24.3	3.8	16.5	4.7	36.4	6.7	13.7	4.4	29.1	4.4
Jul	16.4	6.3	25.9	3.4	16.5	7.0	30.4	4.6	18.7	7.9	31.6	4.9	17.6	8.7	32.5	5.0
Aug	17.0	7.8	27.9	4.0	15.9	5.3	28.5	4.4	17.5	5.1	34.5	5.6	18.8	7.8	31.0	4.5
Sep	12.8	0.2	24.0	4.2	15.0	6.8	27.4	4.2	12.6	1.7	24.6	3.7	-	-	-	-
Oct	6.3	-2.2	13.7	3.6	8.3	-3.8	21.0	4.7	6.8	-2.4	12.9	3.1	-	-	-	-
Nov	4.3	-8.4	11.0	4.4	3.4	-3.4	12.4	3.0	4.2	-2.2	12.4	2.8	-	-	-	-
Dec	2.7	-7.0	7.3	2.4	2.9	-3.1	8.4	2.3	-1.9	-15.6	9.2	4.2	-	-	-	-

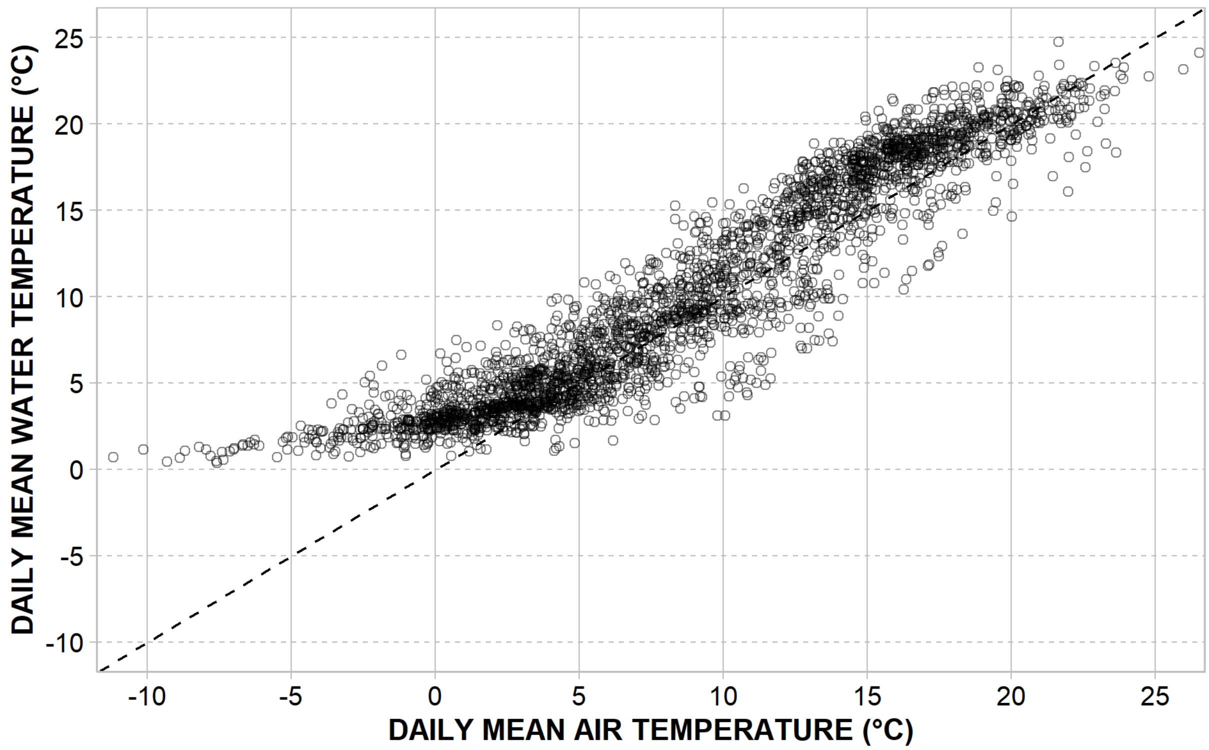
[1] "Avg", "Min", "Max" and "SD" denote the monthly average, minimum, maximum and standard deviation of air temperatures.

[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 2022. 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 2022.

Description[1]	Sampling Date	Recommended Hold Time (days)	Actual Hold Time (days)
Nitrite in Water by Ion Chromatography	19-Aug-14	3	8
Nitrate in Water by IC (Low Level)	10-May-18	3	5
Turbidity by Nephelometry	10-Jun-21	3	4
Turbidity by Nephelometry	15-Sep-22	3	4

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

Table 18. Results of field blank and trip blanks for water samples analysed by ALS laboratories, 2014 to 2022.

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
2021	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	5.5
2022	16-May	Field Blank	<1.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.25
		Trip Blank	<1.0	<5.0	<2.0	<1.0	<5.0	<1.0	<10	<2.0	<1.0	<0.10	5.24

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Appendix B. Supplementary Results of Invertebrate Drift Analysis

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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 to measure density, biomass and CEFI, while nets were combined into one sample per site to calculate biodiversity metrics (family richness, Simpson's diversity) in 2014, 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)*			Biomass (mg/m^3)*			CEFI*,†			Simpson's Diversity Index (1-λ)‡	Richness (# of Families)‡
			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

* Replicates were averaged where applicable prior to calculating metric

† Calculation considers only aquatic taxa

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

Table 1. Continued (2 of 2).

All Taxa (Aquatic, Semi-Aquatic, and Terrestrial)													
Year	Date	# of Replicates	Density (#/m³)*			Biomass (mg/m³)*			CEFI*,†			Simpson's Diversity Index (1-λ)‡	Richness (# of Families)‡
			Value	S.D.	C.V.	Value	S.D.	C.V.	Value	S.D.	C.V.	Value	Value
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
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
2021	06-May	1	0.83	-	-	0.14	-	-	0.38	-	-	0.75	33
	13-May	1	1.47	-	-	0.28	-	-	0.38	-	-	0.78	40
	18-May	1	0.85	-	-	0.17	-	-	0.37	-	-	0.73	28
	25-May	1	1.56	-	-	0.16	-	-	0.38	-	-	0.64	40
	10-Jun	1	2.24	-	-	0.16	-	-	0.36	-	-	0.75	36
	08-Jul	1	6.79	-	-	0.27	-	-	0.34	-	-	0.78	58
	16-Aug	1	10.68	-	-	0.23	-	-	0.33	-	-	0.60	20
	16-Sep	1	14.85	-	-	0.26	-	-	0.32	-	-	0.41	19
	07-Oct	1	2.12	-	-	0.10	-	-	0.32	-	-	0.72	29
2022	16-May	1	1.38	-	-	0.34	-	-	0.36	-	-	0.81	50
	06-Jun	1	1.47	-	-	0.28	-	-	0.37	-	-	0.73	37
	15-Jun	1	1.69	-	-	0.39	-	-	0.35	-	-	0.71	30
	21-Jun	1	7.51	-	-	0.55	-	-	0.32	-	-	0.48	38
	28-Jun	1	8.38	-	-	0.40	-	-	0.33	-	-	0.55	40
	06-Jul	1	5.51	-	-	0.42	-	-	0.33	-	-	0.81	33
	11-Aug	1	3.14	-	-	0.39	-	-	0.35	-	-	0.83	31
	15-Sep	1	1.59	-	-	0.17	-	-	0.34	-	-	0.79	40
	17-Oct	1	1.17	-	-	0.06	-	-	0.37	-	-	0.87	27

* Replicates were averaged where applicable prior to calculating metric

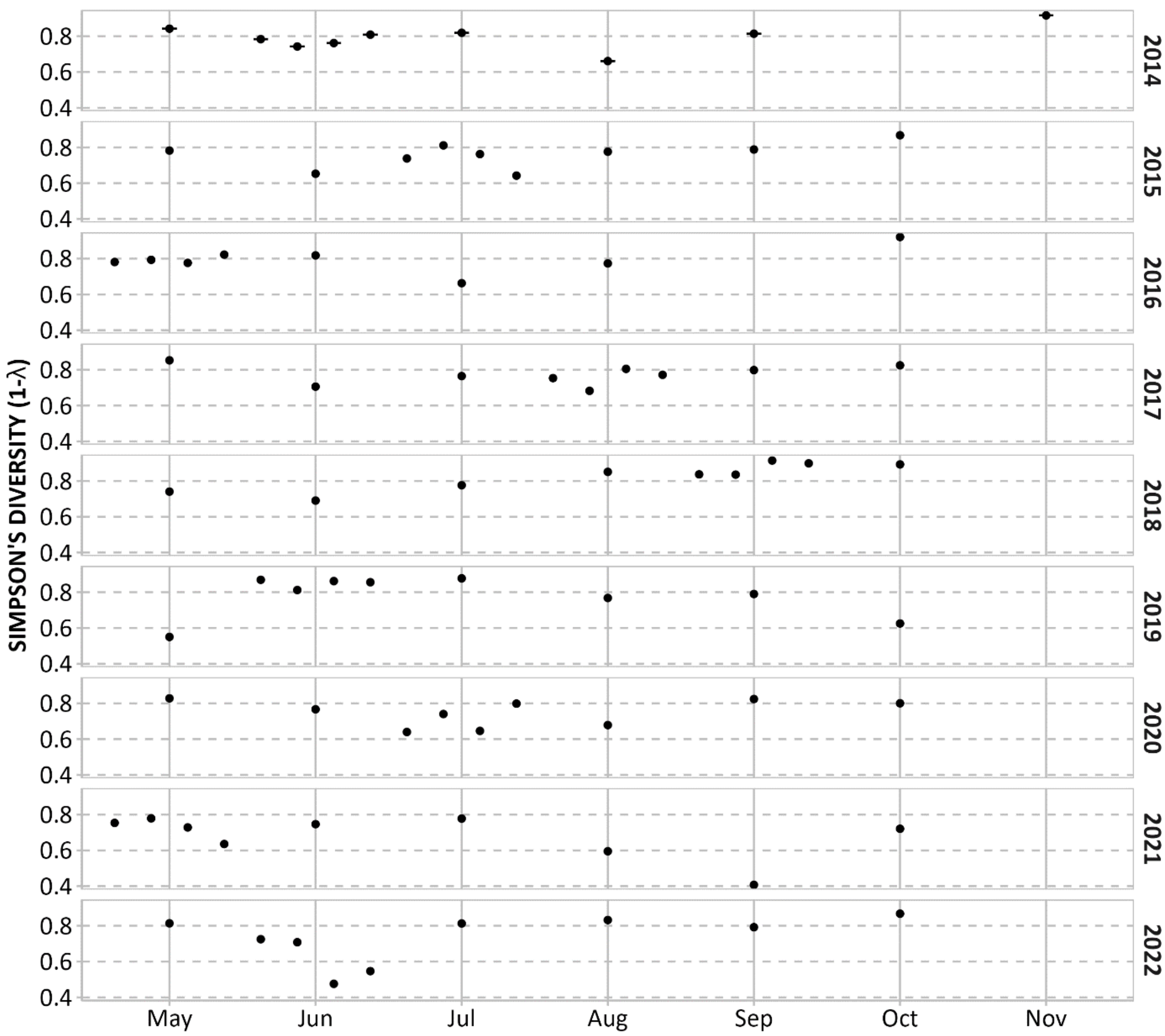
† Calculation considers only aquatic taxa

‡ 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 0.48 – 0.87 in Year 9 (2022). The values were within the range observed in previous years (0.41 – 0.92; Table 1; Figure 1). Simpson's family level diversity was variable throughout Year 9, with the highest value observed on October 17, 2022 and the lowest value observed on June 21, 2022.

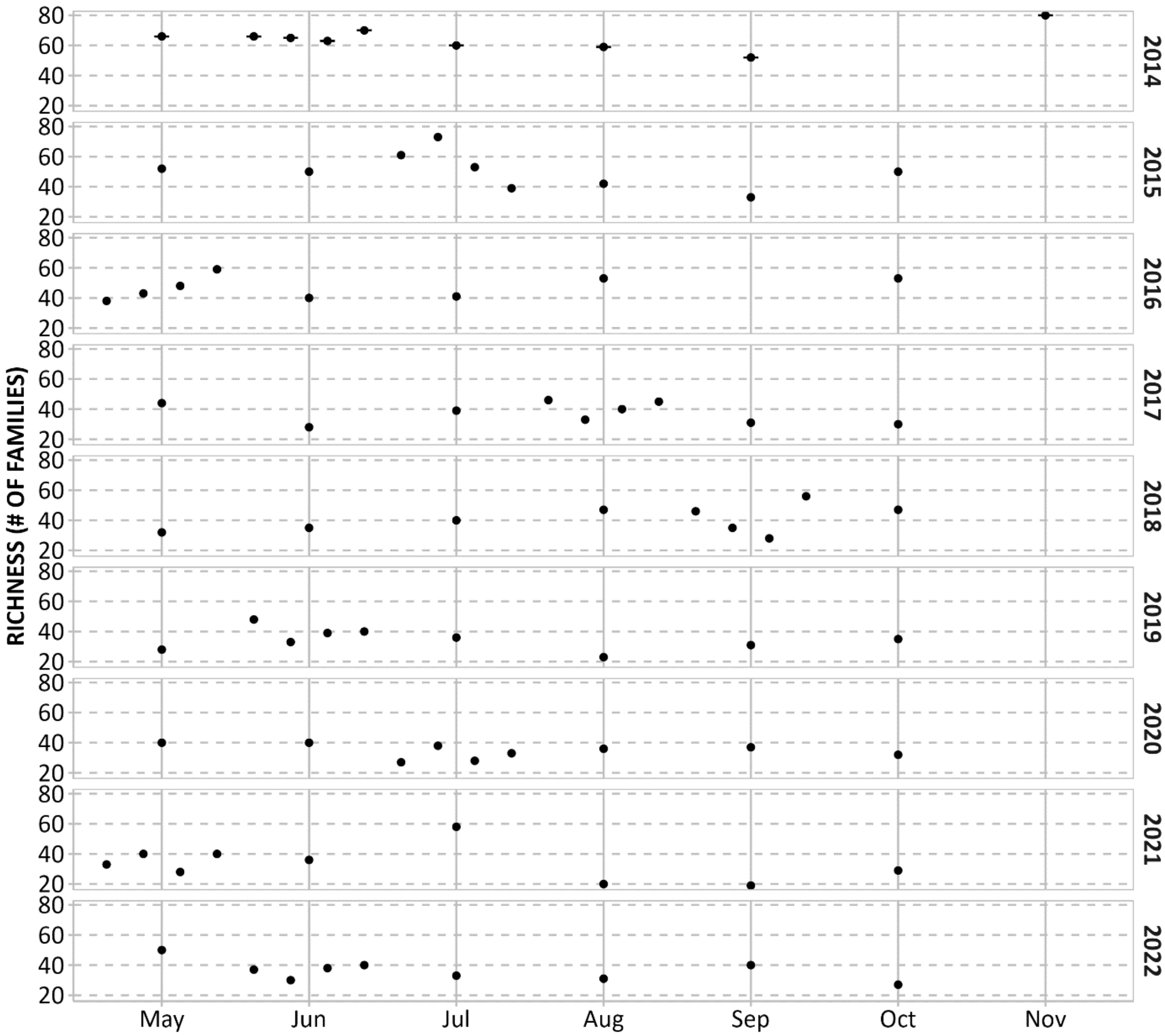
Figure 1. Drift invertebrate Simpson's Diversity (all taxa) in the Quinsam River throughout 2014 - 2022. Standard deviation (SD) is provided for Year 1 (2014) only, which is the only year when samples from all five drift nets were analyzed separately.



3. RICHNESS (# OF FAMILIES)

Family richness measured in Year 9 (2022) ranged from 27 – 50 families across sampling dates (Table 1, Figure 2). There was no clear seasonal pattern, with the lowest value observed on October 17, 2022, and the highest value observed on May 16, 2022.

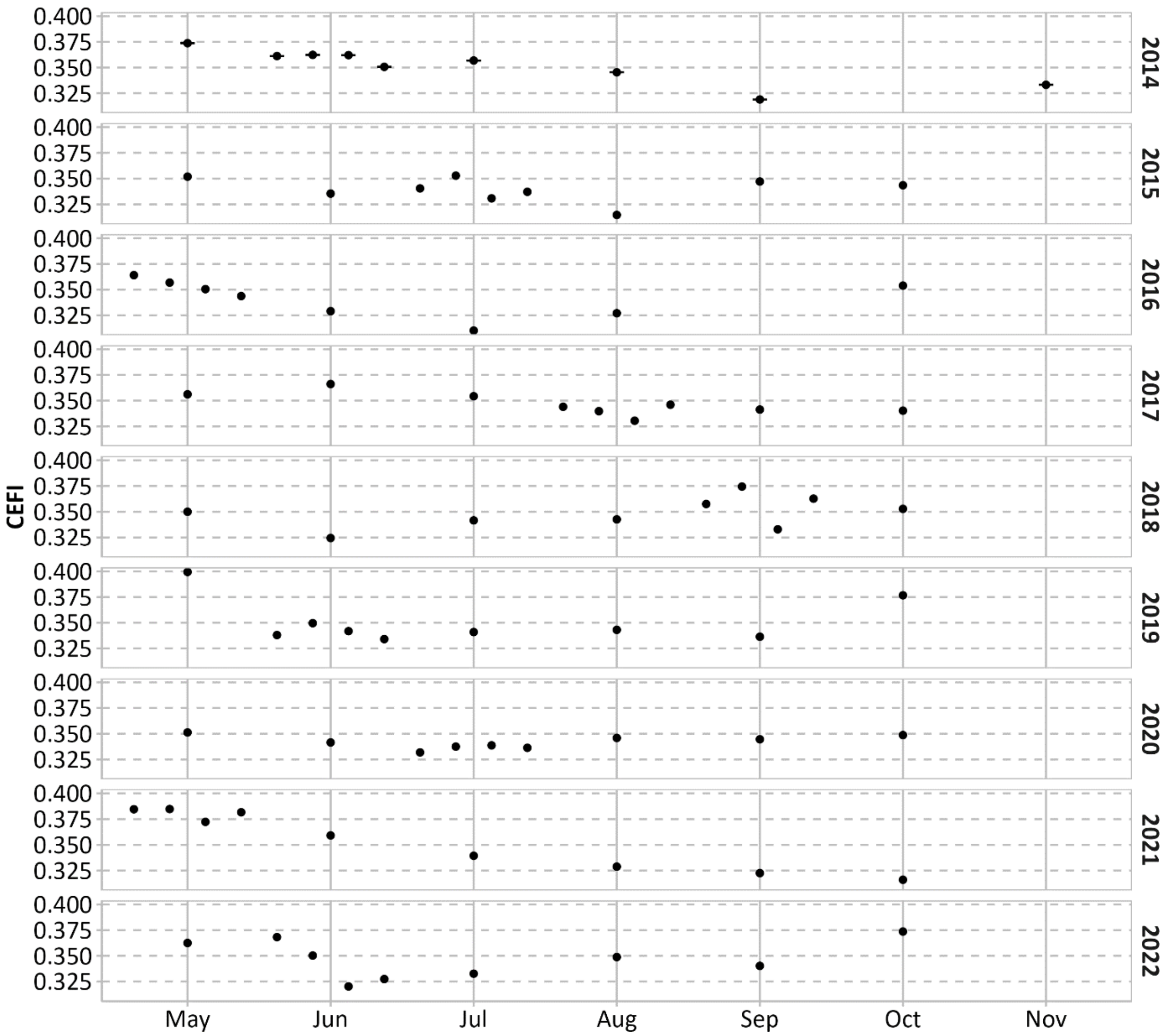
Figure 2. Drift invertebrate family richness (all taxa) in the Quinsam River throughout 2014 – 2022. Standard deviation (SD) is provided for Year 1 (2014) only, which is the only year when samples from all five drift nets were analyzed separately.



4. CANADIAN ECOLOGICAL FLOW INDEX

The CEFI results for Year 9 (2022) are in the range 0.32 – 0.37, which are above the 0.25 threshold of low CEFI values (Armanini *et al.* 2011[1]). In Year 9, the lowest CEFI value occurred on June 21, 2022 while the maximum value was observed on June 6, 2022 and October 17, 2022 (Table 1; Figure 3).

Figure 3. CEFI values for drift invertebrates (aquatic taxa) in the Quinsam River throughout 2014 - 2022. 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.



[1] Armanini, D.G., N. Horrigan, W.A. Monk, D.L. Peters, and D.J. Baird. 2011. Development of a benthic macroinvertebrate flow sensitivity index for Canadian rivers. River. Res. Applic. 27: 723-737.