Cheakamus River Project Water Use Plan

Cheakamus River Juvenile Salmon Migration Enumeration

Implementation Year 9

Reference: CMSMON1a

Cheakamus River Juvenile Salmonid Migration

Enumeration Assessment

Annual Data Report 2016

Study Period: February to June 2016

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Prepared for BC Hydro

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Executive Summary

In 2000, a juvenile salmonid migration monitoring program was initiated by the Cheakamus Water Use Plan Consultative Committee to evaluate anadromous fish productivity in the Cheakamus River under the Interim Flow Agreement. Changes to the flow regime were initiated in February of 2006 and monitoring of the juvenile migration of anadromous salmonids has continued as part of the evaluations of flow changes implemented under the Water Use Plan. This Cheakamus Monitor #1a produces yield evaluations of smolt and fry migrants for five species of salmonids: Coho Salmon (*Oncorhynchus kisutch*), Chum Salmon (*O. keta*), Chinook Salmon (*O. tshawytscha*), Pink Salmon (*O. gorbuscha*) and Steelhead Trout (*O. mykiss*).

Data collected for Chum Salmon and Steelhead Trout are analyzed in detail by the Chum Salmon Adult Escapement Monitor #1b and the Cheakamus River Steelhead Adult and Juvenile Abundance Monitor #3.

In 2016, 5,491,140 Pink fry 56,470 Chinook fry, 69,120 Coho smolts and 4,918 Steelhead smolts were produced in the area of the Cheakamus River upstream of the monitoring site at the Cheakamus Center (formerly the North Vancouver Outdoor School) property. No estimate was formed for Chinook smolts in 2016 as catches were too low. Over the years evaluated, the 2016 estimates ranked: 9th out of 12 for Steelhead smolts, 10th out of 16 for Coho smolts, 4th out of 8th for Pink fry, and 13th out of 15 for Chinook fry.

Side channel production estimates have been derived for Coho smolts and Chum fry since 2008. In 2016, Coho smolt production from the Cheakamus Center and BC Rail side channels was the second lowest on record. The total side channel production of Coho smolts was 4,516, 6.5% of the total upper river production estimate. Side channel production for Chum salmon is evaluated in Monitor #1b.

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1.0 INTRODUCTION

1.1 Background History of Study and Watershed

The Cheakamus River is a major tributary of the Squamish River Watershed in the Coastal Mountain range of south-western British Columbia. The Cheakamus River originates in the Fitsimmons Range, between the communities of Whistler and Squamish, draining an area totaling 1010 km^2. The Cheakamus River enters the Squamish River upstream of the Brackendale gauging station (WSC 08GA043) approximately 12.5 km north of Howe Sound. Discharge on the Cheakamus River is affected by BC Hydro through the operation of the Daisy Lake Reservoir and the Cheakamus generating plant, a 157 megawatt storage and diversion project located approximately 40 km north of Squamish. The generation project, completed in 1957, consists of a 28 m high, 680 m long dam that impounds Daisy Lake Reservoir. From this reservoir, a portion of the rivers inflow is diverted through an 11 km long tunnel to a powerhouse on the Squamish River (Figure 1). The operating range of the Daisy Lake Reservoir is between 364.90 m and 377.25 m above sea level (a fluctuation of 12.35 m), during normal operations. The reservoir can store approximately 55 million cubic meters of water, which is approximately 3.5 percent of annual inflows.

The Cheakamus River, downstream of the reservoir, extends 26 km to its confluence with the Squamish River. Only the lower 17.5 km of the river are accessible to anadromous salmon as a series of impassable falls (at river kilometer 17.5) create a natural barrier precluding further upstream migration (Figure 2). Anadromous habitat in the mainstem of the Cheakamus River is complimented by a large area of man-made restoration channels which are fed either by groundwater or river water diverted from the mainstem.

In June 1999, the Cheakamus Consultative Committee (CC) was formed. The CC consisted of 20 members representing Federal, Provincial, Regional and Municipal Governments; the Squamish First Nation; BC Hydro; environmental and recreational interests and local stakeholders. Two sub-committees; a Fisheries Technical Committee (FTC) and a Power Studies Technical Committee comprising of professionals were formed to inform the CC (Mamorek and Parnell 2002).

In 1999, the CC identified the need to determine the response of juvenile salmonid populations to the Interim Flow Order (IFO), which was implemented in 1997, and the subsequent Instream Flow

Agreement (IFA), which was implemented in 2000. A juvenile salmon migration study utilizing rotary screw traps (RSTs) commenced in the spring of 2000 (Melville and McCubbing 2001) and has continued annually through to 2015.

The CC held its last meeting in January 2002 and was unable to reach consensus on a new operating alternative and recommended continuing with the IFA for another 3-5 years to thoroughly assess its effects. The CC recognized that it was essential to address critical scientific uncertainties that could affect future decision making and to comprehensively assess the response of the system to the operating alternative implemented. The FTC developed a comprehensive monitoring plan to address the critical points of scientific uncertainty and disagreements within the CC. The CC agreed that the highest priority ecological indicator was salmonid spawning and juvenile production (Mamorek and Parnell 2002).

In 2005, the Cheakamus River Water Use Plan (WUP) was developed by the CC committee (BC Hydro 2005) and presented a matrix of discharge arrangements for Water Comptroller approval. The WUP incorporates a number of discharge rules for the Cheakamus River designed to balance environmental, social and economic values. A fundamental objective of the Cheakamus River WUP is to maximize wild fish populations. The proposed changes to the existing IFA were based in part on expected benefits to wild fish populations (BC Hydro 2007). The new flow order for the Cheakamus River was approved by the Water Comptroller and the WUP was implemented on February 26th, 2006.

The IFA specified that the greatest of 5 m^3/s or 45% of the previous days' inflows to the reservoir be released from Daisy Dam (within a daily range of 37% to 52% and within 45% of the previous 7 days' average). Under the WUP, the discharge rules for operations are based on minimum flows measured at the following two locations:

1) Minimum required flow below Daisy Lake Dam:

i) 3.0 m^3/s from Nov. 1st to Dec. 31st
ii) 5.0 m^3/s from Jan. 1st to Mar. 31st
iii) 7.0 m^3/s from Apr. 1st to Oct .31st

2) Minimum required flow at the Water Survey of Canada (WSC) Brackendale gauge (08GA043):

i) 15.0 m^3/s from Nov. 1st to Mar. 31st
ii) 20.0 m^3/s from Apr. 1st to Jun. 30th
iii) 38.0 m^3/s from Jul. 1st to Aug. 15th
iv) 20.0 m^3/s from Aug 16 to Aug. 31st, unless directed by Comptroller to maintain 38.0 m^3/s for recreation
v) 20.0 m^3/s from Sept. 1st to Oct. 31st

The likely effects on fish populations of the new operating regime were uncertain because the benefits presented during the WUP process were modeled using complex relationships between fish habitat and flow, and assumed relationships between fish habitat and fish production (Mamorek and Parnell 2002). The Juvenile Migration Monitor #1a in conjunction with other monitors was developed to reduce this uncertainty and evaluate potential effects of the new flow regime on salmon populations (Parnell et al. 2003; Cheakamus Water Use Plan Monitoring Program Terms of Reference, Feb 2007).

1.1.1 Management Questions

Prior to the implementation of the new flow order in 2006, the Juvenile Migration monitor was limited to assessing the total production of juvenile salmon upstream of the RST site (Figure 2). Partitioning of side channel and mainstem production was not included in the initial study design implemented in 2000.

In 2007, the study was expanded to include population assessments of salmonids from key restoration side channels to better answer two key management questions:

1. What is the relationship between discharge and juvenile salmonid production, productivity, and habitat capacity of the mainstem and major side channels of the Cheakamus River?

2. Does juvenile salmonid production, productivity, or habitat capacity change following implementation of the WUP flow regime?

The migration data is used in conjunction with data collected as part of the Chum Salmon Adult Escapement Monitor #1b (Fell et al. 2015) and the Cheakamus River Steelhead Adult and Juvenile Abundance Monitor #3 (Korman et al. 2015) to address the management questions:

1. How does Chum fry yield correlate to Chum adult escapement distribution and density and is this affected by variance in discharge?
2. How does Steelhead smolt yield correlate to Steelhead adult escapement and fry/parr densities, and is this affected by variance in discharge?

In addition, migrant data from this program was used as part of the Groundwater Side-channels Monitor #6 (Gray et al. 2012) to address the management question:

1. To what extent does salmonid production vary in Cheakamus Center and Tenderfoot Hatchery (TH) side channels in relation to groundwater flow interaction with the Cheakamus River when discharge is $\leq 40m^3/s$, and to what extent has the implementation of the WUP affected salmonid production in the Cheakamus Center and TH side channel habitats compared to the pre-WUP state?

The expanded study includes detailed assessments of juvenile salmonid migration using a combination of total capture and estimated counts from mark-recapture (Cheakamus Water Use Plan Monitoring Program Terms of Reference, Feb 2007).

Monitor #1a collects data that informs three other monitors: Monitor #s 1b, 3 and 6. Detailed analyses of the data as it relates to those specific monitors will be reported in the respective reports, i.e.:

- Chum fry production and egg to fry survival will be reported in the Monitor 1b (Fell et al. 2016);
- Steelhead smolt production as it relates to stock recruitment will be reported in Monitor 3 (Korman et al. 2016);
- Chum fry production as it relates to groundwater in side channels will be reported in Monitor 6 (Gray et al. 2016).

A report summarizing results of this study from 2001 through 2012 as they related to the two key management questions in Section 1.1.1 was completed in the fall of 2012 (Melville et al. 2012) and an interim review meeting of the Consultative Committee was held to discuss the results. It was decided by the committee in 2012 to continue Monitor #1a for a further five years of data collection to increase the analytical scope of data analysis and to better inform a future final report and flow related decisions thereafter. Here we present a further year of data; 2016. This has been added to the data set and we provide a brief update on the status of analysis as it relates to the management questions.

1.2 Study Area and Trapping/Enumeration Locations

The primary location of juvenile fish enumeration consists of two rotary screw traps (RSTs) operated adjacent to the Cheakamus Center (formerly North Vancouver Outdoor School) property (10U 0489141:5518035, Figure 2 & 3) at river kilometer (RK) 5.5. Secondary enumeration sites were operated on both ground water and river augmented (flow through) side channels at locations on the Cheakamus Center property, BC Rail channel and Tenderfoot Creek/Lake (Figure 3).

1.3 Hatchery Releases

Releases of hatchery fish are undertaken annually into the Cheakamus River by various organizations. Species that have been augmented include Chinook, Coho, Pink, and Chum Salmon and Steelhead Trout.

Due to observed losses of Chinook adults following the caustic soda spill in 2005 (McCubbing et al. 2006), a hatchery enhancement program targeting Cheakamus River Chinook was implemented in the fall of 2005. Chinook salmon adults are captured in the river and placed in Tenderfoot Hatchery (TH) where they are spawned and their progeny raised and released as both young-of-the-year (YOY) and yearling smolts (1+). The YOY are released to the Cheakamus mainstem at RK 12 to 15. The yearling Chinook are released at multiple locations along the length of the Cheakamus mainstem. Prior to 2013 Chinook brood collection and juvenile releases occurred in Howe Sound.

Coho yearling smolts are released every spring directly from the hatchery into Tenderfoot Creek. These fish are marked with an adipose clip and can be easily identified. Commencing in 2007, additional unmarked Coho smolts were also released at RK 12-15. As for Chinook YOY, the upper river releases are done to mitigate losses observed during the caustic soda spill in 2005 (McCubbing et al. 2006). Generally, RST operations are suspended for one to two days following Coho and Chinook hatchery releases, thus allowing the majority of the migrants to pass the RST site without the risk of capture.

The Cheakamus Center and Tenderfoot Creek Hatchery release Chum fry each spring. Depending on release numbers, RSTs and/or side channel fyke net operations are usually suspended for one day to allow fish passage. This operational protocol has been established because hatchery chum fry cannot be differentiated from wild fry based on size or morphology and as Chum fry migrate quite quickly (usually overnight) past the traps (C. Melville, pers. obs.). If trapping was not suspended, Chum fry catch for the day after the release is removed from the annual data set, thus, eliminating these fish from being included in Chum fry estimates.

Commencing in fall 2005, in response to the observed mortality of Pink salmon during the 2005 caustic soda spill, a hatchery enhancement program targeting Cheakamus River Pinks was implemented. Pink salmon adults are captured at the Cheakamus Center side channel trap and the Tenderfoot Creek fish fence. Adults are spawned at Tenderfoot Hatchery (TH) and their progeny released downstream of the RSTs the following spring as young-of-the-year (YOY).

In 2007 and 2008 hatchery steelhead smolts were released into the Cheakamus River. As with the mainstem Coho, Chinook and Pink releases, the Steelhead hatchery program was implemented due to the Steelhead mortality incurred in 2005 as a result of the caustic soda spill.

Specific annual release dates and numbers for each species are kept on file.

1.4 2003 Flood and 2005 NaOH Spill

Two events that have had an effect on fish populations outside of the WUP flow changes have occurred on the Cheakamus River since the juvenile monitor began in 2001.

On October 18th and 19th, 2003 an extreme flood event occurred. The second highest maximum mean daily discharge on record of 709 m^3/s was recorded at the WSC Cheakamus @ Brackendale gauge (08GA043), on October 19th. This discharge had been exceeded on October 18th when the greater of the two peaks in flow occurred; however, flows exceeded the rating curve for the gauge and a maximum value was not recorded. Prior to the flood event in 2003, the highest mean daily discharge recorded was on December 27th, 1980 when the discharge was estimated at 712 $m^{3/}s$ (WSC records). During the 2003 flood, the river inundated the area of the Cheakamus Center restoration channels and moved large amounts of sediment and debris in the mainstem of the river. Concerns were expressed over egg-to-fry survival of both Pink and Chinook Salmon in the side channels and the mainstem of the Cheakamus River as the flood occurred just as Pink and Chinook spawning concluded.

On August 5th 2005, 41,000 litres of caustic soda (NaOH) spilled into the Cheakamus River when a train derailed at approximately RK 19. This chemical killed a large proportion of all fish species residing downstream in the mainstem (McCubbing et al 2006). Species affected were Chinook, Pink, and Coho Salmon, Steelhead, Rainbow, Cutthroat and Bull Trout, sculpins, lampreys, and stickleback (McCubbing et al. 2006).

1.5 Fish Restoration Projects

A number of restoration projects have been completed on the Cheakamus River since 2001. These included the addition of these projects upstream of the RST site (Fish and Wildlife Compensation Program Cheakamus River Restoration Project Reports 2002-2006; Harper and Wilson 2008; Triton Environmental Consultants Ltd. 2008, 2009):

- Cheakamus Gravel Recruitment (ground water): constructed in 2002; created 700 m^2 of additional head pond area in the upper Kisutch channel. Target species: Chum and Coho Salmon.

- Gorbuscha 1 (river intake): constructed in 2002; created 750 m of channel and 4600 m^2 habitat. Target species: Pink and Chinook Salmon.

- Gorbuscha 2 (river intake): constructed in 2003; created 478 m channel and 3225 m^2 habitat. Target species: Pink Salmon.

- Sue’s channel (river intake): constructed in 2006; created 380m channel and 2400 m^2 habitat. Targeted species: Pink, Chinook, Chum, and Coho Salmon, and Cutthroat and Rainbow/Steelhead Trout.

- Mykiss channel (river intake): constructed in 2006; created 1600m^2 spawning habitat and 3800 m^2 of rearing habitat. Target species: Rainbow/Steelhead Trout and Coho Salmon.

- Km 6.5 side channel re-watering (river intake): constructed in 2007; created 1400 m^2 habitat. Targeted species: Chinook Salmon and Rainbow/Steelhead Trout.

- Large Wood Restoration Project (mainstem structures): constructed in 2007; created 900m^2 of habitat. Targeted species: Rainbow/ Steelhead Trout.

- Km 8 (Swift Creek) Channel (river intake): constructed in 2008; created 590m of channel and 3,540m^2 habitat. Targeted species: Chinook and Rainbow/ Steelhead Trout.

- Duck Pond (river intake): constructed in 2014 to increase flow into the Canoe Pond and Moody's channel.

2.0 METHODS

2.1 Fish Trapping Methods

Prior to 2007, only mainstem juvenile fish production was assessed. In order to meet the objectives of the WUP monitor to partition side channel production from mainstem production, side channel assessments were added to the study plan using various trapping methods in 2007. Three methods have been used for enumerating migrant salmonid fry and smolts in the Cheakamus River during this study:

1) partial traps (RSTs, fyke nets and minnow traps) which rely on mark recapture methodology to evaluate fry and smolt migration;
2) complete channel traps which allow for manual counting of all migrant smolts from a designated area;
3) resistivity counters in combination with trap boxes built into diversion weirs which electronically enumerate migrant smolts while being calibrated by manual counts.

During the study design a method was chosen based on the logistics of each trapping location. Considerations evaluated when choosing trapping methodology included species life-stage (i.e. fry or smolt), number of fish that can reasonably be enumerated during a 24-hour sample period (i.e. fry), potential stress and mortality of fish (i.e. ensuring that the method reduced the risk of mortality to the population), manpower requirements, and environmental factors (i.e. flow and location).
Changes in trapping methods made since 2013 are described below; other changes made over the study period (2001-2013) are described in detail in Melville et al. 2013.

2.1.2 Side Channel Fyke Net Traps

Fry production from Tenderfoot Creek continued to be assessed in 2016 using a single fyke net at (F10) as both a mark and recapture trap. F10 has been used as both a mark and recapture trap since 2014 and is located at the Department of Fisheries and Oceans (DFO) Tenderfoot Creek fish fence which is used for enumeration of adult Chum Salmon. During the first year of assessment of this tributary (2013), two fyke nets (F9 and F10) were operated to evaluate fry production upstream of the DFO fish fence and one fyke net (F11) was operated at the confluence of Tenderfoot Creek and the Cheakamus River to assess fry production from the entire creek. Use of F9 and F11 were discontinued due to insufficient catches of chum fry to generate estimates. Surveys conducted on adult spawners in Tenderfoot Creek also indicate the majority of spawning occurs in Tenderfoot Pond. Only small pockets of spawning gravel are utilized between the DFO fish fence and the Cheakamus Confluence (Fell et al. 2013). Results for the 2016 Tenderfoot Creek chum production are reported in Fell et al. 2016.

2.2 Population Estimate Methods

In 2008 with the technical advice of Dr. Carl Schwarz and Dr. Simon Bonner, from the Department of Statistics and Actuarial Science at Simon Fraser University, marking techniques were altered to better assess some of the issues with meeting the assumptions made by Seber (2002). In particular, techniques were modified to evaluate changing catchability as flows fluctuate during the spring. A Bayesian Time Stratified Spline Model (BTSPAS) was developed over the period of 2009-2011 (Bonner 2008; Schwarz 2009; Bonner and Schwarz 2011) that has many advantages over existing methods. Benefits of the model include the ability to share data amongst weekly strata if data are sparse for a particular week (e.g. inability to fish due to high water or hatchery release), as well as, the ability to interpolate between data points. The method is self-calibrating in the sense that if the data are sparse, the equivalent of simple Petersen methods where the catchability is assumed to be roughly the same over the study are fit, but when the data are rich, more complex models are fit. Estimates of abundance are provided for each recapture stratum so it is relatively simple to estimate derived quantities such as the time at which 50% of the run has passed, or the time needed to reach a pre-specified target number of fish. A full explanation and list of advantages and limitations of the BTSAPS model are described fully in Schwarz et al. (2009), and Bonner and Schwarz (2011).

In 2012, all previous estimates of juvenile abundance were recalculated utilizing the BTSPAS and this model will be used for all future production estimates. A detailed description of methods used for collecting the field data and calculating the BTSPAS population estimates for the Cheakamus are described fully in Schwarz and Bonner (2011).

This report provides an annual update on the population trends of juvenile salmonid migrating from the Cheakamus River. Further analysis and comparisons between the population trends under the IFA and WUP flow regimes will be conducted during the 2017 final report.

2.3 Discharge Data Collection and Analysis

Mean daily and weekly discharge (Q) is computed annually from the Water Survey of Canada (WSC) hourly discharge record for the Cheakamus River at the Brackendale gauge, WSC 08GA043 (10U 0489186:5518291), located 100 m upstream of the RST site (Figure 3). These readings are used for all analysis relating to discharge and fish production in this study.

2.4 Temperature Collection and Analysis

Prior to 2007, hourly temperature data for this study was only collected during the study period (Feb 15 to June 15) using a temperature logger at the RST site (Figure 3).

As part of the expanded monitoring plan, five temperature loggers have been maintained for the full calendar year and hourly data is collected. Loggers are downloaded once every month and the data are archived for use in other Cheakamus WUP monitors.

The five temperature logger locations are described as follows and are shown in Figure 3:

1) Downstream of Daisy Dam (upstream of Rubble Creek, RK26, 10U 0489781:5535658)
2) Upstream of Cheakamus Canyon (anadromous barrier, RK20, 10U 0489782:5535665)
3) Suspension Bridge (upstream of Culliton Cr., RK13, 10U 0486976:5525175)
4) Rotary Screw Trap site (downstream of Culliton Cr., RK5.5, 10U 0489141:5518035)
5) Downstream of Cheekye (RK2, 10U 0487911:5515362)

The temperature data recorded at the RSTs (Temperature Logger 4) are primarily used for analysis in this study.

2.5 Bio-sampling and Age Data Collection

A sub-sample of all species captured have been sampled for lengths and weights at the RST site and at Upper Paradise side channel trap (Site 1 and 6) throughout the study (2001-2016). Methods are more fully described in Melville and McCubbing (2011).

Pink and Chum juveniles are all 0+ when migrating from fresh to salt water and in general spend less than 2 weeks post emergence prior to migrating to saltwater (Fell et al. 2012) therefore no ageing data is collected.

Coho, Chinook and Steelhead juveniles have varied freshwater life histories prior to migration to salt water. For the purpose of marking and enumeration estimates it is necessary to have straightforward criteria (length) to identify which life stage these species are at when captured during the spring migration period. Length frequency data from 2000-2003 and in the case of Steelhead juveniles age and length frequency data were used to identify length cut-offs for the various life stages (Table 1):

- **Coho:** smolts (1+ migrating) : >70 mm, parr (1+ non-migrating): 60-70mm, fry (0+ non-migrating) < 60mm.
- **Chinook:** smolts (1+ migrating) : >80 mm, fry (0+ migrating) <80mm.
- **Steelhead:** smolts (2+ and 3+ migrating) : >140 mm, parr (1+ non-migrating): <140mm.

In all years of the study scale samples were taken from a stratified sub-sample of Steelhead (1+, 2+ and 3+), Coho (1+) and Chinook (1+) juveniles by the methods detailed in Ward et al. (1989). All Steelhead scale samples taken since 2001 have been aged once and corroborated independently by a second technician. Coho scale samples have not been analyzed because length frequency data in all years of the study indicates that the majority of migrating Coho are 1+ (Melville and McCubbing 2001-2013; Lingard et al 2014, 2015). Chinook samples will be aged in fall of 2016 as part of a related study on juvenile Chinook salmon use of the Squamish Estuary.

3.0 RESULTS

3.1 Juvenile Chinook Salmon

3.1.2 Chinook Fry Migration and Production

The migration of Chinook fry out of the Cheakamus River, in 2016, did not have the typical early peak as seen in the majority of previous years. Based on estimated weekly abundance, 1% of the total yield was estimated to have migrated in the first two sampling strata (Figure 4). In comparison from 2001 through 2015 an average of 26% of the total yield was estimated to have migrated in these strata (Figure 4). In 2016, the migration appeared to be climbing to a peak when fishing was suspended on April 12th due to high water. An estimated 37% of the run was migrated in the final week of operation with fry drums on the RSTs (Figure 4).

The peak of Chinook fry migration has varied in timing from as early as February to as late as May over the 16 years of the study. In nine of the years studied (2001-2003, 2005, 2007, 2009, 2010, 2013 and 2014) a peak of Chinook migration occurred prior to or at the beginning of the study in February, and in three years (2011, 2012, 2014) a peak in migration occurred at the end of the mark-recapture program at the beginning of May (Figure 4). In two years (2004, 2015) following winters with abnormally high flows, peaks of migration occurred between mid- March and mid- April. The peaks of Chinook fry abundance across all years have not consistently coincided with spikes in temperature or discharge. It is not possible to say, with confidence, when the peak of migration occurred in 2016 as trapping for fry was suspended on April 12th, due to high flows that persisted until the end of April resulting in 3 missed strata.

Estimates of Chinook fry abundance from the Cheakamus River have been calculated for nearly every year of the study (2001-2016), the exception being 2006 when insufficient numbers (499) were captured to derive a mark-recapture estimate. The 2006 migration was, in part, affected by adult spawner mortality resulting from the chemical spill event in the summer of 2005.

In 2016, the estimated emigration of Chinook fry was 56,470 (SD = 8,474). The 2016 estimate ranked 13th out of the 15 years Chinook fry abundance has been assessed. Estimated production of Chinook fry from the mainstem of the Cheakamus River for all previous years has ranged from a low of 16,484 in 2015 to a high of 874,946 in 2011 (Figure 5). The average estimated production for all years (2001 to 2016) was 262,441 (SD = 226,801) (Table 2 and Figure 5). There have been five IFA and ten WUP estimates of Chinook fry production. Average IFA and WUP abundances were 250,860 fry and 268,232 fry, respectively. These estimates equate to an average change in abundance of 17,371 fry or a 7% increase in production (Table 2).

There are no estimates of Chinook fry abundance in the side channels as very few fish are captured at these sites. In 2016, 11 Chinook fry were captured at F1 enumeration fyke on the Cheakamus Center side-channel complex compared to an average catch of 287 fish since 2007 (range of 99-598). A total of 3 Chinook fry were captured at F7 on the BC Rail side channel complex in 2016, the first time Chinook have been captured at this location (Figure 3).

3.1.2 Chinook Smolt Migration and Production

In most study years, insufficient capture of fish has resulted in too few fish to mark to allow generation of an estimate for 1+ Chinook smolts. In the four years (2001-2003 and 2009) where weekly abundance estimates of Chinook smolts were calculated it appears that the peak migration timing is between April 20^{th} and May 10^{th}.

In 2016, a total of 79 Chinook smolts were captured at the RST and in the Cheakamus Center smolt trap. An estimate of Chinook smolt abundance was not calculated due to the low catch. In the years a population estimate was derived (2001-2003 and 2009), Chinook smolt abundance ranged from 6,020 to 14,439 smolts (Table 2 & Figure 7). A total of 13 Chinook smolts were captured at the Site 1 fish trap at the Cheakamus Center side channels (Figure 3). Since 2009, an average of 11 (range: 2-37) Chinook smolts have been captured at this location.

3.1.3 Juvenile Chinook Length and Age Data

In the years that both Chinook fry and smolt estimates were derived (2001-2003 & 2009); the fry component is estimated on average to be 94% of the migrant population. This is similar to the proportion of total Chinook caught at the RSTs over-all years: 99% are Chinook fry.

In 2016, length frequency data for all Chinook juveniles captured at the RST was bi-modal with the first mode generally falling between the 35 to 45 mm range representing 0+ fry. The second smaller mode fell between 55 and 95 mm which represent a mixture of large 90 day fry and 1+ smolts.

Mean length for Chinook fry (< 80 mm) captured at the RSTs between February 15th and May 2nd, 2016 was 42 mm and ranged from 32-72 mm (Table 3). A third (34%) of the fry sampled were between 35 and 44 mm and nearly half (49%) were between 55 and 79 mm range. In all other years analyzed (2002-2015) an average of 73% of Chinook fry fell into the 35-44 mm range (Figure 8).

No statistically significant difference was observed in Chinook fry length amongst the sixteen sample years (2001 to 2016) (ANOVA: $F_{(1,14)}= 2.517$ $P= 0.135$). The largest Chinook were observed in 2006 (46 mm) and the smallest in 2011 (38 mm). Mean length of Chinook fry for both IFA and WUP years was 42 mm. No significant difference between the mean lengths of Chinook fry was observed between IFA and WUP years (F-test: $F_{(5,9)} = 0.225$, $P= 0.115$; T-test unequal variance: $t_{(13.6)}= 0.078$, $P= 0.940$). Condition factor was not examined for Chinook fry as these fish are resident in the river for a short period of time with limited opportunity for feeding.

The mean length, weight and condition factor (K) of Chinook smolts measured at the RST in 2016 were 86.7 mm, 7.5 g, and 1.1, respectively. The mean size of Chinook smolts in both 2015 and 2016 fell below the range of all previous years sampled. From 2002 to 2014[1] the mean length, weight and condition factor (K) of Chinook smolts ranged from 101-117 mm, 10.6-15.1 g and 1.0-1.1, respectively.

No statistically significant difference in mean length of Chinook smolts was found amongst sample years 2002, 2003 and 2007 through 2016 (ANOVA: $F_{(1,13)}= 2.345$, $P= 0.150$). An insufficient number of fish were sampled from 2004 to 2006 and in 2001 data contained an unknown number of hatchery fish which leaves only 2 years of IFA affected years to compare to 7 WUP affected years; therefore, no comparison was done. Fish were largest in 2003 (111 mm) and smallest in 2015 (84mm) (Table 3).

[1] The data from 2005 and 2006 were excluded in the analysis of Chinook smolt length frequency because only 1 Chinook smolt was captured in both of these years. The 2001 data was also excluded as hatchery fish were included in the sample.

3.2 Juvenile Pink Salmon

3.2.1 Pink fry Migration and Production

In 2016, a total of 5,491,140 (SD 260,514) Pink fry were estimated to have past the RSTs over the period February 16th to April 18th, 2016 (Figure 9). The migration started prior to the beginning of the mark recapture program as 95,307 fry (SD 69,656) were estimated in the first strata (February 16th to 22nd). The migration was not complete when trapping for fry was cut short due to prolonged high water on April 12th. In the last strata ending April 18th, 2.3 million fry (or 43% of the total migration) were estimated to pass the RST.

In 2016 the migration curve was incomplete and appeared to be approaching the peak of the migration when trapping stopped. The peak of migration for Pink fry from 2002-2012, occurred between March 25th and April 15th (weekly strata 6-9) when on average 86% of the migration has taken place in these 3 strata (Figure 9). Although it is not possible to say for sure, it appears the 2016 migration of Pink fry would have followed this pattern. In strata 6-9 (March 22nd to April 18th) in spring 2016, 74% of the total estimated migration occurred, and the run appeared to be moving towards a defined peak in the week ending April 18th (Figure 9).

There have been three IFA and five WUP estimates of Pink fry abundance over the study period 2002 to 2016. Average fry abundance over the years studied (2001-2016) was 8,808,936 (SD 11,700,397). Average abundances for IFA and WUP years were 686,706 (SD 861,934) and 13,682,275 (SD 12,650,594), respectively. Pink fry abundance has increase by 1892% from IFA to WUP affected years (Figure 10).

Estimates of Pink fry production have been derived in all on-years since 2008 from Site F1 at the Cheakamus Center channels. Estimates have ranged from 627,542 in 2010 to 3,677,691 in 2014 (Table 2). The 2016 estimate of 1,038,733 fry ranks 4th highest out of the seven years of data, and is less than half the estimate for 2014. Pink fry abundance leaving the Cheakamus Center channels was the highest contribution (19%) out of the 4 years data has been collected from these channels (Table 2).

3.2.2 Pink Fry Length Data

Mean length for Pink fry sampled at the RSTs in even years from 2002 to 2016 ranged from 27-44 mm, and the average length has been 34 mm in all years except 2010, 2014 and 2016 when it was 33 mm (Table 3, Figure 11). Weight data for fry was not analyzed as it is difficult to get accurate weights of fish this size in the field. No bio-sampling was undertaken at either the F1 or at the Cheakamus Center side channel traps.

A statistically significant difference in mean length of Pink fry was not observed among the eight years of data (ANOVA: $F_{(1,6)}$=3.176, P=0.125).

3.3 Juvenile Coho Salmon

3.3.1 Coho Smolt Migration and Production

The migration timing of Coho smolts, based on estimated weekly abundance at the Cheakamus RST site, indicates that in most years sampling is capturing the majority of the run (i.e. migration does not begin until after trap operations commence and the majority of fish have migrated before trap operations are suspended in June). From 2001 to 2016 (with the exception of 2014), Coho smolt migration consistently commenced in early April with an average 15% of the run migrating by April 15th. The peak of migration has generally occurred between May 1st and May 25th (weekly strata 11-14) with an average 55% of the annual abundance migrating by this date. An average of 90% of the abundance has migrated by May 31st over the 15 years of study (Figure 12). Migration timing in 2014 varied from all other years of study with an early abundance of Coho smolts in February and no clear peak in May (Figure 12).

In 2016, Coho smolt migration appeared to have just commenced when trapping began on February 15th (Figure 12). In the first week of trapping an estimated 0.66% (436 smolts) of the total population migrated past the RST (Figure 12). The migration reached the 50% point by April 24th and peaked in the week of March 29th to April 3rd (strata 8) when 15% of the migration occurred (Figure 12). By May 31st, 97% of the fish had migrated (Figure 12). In 2016, peak Coho smolt migration occurred when the average daily water temperature reached 7^{o}C (Figure 12).

Estimates of Coho smolt abundance in the Cheakamus River at the RST site have been generated every year of the study (2001-2016). In 2016, the estimated emigration of Coho smolts was 69,120 (SD = 8,539). Estimated annual abundance of Coho smolts from the mainstem has varied from a low of 28,712 smolts in 2015 to a high of 119,815 smolts in 2014 (Table 2, Figure 13). However, the 2006 estimated abundance of 35,444 smolts was affected by fish mortality caused by the chemical spill event in the summer of 2005 (McCubbing et al. 2006).

There have been six IFA and nine WUP estimates of Coho smolt abundance. The 2007 estimate was excluded from analysis of changes in abundance (IFA vs. WUP) because these Coho smolts were partially affected by both flow regimes. The average migration of Coho smolts was 76,958 in IFA affected years (SD = 29,183) and 74,941 (SD = 27,346) smolts in WUP years. An average change in abundance of -2,017 smolts or a 3% decrease in Coho smolt abundance has been observed since the implementation of the WUP. The average estimated abundance for all years (2001 to 2016) was 77,128 (SD = 26,012) (Table 2, Figure 13). The 2016 estimate of 69,120 Coho smolts ranks 10th out of all years assessed (Table 2, Figure 13).

Full trap counts of Coho smolt abundance from the Cheakamus Centre side channels and BC Rail side channel (Site 1 and 4) were produced in 2001 and from 2009 to 2016. In 2016, 4,516 Coho smolts were counted out of these channels; however, due to high water multiple days of counts were missed out of the Cheakamus Centre side channel. Due to missed days of counts where water levels exceeded fence height, the 2016 estimated side channel abundance of Coho is the lowest among all years at 6.5% of the total migration.

An average abundance of 14,889 Coho smolts (SD = 8,322) in the side channels, ranging from 4,516 in 2016 to 24,137 in 2010, has been observed in the years of evaluation. In the nine years that both mainstem and side channel abundance have been estimated the contribution from the side channels has averaged 20% of the estimated migrating Coho smolt population. The largest contribution to the estimated population occurred in 2001 when 36% of the fish originated from the Cheakamus Center and BC Rail side channels. Since 2009, the contribution of these two channels appears to be slightly less, ranging from 11% to 24% of the estimated upper river population of Coho smolts (Table 2).

3.3.2 Coho Smolt Length and Age Data

Length frequency for all Coho smolts ($\geq$ 70 mm) captured and sampled at the RST and side channel sites is uni-modal in all years (2001-2016). The majority of migrating Coho smolts are likely 1+ but a small percentage of larger fish may be 2+ (Figure 14). Coho scales have not been aged, but have been taken and archived.

Mean length, weight and condition factor (K) for Coho smolts in 2016 was 94 mm, 9.1 g and 1.1, respectively. These values fall within the range of all previous years (2001-2016) when mean length, weight and condition factor (K) ranged from 86-95 mm, 7.1-10.7 g and 1.0-1.2, respectively (Table 3). Coho smolt length frequency, in 2016, peaked between the 80 and 104 mm range, with the majority (83%) of the fish sampled falling within this range. The peak of Coho length frequency in 2016 was similar to all other years assessed. From 2001 to 2015, on average 65% of Coho smolts were between 80 and 99 mm in length and in 2016, 67% of fish sampled fell in the same range. Between IFA and WUP years, there does not appear to be any detectable shift in the length of Coho smolts: 67% of smolts fell within the 80-99 mm size range during the IFA compared to 65% during the WUP.

No statistically significant difference was observed in mean length of Coho smolts between the sixteen sample years, 2001 to 2016, (ANOVA: $F_{(1,13)}$=0.032, p= 0.860). The largest smolts were observed in 2005 and 2010 (95 mm) and the smallest smolts were observed in 2012 (85 mm). No significant difference were observed between the variance in lengths (F test: $F_{(5,7)}$=0.517, p= 0.486) or between mean lengths of Coho smolts (T-test equal variance: $t_{(12.0)}$= 1.124, p=0.283) under the two flow regimes (IFA and WUP).

3.4 Juvenile Steelhead Trout

3.4.1 Steelhead Smolt Migration and Production

Estimates of Steelhead smolt (aged 2 to 4 years) population abundance have been calculated in eleven of the sixteen study years; 2001-2003 and 2008-2016. In 2004 through 2007 insufficient Steelhead smolts were captured (<25) to mark (Table 2).

The migration timing of Steelhead smolts, based on estimated weekly abundance at the RST site, indicates that in most years sampling is capturing the majority of the run (i.e., the run does not begin until after trap operations commence and approaches zero as the study period ends). In 9 of the 11 years assessed a downward trend in abundance is observed before trap operations were suspended in June; however, in two years (2003 and 2009) had an upward trend in strata estimates at the end of the sampling period. The increase at the end of 2003 and 2009 was caused by slight upwards trends in catches compared to the previous strata as well as missed days of trapping due to high flows. The BTSPAS model has difficulty dealing with this type of data, so anomalies the final strata estimates such as those observed in 2003 and 2009 have the potential to bias the estimate high[2].

In the 9 years of this study where a migration curve was evident (2001-2002, 2008 and 2010-2016) Steelhead smolt migration has generally started in the week of April 15th to 22nd (weekly strata 10). On average, 7% of the run has migrated by the third week of April. The peak of migration generally occurred between May 5th and May 20th (weekly strata 12-14), when on average 53% of the estimated population migrates downstream. On average, 90% of the run has migrated by May 31st (Figure 15).

In 2016, the peak of migration occurred earlier from previous years with the peak occurring in the 3-week period extending from April 17th to May 8th. Similar to most previous years, the Steelhead migration was minimal at the commencement of trapping with 0.8% of the total population passing the trap in the first week. In 2016, the bulk of the migration commenced in April, with the migration reaching 20% of the total Steelhead abundance by April 17th. Over the three-week peak, 54% of the estimated migration occurred. The migration reached 98% of Steelhead abundance by May 29th (Figure 15). In 2016, peak weekly Steelhead smolt abundance occurred when the mean daily water reached 8^0 C (Figure 15).

Abundance estimates of Steelhead smolts for the mainstem Cheakamus River have been calculated in 11 years of the study. Two estimates were excluded due to effects from the flood and chemical spill (2003 and 2005, respectively), and no estimates of production were derived from 2004 to 2007 due to insufficient numbers. Steelhead smolt abundance estimates have ranged from a low of 2,208 in 2012 to a high of 14,223 in 2008 (including adjusted BTSPAS estimates from 2003 and 2009) (Table 2, Figure 16).

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[2] Bonner and Schwarz 2011 - The spline-based methods can deal with these strata in which no marks are released or recapture strata where no sampling takes place. The underlying spline is used to interpolate the run for the latter, while the hierarchical model pools information from neighboring strata for the former, but the uncertainty of the extrapolation increases rapidly the further out the extrapolation is taken. These types of extrapolations will be most successful on the increasing or decreasing limb of the run curve. They are unlikely to be successful if the survey starts collecting data in the middle of the run and the shape of the curve is not determined. Some care needs to be taken with extrapolations that extend more than 1 or 2 strata prior to or after the study window. Because the extrapolations have such a wide uncertainty (SD), it is possible that the estimated stratum abundance can be (unrealistically) too large and so greatly inflates the average of the posterior distribution leading to nonsensical results from the extrapolation. In these cases, the median of the posterior is likely a more sensible estimate than the mean (Schwarz 2012).

The average population estimates of all the years assessed (2001-2002, 2008-2016) was 6,539 (SD= 3,822).

There have been two IFA and eight WUP estimates of steelhead smolt abundance. The 2008 estimate is also excluded from analysis of changes in abundance (IFA vs. WUP) due to being partially affected by both flow regimes. Average IFA and WUP abundance was 7,311 (SD 1,710) and 6,377 (SD 3,640) smolts, respectively. This equates to a 16% decrease in Steelhead smolt abundance from IFA to WUP flow condition. The 2016 estimate of 4,918 (SD = 760) Steelhead smolts ranks 4th lowest out of the years assessed (2001-2002, 2009-2016) (Table 2, Figure 16).

Full trap counts of Steelhead smolt abundance from the Cheakamus Center side channels and BC Rail side channel (Site 1 & 4) were completed in 2001 and 2009 through to 2016. Counts of Steelhead in the side channel traps ranged over from 35 to 403 with an average of 144 over the years assessed. In 2016, 55 Steelhead smolts (1% of the total yield upstream of the RSTs) were captured at these two channels. The 2016 estimate ranked 7th amongst the 8 years evaluated. In the eight years that both mainstem and side channel abundance were evaluated, an average of 3% (range 1-6%) of the total yield of Steelhead smolts upstream of the RSTs came from the side channel habitats (Table 2).

3.4.2 Steelhead Parr

The Steelhead parr (1+) population has not been estimated as it is assumed that these fish are not actively migrating from freshwater and are likely just moving around in the system. Catches of Steelhead parr in the RSTs has ranged from 6 in 2006 to 3,585 in 2014. In the Cheakamus Center side channel trap, the number Steelhead parr captured has ranged from a low of 113 in 2008 to a high of 2,223 in 2014. In 2016, there were 848 Steehead parr captured at the RSTs and 556 in the Cheakamus Center side channels.

3.4.3 Steelhead Length and Age Data

Mean length, weight and condition factor (K) for Steelhead smolts in 2016 were 161 mm, 43.2 g and 1.0, respectively. The size and condition of Steelhead smolts in 2016 was slightly outside the range observed in all previous years sampled (2001-2015) when mean length, weight and condition factor (K) ranged from 162-178 mm, 50.2-69.0 g and 1.0-1.1, respectively (Table 3). In 2016, the length frequency for all Steelhead juveniles captured at the RSTs and side channels was bi-modal with the first mode falling between the 85 and 125 mm range (age-1 parr) representing 57% of the fish sampled and a smaller mode ranging from 140 to 165 mm (age 2 through 4 year old smolts) representing 20% of the fish sampled (Figure 17).

No statistically significant difference in mean length of Steelhead smolts was observed amongst the sixteen sample years (from 2001 to 2016) (ANOVA: $F_{(1,14)}=2.934$, $p=0.109$). The largest Steelhead smolts were observed in 2002 (176 mm) and 2014 (177 mm) and the smallest Steelhead smolts were observed in 2015 (160 mm). To date, no significant difference between the mean length of Steelhead smolts has been observed between IFA and WUP affect years (F test: $F_{(5,7)}=0.7121$, $p=0.733$; T-test equal variance: $t_{(11.76)}=1.037$, $p=0.321$).

3.5 Biophysical Monitoring

Discharge in the Cheakamus River near Brackendale (measured at the WSC gauge 08GA043) (Figure 2) ranged from an average daily value of 15.7 to 143.1 m^3/s over the juvenile migration period, February 16th to June 16th, 2016 (Figure 18). Two high flow events occurred between the fall of 2015 and spring of 2016. On August 31st, 2015 the river reached 199 m^3/s and on January 29th, 2016 the river reached 309 m^3/s (Figure 18). The first of these events occurred in the spawning window for both Chinook and Pink salmon. The second event occurred at a time when juvenile salmon would have been ranging from incubating eggs to emerging fry, or overwintering yearlings in the case of Coho, Chinook and Steelhead.

Average daily water temperature at the RST data logger (Figure 2) during the juvenile migration period of February 16th to June 16th, 2015 ranged from 4.4 to 10.9 ^{0}C (Figure 19).

4.0 Discussion

One of the primary goals of this study is to evaluate changes to the productivity of salmonid juveniles in the Cheakamus River in response to the changes in the flow regime created by the Water Use Plan implemented in 2006. The fish habitat modeling work that was conducted prior to the implementation of the WUP predicted that there would be no net loss of habitat for juvenile salmonids as a result of these changes (Cheakamus Water Use Planning Fish Technical Committee 2001; Marmorek and Parnell 2002).

If there was no net loss in habitat, it was assumed that juvenile fish productivity would remain unaffected and that no change in fish production greater than a 25% (increase or decrease) would occur (Marmorek and Parnell 2002).

In September 2012, the Cheakamus Monitoring Committee was presented with a summary of data and analyses on juvenile salmonid population estimates from 2001 through to 2012 (Melville et al. 2012). The summary report examined the mean and variance of annual fish production for migratory salmonids and the power to detect a significant change based on these data. It was decided in September 2012 based on the analyses performed that the ability to detect changes in fish production in relation to the flow change (IFA vs. WUP) had generally not been achieved and additional data were required to evaluate a statistically significant variance between the two flow regimes. The Cheakamus Monitoring Committee's recommendation was that this study (Monitor #1a) should be continued for a further five years with annual reporting on fish production in 2017 when further statistical analysis will be undertaken to assess the effects of the flow change on productivity.

As of 2016, based on juvenile data collected from the RST site at RK 5.5, there is indication of small decreases in the mean out-migrant population size of Coho and Steelhead smolts since the implementation of the WUP in 2006. A 3% reduction in Coho smolts abundances and 16% reduction in Steelhead smolts abundances have been observed under the WUP flow regime. However, the observed changes in both these species are small compared to the inter-annual variation in abundance estimates and may change slightly with the final year of data collection. Further statistical analysis of the significance in abundance changes will be reserved for the draft final report due in early 2017. A more detailed analysis of the trends in Steelhead smolts abundances throughout the Cheakamus River have been conducted in Monitor #3 (Korman and Schick 2013-2015). No comparison of Chinook smolt (1+) abundance has been attempted due to the limited number of years when estimates were able to be derived.

Changes in the abundances of both Chinook and Pink fry have also been observed since the implementation of the WUP. The largest increase observed in juvenile salmonids has been observed in Pink fry. There has been a 1,892% increase in the mean abundance of Pink fry over the 8 years of data collection for this species. A small (7%) increase in the mean abundance of 0+ Chinook fry has also been observed since the implementation of the WUP. Variation in Chum fry abundance has also been observed since the implementation of the WUP. For details on the changes in Chum fry abundances refer to Fell et al. (2016). As of 2016, changes in abundance of both Coho and Steelhead smolts and Chinook fry are below the 25% threshold set by the CC, further statistical analyses on the variances between IFA and WUP flow regimes will be conducted for the final report.

The juvenile Chinook salmon populations in the Cheakamus have been dominated by 14-60 day migrants in all sixteen years of study. Yearling smolts make up less than 5% of the Chinook migrants annually. Thus, the population can be characterized as predominantly ocean-rearing. The 2016, abundance estimate for Chinook fry was the 3rd lowest on record. The 2016 Chinook fry estimate was, however, a 343% increase from 2015, the previously lowest year on record.

Migration timing of Chinook fry, in 2016, followed an anomalous pattern from most years of the study with few Chinook fry present from mid-February to mid-April. In the majority of other years (13 out of 15) there has been modest to large peaks in Chinook Fry abundance between mid-February and mid-March. The absence of Chinook fry in February and March in 2016 may be related the to over 300 m^3/s flow event in January 2016. It is likely many of the early emerging Chinook were washed out of the river during the extreme flows. There are many environmental factors with the potential to affect annual runtiming of juvenile Chinook in the Cheakamus River including: spawning timing and incubation temperatures, large flow events in the Cheakamus River (natural or regulated), and seasonal variances in air temperatures). Other factors such as spawner abundance (on which there is a shortage of accurate data) (Golder and Associates 2009), the impacts of the CN caustic soda spill fish mortality (McCubbing el at. 2006), changes in the hatchery program intensity and methods (DFO unpublished data), increases in Pink salmon abundance, and the effect of the 2003 flood are all also likely contributors to the high variances observed in Chinook abundance over the 16 years of this study, and will be explored further in the 2017 draft final report.

Over the sixteen years of this study (with the exception of 2014) Coho smolt migration has consistently followed the timing pattern observed at other study sites where full river fences or partial traps have been operated in British Columbia with peak smolt migration occurring in May (McCubbing and Johnston 2012; Ladell and McCubbing 2011). The typical migration timing for Coho in the Cheakamus River is characterized by low abundance in February and March, followed by an increase in abundance in early April, a peak in migration somewhere between mid-April to mid-May, followed by a decline in abundance that reaches near zero by mid- June. In 2016, the peak in abundance occurred in early April roughly two weeks earlier than is typical for this system.

Juvenile Coho Salmon typically rear in fresh water for one year prior to migrating to the ocean; however, some hold in fresh water for up to 2 years while other migrate as young of the year (0+) (Koski 2009). In fish that rear for 1-2 years in fresh water, migration timing is likely not driven by spawning and incubation timing but by other environmental factors (Spence and Dick 2013). Growth rate has been demonstrated to influence migration timing in juvenile salmonids (Okland et al. 1993; Beckman et al. 1998; Quinn 2005). Coho smolt migration timing has also been shown to vary based on stream flow characteristics with significant portions of populations choosing to migrate in fall/ winter (Nordholm 2014). Recent studies in several coastal Oregon and Washington watersheds have recorded large abundances of juvenile Coho migrating between October and January (Bennett et al. 2014; Jones et al. 2014; Nordholm 2014). Winter migrations of Coho juveniles are suspected to be in response to several factors including food availability and flow conditions (Nordholm 2014).

Although there was an increase in Coho abundance from 2015 to 2016, the 2016 estimate ranked 10th out of the sixteen years of this study. Overall there has been a 3% decrease in the abundance of Coho smolts between February 15th and June 15th between mean IFA and WUP abundances. As mentioned above changes in migration timing may occur in response to environmental factors (i.e. high flow events) and as such it is possible that the lower number of Coho present in 2015 and 2016 are, in part, related to the high (over 300 m3/s) flow events observed in these two winters. Because no information is collected on summer, fall and winter migrating Coho yearlings it is not possible to assess whether the decrease in abundance of Coho yearlings between the IFA and WUP flow regimes indicates a decrease in the productivity of the Cheakamus River Coho population or shifts in life history strategies (i.e. migration timing) in response to environmental conditions with the Cheakamus River.

Another goal of this study is to establish the relationship between mainstem and side channel abundance of Coho smolts on an annual basis to evaluate how discharge variance may affect the proportional productivity. Unfortunately, due to limitations placed on trapping in Tenderfoot Creek associated with large hatchery released into the lake, estimates from this side channel have had broad confidence limits on mark-recapture estimates surrounding the releases. Therefore, it has only been possible to evaluate abundance in the Cheakamus Center and BC Rail side channels. These channels are clearly important habitat for rearing juvenile Coho Salmon. The Cheakamus Center and BC Rail side channels contribute between 14 and 24% of the total yield above the RSTs annually. The estimate of 4,516 smolts for 2016 was on the lower end of the observed output from the Cheakamus Center and BC Rail channels, representing 6.5% of the total yield. The lower count of Coho out of the side channels and contribution to total abundance is likely due to missed days of fishing in the spring of 2016 and not a decrease in productivity in the side channels. A total of ten days of fishing were missed due to high water levels in April and June 2016 at Cheakamus Center. Overall, the proportion of fish leaving the side channels has remained relatively consistent since 2009 with 17-24% of the total estimate being derived from these two channels. There is one outlier in 2011 where only 14% (8,691) of the total estimate was contributed from side channels. Overall, the channels appear to have a maximum output of approximately 24,000 smolts with an average of 17,000 smolts.

Steelhead smolt migration has generally followed the similar timing to other study sites where full river fences or partial traps have been operated in British Columbia (McCubbing et al. 2012; McCubbing and Ramos-Espinoza 2011) with peak smolt migration occurring in May. In general, the entire sampling period has been captured throughout the study. The 2016 estimate was the fourth lowest estimate generated (the lowest being 2012) since the study commenced, but was nearly double the 2015 estimate. The number of Steelhead parr caught in both the RSTs and Cheakamus Center side channel trap increased by 188% and 230% from 2015 to 2016, respectively. Further discussion on Steelhead production numbers can be found in Korman et al. (2013- 2016).

5.0 Recommendations and Conclusions

The data collected from 2001 to 2016 indicate that ongoing juvenile production studies can potentially be used to establish the linkages between discharge and salmonid productivity on the Cheakamus River. Although the lack of comparative data from other treatments/controls reduce the ability to conclusively assess the potential positive or negative impacts of different discharge treatments on juvenile salmon populations.

The data presented in this report add to the time series which will be analyzed in the 2017 final report and attempt to answer the following management questions:

1. What is the relationship between discharge and juvenile salmonid production, productivity, and habitat capacity of the mainstem and major side-channels of the Cheakamus River?

2. Does juvenile salmonid production, productivity, or habitat capacity change following implementation of the WUP flow regime?

However, without some key pieces of data i.e. corroborative adult and hatchery production data in some species (i.e. Chinook and Pink salmon) even large variance in population levels (75% or greater) may not be functionally attributed to changes in treatment discharge. In Coho salmon, more rigorous analysis of the data in the final report should allow for assessment of the likelihood of statistically greater variance than 50% in smolt abundance which is less precise than the CC originally intended (25%).

The expanded life history studies which include assessment of adult abundance on Steelhead Trout and to a lesser extent on Chum Salmon may provide a more confident evaluation of the changes in watershed production and how these may relate to discharge, although parts of the management questions may remain un-answered due to the lack of other treatment data. In these cases the data collected in this study will perform a supporting role to potentially analyze the effects of flow on productivity in 2017.

The linkage between side channel and mainstem abundance of fry and smolts has been examined but presents several obstacles to complete analysis. For Coho smolts, the inability to derive a defensible estimate of abundance in Tenderfoot Creek and the addition of new channels upstream of the RST site confound the ability to clearly define mainstem versus side channel production. For Chum fry abundance, it was recently identified that an estimate from Tenderfoot Creek is required to better establish this linkage (McCubbing et al. 2012). This year was the third year of fry monitoring in Tenderfoot Creek and this work will be continued through 2017 and reported in CMSMON 1b

6.0 TABLES

Table 1. Summary of size ranges for age classes of salmonids on the Cheakamus River

Species	Age(s)	Code	Size Range	Reference
Coho Smolt	1+	COS	≥ 70mm	Cheakamus length frequency data (2000-2006)
Coho Fry	0+/YOY	COF	< 70mm	Cheakamus length frequency data (2000-2006)
Steelhead Smolt	2+ and 3+	SHS	≥ 140mm	Melville & McCubbing 2004, Korman & McCubbing 2007
Steelhead Parr	1+	SHP	< 140mm	Melville & McCubbing 2004, Korman & McCubbing 2007
Chinook Fry	0+ (YOY)	CHF	< 80mm	Cheakamus length frequency data (2000-2006)
Chinook Smolts	1+	CHS	≥ 80mm	Cheakamus length frequency data (2000-2006)

Table 2. Annual number of juvenile salmonids caught, marked and recaptured at the RSTs and side channel fyke nets (SC) on the Cheakamus River from 2001-2016 and Bayesian Time-Stratified Population Analysis System (BTSPAS) Estimates, standard deviation (SD) and relative standard deviation (Rel. SD).
Bold = post-WUP estimates. Relative SD > 0.3 = Poor precision.

Species	Year	Total Caught	Total Marked	Total Recap	BTSPAS Estimate	SD	Rel. SD
Chinook Fry	2001	8,578	3,109	207	241,913	39,688	0.18
Chinook Fry	2002	7,567	1,486	91	137,254	18,966	0.14
Chinook Fry	2003	5,859	2,376	77	400,964	98,652	0.25
Chinook Fry	2004	1,232	415	4	236,717	159170	0.67
Chinook Fry	2005	1,107	386	4	237,454	154,692	0.65
Chinook Fry	2006	499					
Chinook Fry	**2007**	**8,737**	**2,904**	**141**	**238,180**	**27,475**	**0.12**
Chinook Fry	**2008**	**5,127**	**2,036**	**45**	**564,313**	**132,302**	**0.23**
Chinook Fry	**2009**	**8,039**	**3,172**	**193**	**157,151**	**21,335**	**0.14**
Chinook Fry	**2010**	**3,649**	**1,082**	**73**	**60,040**	**7,799**	**0.13**
Chinook Fry	**2011**	**31,933**	**10,127**	**435**	**874,946**	**46,220**	**0.05**
Chinook Fry	**2012**	**8,787**	**4,127**	**189**	**323,375**	**32,315**	**0.10**
Chinook Fry	**2013**	**22,248**	**11,556**	**943**	**340,834**	**14,405**	**0.04**
Chinook Fry	**2014**	**3,154**	**990**	**107**	**39,001**	**9,413**	**0.24**
Chinook Fry	**2015**	**1,111**	**519**	**49**	**16,484**	**3,100**	**0.18**
Chinook Fry	**2016**	**1,922**	**881**	**49**	**56,470**	**8,474**	**0.15**
Chinook Smolt	2001	404	304	31	8,439	5,120	0.61
Chinook Smolt	2002	94	61	2	13,439	16,034	1.19
Chinook Smolt	2003	94	55	3	6,020	5,213	0.87
Chinook Smolt	2004	4					
Chinook Smolt	2005	2					

Chinook Smolt	2006	1					
Chinook Smolt	2007	47					
Chinook Smolt	**2008**	**52**					
Chinook Smolt	**2009**	**417**	**128**	**11**	**14,439**	**10,165**	**0.28**
Chinook Smolt	**2010**	**83**					
Chinook Smolt	**2011**	**56**					
Chinook Smolt	**2012**	**50**					
Chinook Smolt	**2013**	**49**					
Chinook Smolt	**2014**	**30**					
Chinook Smolt	**2015**	**77**					
Chinook Smolt	**2016**	**79**					

Table 2. continued

Species	Year	Total Caught	Total Marked	Total Recap	BTSPAS Estimate	SD.	Rel. SD
RST Pink Fry	2001[1]						
RST Pink Fry	2002	27,038	5,301	113	1,673,795	286,619	0.17
RST Pink Fry	2003[1]						
RST Pink Fry	2004	2,742	1,415	53	82,834	13,474	0.16
RST Pink Fry	2005[1]						
RST Pink Fry	2006	41,336	10,870	1,567	303,488	9,817	0.03
RST Pink Fry	2007[1]						
RST Pink Fry	**2008**	**41,873**	**19,291**	**848**	**2,060,948**	**89,979**	**0.04**
RST Pink Fry	**2009[1]**						
RST Pink Fry	**2010**	**238,730**	**57,124**	**3,942**	**6,157,377**	**606,896**	**0.1**
RST Pink Fry	**2011[1]**						
RST Pink Fry	**2012**	**1,447,749**	**91,694**	**6,964**	**29,314,436**	**630,824**	**0.02**
RST Pink Fry	**2013[1]**						
RST Pink Fry	**2014**	**1,900,820**	**115,073**	**10,923**	**25,387,473**	**314,061**	**0.01**
RST Pink Fry	**2015[1]**						
RST Pink Fry	**2016**	**258,353**	**71,937**	**6,112**	**5,491,140**	**260,514**	**0.05**
SC Pink Fry	**2008**	**36,066**	**26,084**	**867**	**1,172,050**	**43,524**	**0.04**
SC Pink Fry	**2009[1]**						
SC Pink Fry	**2010**	**35,946**	**31,330**	**2,197**	**627,542**	**16,615**	**0.03**
SC Pink Fry	**2011[1]**						
SC Pink Fry	**2012**	**246,536**	**84,937**	**7,892**	**3,127,546**	**41,406**	**0.01**
SC Pink Fry	**2013[1]**						
SC Pink Fry	**2014**	**258,658**	**39,469**	**3,057**	**3,677,691**	**74,065**	**0.02**
SC Pink Fry	**2015[1]**						
SC Pink Fry	**2016**	**36,422**	**9,820**	**448**	**1,038,732**	**66,746**	**0.06**

1. “off” brood years for Pink salmon on the Cheakamus River.

Table 2. continued

Species	**Year**	**Total Caught**	**Total Marked**	**Total Recap**	**BTSPAS Estimate**	**SD.**	**Rel. SD**
RST Steelhead Smolt	2001	231	162	14	6,101	8,726	1.40
RST Steelhead Smolt	2002	116	76	2	8,520	7,152	0.84
RST Steelhead Smolt	2003	379	286	11	8,516 (63,591)	63,833	1.00
RST Steelhead Smolt	2004	9					
RST Steelhead Smolt	2005	21					
RST Steelhead Smolt	2006	5					
RST Steelhead Smolt	2007	20					
RST Steelhead Smolt	2008	379	208	11	14,223	7,781	0.55
RST Steelhead Smolt	**2009**	**647**	**491**	**60**	**7,197 (11,088)**	**3,505**	**0.32**
RST Steelhead Smolt	**2010**	**366**	**437**	**35**	**4,974**	**973**	**0.20**
RST Steelhead Smolt	**2011**	**417**	**442**	**47**	**5,518**	**2,545**	**0.46**
RST Steelhead Smolt	**2012**	**251**	**178**	**23**	**2,208**	**507**	**0.23**
RST Steelhead Smolt	**2013**	**597**	**524**	**94**	**4,455**	**910**	**0.20**
RST Steelhead Smolt	**2014**	**811**	**590**	**53**	**10,107**	**1789**	**0.17**
RST Steelhead Smolt	**2015**	**279**	**279**	**34**	**2,745**	**435**	**0.15**
RST Steelhead Smolt	**2016**	**359**	**394**	**42**	**4,918**	**760**	**0.15**
SC Steelhead Smolt	**2001**	**151**					
SC Steelhead Smolt	**2009**	**403**					
SC Steelhead Smolt	**2010**	**217**					
SC Steelhead Smolt	**2011**	**153**					
SC Steelhead Smolt	**2012**	**35**					
SC Steelhead Smolt	**2013**	**132**					
SC Steelhead Smolt	**2014**	**93**					
SC Steelhead Smolt	**2015**	**62**					
SC Steelhead Smolt	**2016**	**55**					

Table 2. continued

Species	Year	Total Caught	Total Marked	Total Recap	BTSPAS Estimate	SD	Rel. SD
RST Steelhead Parr	2001	238					
RST Steelhead Parr	2002	143					
RST Steelhead Parr	2003	256					
RST Steelhead Parr	2004	36					
RST Steelhead Parr	2005	42					
RST Steelhead Parr	2006	6					
RST Steelhead Parr	**2007**	**621**					
RST Steelhead Parr	**2008**	**171**					
RST Steelhead Parr	**2009**	**314**					
RST Steelhead Parr	**2010**	**620**					
RST Steelhead Parr	**2011**	**202**					
RST Steelhead Parr	**2012**	**832**					
RST Steelhead Parr	**2013**	**1012**					
RST Steelhead Parr	**2014**	**3,585**					
RST Steelhead Parr	**2015**	**434**					
RST Steelhead Parr	**2016**	**848**					
SC Steelhead Parr	**2008**	**113**					
SC Steelhead Parr	**2009**	**216**					
SC Steelhead Parr	**2010**	**380**					
SC Steelhead Parr	**2011**	**488**					
SC Steelhead Parr	**2012**	**1635**					
SC Steelhead Parr	**2013**	**681**					
SC Steelhead Parr	**2014**	**2,223**					
SC Steelhead Parr	**2015**	**243**					
SC Steelhead Parr	**2016**	**556**					

Table 2. continued

Species	Year	Total Caught	Total Marked	Total Recap	BTSPAS Estimate	SD	Rel. SD
RST Coho Smolt	2001	3,696	30,613	2,731	74,537	12,713	0.29
RST Coho Smolt	2002	2,549	17,879	810	100,653	26,972	0.27
RST Coho Smolt	2003	5,823	25,601	1,818	118,161	9,833	0.11
RST Coho Smolt	2004	1,048	8,727	191	71,481	15,437	0.25
RST Coho Smolt	2005	1,609	3,355	139	61,472	8,316	0.14
RST Coho Smolt	2006	1,165	4,578	174	35,444	3,744	0.12
RST Coho Smolt	2007	7,237	7,422	675	97,832	5,882	0.07
RST Coho Smolt	**2008**	**3,036**	**5,972**	**196**	**81,624**	**11,367**	**0.15**
RST Coho Smolt	**2009**	**6,614**	**8,764**	**1,035**	**60,686**	**8,239**	**0.13**
RST Coho Smolt	**2010**	**10,681**	**14,857**	**2,030**	**101,271**	**3,687**	**0.04**
RST Coho Smolt	**2011**	**5,238**	**5,720**	**499**	**62,593**	**4,359**	**0.09**
RST Coho Smolt	**2012**	**6,194**	**6,870**	**918**	**66,944**	**5,599**	**0.08**
RST Coho Smolt	**2013**	**7,244**	**11,184**	**2,109**	**83,707**	**3,322**	**0.04**
RST Coho Smolt	**2014**	**15,060**	**1,644**	**11,564**	**119,815**	**15,425**	**0.13**
RST Coho Smolt	**2015**	**3,999**	**2,748**	**460**	**28,712**	**1,541**	**0.05**
RST Coho Smolt	**2016**	**6,250**	**2,936**	**494**	**69,120**	**8,539**	**0.12**
SC Coho Smolt	2001	26,828					
SC Coho Smolt	**2009**	**13,437**					
SC Coho Smolt	**2010**	**24,408**					
SC Coho Smolt	**2011**	**8,691**					
SC Coho Smolt	**2012**	**12,799**					
SC Coho Smolt	**2013**	**15,420**					
SC Coho Smolt	**2014**	**23,072**					
SC Coho Smolt	**2015**	**4,827**					
SC Coho Smolt	**2016**	**3,583**					

Table 3. Summary of mean annual lengths (mm), weight (g) and condition factor (K) of juvenile salmonids in the Cheakamus River from 2001-2016

Species	Year	N	Mean Length	Range
Chinook Fry (early)	2001	263	41	32-79
	2002	346	39	30-57
	2003	93	43	33-66
	2004	23	39	35-53
	2005	22	44	39-59
	2006	16	46	37-72
	2007	**354**	**39**	**32-77**
	2008	**354**	**39**	**31-77**
	2009	**358**	**39**	**32-79**
	2010	**372**	**40**	**32-77**
	2011	**451**	**38**	**33-76**
	2012	**383**	**38**	**31-47**
	2013	**442**	**39**	**27-62**
	2014	**237**	**40**	**33-79**
	2015	**356**	**42**	**31-77**
	2016	**253**	**41**	**32-79**

Species	Year	N	Mean Length	Range
Pink Fry	2001[1]			
	2002	358	34	27-45
	2003[1]			
	2004	53	34	30-37
	2005[1]			
	2006	161	34	29-39
	2007[1]			
	2008	**455**	**34**	**29-44**
	2009[1]			
	2010	**427**	**33**	**29-37**
	2011[1]			
	2012	**393**	**34**	**30-38**
	2013[1]			
	2014	**405**	**33**	**29-39**
	2015[1]			
	2016	**274**	**33**	**29-39**

1. "off" brood years for Pink salmon on the Cheakamus River.

Table 3. continued

Species	Year	N	Mean Length	Mean Weight	Mean K
	2001[1]				
	2002	24	109	14.9	1.1
	2003	13	111	12.0	1.1
	2004	0			
	2005	1	103		
	2006	1	80	5.4	1.1
	2007	30	109	15.1	1.1
Chinook	**2008**	**35**	**103**	**12.2**	**1.1**
Smolts	**2009**	**210**	**101**	**10.6**	**1.1**
	2010	**60**	**106**	**12.5**	**1.0**
	2011	**56**	**107**	**13.5**	**1.1**
	2012	**36**	**103**	**12.7**	**1.1**
	2013	**41**	**102**	**12.0**	**1.1**
	2014	**20**	**106**	**20.9**	**1.2**
	2015	**77**	**84**	**6.8**	**1.1**
	2016	**79**	**87**	**7.5**	**1.1**

1. Sample not included due to hatchery Chinook smolts being sampled and not differentiated from wild.

Species	**Year**	**N**	**Mean Length**	**Mean Weight**	**Mean K**
	2001	179	175	69.0	1.0
	2002	136	176	56.3	1.0
	2003	193	174	59.0	1.0
	2004	27	162		
	2005	60	176	66.2	1.1
	2006	23	177	58.9	1.0
	2007	50	172	54.4	1.0
Steelhead	2008	192	170	52.1	1.0
Smolts	**2009**	**217**	**171**	**50.2**	**1.0**
	2010	**87**	**176**	**52.9**	**1.0**
	2011	**142**	**172**	**54.2**	**1.0**
	2012	**89**	**175**	**57.5**	**1.0**
	2013	**137**	**167**	**50.9**	**1.1**
	2014	**123**	**178**	**61.6**	**1.0**
	2015	**228**	**160**	**43.2**	**1.0**
	2016	**279**	**161**	**42.3**	**0.97**

Table 3. continued

Species	Year	N	Mean Length	Mean Weight	Mean K
Steelhead Parr	2001	215	85	6.2	1.1
	2002	308	94	9.2	1.2
	2003	558	92	8.7	1.5
	2004	614	100	n/a	n/a
	2005	117	99	19.9	1.3
	2006	24	119	19.8	1.2
	2007	**939**	**97**	**11.2**	**1.1**
	2008	**274**	**89**	**8.7**	**1.1**
	2009	**174**	**86**	**9.2**	**1.1**
	2010	**306**	**106**	**14.4**	**1.1**
	2011	**178**	**90**	**9.6**	**1.1**
	2012	**433**	**82**	**7.2**	**1.2**
	2013	**491**	**96**	**11.6**	**1.2**
	2014	**1106**	**96**	**10.8**	**1.1**
	2015	**321**	**94**	**11.4**	**1.1**
	2016	**711**	**102**	**12.3**	**1.1**

Species	Year	N	Mean Length	Mean Weight	Mean K
	2001	2280	89	8.0	1.1
	2002	2151	91	9.3	1.2
	2003	2667	91	9.0	1.1
	2004	1606	93	n/a	n/a
	2005	1648	95	9.5	1.1
	2006	1333	94	10.0	1.2
	2007	1689	91	8.5	1.1
Coho	**2008**	**845**	**90**	**8.4**	**1.1**
Smolts	**2009**	**1566**	**89**	**7.5**	**1.0**
	2010	**2521**	**95**	**9.3**	**1.0**
	2011	**2215**	**88**	**7.7**	**1.1**
	2012	**2335**	**86**	**7.1**	**1.1**
	2013	**2734**	**87**	**7.8**	**1.2**
	2014	**3671**	**94**	**9.6**	**1.1**
	2015	**3054**	**93**	**9.2**	**1.1**
	2016	**2056**	**94**	**9.1**	**1.1**

7.0 FIGURES

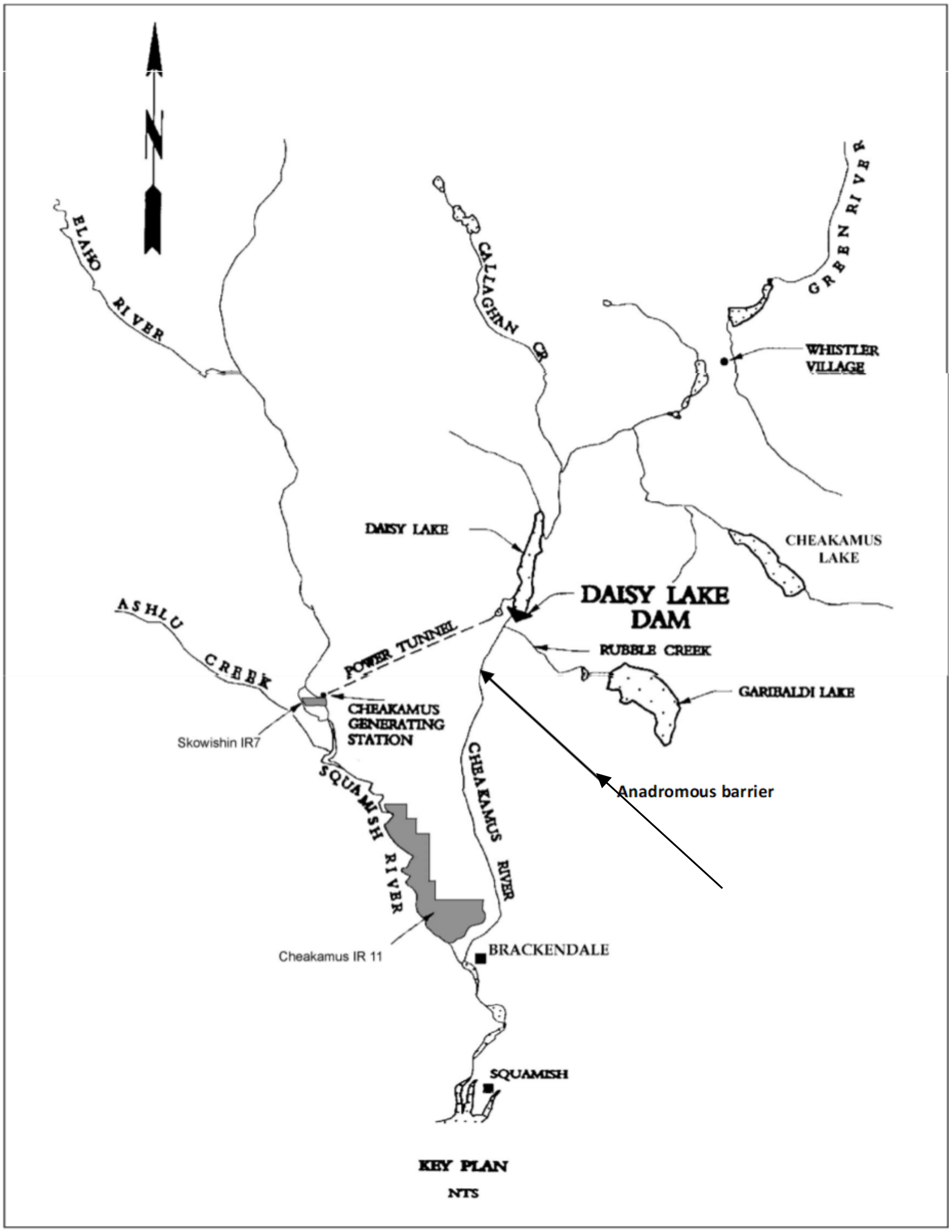

Figure 1. Map of the Cheakamus River Watershed indicating the location of Daisy Lake Dam and the diversion tunnel

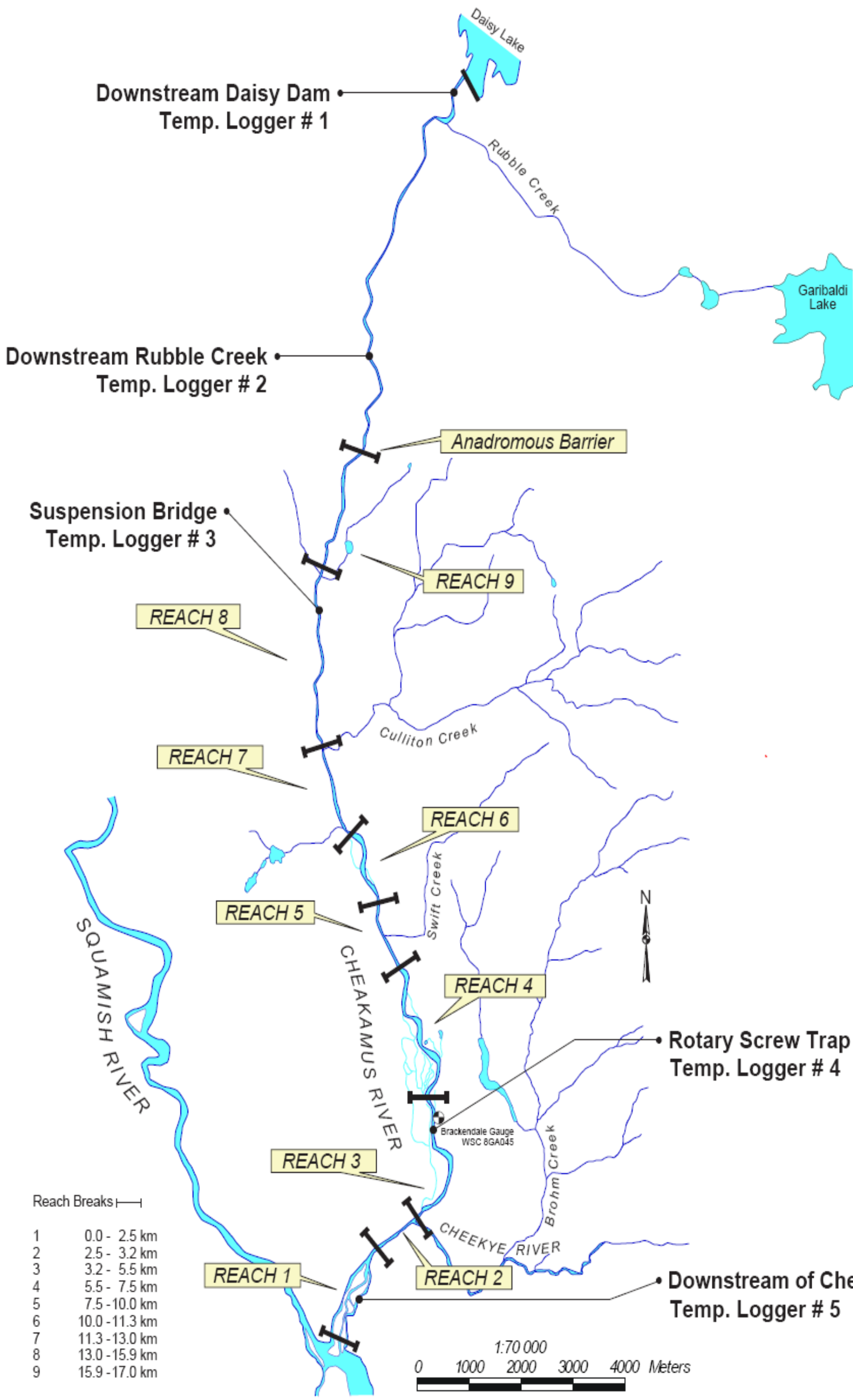

Figure 2. Cheakamus River watershed indicating Reaches 1 through 9, WSC Brackendale Gauge (08GA043), temperature loggers and RST trap location

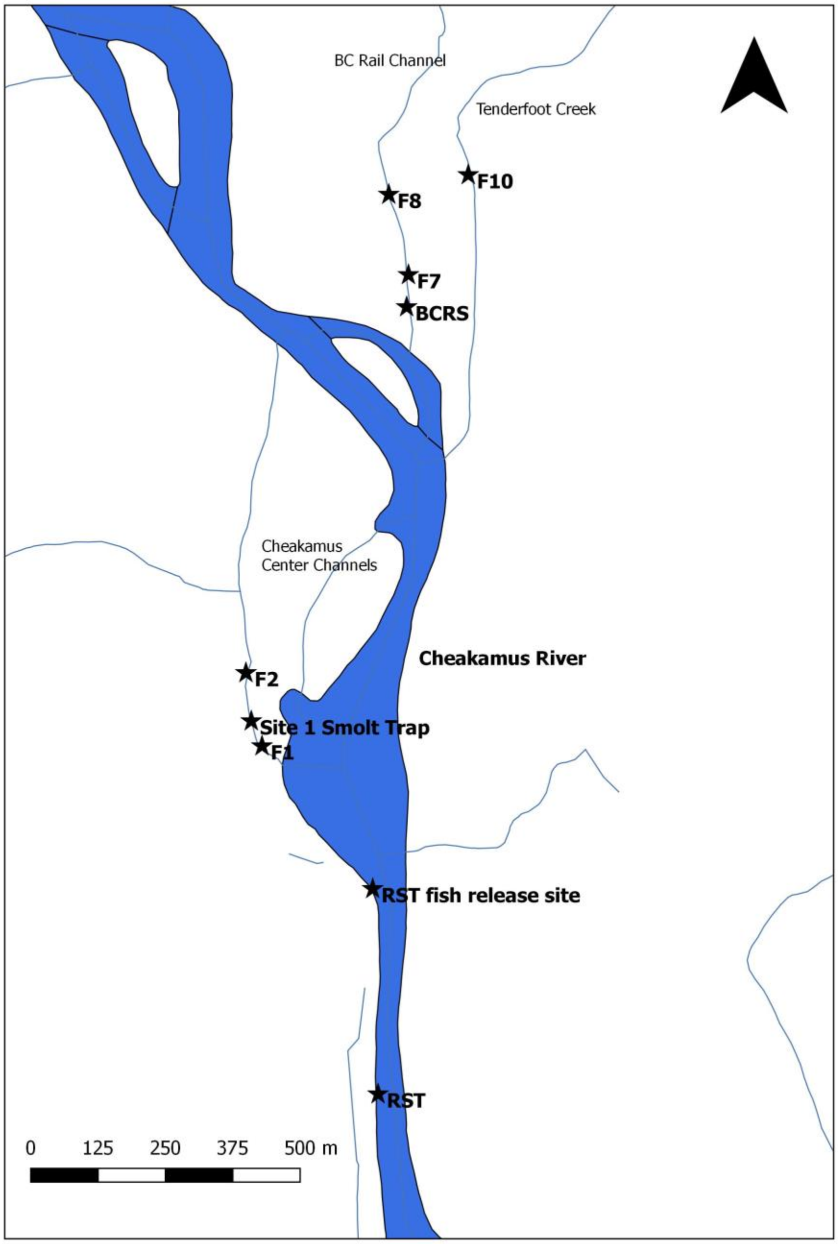

Figure 3.Site map indicating fyke and RST trap locations utilized for the Cheakamus River Juvenile Migration Monitor #1a

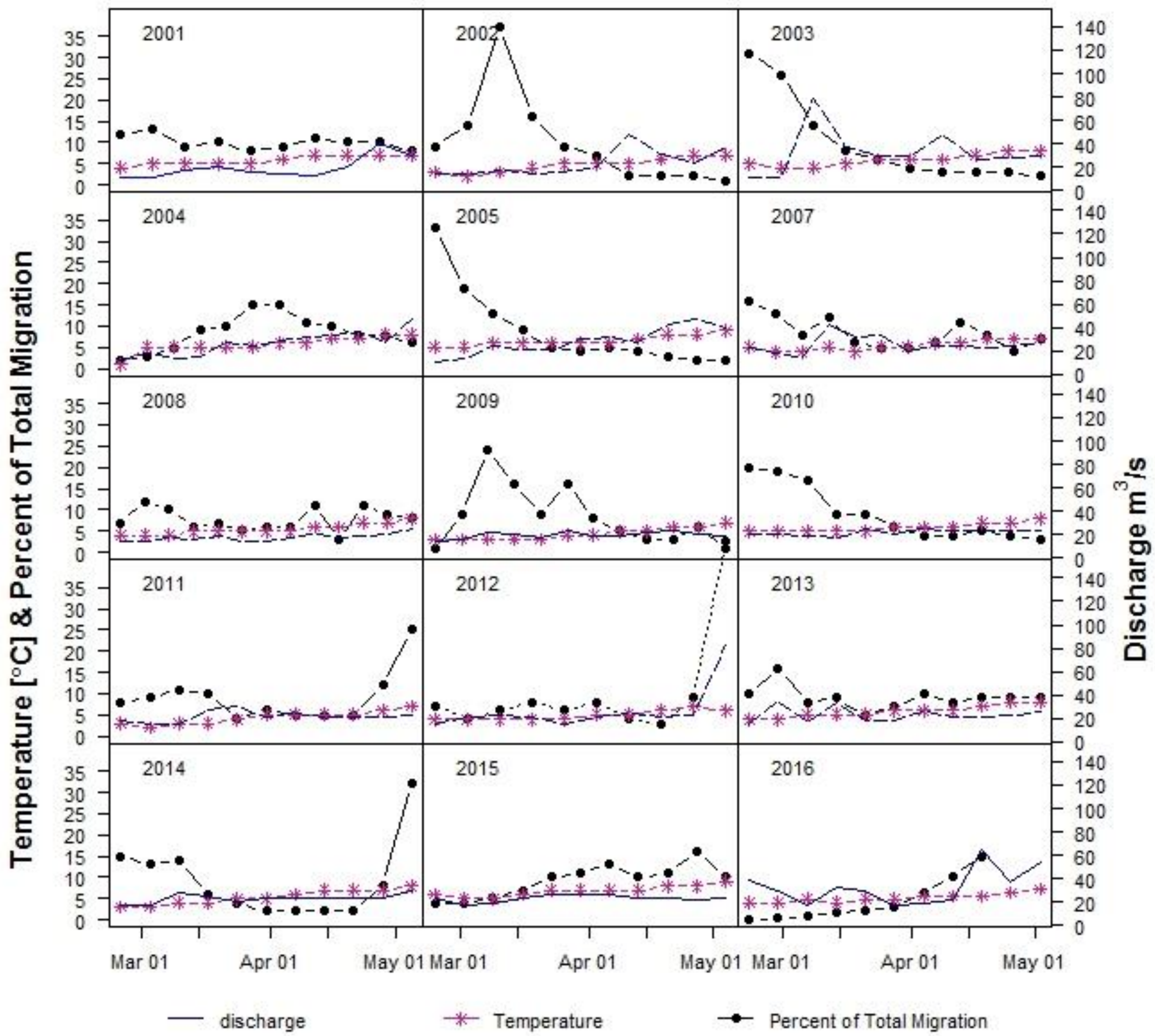

Figure 4. Weekly abundance estimates of Chinook fry (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River 2001-2016

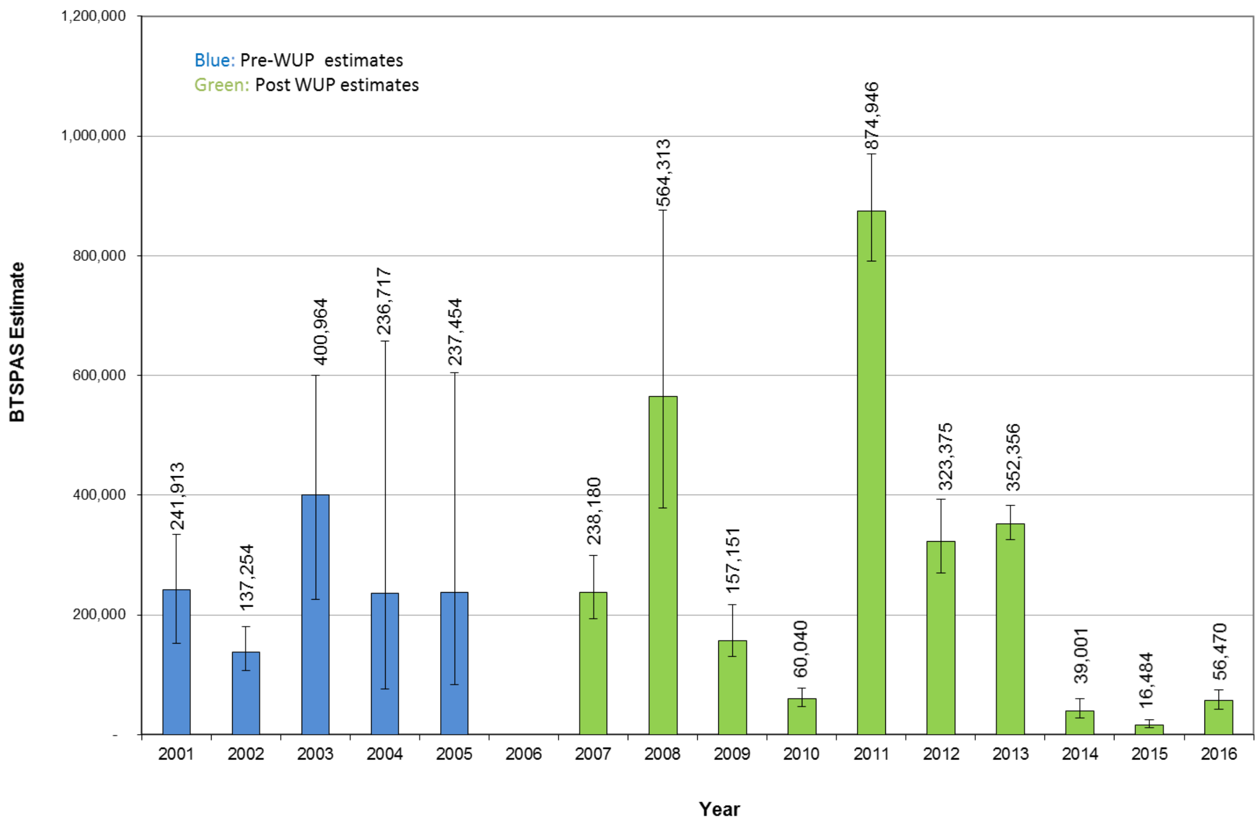

Figure 5. Bayesian Time-Stratified Population Analysis System (BTSPAS) Estimates of Chinook fry migrants from upstream of the RSTs on the Cheakamus River from 2001-2015, including 95% confidence limits

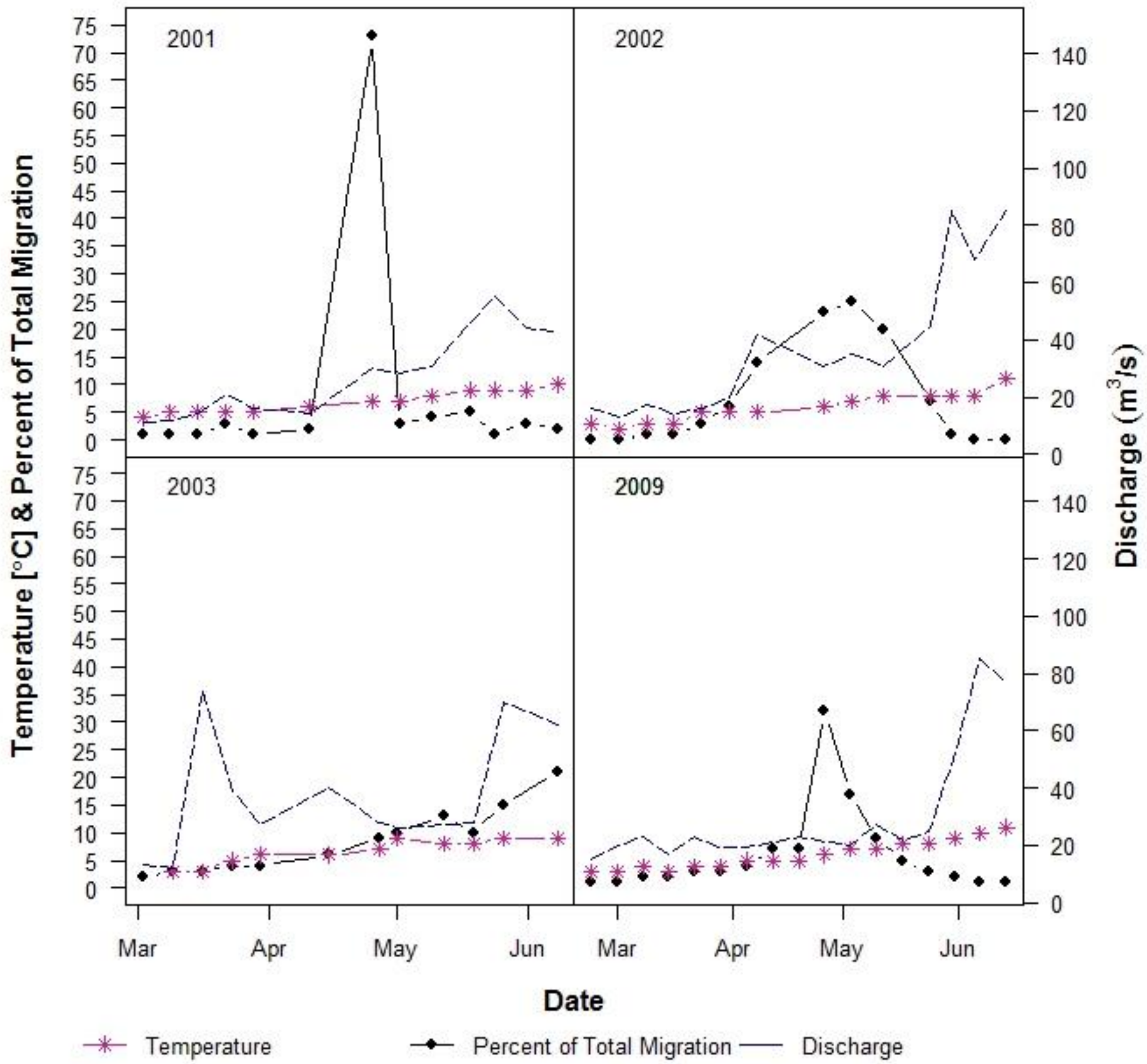

Figure 6. Weekly abundance estimates of Chinook smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

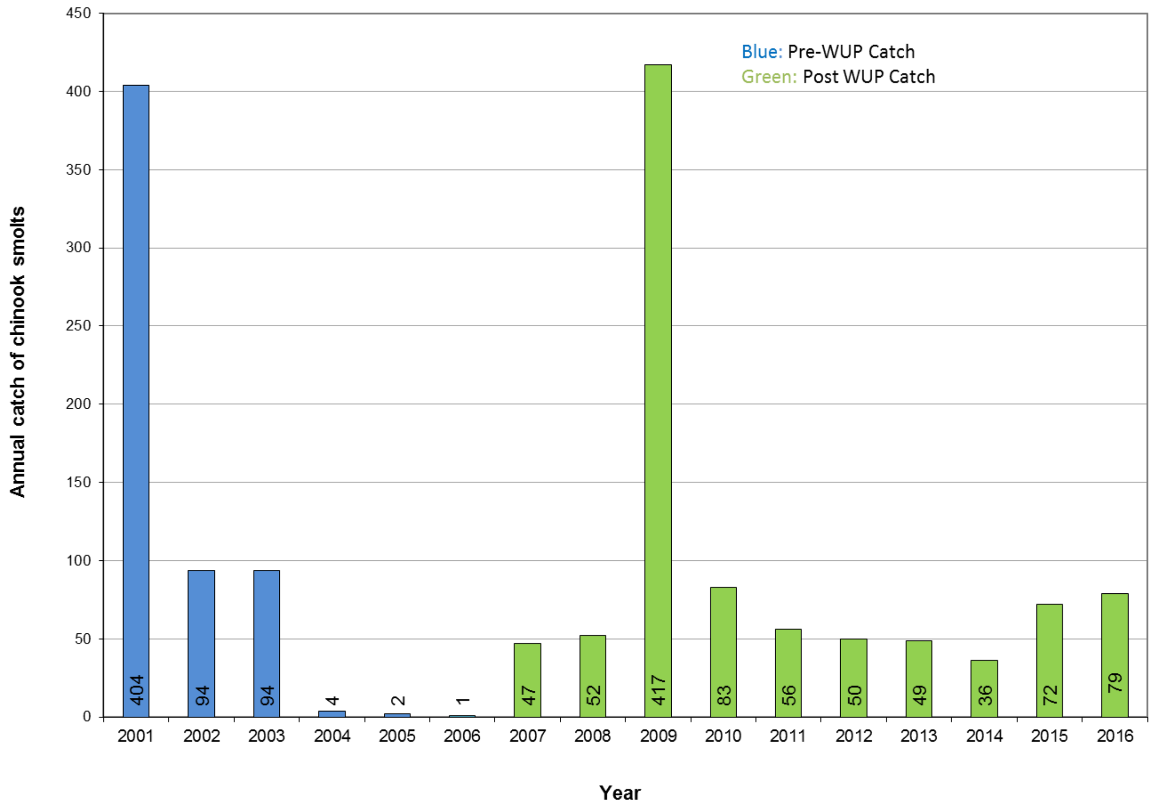

Figure 7. Annual number of Chinook smolts captured in the RSTs on the Cheakamus River from 2001-2016

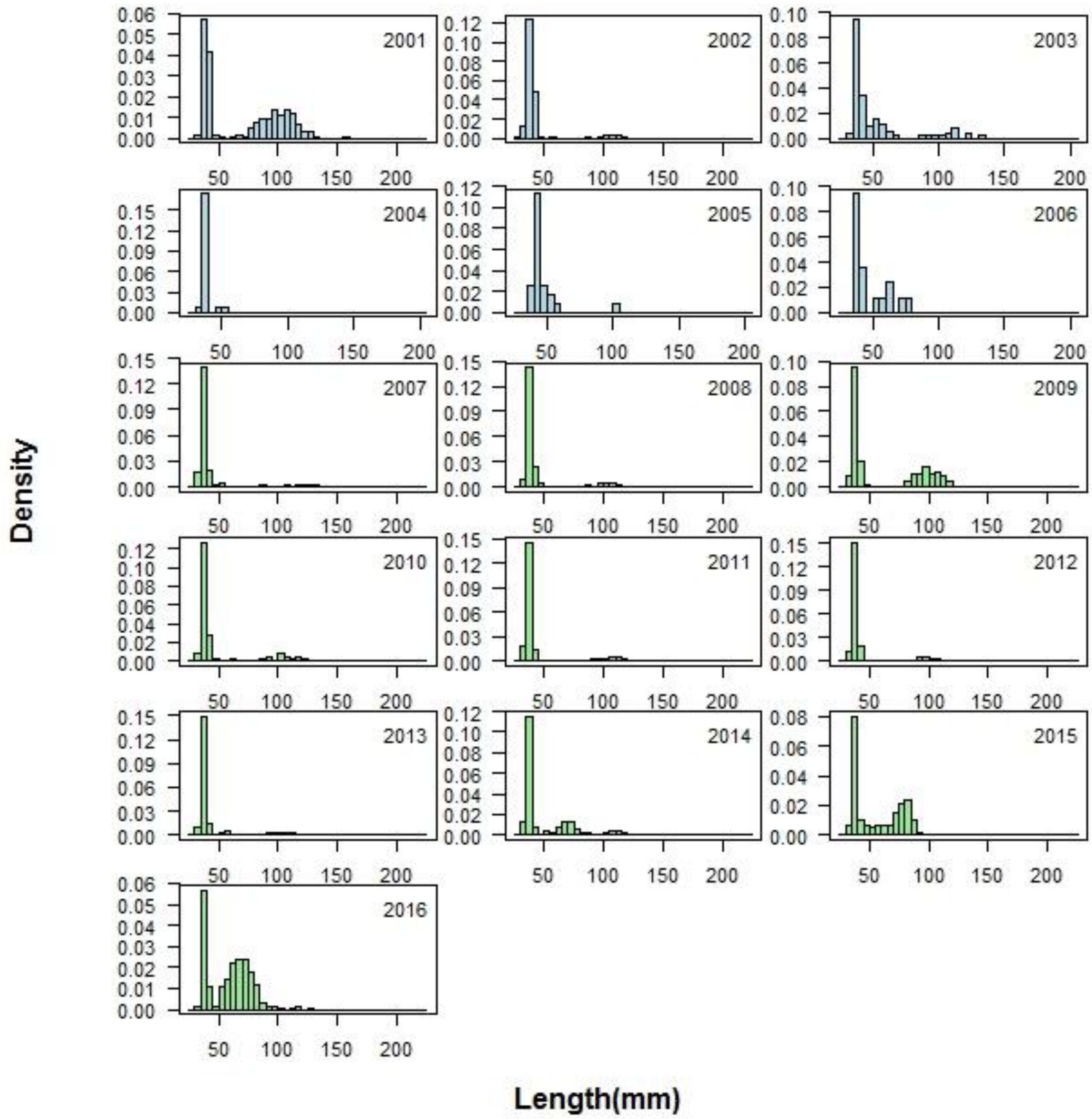

Figure 8. Distribution of fork lengths taken from Cheakamus River juvenile Chinook for both IFA (blue) and WUP (green) affected years

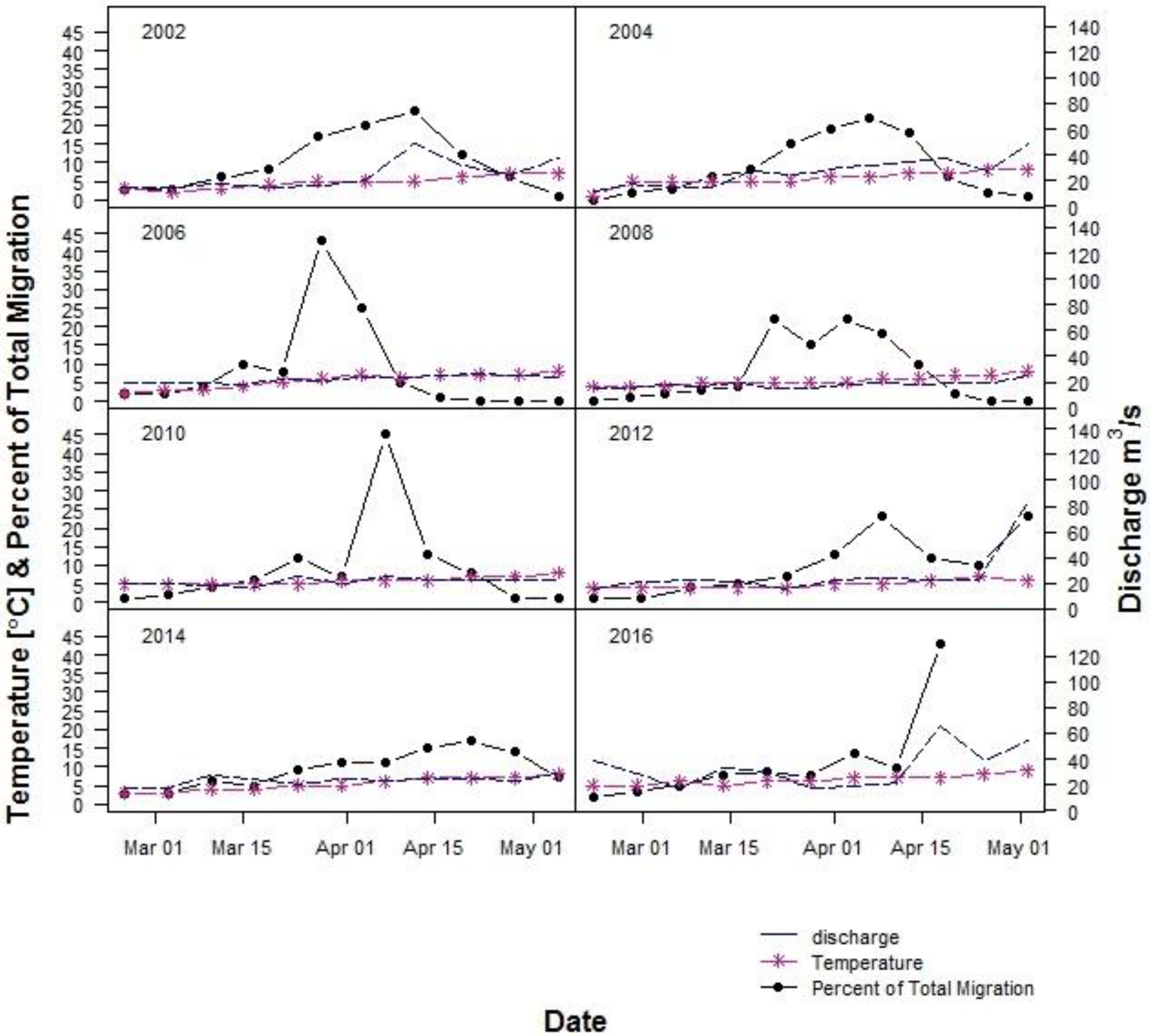

Figure 9 Weekly abundance estimates of Pink fry (solid line, circles) related to temperature in ^{0}C (Pink asterisks) and discharge (dashed line) from the Cheakamus River 2001-2016.

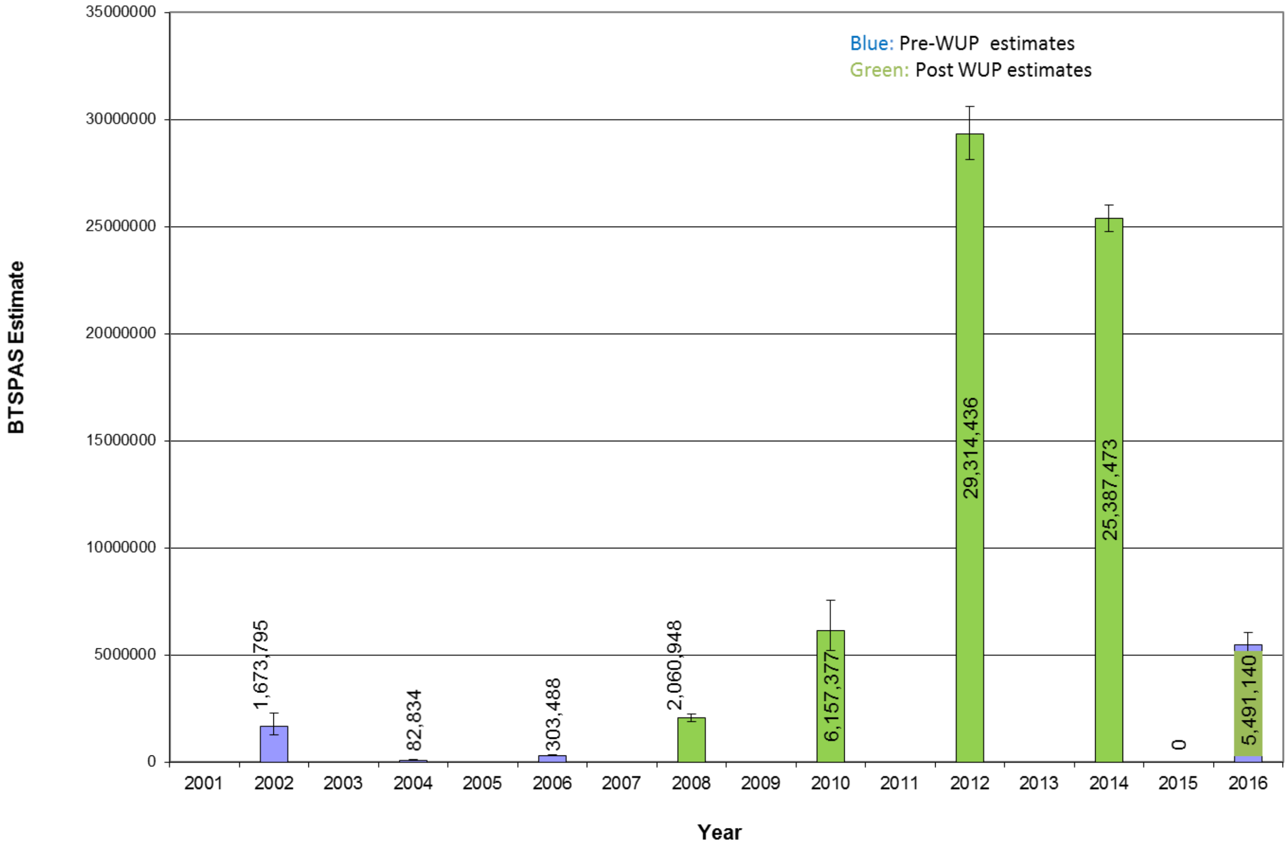

Figure 10 Bayesian Time-Stratified Population Analysis System (BTSPAS) Estimates of mainstem Pink fry migrating from upstream of the RSTs on the Cheakamus River from 2001-2016, including 95% confidence limits

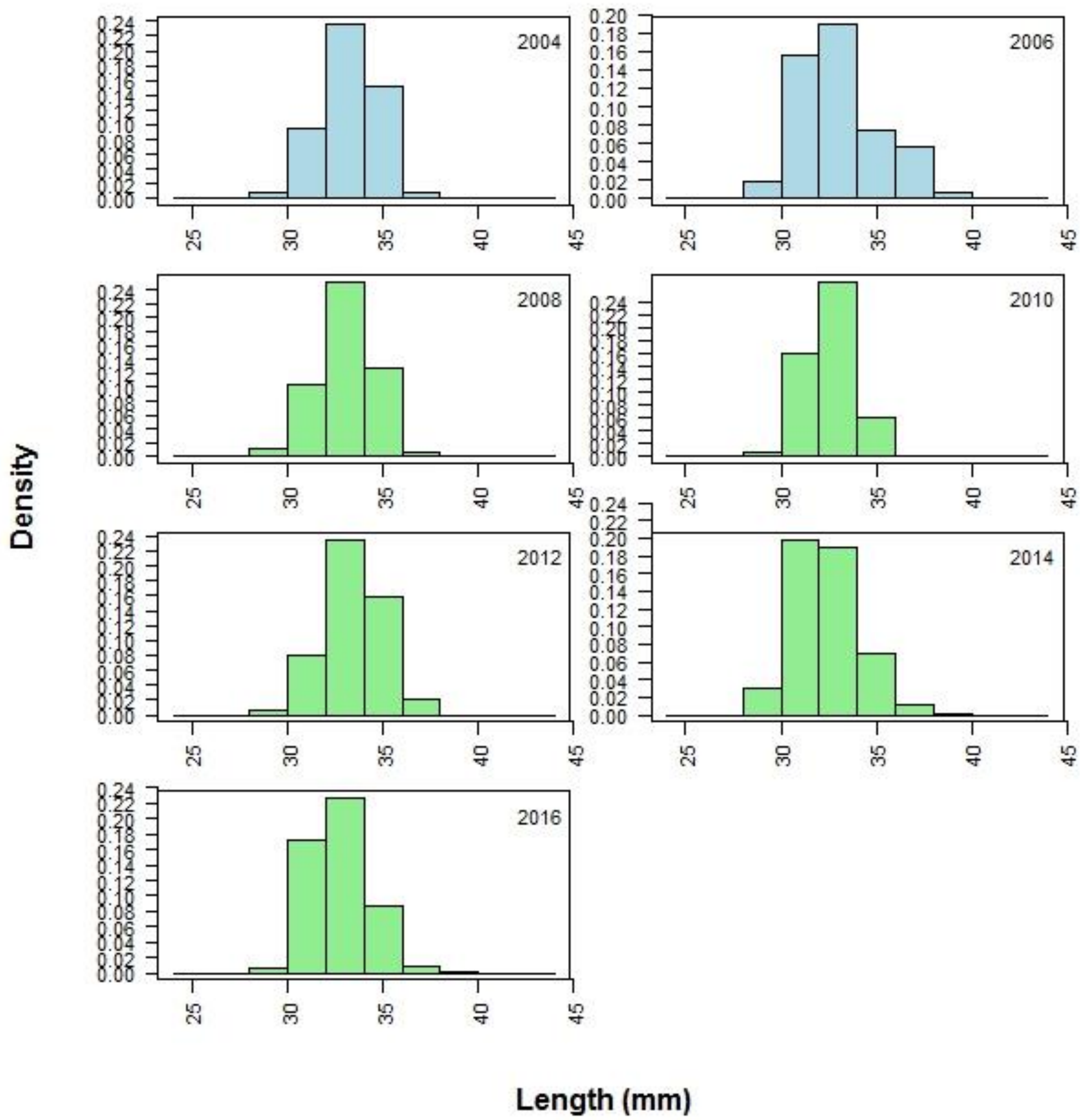

Figure 11 Distribution of fork lengths (mm) taken from Cheakamus River Pink fry for both IFA (blue) and WUP (green) affected years

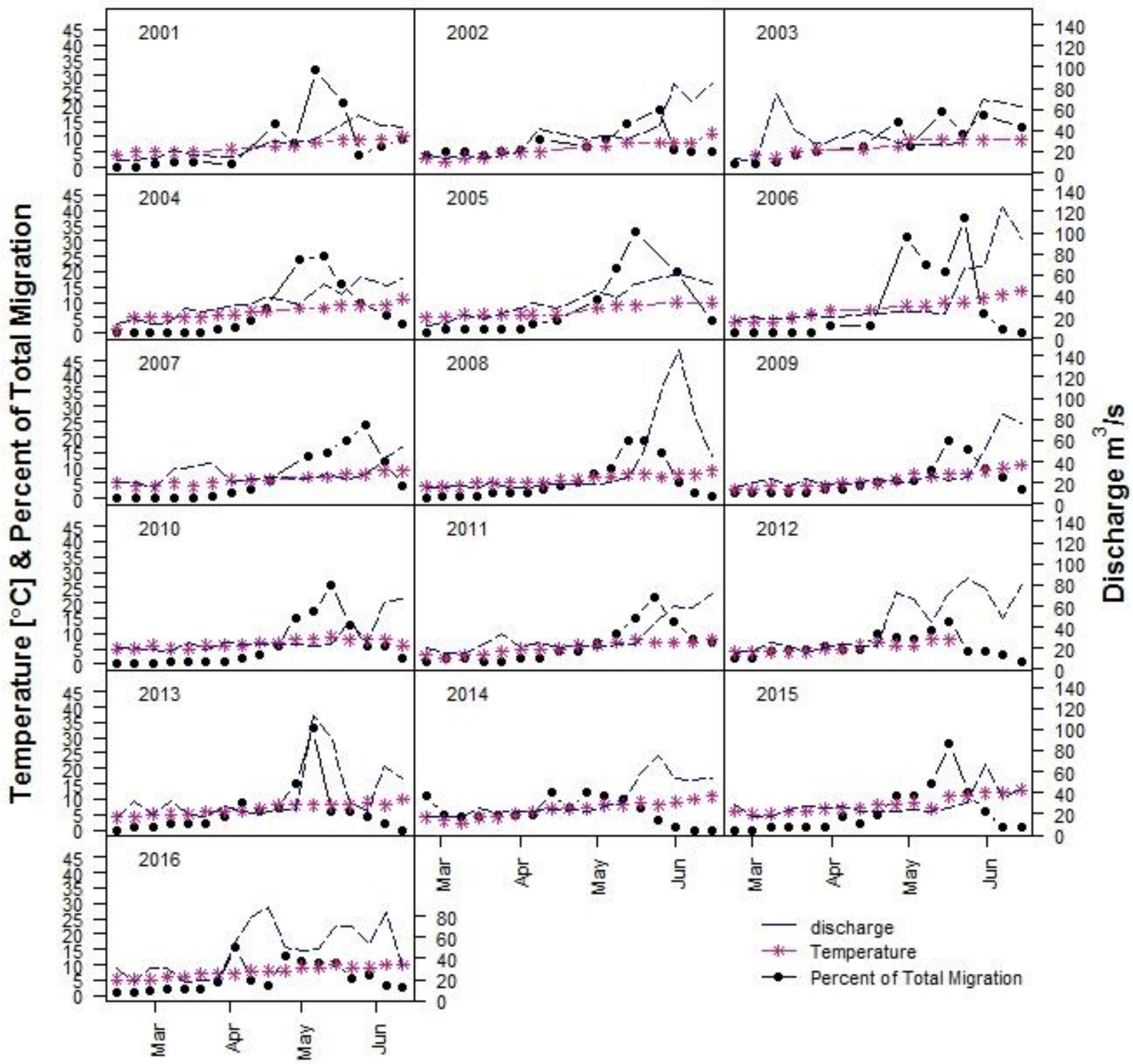

Figure 12. Weekly abundance estimates of Coho smolts (solid line, circles) related to temperature in ^{0}C (Pink asterisks) and discharge (dashed line) from the Cheakamus River 2001-2016

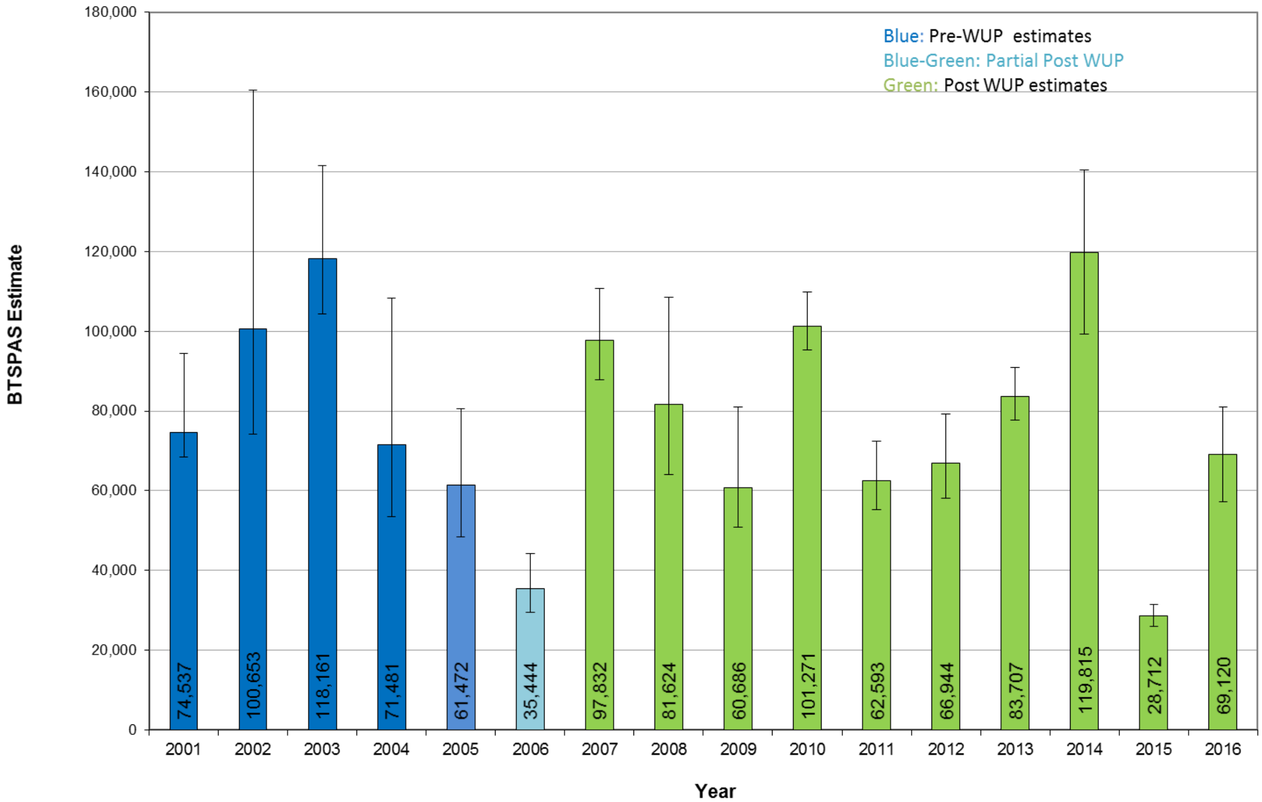

Figure 13. Bayesian Time-Stratified Population Analysis System (BTSPAS) Estimates of mainstem Coho smolt migrating from upstream of the RSTs on the Cheakamus River from 2001-2016, including 95% confidence limits

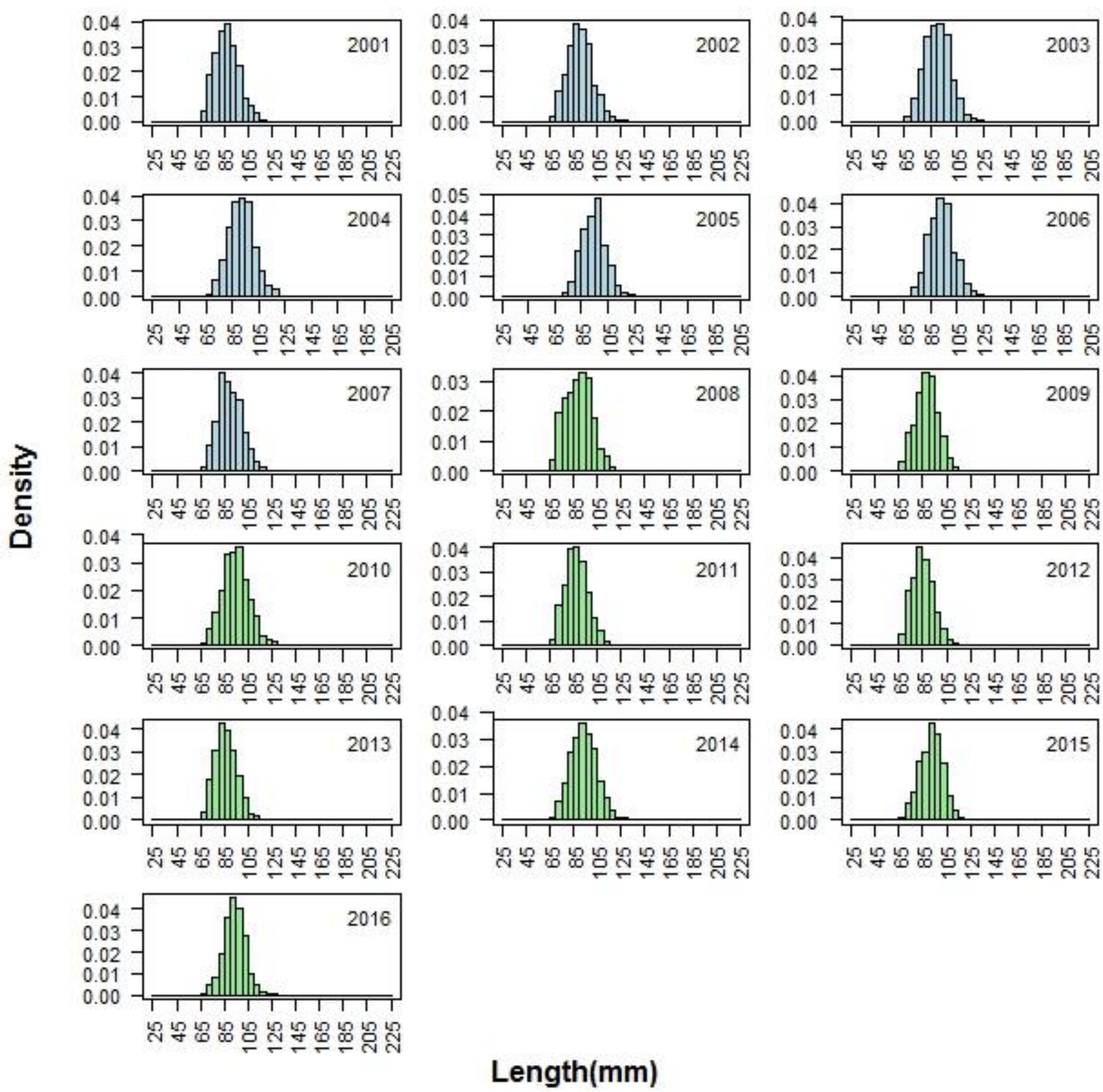

Figure 14. Distribution of fork lengths (mm) taken from Cheakamus River Coho smolts for both IFA (blue) and WUP (green) affected years

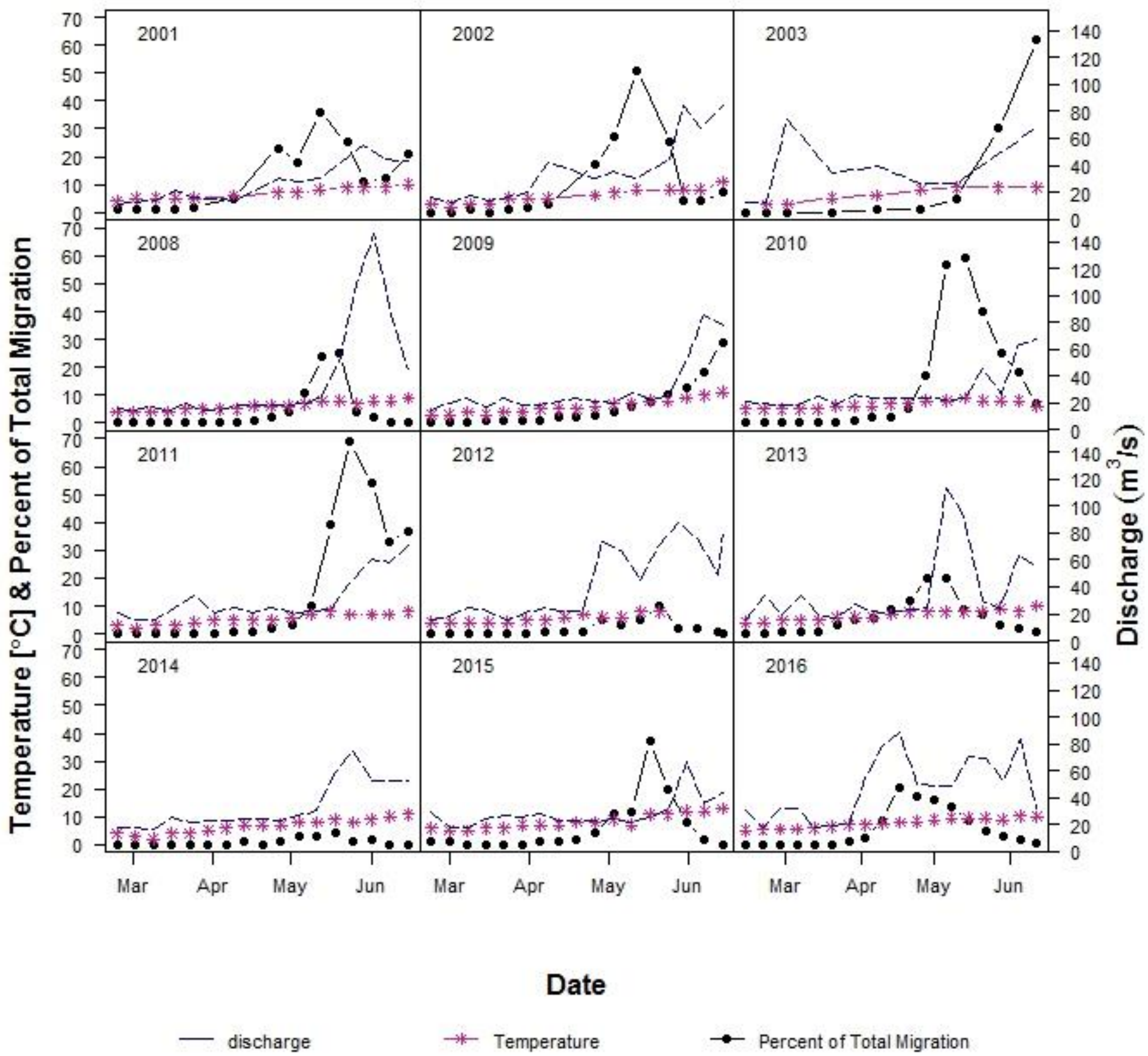

Figure 15. Weekly abundance estimates of Cheakamus River Steelhead smolts (black line, circles) related to temperature in ^{0}C (Pink asterisks) and discharge (blue)

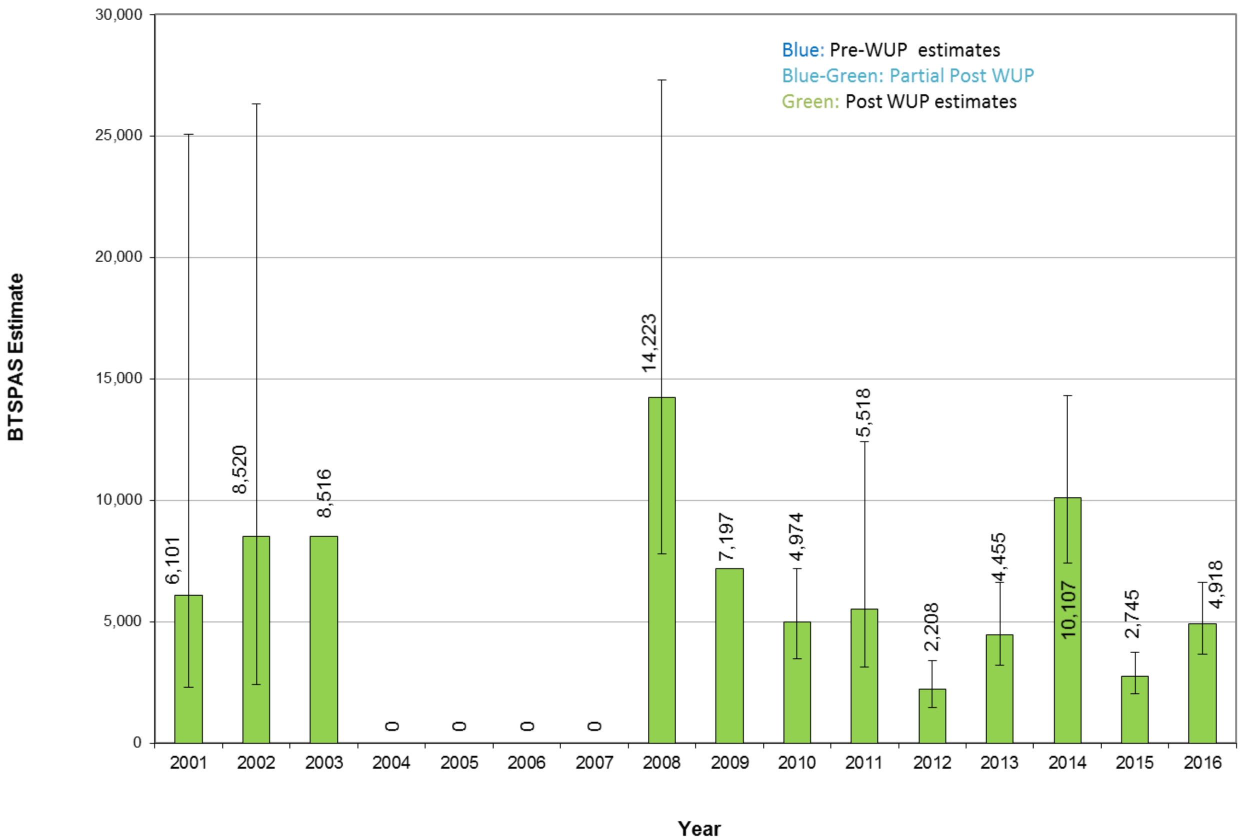

Figure 16. Bayesian Time-Stratified Population Analysis System (BTSPAS) Estimate of Steelhead smolt outmigrats from upstream of the RSTs on the Cheakamus River from 2001-2016 including 95% confidence limits

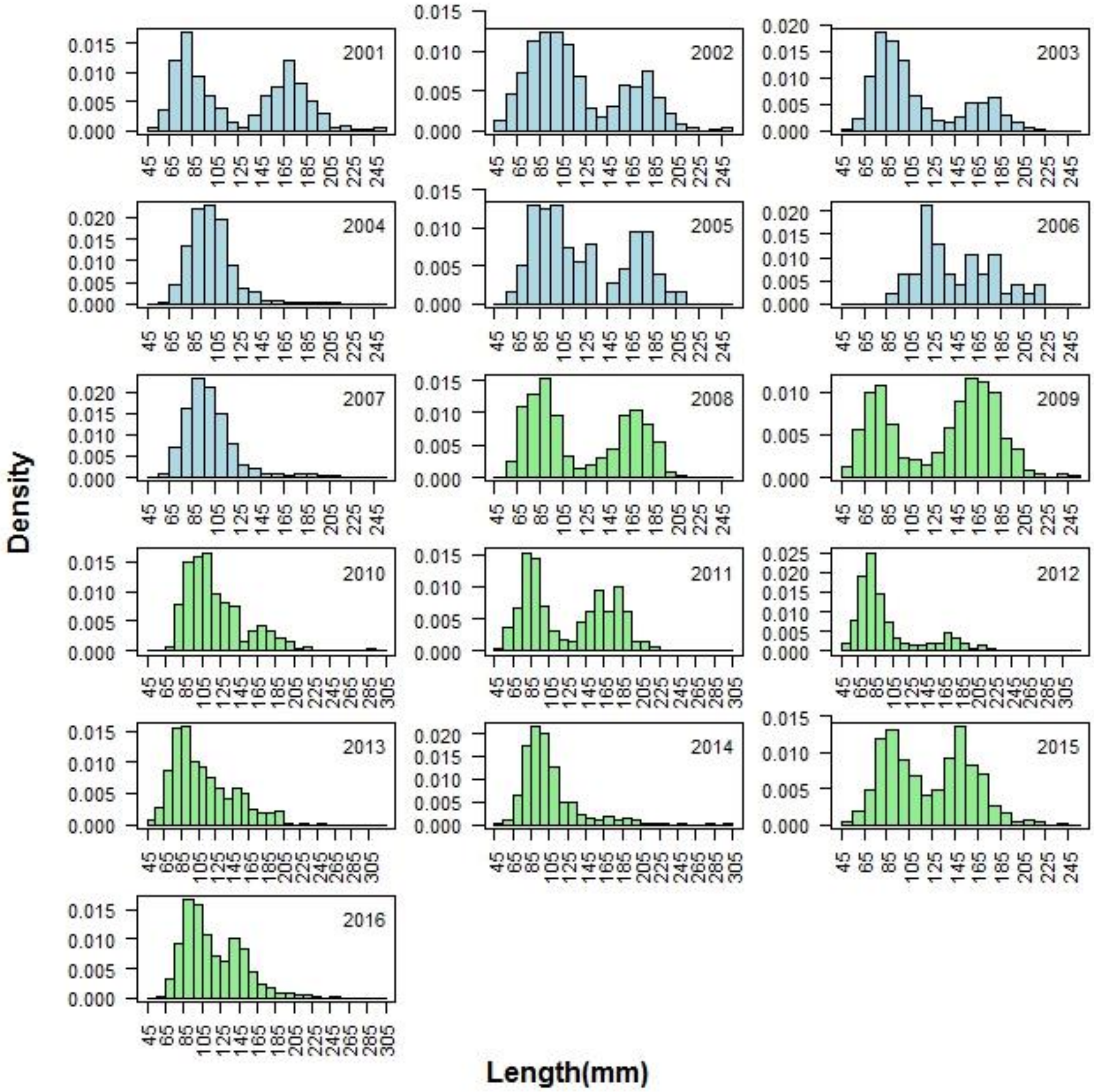

Figure 17. Distribution of fork lengths taken from Cheakamus River Steelhead juveniles for both IFA (green) and WUP (blue) affected years

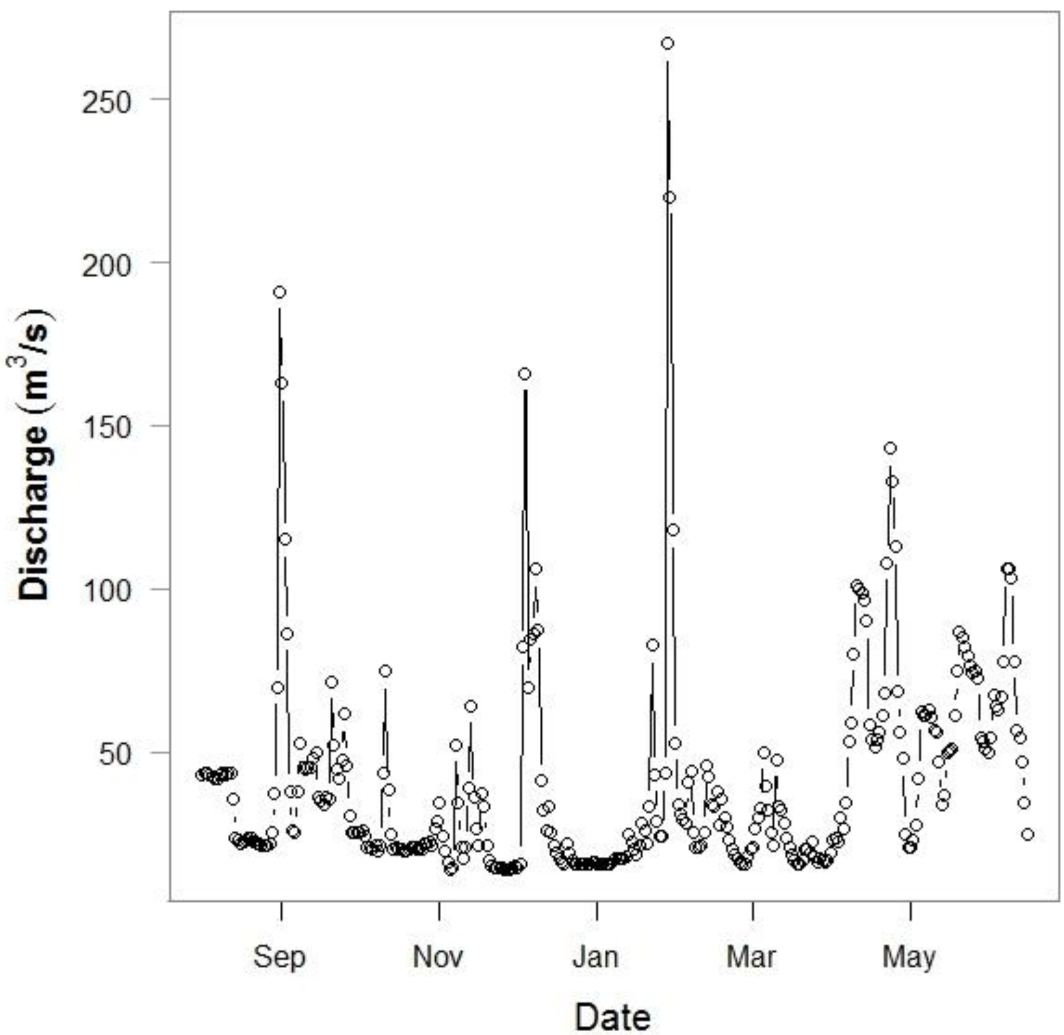

Figure 18. Mean daily discharges from the Cheakamus River at the Brackendale WSC Gauge (08GA043) from August 2015 to June 2016

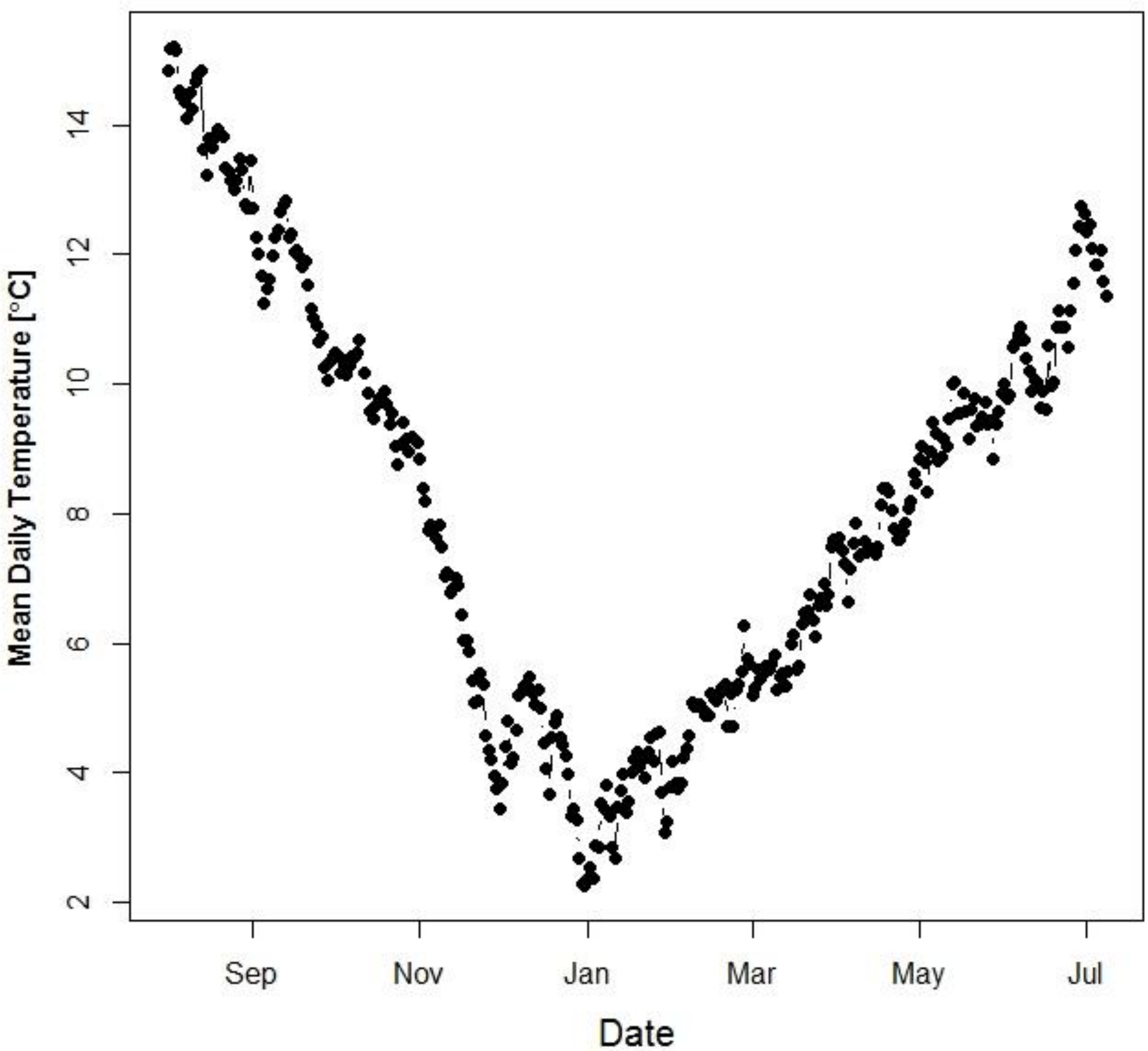

Figure 19. Mean daily temperature from Cheakamus River at the RST site from August 2015 to July 2016

8.0 GLOSSARY OF ABBREVIATIONS

BB: Bismark Brown Dye

BCR: BC Rail

CHF: Chinook Fry (< 90mm YOY)

CHS: Chinook Smolts (≥ 90mm; 1+)

CMF: Chum Fry (YOY)

COS: Coho Smolts (≥ 70mm; 1 and 2+)

DFO: Department of Fisheries and Oceans Canada

ECE: Estimated Capture Efficiency

IFA: Interim Flow Agreement

IFO: Interim Flow Order

LC: Lower Caudal Clip

NR: Neutral Red Dye

CHEAKAMUS CENTER: North Vancouver Outdoor School

PKF: Pink Fry (YOY)

PPE: Pooled Petersen Estimate

Q: discharge

RK: River Kilometre from confluence

RST: Rotary Screw Trap

SHP: Steelhead Parr (< 140mm; 1+)

SHS: Steelhead Smolts (≥140 mm; 2 & 3+)

Site 1: Upper Paradise/Gorbushca Smolt Trap; enumerating production of Coho (1 and 2+ smolts) and Steelhead parr (1+) and Steelhead smolts (2 & 3+), including Farpoint channel to Birth of a Stream South.

Site 2: Upper Paradise Groundwater Channel Smolt Trap. Not operated. Only operated in 2007 due to insufficient population to meet Groundwater Study Monitor 6 data requirements, effort shifted to BC Rail.

Site 3: Kisutch Smolt Trap and Counter Site; enumerating production of Coho (1 and 2+ smolts) and Steelhead parr (1+) and Steelhead smolts (2 & 3+) to meet Groundwater Study Monitor 6 data requirements.

Site 4: BC Rail Smolt Trap and Counter Site; enumerating production of Coho (1 and 2+ smolts) and Steelhead parr (1+) and Steelhead smolts (2 & 3+).

Site 5: Tenderfoot Creek Smolt Trap and Counter Site; enumerating production of Coho (1 and 2+ smolts) and Steelhead parr (1+) and Steelhead smolts (2 & 3+). Not operated in 2009. Replaced with minnow trapping mark recapture to assess Coho production.

Site 6: Upper Paradise Smolt Trap: Smolt Trap and Counter Site; enumerating production of Coho (1 and 2+ smolts) and Steelhead parr (1+) and Steelhead smolts (2 & 3+). Operated since 2001 to obtain smolts to mark for RST population estimates.

Site F1: CHEAKAMUS CENTER sidechannel Enumerator Fyke Net; recapture trap for Chum & Pink fry to obtain productivity of side channels.

Site F2: Upper Paradise Marking Fyke; capture Chum & Pink fry to mark for productivity estimate at Site F1.

Site F3: Kisutch Enumerator Fyke Net; recapture of Chum fry to obtain productivity of groundwater channel to meet Groundwater Study Monitor 6 data requirements.

Site F4: Sue's Marking Fyke; capture Chum & Pink fry to mark for productivity estimate at Site F1.

Site F5: Upper Paradise Marking and Enumerator Fyke Net; mark and recapture of Chum fry to obtain productivity of groundwater channel to meet Groundwater Study Monitor 6 data requirements.

Site F6: Kisutch Marking Fyke Net; to obtain Chum fry to mark for productivity estimate at Site F1 & F3.

Site F7: BC Rail Enumerator Fyke Net; recapture trap for Chum fry to obtain productivity of side channels and Groundwater Study Monitor 6 data requirements.

Site F8: BC Rail Marking Fyke; capture Chum fry to mark for productivity estimate at Site F7.

TH: Tenderfoot Hatchery

UC: Upper Caudal Clip

UP: Upper Paradise channel

CHEAKAMUS CENTER: North Vancouver Outdoor School

VIE: Visible Elastomer Tag

WSC: Water Survey of Canada

WUP: Water Use Plan

YOY: young of the year

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