Cheakamus River Water Use Plan

Cheakamus River Juvenile Outmigrant Enumeration

Implementation Year 8

Reference: CMSMON-1a

Cheakamus River Juvenile Salmonid Outmigration Enumeration Assessment Annual Data Report 2014

Study Period: 2014

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Prepared for BC Hydro

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Executive Summary

In 2000 a juvenile outmigration salmonid 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. This report details information collected during a continuation of this monitoring program as decided by the CC in September 2012. Juvenile outmigration of anadromous fish is now monitored (Cheakmon#1a) as part of the evaluations of flow changes implemented under the Water Use Plan, and the flow regime initiated on this river in February of 2006. This includes yield evaluations of smolt and fry outmigrants for five species of salmonids: Coho salmon (*Oncorhynchus kisutch*), Chum salmon (*O. keta*)[1], 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 2014, 39,001 Chinook fry, 25,387,473 Pink fry, 119,815 Coho smolts, and 10,107 Steelhead smolts were produced in the area of the Cheakamus River upstream of the monitoring site at the North Vancouver Outdoor School (NVOS) property. No estimate was formed for Chinook smolts as catches were too low and the Chum fry estimate is reported in Monitor 1b (Fell et al. 2014). Ranking of production over the fourteen years evaluated indicates that in 2014, Steelhead smolt production ranked 4th, Coho smolts 1st, Chinook fry 14th and Pink fry 1st.

Side-channel production estimates were obtained for Coho smolts, Pink fry, and Chum fry[1]. Coho smolt production from the NVOS and BC Rail side channel was the 3rd highest on record at 23,072 or 19% of the total estimate. While Pink fry production from the NVOS side channel complex was the highest on record (258,658), with the majority (85%) of the Pink fry estimate generated by the mainstem.

[1] Reported in Monitor 1b. Fell et al 2014.

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1.0INTRODUCTION

1.1 Background History of Study and Watershed

The Cheakamus River is a major tributary of the Squamish Watershed and drains upstream of Brackendale gauging station (WSC 08GA043), an area totaling 1010 km^2 of the Coastal Mountain range in south-western British Columbia. River discharge is affected by BC Hydro through operation of Daisy Reservoir and the Cheakamus generating plant, a 155 MW storage and diversion project. The generation project, completed in 1957, consists of a 28 m high, 680 m long dam that impounds Daisy Reservoir. From this reservoir, a portion of the river flow is diverted through an 11km long tunnel to a powerhouse on the Squamish River (Figure 1). During normal operations Daisy Reservoir has an operating range of 364.90m and 377.25m above sea level, a fluctuation of 12.35m. The reservoir can store approximately 55 million cubic meters of water, which is approximately 3.5 percent of annual inflow.

The Cheakamus River, downstream of the reservoir, extends 26 km to its confluence with the Squamish River. Only the lower 17 km of this river are accessible to anadromous salmon as a number of natural barriers preclude further upstream migration (Figure 2). The Cheakamus River anadromous mainstem habitat 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 as part of the Cheakamus Water Use Planning Process (WUP). Its 20 members represent 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 an Interim Flow Order (IFO) which was implemented in 1997, and the subsequent Instream Flow Agreement (IFA). A juvenile salmon outmigration study utilizing rotary screw traps commenced in the spring of 2000 (Melville and McCubbing 2001) and has continued annually through 2014.

The CC held its last meeting in January, 2002 and was unable to reach consensus on a new operating alternative. The CC recognised 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 disagreement 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 WUP (BC Hydro 2005) 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 2006). The new flow order for the Cheakamus River was approved by the Water Comptroller and implemented on February 26th, 2006.

Under the implemented WUP, the discharge rules for operations were varied from the existing IFA, which specified that the greatest of 5 m^3/sec 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), to a required minimum measured flow at the following two locations:

1) Minimum required flow below Daisy Lake Dam:

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

2) Minimum required flow at the Brackendale gauge (WSC 08GA043):

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

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 (Marmorek and Parnell, 2002). The Juvenile Outmigration Monitor #1a in conjunction with other monitors was developed to reduce this uncertainty and monitor 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 Outmigration 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 relation 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 outmigration data will also be used in conjunction with data collected as part of the Chum Salmon Adult Escapement Monitor #1b (Fell et al, 2014) and the Cheakamus River Steelhead Adult and Juvenile Abundance Monitor #3 (Korman & Schick, 2014) 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, outmigrant data from this program was used as part of the Groundwater Side-channels Monitor #6 (Grey et al, 2012) to address the management question:

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

The expanded study includes detailed assessment of juvenile salmonid outmigration 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 3 other monitors (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, 2014),
- Steelhead smolt production as it relates to stock recruitment will be reported in Monitor 3 (Korman & Schick, 2014),
- Chum fry production as it relates to groundwater in side channels will be reported in Monitor 6 (Grey et al, 2012).

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 synthesis report and flow related decisions thereafter. Here we present a further year of data; 2014. 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 North Vancouver Outdoor School (NVOS) property (10U 0489141:5518035, Figure 2 & 3) at river kilometer (RK) 5.5. Secondary enumeration sites were operated on both river augmented and ground water side-channels at locations on the NVOS 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, Steelhead and Chum.

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 the following spring as young-of-the-year (YOY). These YOY are released to the Cheakamus mainstem at RK 12 to 15. This varies from hatchery practice prior to fall 2005 when all Chinook brood collection and young release occurred in Howe Sound.

Coho 1+ 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 being done to mitigate losses observed during the caustic soda spill in 2005 (McCubbing et al. 2006).

Generally RST operations were suspended for one to two days following Coho and Chinook hatchery releases, thus allowing the majority of the outmigrants to pass the RST site without the risk of capture.

The NVOS and Tenderfoot Creek Hatchery release Chum fry each spring. Depending on release numbers, RST and/or side channel fyke net operations are 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 Pinks during the 2005 caustic soda spill a hatchery enhancement program targeting Cheakamus River Pinks was implemented. Pink salmon adults are captured at the smolt trap Site 1 on NVOS side channel and placed in Tenderfoot Hatchery (TH) where they are spawned and their progeny released downstream of the RSTs the following spring as young-of-the-year (YOY).

In 2007 & 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.

The first event was on October 18th-19th, 2003 when an extreme flood occurred. The second highest maximum mean daily discharge on record of 709m^3/s was recorded at WSC Cheakamus @ Brackendale on October 19th. This discharge was exceeded on Oct 18th when the peak of flow occurred and the gauge exceeded the rating curve. The previous highest mean daily discharge recorded was on Dec. 27, 1980 when 712 $m^{3/}s$ was estimated, (WSC records on file). During the 2003 flood the river inundated the area of the NVOS restoration channels, and moved large amounts of sediment and debris in the mainstem river. Concerns were expressed over Pink and Chinook salmon egg-to-fry survival in the channels and in the mainstem of the Cheakamus River as the flood occurred just as Pink and Chinook spawning concluded.

On August 5th 2005, the second event occurred; 41,000 litres of caustic soda (NaOH) was 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 and cutthroat trout, char, cottids, lamprey, and stickleback (McCubbing et al., 2006).

The potential effects of the 2003 flood and the 2005 NaOH spill on this time series of data are noted in this report.

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 (FWCP completion reports 2002-2006 and Triton Environmental 2008 & 2009):

- Cheakamus Gravel Recruitment (ground water): constructed in 2002; created 700m^2 of additional head pond area in the upper Kisutch channel. Target species: Chum & Coho salmon.
- Gorbuscha 1 (river intake): constructed in 2002; created 750m of channel and 4600m^2 habitat Target species: Pink & Chinook salmon.
- Gorbuscha 2 (river intake): constructed in 2003; created 478m channel and 3225m^2 habitat. Target species: Pink salmon
- Sue's Channel (river intake): constructed in 2006; created 380m channel and 2400m^2 habitat. Targeted species Pink, Chinook, Chum, and Coho salmon, and rainbow/cutthroat trout.
- Mykiss channel (river intake): constructed in 2006; created 1600m^2 spawning habitat and 3800m^2 of rearing habitat. Target species Steelhead/rainbow trout and Coho.
- Km 6.5 side-channel re-watering (river intake): constructed in 2007; created 1400m^2 habitat. Targeted species Chinook and rainbow trout.
- Large Wood Restoration Project (mainstem structures): constructed in 2007; created 900m^2 of habitat. Targeted species rainbow/steehead 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 trout.

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

2.0 Methods Summary (Consistencies and Changes over sample years)

2.1 Fish Trapping Methods

Prior to 2007 only mainstem juvenile fish production were assessed. In order to meet the objectives of the WUP monitor to partition side channel from mainstem fish production side-channel assessments were added to the study plan using various trapping methods in 2007. Three methods have been used for enumerating outmigrant 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 outmigration,
2) complete channel traps, which allow for manual counting of all outmigrant smolts from a designated area,
3) resistivity counters in combination with trap boxes built into diversion weirs, which electronically enumerate outmigrant 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

In 2014 assessment of Chum fry production from Tenderfoot Creek was continued to assess the contribution of this tributary to the Chum population. In 2013 three fyke nets (F9, 10 and 11) were operated to evaluate fry production upstream of the fish fence where adult enumeration occurs and one at the confluence with the Cheakamus River to assess the entire creek contribution. In 2014, a single fyke net (F10) was operated as both a marking and recapture trap upstream of the adult fish fence (Figure 3). The number of fyke nets was reduced because in 2013 the F9 trap did not catch sufficient numbers of Chum fry to mark and production from F11 had no relativity to adult recruitment in the creek as the number of adult spawners below the fish trap is unknown. Results of Tenderfoot Creek Chum production is reported in Fell et al. 2014.

2.2 Subsampling Methods

Due to an overwhelming abundance of Pink fry in 2014 subsampling of the RST catch was necessary during the peak of Pink fry migration (mid-March through April) as the resources required to manually count the number of fish captured was not feasible. This differs from previous years when all fish captured at the RSTs during each 24 hour sample period were counted (Melville & McCubbing, 2011).

The subsampling methods were designed in an effort to reduce the number of fish counted without biasing capture efficiency or decreasing the precision of abundance estimates. Subsampling was done by dipping a consistent amount of fry into buckets (measured by water displacement) and manually counting every 2nd or 3rd bucket in the order they were dipped out of the trap. The frequency of buckets sampled was dependent on the number of fry captured. The remaining buckets were released downstream. Species composition and the proportion of recaptures has been observed to change as the trap box is emptied in past years of the study; therefore, sampling every 2nd or 3rd bucket was done to ensure that the species and recapture proportions would be represented accurately throughout the sample.

The catch at the RSTs consists of both free-swimming fry and a debris layer on the bottom of the trap which contains both dead and live fry. Subsampling the debris layer proved difficult due to the inconsistent number of fish that are dipped in conjunction with debris therefore subsampling was only employed on the free swimming component of the catch and the debris layer was counted out in its entirety. If subsampling was started at the beginning of a strata it was employed across the entire strata to ensure consistency of sampling methodology throughout the strata.

2.3 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 to evaluate changing catchability as flows fluctuate during the spring, often at the same time as outmigration for some species is expected to peak (i.e. Coho and Steelhead). In the interim (2008 through 2011) as described fully in Bonner (2008), Schwarz et al. (2009), and Bonner and Schwarz (2011) an alternate method (Bayesian spline model) for calculating population estimates was developed that has many advantages over existing methods.

In 2012 all previous estimates of juvenile abundance were recalculated utilizing the Bayesian spline model (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 Bayesian spline model (BTSPAS) population estimates for the Cheakamus are described fully in Schwarz and Bonner, 2012.

2.4 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 Brackendale WSC 08GA043 (10U 0489186:5518291), located 100m upstream of the RST site (Figure 3). These readings are used for all analysis relating to discharge and fish production in this study.

2.5 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 collected. Loggers are downloaded once every month and the data are archived for use in other Cheakamus WUP monitors.
The five 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.

2.6 Bio-sampling and Age Data Collection

A sub-sample of all species captured has been sampled for lengths and weights at the RST site and at Upper Paradise side channel trap (Site 1 and 6) throughout the study (2001-2013) and 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 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+ & 3+ migrating): >140 mm, parr (1+ non-migrating): <140mm.

In all years of the study scale samples were taken for 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 and Chinook samples have not been analyzed because length frequency data in all years of the study indicates that the majority of migrating Coho are 1+ and Chinook are 0+ (Melville and McCubbing 2001-2011).

3.0 Results

3.1 Chinook

3.1.2 Chinook Fry Migration and Production

As in all years of the juvenile study the migration timing of early Chinook fry (YOY) in 2014 indicates that the migration was already under way when the mark-recapture program began on February 18th. In 2014 based on estimated weekly abundance, 28% of the total yield was estimated to have migrated in the first two sampling strata. In comparison from 2001 through 2013 an average of 26% of the total yield was estimated to have migrated in these strata. In 2014, the out-migration did not appear to be fully completed when the RST drums were changed to larger mesh on May 5th, as 32% of the total yield was estimated to have occurred in the last strata assessed. This is similar to 2011 and 2012 an increase of abundance occurred in the last strata (46% and 25% of total estimate respectively). It does not appear that increased temperature or discharge affect the migration timing of early Chinook fry. It is likely spawner timing in conjunction with water temperature during incubation that drives migration timing of early fry (Figure 4).

Estimates of Chinook fry production from the Cheakamus River have been calculated for all years of the study (2001-2014) except 2006. In 2006 insufficient numbers (499) were captured to derive a mark-recapture estimate. The 2006 outmigration was in part affected by adult spawner mortality resulting from the chemical spill event in the summer of 2005.

In 2014 the estimated emigration of Chinook fry was 39,001 (SD = 9,413). Estimated production of Chinook fry from the mainstem of the Cheakamus River has ranged from 60,040 in 2010 to 874,946 in 2011. The average estimated production for all years (2001 to 2014) is 297,205, SD = 58,685. To date there have been five IFA and eight WUP estimates of production. Average IFA and WUP abundance is 250,860 fry and 326,170 fry respectively, this equates to an average change in abundance of 75,310 or a 30% increase in WUP years. The 2014 estimate of 39,001 Chinook fry ranks as the lowest year during the years assessed; 2001-2014 (Table 2 & Figure 5).

There are no estimates of early Chinook fry production in the side channels as very few fish are captured. In 2014, 178 Chinook fry were captured at the F1 enumeration fyke on the NVOS side-channel complex compared to an average catch of 287 fish since 2007 (range of 99-598). As in other years no fish were captured at site F7 on the BC Rail side channel complex (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 for the derivation 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 20th and May 10th. Chinook smolts appear to begin their peak outmigration period when average daily water temperatures reach 7^{0}C, (Figure 6).

In 2014 a total of 35 Chinook smolts were captured at the RST traps therefore an estimate of Chinook abundance was not calculated. In the years where an estimate was derived, smolt abundance has ranged from 6,020 to 14,439 (Table 2 & Figure 7)

In 2014, 32 Chinook smolts were captured at the Site 1 fish trap at the NVOS side channels (Figure 3). Since 2009, an average of 11 (range: 2-37) smolts have been captured at this location.

3.1.3 Chinook Length and Age Data

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

No early Chinook fry or smolts were sampled for lengths or weights at the side channels as numbers captured are small.

In 2014 length frequency for all Chinook juveniles captured at the RST was tri-modal with the first mode generally falling between the 35 to 39 mm range and a second mode falling between 60 and 79 mm, representing 0+ fry. The third smallest mode occurred between 105 and 125 mm representing 1+ smolts (Figure 8).

Mean length for Chinook fry in 2014 was 40 mm and ranged from 33-76 mm (Table 3). Half (50%) of fry sampled were in the size range spanning 35-44 mm and a quarter (24%) fell into the 60-79 mm range in 2014. In all other years analyzed (2002-2013) an average of 78% of Chinook fry fell into the 35-44 mm range (Figure 8).

No statistically significant difference was observed in mean annual Chinook fry length among the fourteen sample years 2001 to 2014 (ANOVA: $F_{(1, 12)}$=2.99, P=0.109). Largest fish were observed in 2006 (46 mm) and smallest in 2011 (38 mm). A statistical test was conducted to compare the mean lengths of IFA and WUP Chinook fry which had unequal variance (F-test: $F_{(5,6)}$ =19.3473, P=0.002445), and a statistical difference was evident (T test unequal variance: $t_{(5.4)}$= 2.7463 , P=0.037) between mean annual fry length in IFA and WUP affected years. 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.
Note: 2001 was not included in the analysis of Chinook length as hatchery Chinook smolts were included in the sample.

Mean length, weight and condition factor (K) for Chinook smolts measured at the RST (1+) in 2014 was 117mm, 20.9g, and 1.15 respectively. The size of smolts in 2014 falls outside the range of all previous years sampled (2002-2012) when mean length, weight and condition factor (K) ranged from 101-111mm, 10.6-15.1g and 0.98-1.12 respectively.
Note: 2005 and 2006 were excluded due to a sample size of 1 in those years and 2001 as it contained hatchery fish (Table 3).

There was a statistically significant observed difference in mean length of Chinook smolts between the sample years 2002, 2003 and 2007 through 2014 (ANOVA: $F_{(10)}$=5.691, P<0.001). Insufficient fish were sampled in 2004-2006 and 2001 data contained an unknown number of hatchery fish which leaves only 2 years of IFA affected years to compare with 7 WUP affected years; therefore no comparison was done. Fish were largest in 2014 and smallest in 2009.

3.2 Pink Fry

3.2.1 Pink fry Migration and Production

In 2014, a total of 25,387,473 (SD 314,061) Pink fry were estimated to have past the RSTs over the period February 18th to May 5th, 2014 (Figure 10). The migration started prior to the beginning of the mark recapture program as 671,415 fry (SD 19,613) were estimated in the first strata (February 18th to 24th). In the last strata ending May 5th 1.7 million fry (or 7% of the total migration) were estimated. A slight peak in abundance occurred in the week of April 8th to April 28th with a total of 11.6 million fry; 46% of the total migration was estimated (Figure 9).

In 2014 the migration curve was again uni-modal although it was flatter and broader. The peak of migration for Pink fry from 2002-2012, generally occurs between March 25th and April 15th (weekly strata

6-9) when on average 86% of the outmigration has occurred (Figure 9). In comparison this year's migration required 8 strata (March 4th to April 28th) for a contribution of 88% of the estimated abundance. Since the first year of Pink fry assessment in 2002 the estimated abundance in the first strata has increased from 46K to 671K in 2014 suggesting that a larger portion of fish are migrating prior to sampling commencing in mid-February. A similar increase in the last strata assessed of 19K to 1.7M indicates that a larger proportion of the migration continues after the drums are changed in early May. This is likely due to the 20-30 fold increase in Pink fry abundance over the course of the study.

When the migration timing for all years assessed is compared, 2012 appears to have an uncharacteristic upswing in migration in the last strata (Figure 9). The last strata in 2012 (week ending April 30th) represented 23% of the total abundance estimate of 29M fry. In all other years assessed (2002-2010 and 2014) this strata contributed on average 6% of the total population (range: 2-7%) of the total abundance estimate. Due to weather conditions in 2012 only one of the 7 days in the last strata was fished resulting in little confidence in the estimate for this particular week. The BTSPAS model has difficulty dealing with sparse data at the beginning or end of the migration curve likely biasing these strata high[1]. For these reasons the estimate for the last strata in 2012 was re-calculated using the average of 6% of the estimated population observed for all other years; this reduced the estimated migration from 6.7M to 1.3M fry in this strata. This re-calculation of the last strata results in a total abundance estimate of 24M for 2012.

There have been two IFA and four WUP estimates of Pink fry production over the study period 2002 to 2014. Average fry abundance over the years studied (2001-2014) was 8,504,908 (SD 261,813). Average abundances for IFA and WUP years were 686,706 (SD 158,767) and 14,368,560 (SD 257, 648), respectively. There has been a 2191% increase in Pink production from IFA and WUP affected years (Figure 10).

[1] Schwarz 2012 - The spline-based methods can deal with these strata in which no marks are released or recapture strat**a** 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).

Estimates of Pink fry production have been derived in all on-years since 2008 from Site F1 at the NVOS channel. The estimates range from 627,542 to 3,677,691 (Table 2). The 2014 estimate of 3,677,691 fry is the highest to date and is 18% higher than the estimate of 3,127,546 in 2012. Side channel estimates of Pink fry production for 2012 and 2014 were both 3 fold higher than the previous highest estimate of 1.2 million fry in 2008. In the past three on-years (2010-2014) that both mainstem and side-channel estimates have been calculated the estimated contribution from the NVOS channels has ranged from 10-14%. In 2008 the contribution was 57% (Table 2).

3.2.2 Pink Fry Length Data

Mean length for Pink fry sampled at the RSTs in even years from 2002 to 2014 ranged from 27-44mm, and the average length has been 34mm in all years except 2010 and 2014 when it was 33mm (Figure 11, Table 3).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 NVOS side channel traps.

There was a statistically significant observed difference in mean length of Pink fry between the seven years of capture (ANOVA: $F_{(6)}=21.4$, $P<0.001$); however the largest difference between annual mean length was 1.1mm and likely within the range of observer error excluding the need for further statistical tests.

3.3 Coho Smolts

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 production, i.e. limited outmigration occurs prior to the mark-recapture program commencing on April 1st and the majority of fish have migrated before trap operations are suspended in June. Prior to 2014, in all years of the study (2001-2013) an average 15% of the run has migrated by April 15th. The peak of migration generally occurs between May 1st and May 25th (weekly strata 11-14; generally in 3 strata) when an average 55% of the estimated abundance migrates. On average 90% of the fish have migrated by May 31st (Figure 12).

In comparison the 2014 migration curve appears to be begin earlier and is flatter than in previous years with more strata contributing to the total population (Figure 12). This year 2,668 smolts were captured between Feb 15th and 28th; with a total of 5,365 captured by March 31st. In comparison an average of 43 (range 0-127) have been captured in February and an average of 341 (range 45-1311) by March 31st in 2001 through 2013 (Table 4). In the first week of trapping (ending February 23rd) an estimated 11%

(12,709) of the total abundance was estimated to pass the trap, and by April 15th fifty percent of the estimated run had migrated. The migration did not have as defined a peak as in previous years with the peak of migration occurring between April 7th and May 11th (weekly strata 9-13; 5 strata) when 39% of the estimated abundance migrated. Similar to previous year's 99% of the fish had migrated by May 25th. Peak outmigration abundance occurred when average daily water temperatures reached 6.5^{0}C. Discharge does not appear to determine when migration occurs on this river.

Estimates of Coho smolt production from the Cheakamus River at the RST site have been calculated for every year of the study (2001-2014). In 2014 the estimated emigration was 119,815 (SD = 15,425). Estimated annual production of has varied from 60,686 smolts in 2009 to 118,161 smolts in 2003 excluding 2006 data (Table 2 and Figure 13). In 2006 the 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 seven WUP estimates of Coho smolt production. The 2006 & 2007 estimates have been excluded from the analysis of changes in abundance between IFA and WUP regimes. The 2006 estimate because the effects of the spill on this age class of Coho diminish the strength of the relationship between flow and abundance for this particular year and 2007 due to being partially affected by both flow regimes having been spawned (2005 brood year) and partially rearing under IFA conditions. Average abundance of IFA was 85,261 and 82,377 smolts in WUP years, this equates to an average change in abundance of 2,884 smolts or a 3 % decrease. The average estimated production for all years (2001 to 2014) was 81,159 SD = 9,635 (Table 2 and Figure 13). The 2014 estimate of 119,815 Coho smolts ranks highest during the years assessed; 2001-2014 (Table 2 and Figure 13).

Full trap counts of Coho smolt production from the NVOS side channels and BC Rail side channel (Site 1 & 4) have been produced in 2001 and 2009 through 2014. In 2014 23,072 Coho smolts were produced from these two channels representing 19% of the total production estimated at the RST site. The 2014 count ranks 2nd highest among years evaluated.

An average production of 17,808 smolts from the side channels, ranging from 8,691 to 24,137 has been observed in the years of evaluation. In the seven years that both mainstem estimates and side channel production have been calculated the contribution from the side channels has averaged 22% of the estimated Coho population. The largest contribution to the estimated population occurred in 2001 when 36% of the fish originated from the NVOS and BCR channels. Since 2009 the contribution of these two channels appears to be slightly less; ranging from 11-24% of the estimated upper river population (Table 2).

3.3.2 Coho Length and Age Data

Length frequency for all Coho smolts ($\geq$70mm) captured and sampled at the RST and side channel sites is uni-modal in all years (2001-2014) indicating that the majority of migrating smolts are 1+ with a small percentage of larger fish (likely 2+) (Figures 14). Coho scales have not been aged, but have been taken and archived.

Mean length, weight and condition factor (K) for Coho smolts in 2014 was 94 mm, 9.6g and 1.11 respectively. This falls within the range of all previous years sampled (2001-2013) when mean length, weight and condition factor (K) ranged from 86-95mm, 7.1-10.7g and 1.0-1.2 respectively (Table 3). Coho smolt length frequency in 2014 peaked between the 85 and 104 mm range, with a majority (64%) of the fish sampled falling within this range. The peak of Coho length in 2014 was similar to all other years (2001-2013) assessed when on average 66% of fish fell into the 80-99 mm range. There does not appear to be any detectable shift in the length frequency with 67% of smolts within the 80-99 mm size range during the IFA and 65% during the WUP (Figure 14).

There was a statistically significant observed difference in mean length of Coho smolts between the fourteen sample years 2001 to 2014 (ANOVA: $F_{(13)}=156$, $P<0.001$). The largest smolts were observed in 2005 and 2010, with the smallest in 2012. Statistical tests revealed no significant difference in the variance (F test: $F_{(5,6)}=0.4206$, $P= 0.3603$) or mean lengths (T test equal variance: $t_{(10.3)}= 1.4564$, $P=0.175$) of IFA and WUP affected Coho smolts.

3.4 Steelhead

3.4.1 Steelhead Smolt Migration and Production

Estimates of Steelhead smolt (aged 2 to 4 years) population abundance have been calculated in ten of the fourteen study years; 2001-2003 and 2008-2014. In 2004 through 2007 insufficient 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 in 8 of the 10 years a downward trend in abundance is observed before trap operations are suspended in June. Two years (2003 and 2009) have an upward trend in strata estimates at the end of the sampling period. The BTSPAS model has difficulty dealing with this type of data, so the final strata estimates, which were the largest in the study, likely bias the estimate high[2]. This is particularly troublesome when sparse data occur in these strata. For example the last strata (week ending June 8th) in 2003 had no captures or recaptures and the last two strata in 2009 had few marks (23) and no recaptures and 1 capture respectively.

Steelhead smolt migration has generally started in the week of April 15th to 22nd (weekly strata 10) in the 8 years of the study when a migration curve was evident (2001-2002, 2008 and 2010-2014) on average 7% of the run have migrated by the third week of April. The peak of migration generally occurs between May 5th and May 20th (weekly strata 12-14) when on average 53% of the estimated abundance migrates. On average 90% of the run has migrated by May 31st (Figure 15).

In 2014 the migration timing was similar to previous years; however, a higher number of Steelhead were estimated to have past the trap in the first week of trapping than in any previous year of the study. In the first strata of this year (February 16th to February 23rd) 124 Steelhead smolts migrated past the RSTs, the

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[2] Schwarz 2012 - The spline-based methods can deal with these strata in which no marks are released or recapture strat**a** 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).

previous highest catch for the same strata across all other study years was 34 in 2002. The bulk of the migration commenced in mid-April with the 15% point in the migration reached by April 20th. The peak of migration occurred between April 28th and May 18th (Strata 12-15) when 59% of the estimated migration occurred. By June 1st, 97% of the fish had migrated (Figure 15). As in other study years, peak outmigration occurred when average daily water temperatures reached 7^0 C. Discharge does not appear to determine when migration occurs (Figure 15).

Estimated production of Steelhead smolts from the mainstem have been calculated in 10 years of the study with two of those years appearing to be biased high by inaccurate estimates of late migration strata as described above. In an effort to compare annual abundance of Steelhead smolt migration from 2003 and 2009 with the other seven years where the migration curve trended downward at the end of the study sample period we undertook two adjustments. First we removed strata data calculated for dates ending after May 31st as these appeared un-realistically high. Then we expanded the partial BTSPAS estimate by 10% as in years where a complete estimate was derived approximately 10% of the Steelhead out-migration was derived annually from these later strata. This resulted in a comparative estimated Steelhead smolt abundance in 2003 of 8,516 fish and in 2009 of 7,197 fish, rather than the estimates of 63,591 and 11,088 respectively when the final strata in 2003 and 2009 are included.

Steelhead smolt estimated abundance has ranged from an estimated abundance of 2,208 to 14,223 (including adjusted BTSPAS estimates in 2003 and 2009). The average estimate of abundance of all years assessed (2001-2003, 2008-2014) is 7,182. Large variances in production of Steelhead is likely related to the 2003 flood and the 2005 spill and are evident in the estimates derived in years following the events (2004-2007) when very few smolts were captured (range 9-21). This resulted in no abundance estimates being calculated for these Cohorts (Table 2 and Figure 16).

There have been three IFA and seven WUP estimates of Steelhead smolt production. In addition, to the years (2004-2007) where no abundance estimate was calculated the 2008 estimate has been excluded from analysis of changes in abundance (IFA vs. WUP) due to being partially affected by both flow regimes having 3+ smolts rearing under IFA conditions. Average IFA and WUP abundance was 7,311 and 6,914 smolts respectively. This equates to an average change in abundance of fish of -396 fish or a decrease of 5%. The 2014 estimate of 10,107 Steelhead smolts ranks 2nd highest during the years assessed (Table 2 and Figure 16).

Full trap counts of Steelhead smolt production from the NVOS side channels and BC Rail side channel (Site 1 & 4) have been produced in 2001 and 2009 through 2014 with an average production of 180 smolts, ranging from 35 to 403. In 2014, 100 Steelhead smolts were produced from these two channels. The 2014 estimate ranks 13th among the fourteen years evaluated.

In the seven years that both mainstem estimates and side-channel production have been calculated the contribution from the side channels has averaged 3% (1-6%) of the estimated Steelhead population (Table 2).

3.4.2 Steelhead Parr

The Steelhead parr (1+) population is not estimated as it is assumed that these fish are not actively migrating from freshwater during the spring migration. The range of fish captured at the RSTs between 2001 and 2013 was 6 to 1012. The range for parr captured in the NVOS side channels from 2008 to 2013 was 113 to 1635. In 2014 3,585 Steelhead parr were captured at the RSTs and 2,223 in the side channels, this ranks 1st amongst all years of the study for both sites (Table 2).

3.4.3 Steelhead Length and Age Data

Mean length, weight and condition factor (K) for Steelhead smolts in 2014 was 178mm, 61.6g and 1.02 respectively. This is similar to the range of all previous years sampled (2001-2013) when mean length, weight and condition factor (K) ranged from 162-177mm, 50.2-69.0g and 1.0-1.1 respectively (Table 3). In 2014 the length frequency for all Steelhead juveniles captured at the RST and side channels was bi-modal with the first mode falling between the 70 and 114 mm range (age-1 parr) representing 75% of the fish sampled, and a smaller mode 150-200 mm (age 2 through 4 year old smolts) representing 7% of the fish sampled (Figure 17).

There was a statistically significant observed difference in mean length of Steelhead smolts between the fourteen sample years 2001 to 2014 (ANOVA: $F_{(13)}=3.616$, $P<0.001$). The largest smolts were observed in 2002 and 2014, with smallest in 2004. A statistical test was conducted to compare the mean lengths of Steelhead smolts between IFA and WUP affected years, which had equal variance (F test: $F_{(5,6)}=2.0786$, $P=0.3991$), but no statistically significant difference was evident (T test equal variance: $t_{(8.7)}=0.2777$, $P=0.7877$).

3.5 Biophysical Monitoring

Discharge (measured at WSC 08GA043) at the Cheakamus River near Brackendale (Figure 2) ranged from an average daily value of 16.50 to 116.03 m^3sec^{-1} over the period February 15th to June 15th, 2014 (Figure 18).

Average daily water temperature at the RST data logger (Figure 2) during the juvenile migration period of Feb 15th to June 15th, 2014 ranged from 2.09 to 10.9 ^{0}C (Figure 19).

4.0 Discussion

The primary goal of this study is to evaluate changes to the productivity of salmonid juveniles in the Cheakamus River in response to the change in flow regime as created by the Water Use Plan. The CC evaluated the fish habitat modeling work (Cheakamus WUP, FTC, 2001, Marmorek and Parnell 2002) which indicated that there should be no net loss of habitat during the WUP compared to the IFA. Given the no net change in habitat, it was assumed that fish production would also remain unaffected and that no greater than a 25% reduction (or for that matter increase) in fish production should occur (Marmorek and Parnell 2002).

In September 2012 the CC was presented with a summary of data and analyses on juvenile population estimates from 2001 through 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 yet required to evaluate a statistical variance between treatments. The CC recommendation was that this study (Monitor 1a) should be continued for a further five years with annual reporting on fish production until 2017 when further statistical analysis will be undertaken to assess the effects of the flow change on productivity.

Based on juvenile data collected from the RST site at RK 5.5, there is an indication of moderate to large increases in mean out-migrant population size in three of the six species/age classes studied in the 7 years since the WUP was implemented compared to the IFA affected years. These changes ranged from 25% in Chum fry, 30% for 0+ Chinook fry and a nearly 2200% increase in Pink fry abundance. Coho smolts indicated a slight decrease in average annual production of 3% (2006 data excluded due to caustic soda spill). Steelhead trout smolts annual production decreased by 5% when using the adjusted estimates in 2003 and 2009; however, pre WUP data are limited to three years. No comparison of Chinook smolt (1+) abundance was attempted due to only calculating population abundance in four of the thirteen years of study.

Data in 2014 as in all other years of the study indicate that for Chinook salmon the juvenile outmigrant population is annually dominated by 14-60[3] day out migrants and that yearling smolts numerically represent typically less than 5% of the estimated juvenile migrants. Thus the population can be characterized as predominantly ocean rearing. The 2014 abundance estimate for fry (YOY) is the lowest on record by nearly 50%. Migration timing in 2014 followed the pattern of a number of the years where an unknown portion of the population had out migrated prior to sampling being underway (i.e. 2003, 2005, and 2010). Unless trapping were to start earlier in February it is not possible to ascertain how much of the total population migrates prior to commencement of the study. Reasons for the observed variance in fry outmigration timing are most likely related to spawning timing and associated ATU's on egg incubation which may be affected by river discharge (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, 2009), the impacts of the CN caustic soda spill fish mortality (McCubbing at el 2006), changes in the hatchery program intensity and methods (DFO data on file), increases in Pink salmon abundance, and the effect of the 2003, 1 in 50 year flood are all likely contributing to the high variance observed in Chinook productivity.

Pink salmon fry numbers have increased dramatically over the seven years they have been assessed. The Cheakamus River exhibits an "on year" of Pink juveniles in years with even numbers (i.e. 2008, 2010) and has virtually no Pink salmon production in odd numbered years. Over the course of the assessment although peak migration has increased in size, it still occurs over the same 3 week period extending from April 1st to April 21st. As the abundance of fry has increased, for the last two "on years" (2012 and 2014) indicate that the "tails" of the migration curve are lengthening beyond the bounds of the mark-recapture program resulting in a greater proportion of the population migrating at these times. Over the previous six years (2002-2012) studied an average of 3% of the total estimated fry have been observed in the first two strata assessed suggesting the migration has always commenced prior to the mark recapture program but at low rates; however as the population grows the number of early migrants is increasing with 6% of the population migrating in the first two strata in 2014. During the end of the migration in 2012 and 2014 the final strata contributed 6% (1.3 million) and 7% (1.7 million) of the total estimate whereas in the previous years (2002-2010) the contribution of the final strata averaged a 2% contribution.

Pink salmon fry production on the Cheakamus has increased by 2200% since the study began. The 2014 estimate of 25 million Pink fry is ranked highest of all years assessed. As pink salmon juveniles do not rear in the river presumably changes in discharge would be most manifest on spawner and incubation

[3] Referring to the number of days from emergence at which fry begin downstream movement

habitat. Adult spawners return to the river in August and September (McCubbing 2005) and spawn in the same months, although there is anecdotal evidence that indicate that the timing of spawning like migration is also broadening with more fish spawning earlier in August and continuing into early October in 2013 (C. Fell pers. comm.). With the large abundance of fry emergence commenced in January (C. Melville, EM Report, 2014) in 2014 and a larger portion of the migration now continues into early May. Current discharge practices clearly allow sufficient fry to be produced in the upper river for a potentially very large number of returning adult spawners; 1% marine survival of 2014 fry outmigrants from above the RST site would result in excess of 200,000 returning adults in 2015. This indicates that factors outside the freshwater environment are driving the increase in pink abundance. The high variation of spawner numbers typically associated with pink salmon (Beamish 2012, Irvine and Fukuwaka 2011), is a function of small changes in marine survival on very high numbers of juveniles (Beamish 2012).

With the higher spawning densities and longer spawning, incubation and migration period observed in 2013-2014 to ensure that redd stranding is minimized the chosen date of discharge ramp down from 38 m^3s to 20 m^3s should occur in early August prior to the majority of spawning occurring. Within the WUP there is the option to maintain higher flows for other water users during the August 16th to 31st period, but this may extend into the pink spawning period and could result in a significant amount of redd stranding (Fell et al 2012). Additional studies on redd stranding in 2015, a potential high adult escapement year are perhaps warranted.

Productivity of Coho smolts on the Cheakamus with the exception of the spill effected 2006 migration has been relatively stable (SD=25%) with only a slight decrease in productivity observed between IFA and WUP years. The 2014 estimate of 119K was the highest on record by 1%, with the 2003 estimate of 118K ranked 2nd.

While abundance of Coho smolts in 2014 was not considerably larger than the 2003 estimate, migration timing was unique compared to previous years. Prior to 2014, Coho smolt migration has followed the timing pattern observed at other study sites where full river fences or partial traps have been operated in British Columbia (McCubbing and Johnston 2012, Ladell and McCubbing 2011) with peak smolt outmigration occurring in May and tailing off by the middle of June. In 2014 the migration pattern differed from previous years with 11% of total annual abundance estimated to pass the trap in the first strata (February 17th to 23rd). The early abundance continued through March as 50% of the total estimated production had migrated by April 15th. Over the previous 13 years of the study the first strata has typically produced between 0.12% and 3.7% of the total estimate and only 15% of the run migrated prior to April 15th. In addition to the early abundance of Coho in the first strata there was a slight but broad peak in smolt abundance between April 7th and May 11th when a lower proportion of the population migrated then during this time period in previous years.

As many Coho salmon juveniles are known to rear in the river for at least one year (some fish migrate as YOY or 2 year olds (Bennet et al 2014, Nordholm 2014, DFO unpublished data) we may expect that migration timing is not driven by spawning and incubation timing but other environmental factors (Spence and Dick 2013). The winter of 2013/ 2014 was uncharacteristically dry with few high flow events which may have influenced migration timing. Growth rate, which would likely have been effected by the abundance of Pink fry and associated nutrients from adult spawners in the fall/ winter of 2013-2014, has been linked to migration timing in several studies of juvenile salmonids (Okland et al. 1993, Beckmam et al. 1998; Quinn 2005). An extension of a fall/ winter emigration could also partially explain the early abundance and resulting flatter migration curve in 2014 for Coho juveniles. Significant fall/ winter emigrations (equal to or great than spring abundances) of Coho smolts, parr, and fry have recently been documented in several coastal Oregon and Washington between October and January (Bennet et al 2014, Jones et al 2014, Nordholm 2014). Winter emigration is suspected to be driven by several factors including food availability, growth rate, and flow conditions (Bennet et al 2014, Nordholm 2014). Continued monitoring during years of large Pink abundance and varying flow conditions will aid in expounding the effects of flow and Pink salmon abundance on juvenile Coho productivity and migration timing.

An additional goal of this study is to establish the relationship between mainstem and side channel production 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 releases, estimates from this off channel habitat have had broad confidence limits on alternate mark recapture estimates surrounding the releases. Therefore, it is only possible to evaluate in part the importance of the side-channels. The channels which we have sampled consistently are clearly significant contributors, with 14-24% of the total RST estimate being derived from the two channels sampled (BC Rail and NVOS) since 2009. The estimate of 23,072 smolts for 2014 was on the higher end of the observed output from the NVOS and BC Rail channels, representing 19% of the total estimate. Overall, side channel production has remained relatively consistent since 2009 with 14-24% of the total estimate being derived from these two channels.

Steelhead smolt migration has generally followed the timing pattern observed at 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 outmigration occurring in May. In general the entire sampling period has been captured throughout the study. The 2014 estimate was the second highest estimate generated (the lowest being 2012) since the study commenced. The 2014 catch of Steelhead parr in at the RSTs was 3.5 times the previously highest catch. In addition since 2010, Steelhead parr survival in "on years" for Pink salmon has been double that of "off years". Further discussion on Steelhead production numbers can be found in Korman & Schick, 2014.

5.0 Summary

The data collected from 2001-2014 indicate that ongoing juvenile production studies can be used to establish the potential linkages between discharge and salmonid productivity on the Cheakamus River but that without corroborative adult/hatchery 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, the additional data being collected should within 5 years allow for assessment of the likelihood of statistically greater variance than 50% in smolt production which is less than the CC originally intended (25%).

The expanded life history studies on Steelhead trout and to a lesser extent on Chum salmon will provide a more confident evaluation of the changes in watershed production and how these may relate to discharge, although some questions may remain un-answered. In these cases the data collected in this study will perform a supporting role to better analyze the effects of flow on productivity in 2017.

The linkage between side channel production and mainstem production 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 production 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 in its entirety. For Chum fry production, it was recently identified that an estimate from Tenderfoot Creek is required to better establish this linkage (McCubbing et al. 2012). This year provides the second of these estimates and this work will be continued through 2017.

A relationship between Pink salmon abundance and the migration timing and productivity of several other species of salmon may be emerging in the Cheakamus River. The early abundance of Coho and Steelhead smolts in 2014 as well as the less defined peak of migration for Coho smolts may be a response to Pink fry abundance. Preliminary data also suggest increases in steelhead parr (1+) abundance and survival due to the large fry abundance (Korman & Schick, 2014). More years of data with large Pink returns are necessary to strengthen these relationships between these species.

6.0 TABLES

Table 1. Summary of size ranges for age classes of salmonid and trout species 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 (Feb-April)	0+ (YOY)	CHF	< 80mm	Cheakamus length frequency data (2000-2006)
Chinook Smolts	1+	CHS	>90mm	Cheakamus length frequency data (2000-2006)

Table 2. Fourteen-year summary (2001-2014) of fish caught and marked at the rotary screw trap and side-channels on the Cheakamus River. Bold = WUP estimates
Relative sd. >0.3 = Poor precision.

Species	**Year**	**Total Caught**	**Total Marked**	**Total Recap**	**BTSPAS EST.**	**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	n/a	n/a	n/a	n/a	n/a
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 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**					

Table 2. continued

Species	Year	Total Caught	Total Marked	Total Recap	BTSPAS EST.	SD.	Rel. SD
RST Pink Fry	2001[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	2002	27,038	5,301	113	1,673,795	286,619	0.17
RST Pink Fry	2003[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	2004	2,742	1,415	53	82,834	13,474	0.16
RST Pink Fry	2005[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	2006	41,336	10,870	1,567	303,488	9,817	0.03
RST Pink Fry	2007[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	**2008**	**41,873**	**19,291**	**848**	**2,060,948**	**89,979**	**0.04**
RST Pink Fry	2009[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	**2010**	**238,730**	**57,124**	**3,942**	**6,157,377**	**606,896**	**0.1**
RST Pink Fry	2011[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	**2012**	**1,447,749**	**91,694**	**6,964**	**23,686,442**	**630,824**	**0.03**
RST Pink Fry	2013[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	**2014**	**1,900,820**	**115,073**	**10,923**	**25,387,473**	**314,061**	**0.01**
SC Pink Fry	**2008**	**36,066**	**26,084**	**867**	**1,172,050**	**43,524**	**0.04**
SC Pink Fry	2009[1]	n/a	n/a	n/a	n/a	n/a	n/a
SC Pink Fry	**2010**	**35,946**	**31,330**	**2,197**	**627,542**	**16,615**	**0.03**
SC Pink Fry	2011[1]	n/a	n/a	n/a	n/a	n/a	n/a
SC Pink Fry	**2012**	**246,536**	**84,937**	**7,892**	**3,127,546**	**41,406**	**0.01**
SC Pink Fry	2013[1]	n/a	n/a	n/a	n/a	n/a	n/a
SC Pink Fry	**2014**	**258,658**	**39,469**	**3,057**	**3,677,691**	**74,065**	**0.02**

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

Table 2. continued

Species	Year	Total Caught	Total Marked	Total Recap	BTSPAS EST.	SD.	Rel. SD
RST Steelhead Smolt	2001	231	162	14	6,101	8,726	1.4
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	1.0
RST Steelhead Smolt	2004	9	n/a	n/a	n/a	n/a	n/a
RST Steelhead Smolt	2005	21	n/a	n/a	n/a	n/a	n/a
RST Steelhead Smolt	2006	5	n/a	n/a	n/a	n/a	n/a
RST Steelhead Smolt	2007	20	n/a	n/a	n/a	n/a	n/a
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**
SC Steelhead Smolt	2001	151	n/a	n/a	n/a	n/a	n/a
SC Steelhead Smolt	2009	403	n/a	n/a	n/a	n/a	n/a
SC Steelhead Smolt	2010	217	n/a	n/a	n/a	n/a	n/a
SC Steelhead Smolt	2011	153	n/a	n/a	n/a	n/a	n/a
SC Steelhead Smolt	2012	35	n/a	n/a	n/a	n/a	n/a
SC Steelhead Smolt	2013	132	n/a	n/a	n/a	n/a	n/a
SC Steelhead Smolt	2014	93	n/a	n/a	n/a	n/a	n/a

Table 2. continued

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

Table 2. continued

Species	Year	Total Caught	Total Marked	Total Recap	BTSPAS EST.	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**
SC Coho Smolt	2001	26,828	n/a	n/a	n/a	n/a	n/a
SC Coho Smolt	2009	13,437	n/a	n/a	n/a	n/a	n/a
SC Coho Smolt	2010	24,408	n/a	n/a	n/a	n/a	n/a
SC Coho Smolt	2011	8,691	n/a	n/a	n/a	n/a	n/a
SC Coho Smolt	2012	12,799	n/a	n/a	n/a	n/a	n/a
SC Coho Smolt	2013	15,420	n/a	n/a	n/a	n/a	n/a
SC Coho Smolt	2014	23,072	n/a	n/a	n/a	n/a	n/a

Table 3. Summary of mean fry lengths (mm) 2001-2014 from the Cheakamus River.

Species	**Year**	**N**	**Mean Length**	**Range**
Chinook Fry	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	**167**	**39.5**	**33-76**

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

Table 3. continued

Species	Year	N	Mean Length	Mean Weight	Mean K
Chinook Smolts	2001[1]	n/a	n/a	n/a	n/a
	2002	24	109	14.9	1.12
	2003	13	111	12.0	1.06
	2004	0	n/a	n/a	n/a
	2005	1	103	n/a	n/a
	2006	1	80	5.4	1.05
	2007	30	109	15.1	1.11
	2008	**35**	**103**	**12.2**	**1.08**
	2009	**210**	**101**	**10.6**	**1.01**
	2010	**60**	**106**	**12.5**	**0.98**
	2011	**56**	**107**	**13.5**	**1.07**
	2012	**36**	**103**	**12.7**	**1.09**
	2013	**41**	**102**	**12.0**	**1.10**
	2014	**20**	**117**	**20.9**	**1.15**

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
Steelhead Smolts	2001	179	175	69.0	1.0
	2002	136	176	56.3	1.0
	2003	193	174	59.0	1.0
	2004	27	162	n/a	n/a
	2005	60	176	66.2	1.1
	2006	23	177	58.9	1.0
	2007	50	172	54.4	1.0
	2008	192	170	52.1	1.0
	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**	**1.02**

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**

Table 3. continued

Species	Year	N	Mean Length	Mean Weight	Mean K
Coho Smolts	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
	2008	**845**	**90**	**8.4**	**1.1**
	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**	**1.15**
	2014	**3671**	**94**	**9.6**	**1.11**

Table 4. Catch of Coho smolts at Cheakamus River Rotary Screw traps for February, as well as February and March combined over the period of 2001 to 2014.

Year	February	February & March	Comments
2001	0	105	
2002	0	157	
2003	0	466	
2004	5	2	flood effect
2005	0	45	
2006	12	0	spill effect
2007	8	159	
2008	44	161	
2009	92	253	
2010	54	236	
2011	127	398	
2012	92	1,311	high Pink fry abundance
2013	56	457	
2014	2,668	5,365	high Pink fry abundance

7.0 FIGURES

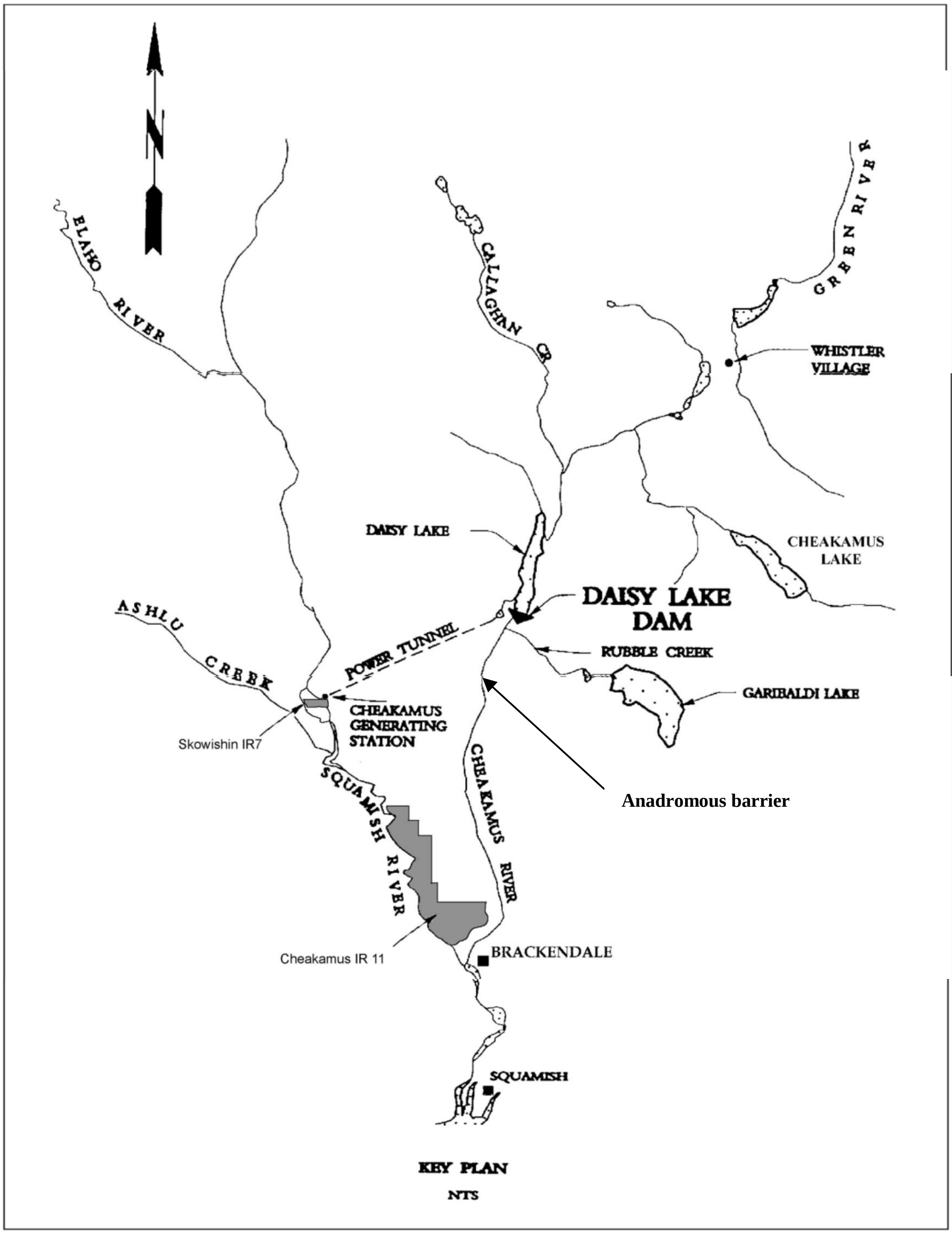

Figure 1. Map of Cheakamus Watershed indicating location of Daisy Dam and diversion tunnel.

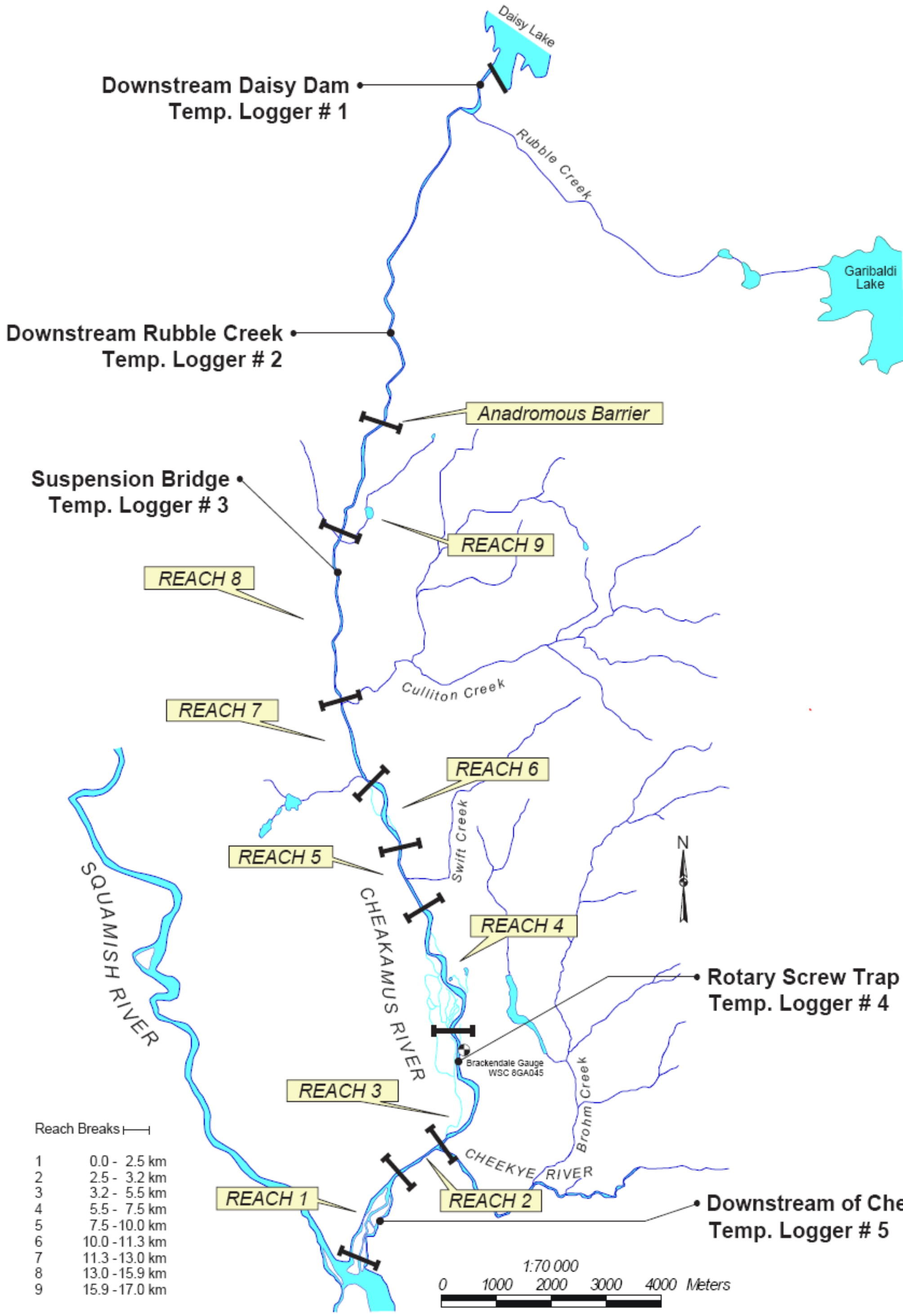

Figure 2. Cheakamus River watershed indicating Reaches 1 through 9, WSC gauging station, temperature loggers, and RST trap location.

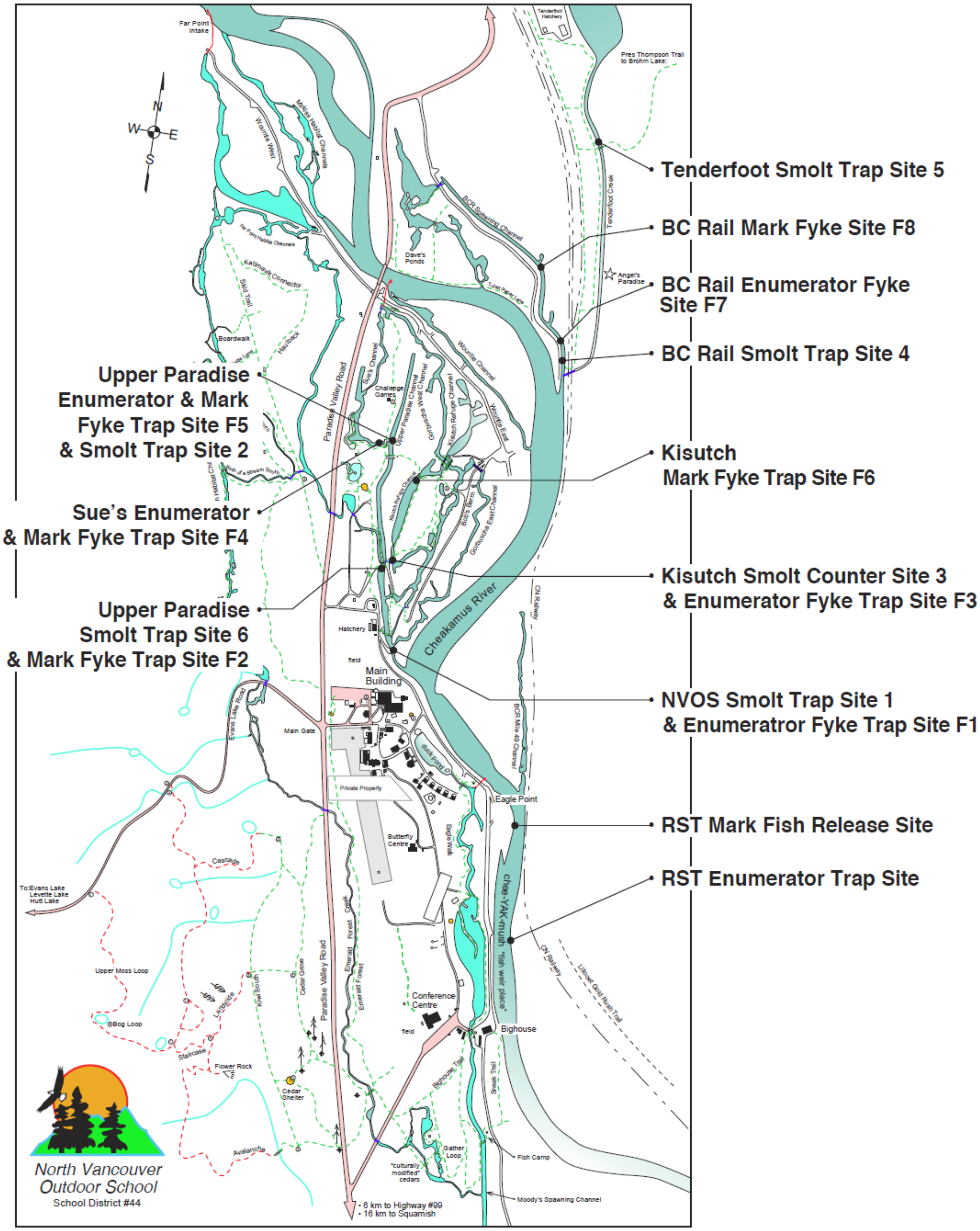

Figure 3. Site Map indicating trap sites utilized for the Cheakamus River Juvenile Outmigration Monitor 1a.

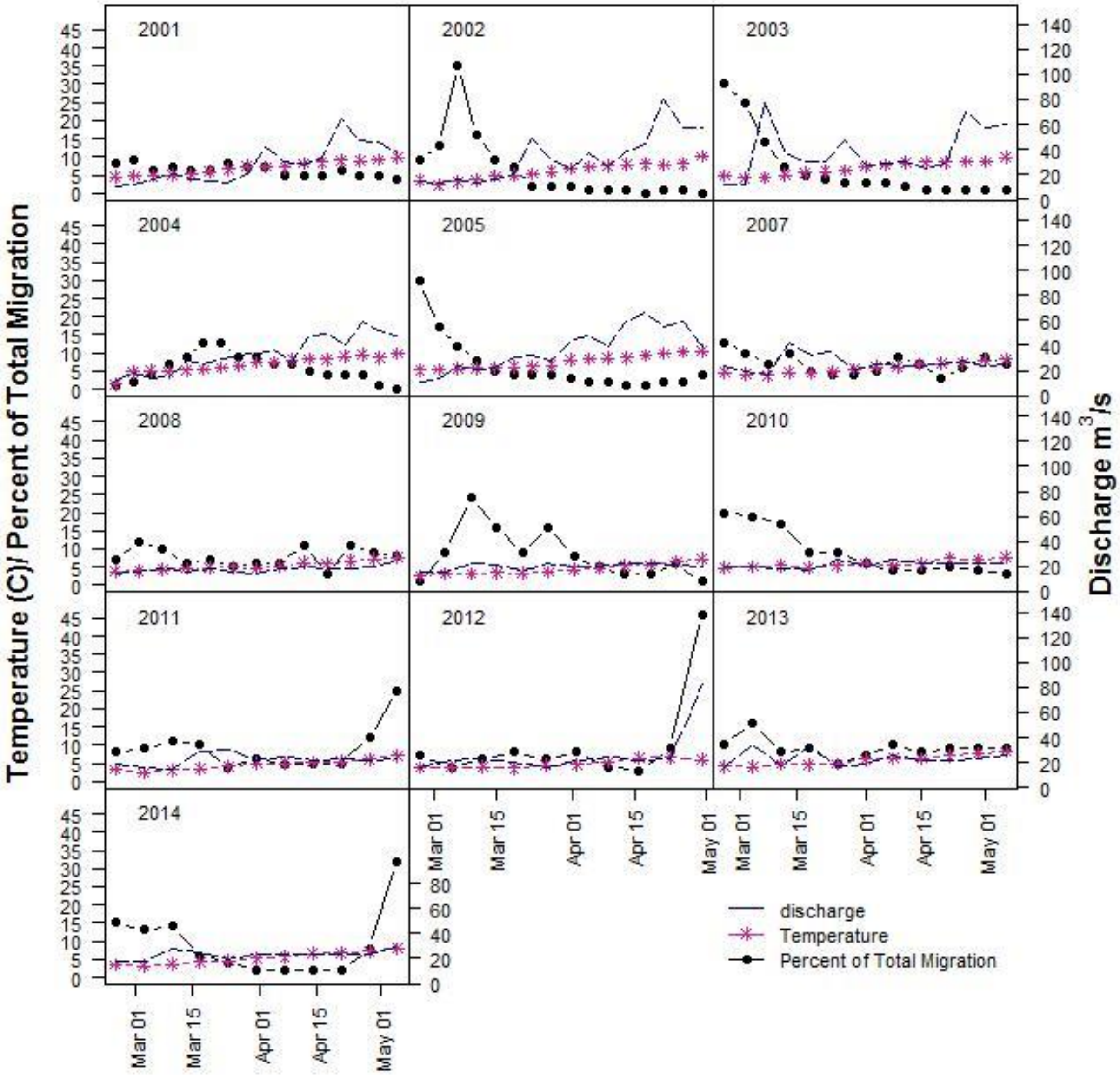

Figure 4. Weekly abundance estimates of Chinook fry related to temperature (^{0}C) and discharge (m^3/sec) from the Cheakamus River 2001-2014.

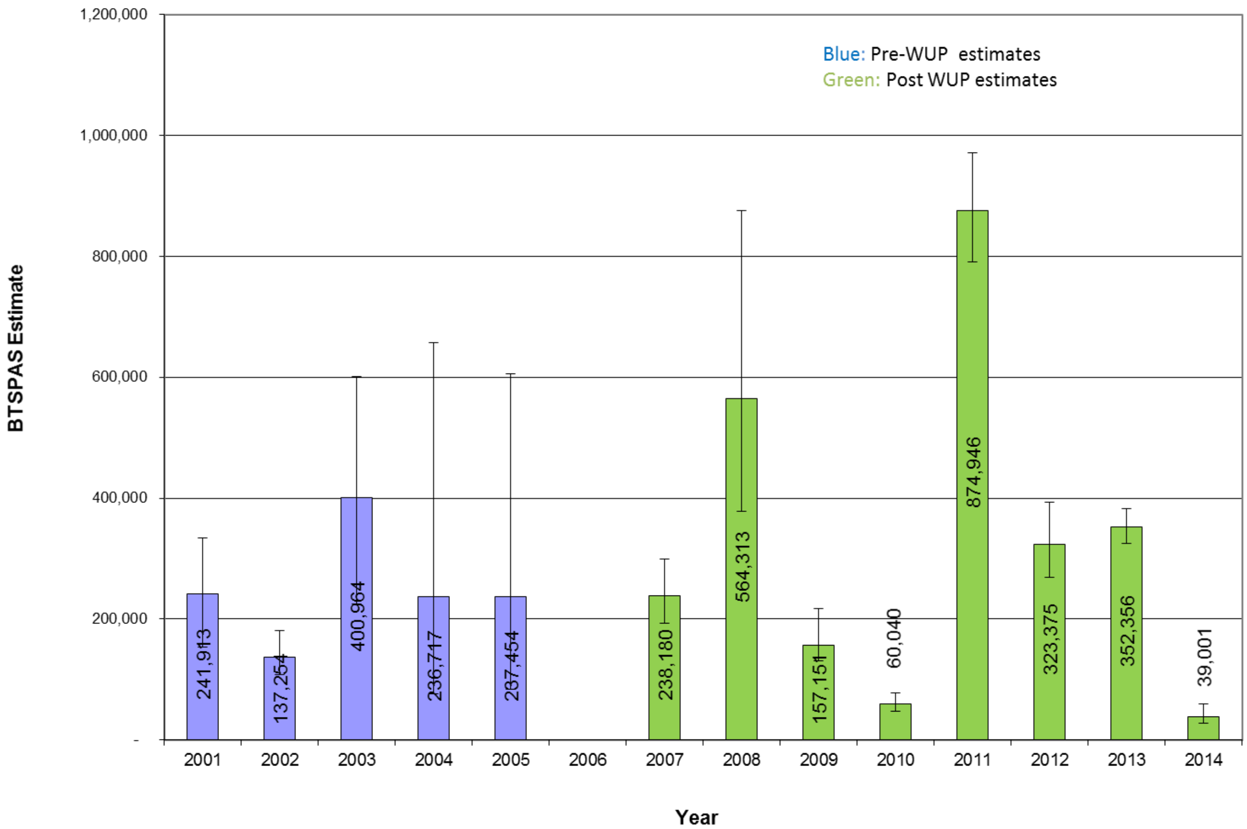

Figure 5. RST derived BTSPAS estimates of Chinook fry from spring 2001 to 2014, including 95% confidence limits.

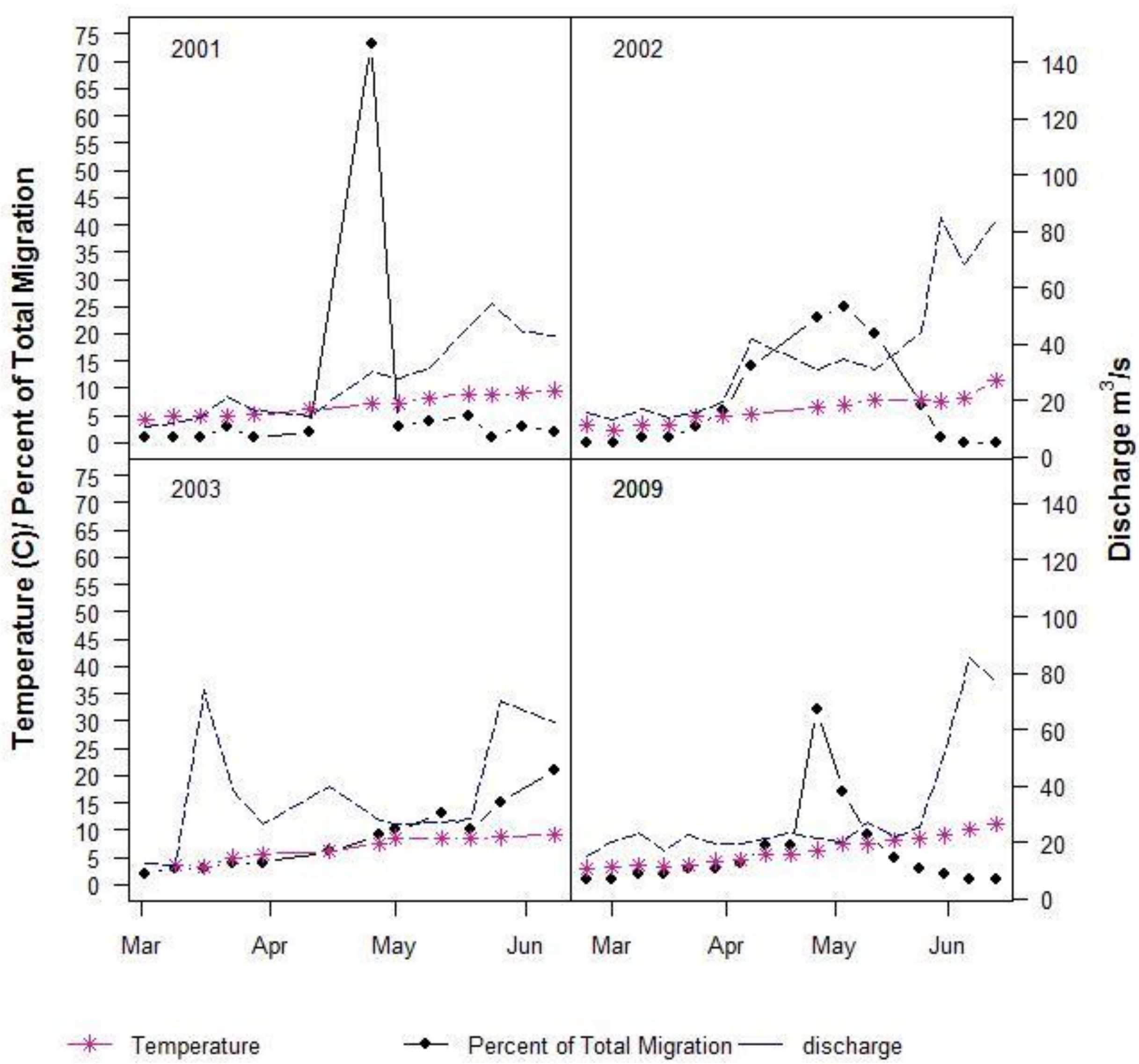

Figure 6. Weekly abundance estimates of Chinook smolts related to temperature (^{0}C) and discharge (m^3/sec) from the Cheakamus River.

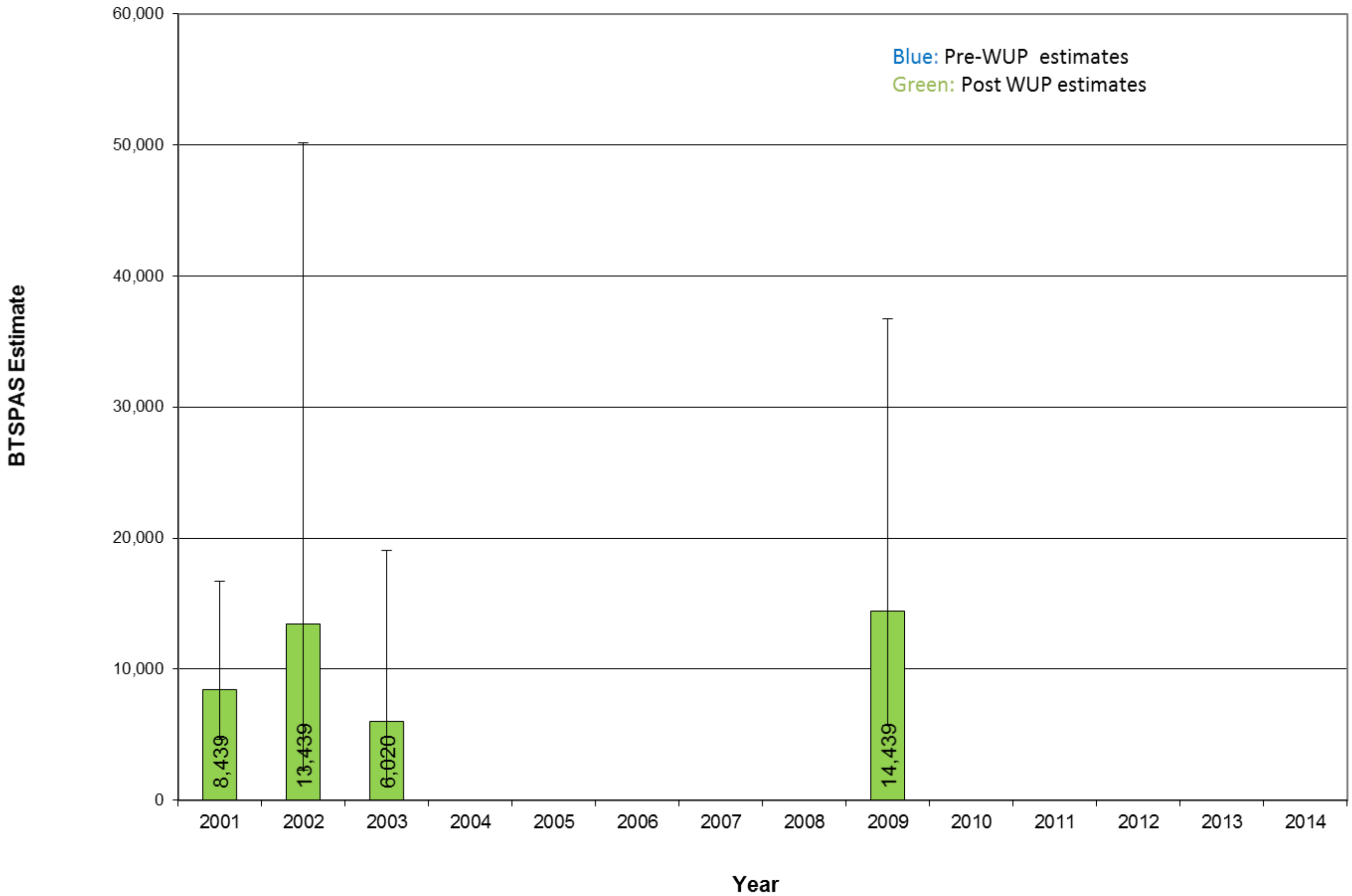

Figure 7. RST derived BTSPAS of Chinook smolts from spring 2001 to 2014, including 95% confidence limits.

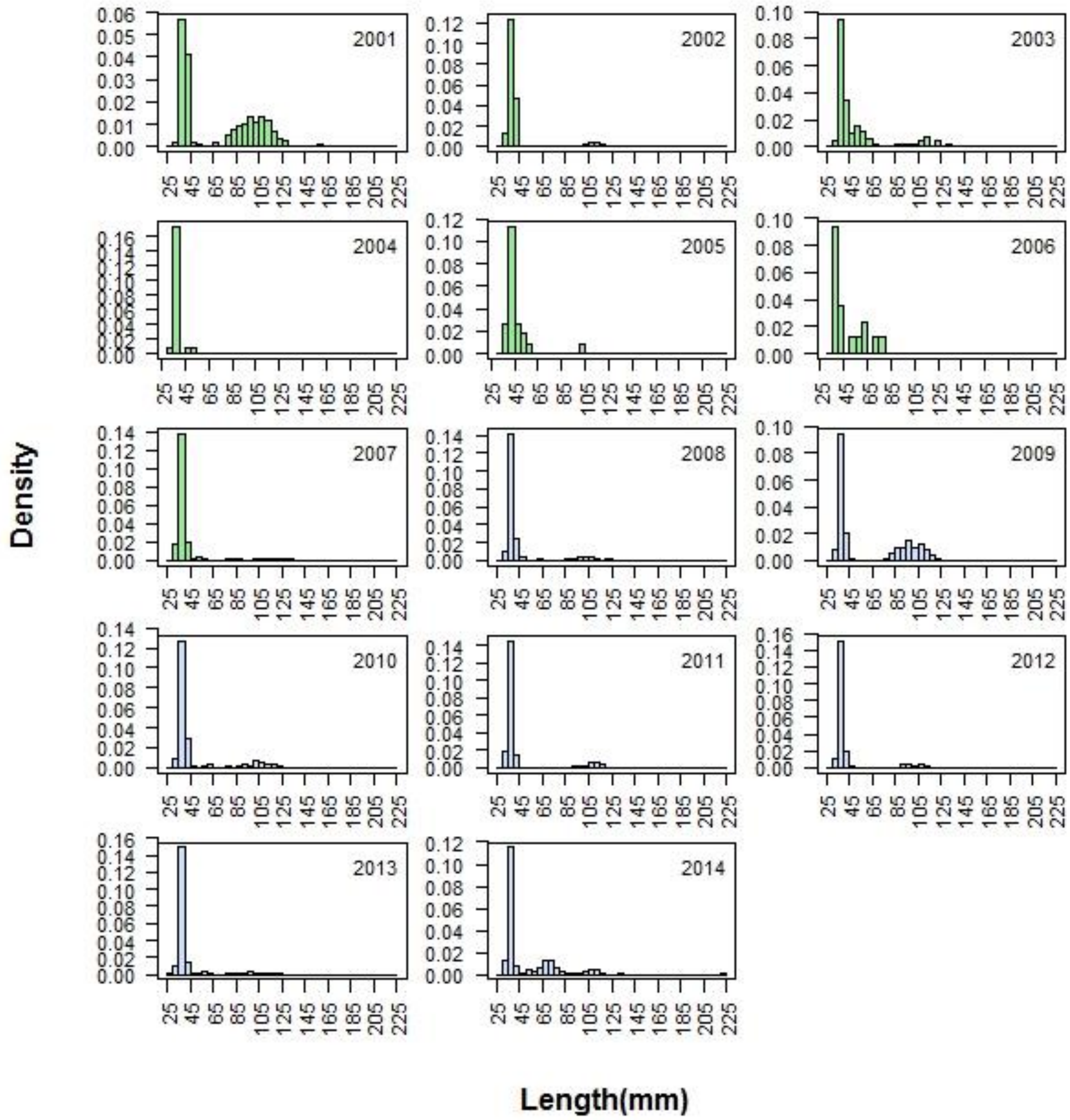

Figure 8. Distribution of fork lengths taken from Cheakamus River juvenile Chinook for both IFA (green) and WUP (blue) affected years.

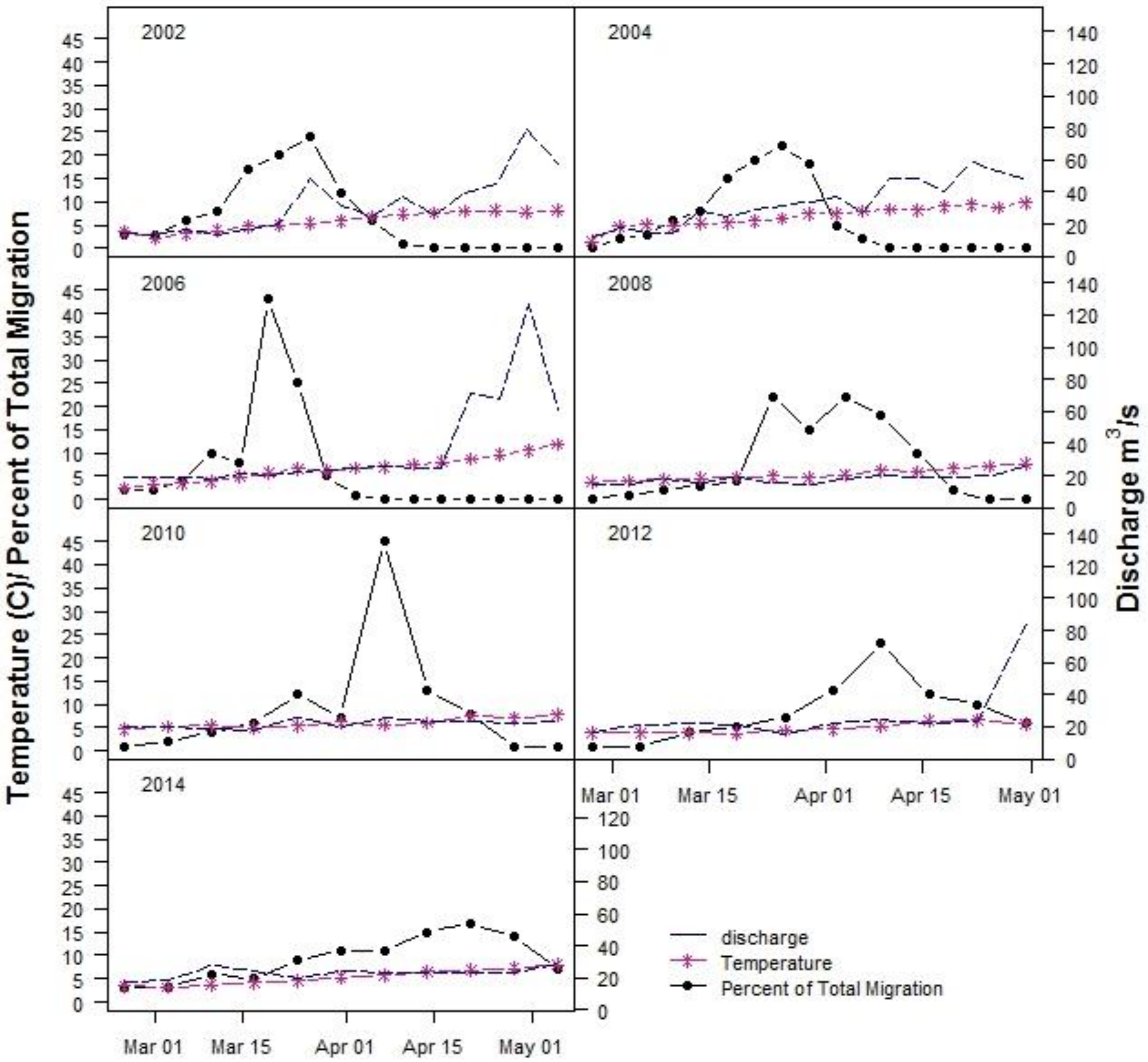

Figure 9. Weekly abundance estimates of Pink fry (solid line, circles) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

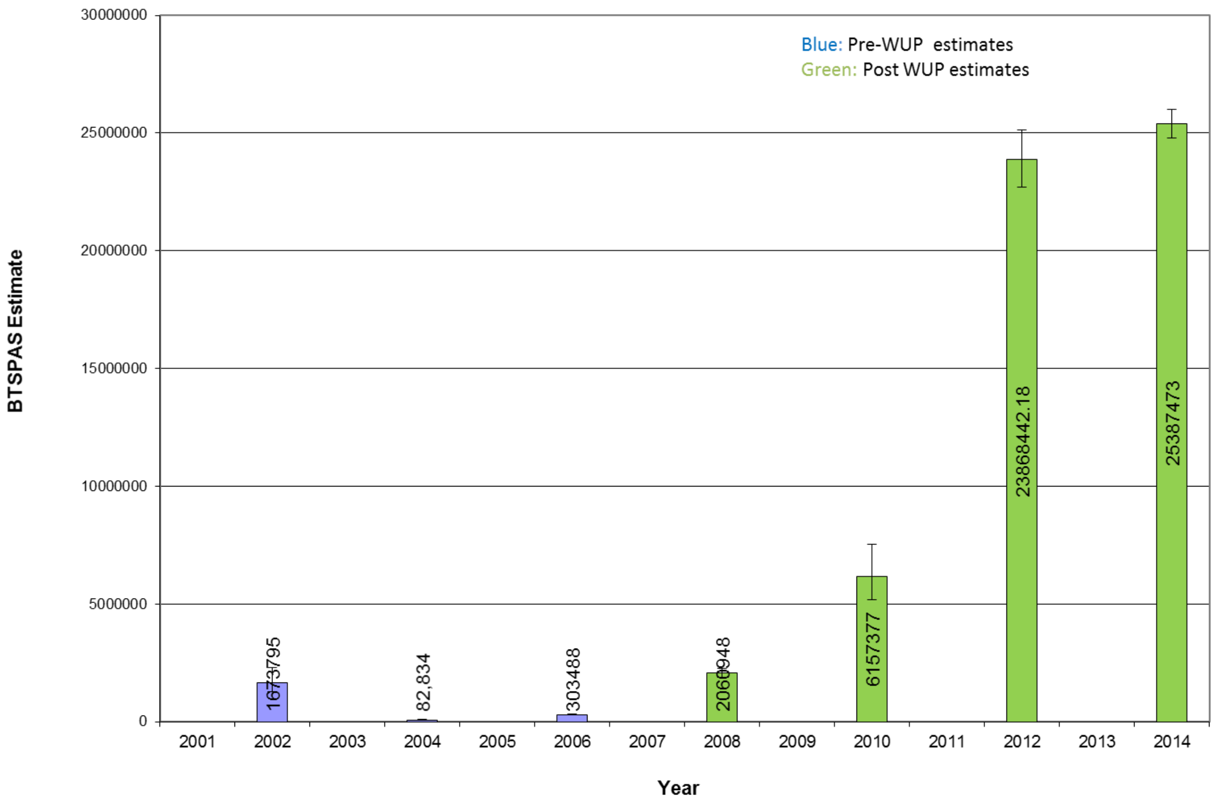

Figure 10. RST derived BTSPAS estimates of Pink fry from spring 2001 to 2014, including 95% confidence limits.

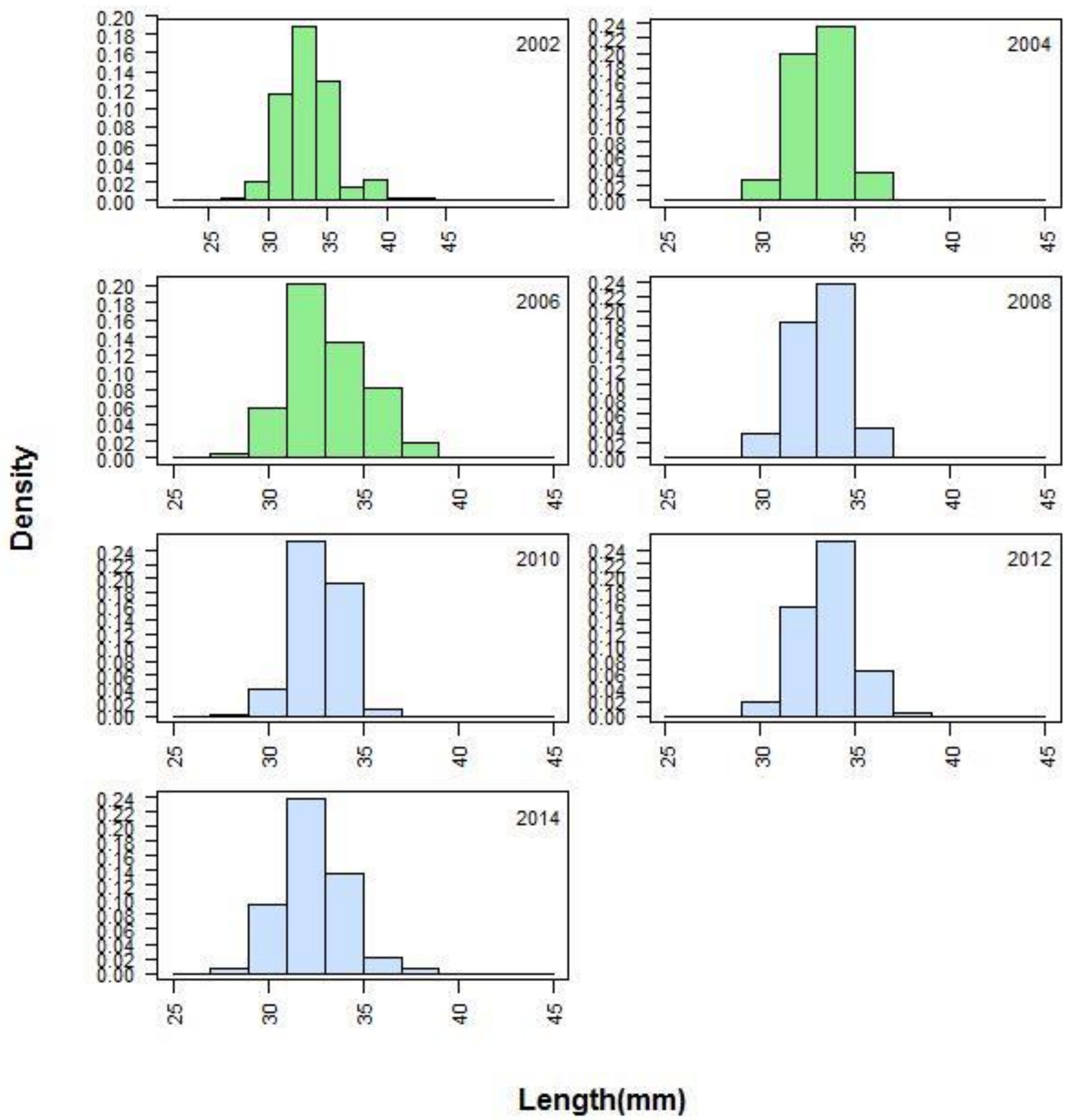

Figure 11. Distribution of fork lengths taken from Cheakamus River Pink fry for both IFA (green) and WUP (blue) affected years.

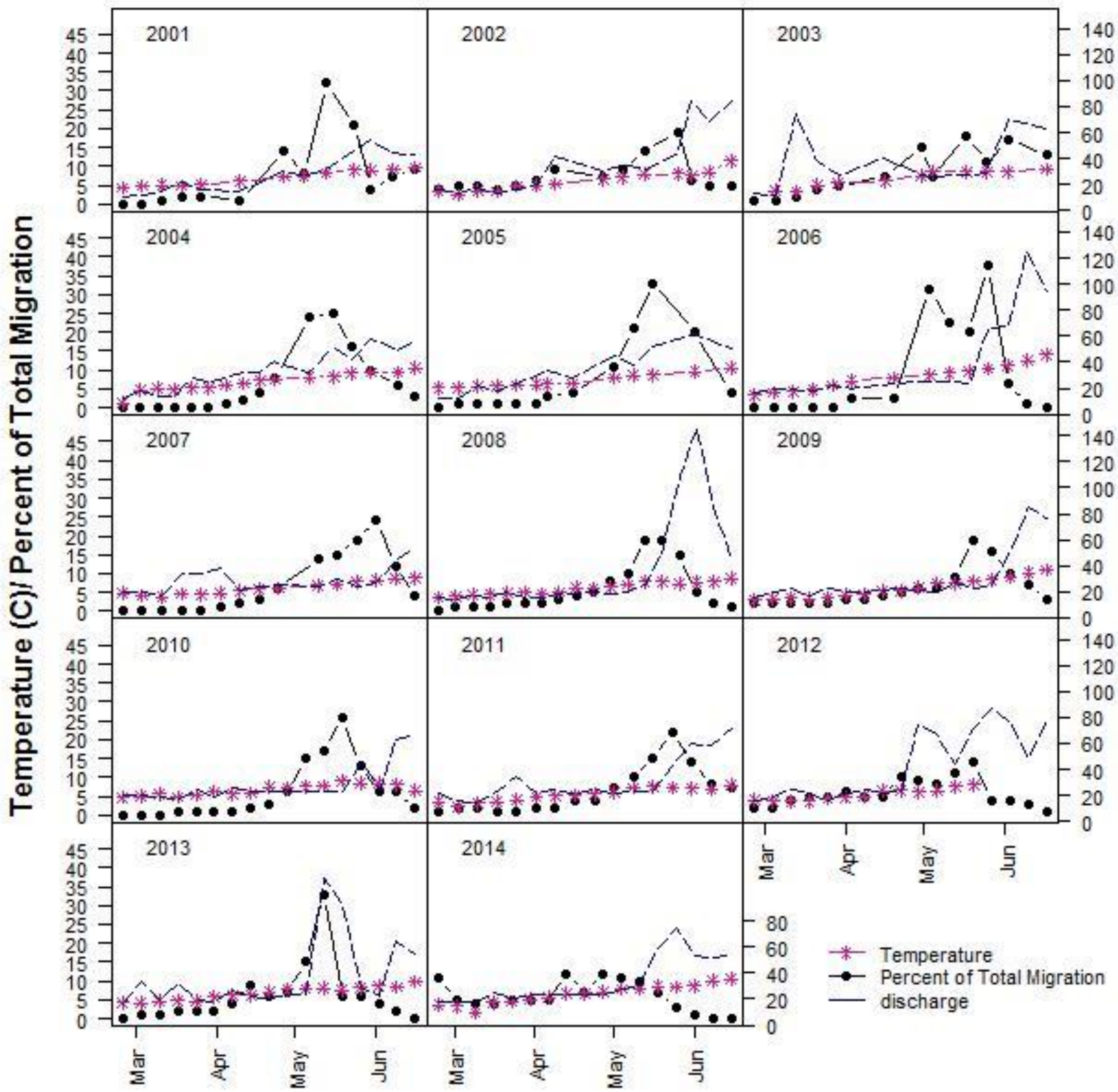

Figure 12. Weekly abundance estimates of Coho smolts (solid line, circles) related to temperature in ^{0}C (Pink asterisks) and discharge (dashed line) from the Cheakamus River.

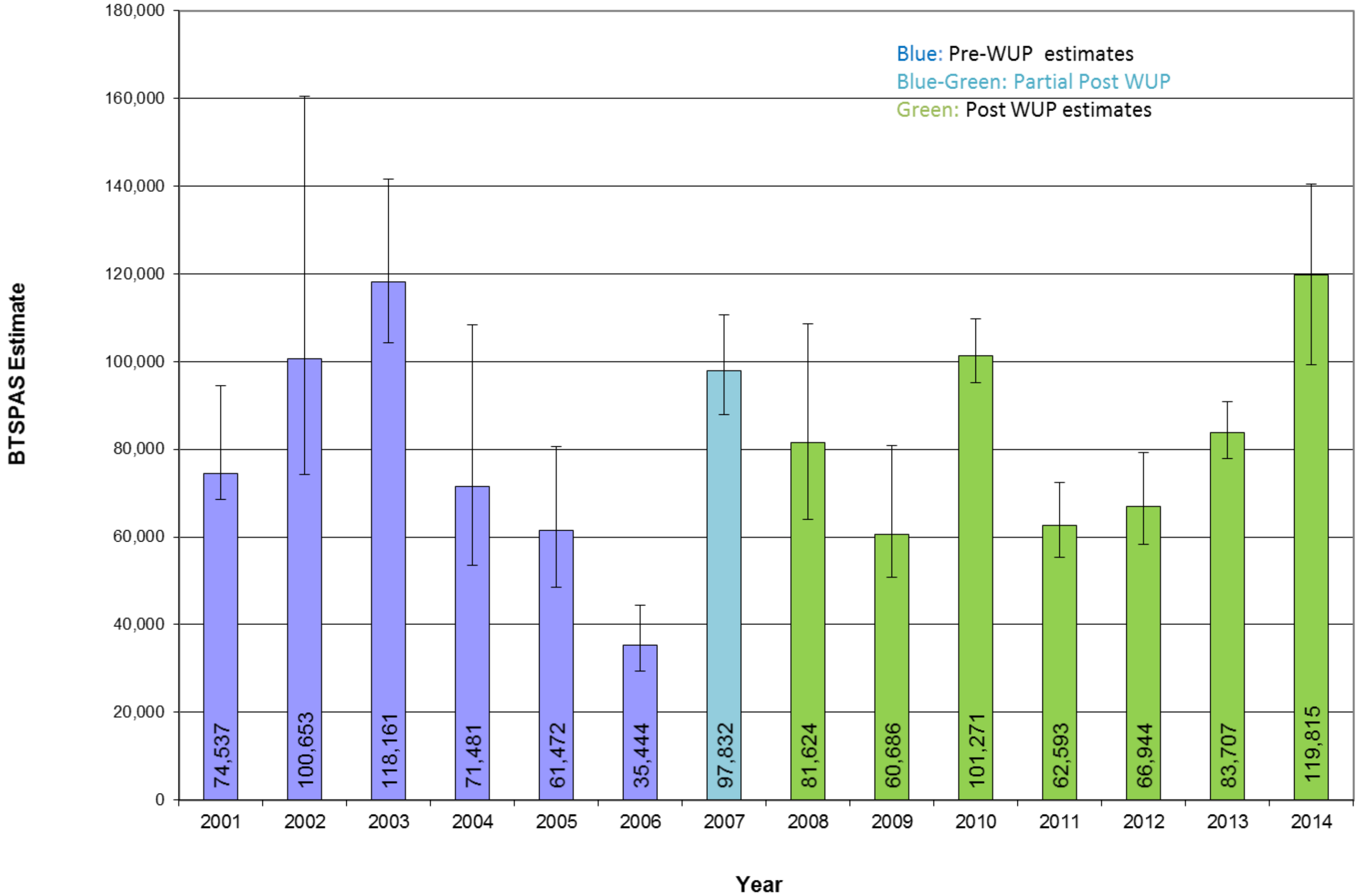

Figure 13. RST derived BTSPAS estimates of mainstem Coho smolts outmigration, from Spring 2001 to 2014

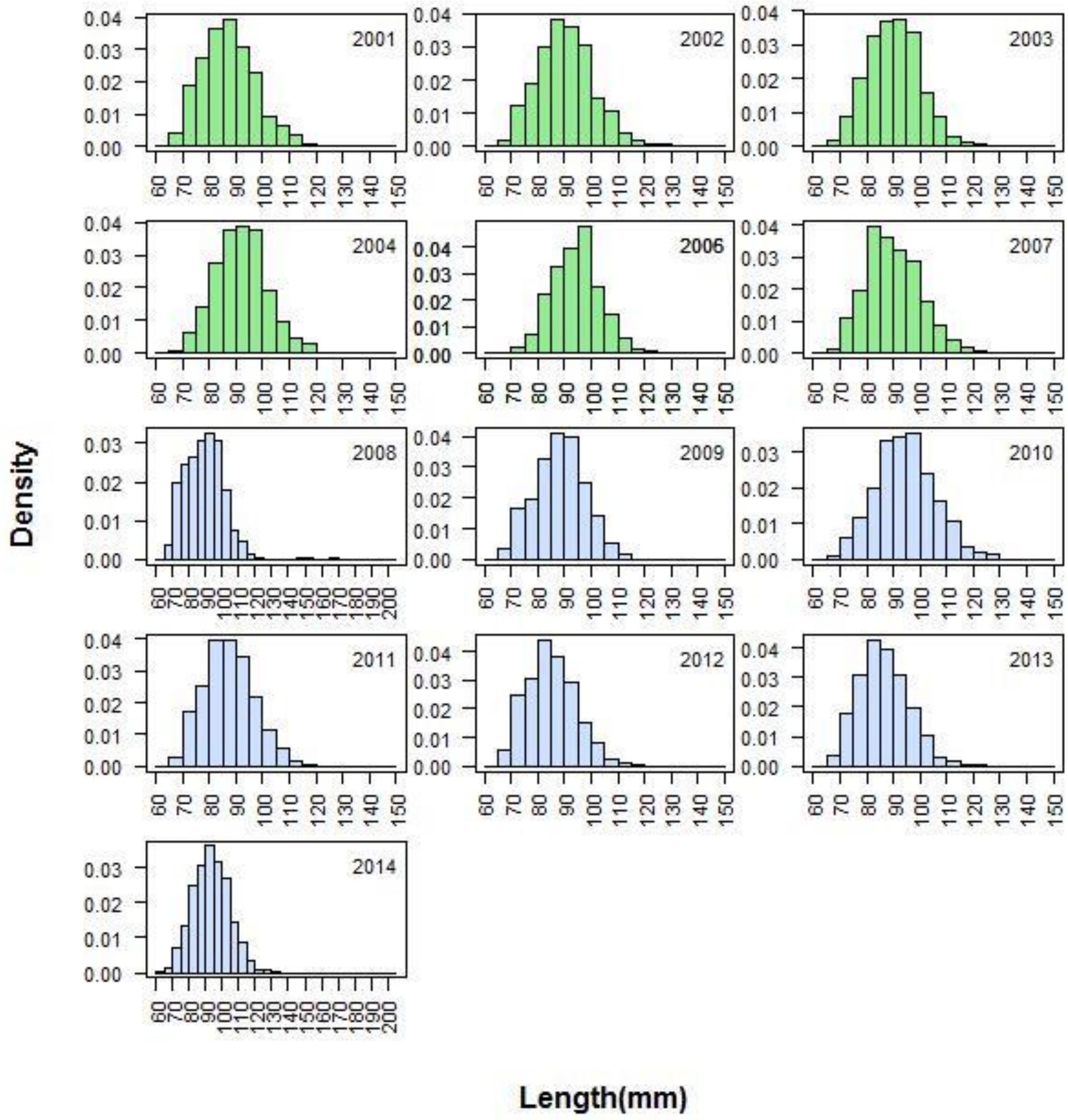

Figure 14. Distribution of fork lengths taken from Cheakamus River Coho smolts for both IFA(green) and WUP (blue) affected years.

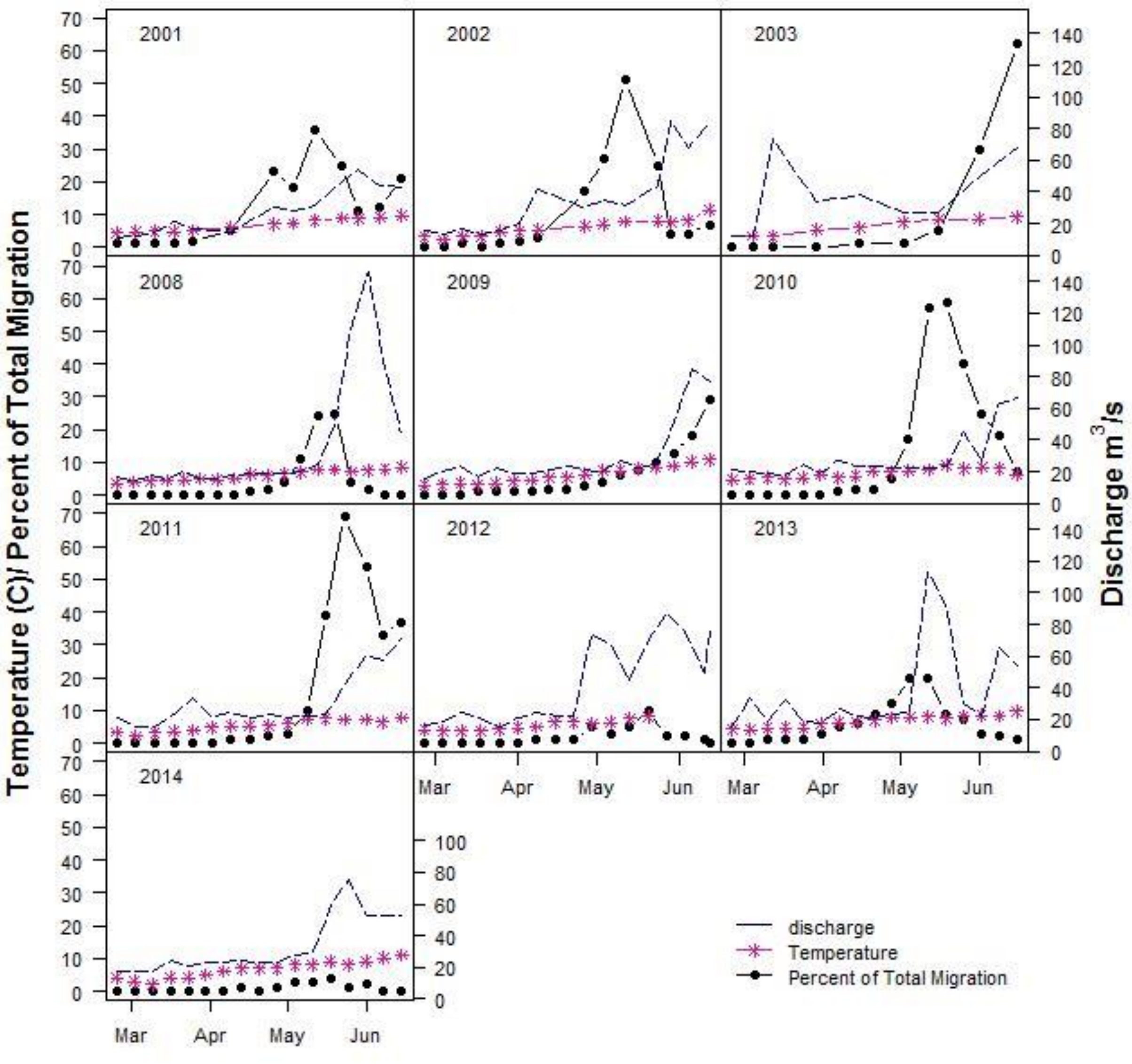

Figure 15. Weekly abundance estimates of Cheakamus River Steelhead smolts (black line, circles) related to temperature in ^{0}C (Pink asterisks) and discharge (blue).

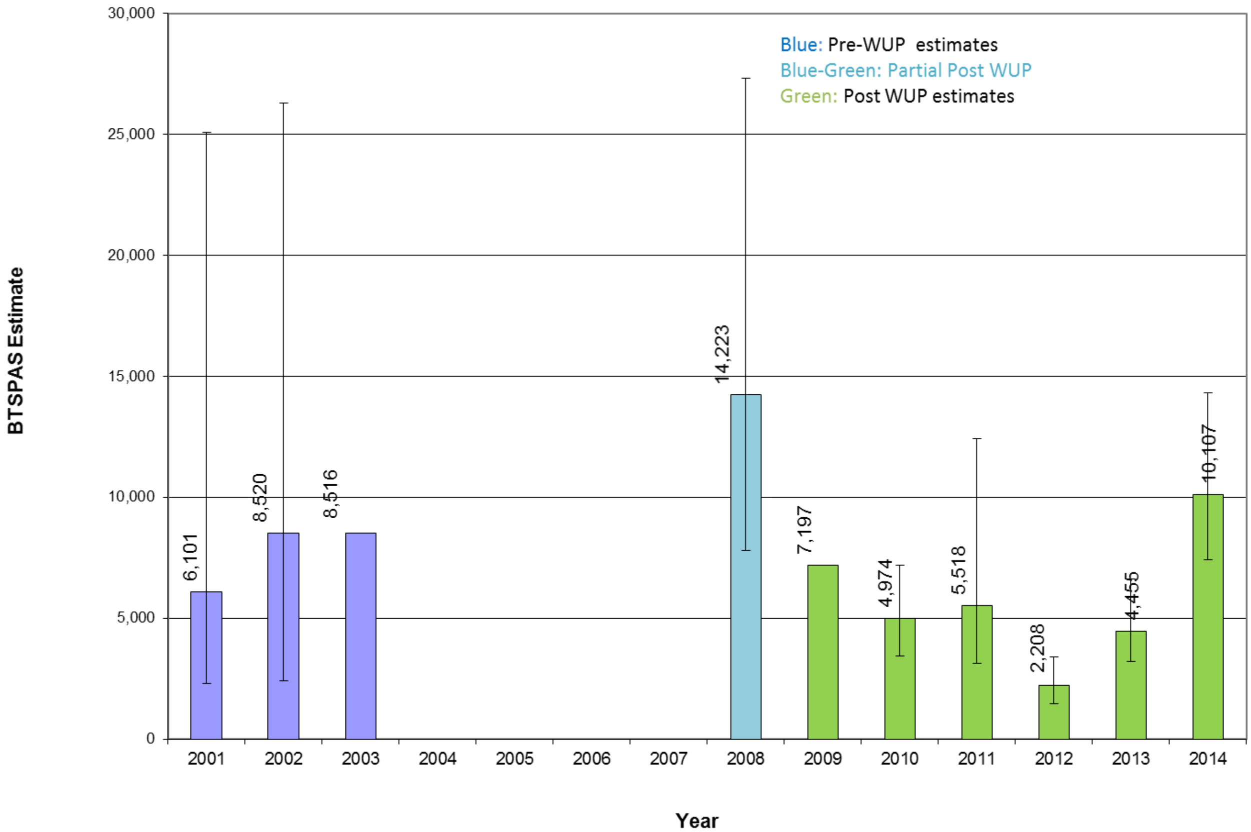

Figure 16. RST derived BTSPAS estimates of Steelhead smolts from spring 2001 to 2014, including 95% confidence limits.

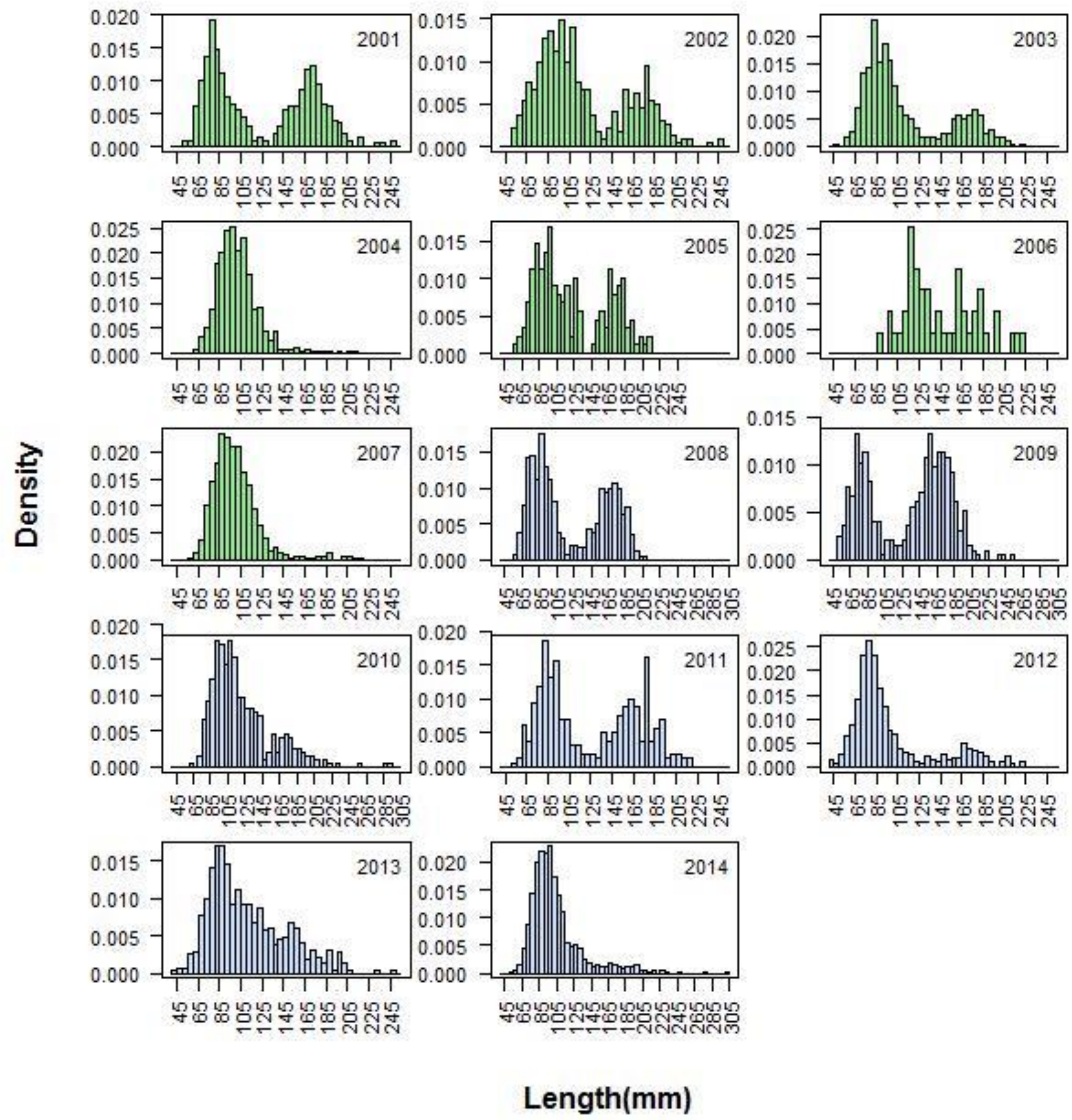

Figure 17. Distribution of fork lengths taken from Cheakamus River Steelhead juveniles for both IFA(green) and WUP (blue) affected years.

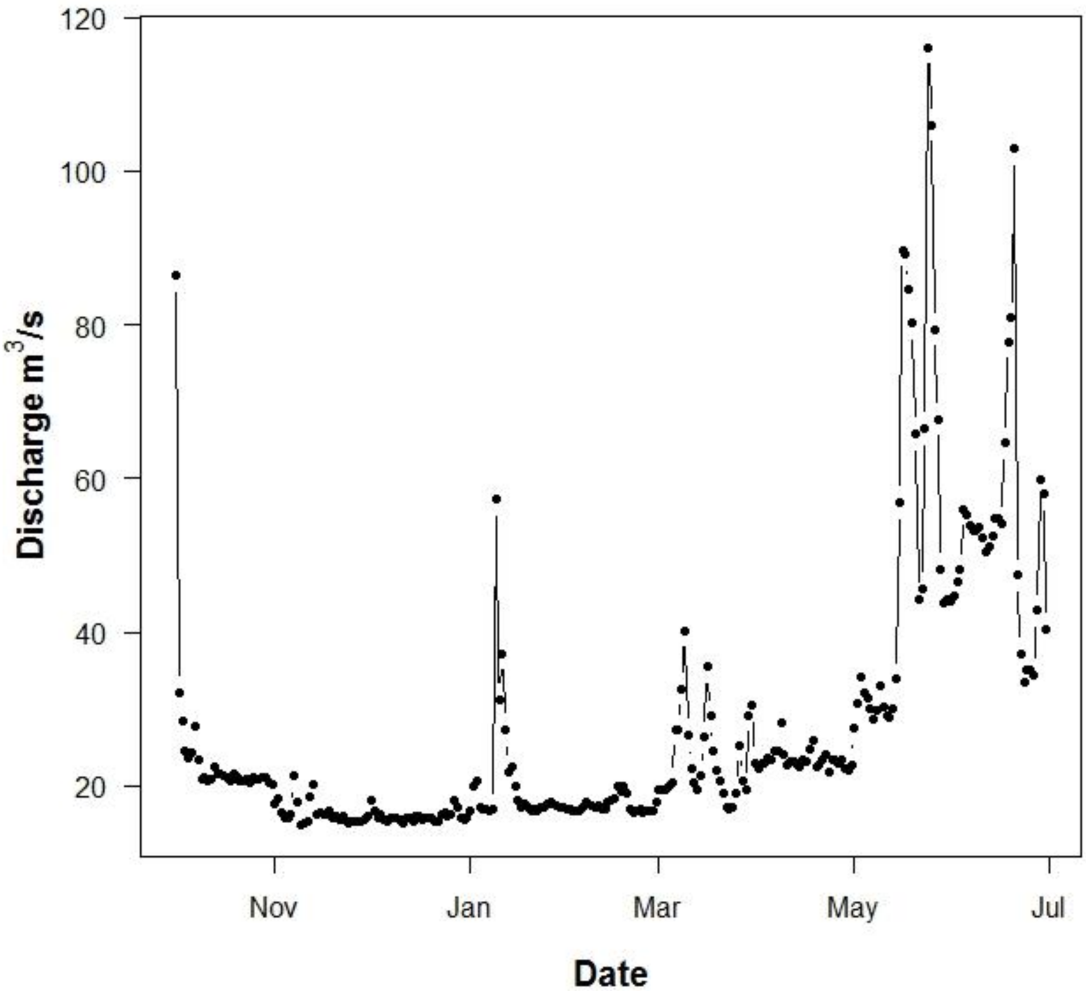

Figure 18. Mean daily discharges from Cheakamus at Brackendale WSC Gauge 08GA043, winter 2013- spring 2014.

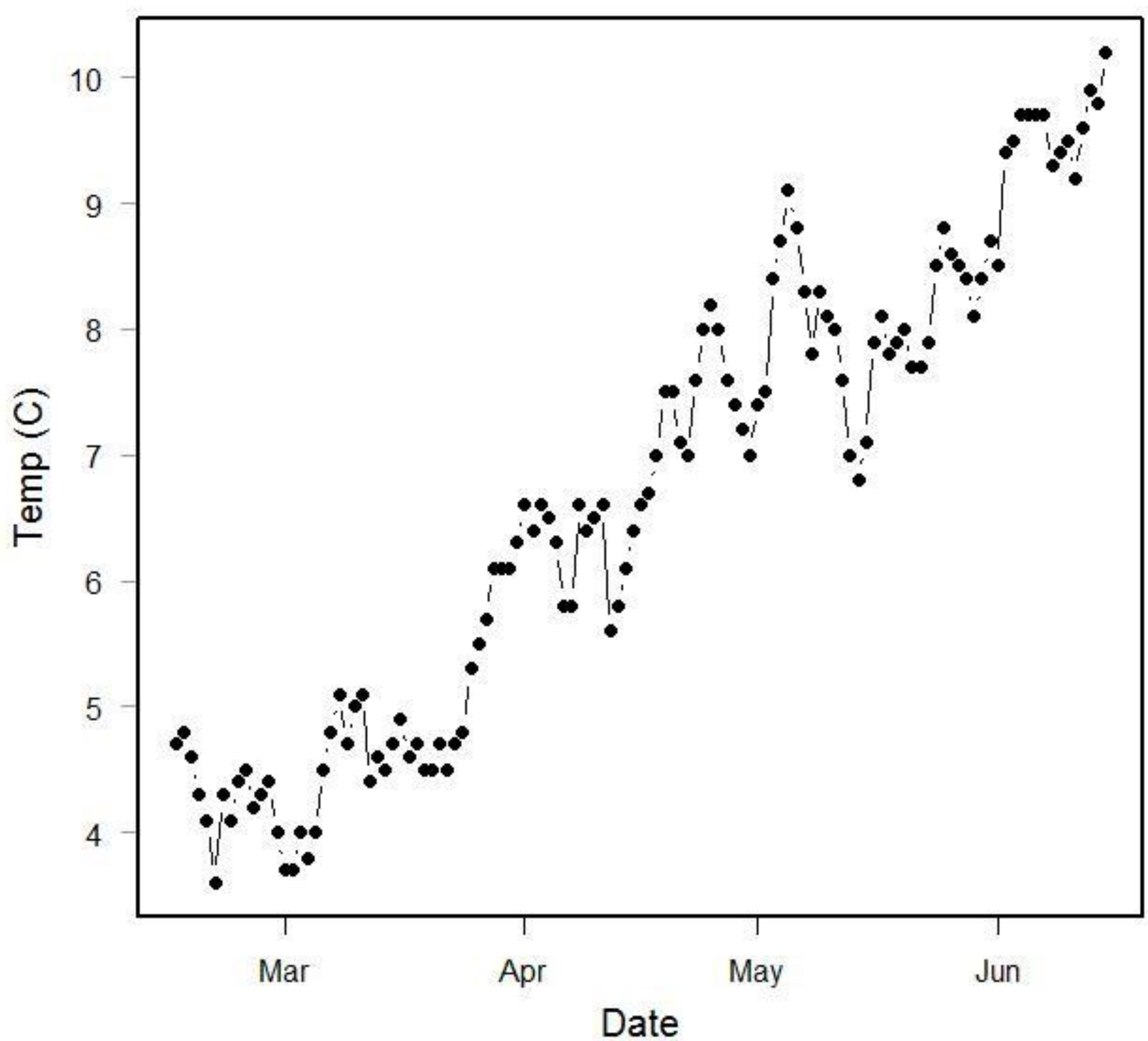

Figure 19. Mean daily temperature from Cheakamus River at the RST site, spring 2014.

8.0 GLOSSARY OF ABBREVIATIONS

BB: Bismark Brown Dye

BCR: BC Rail

CHF: Chinook Fry (< 90mm YOY)

CHS: Chinook Smolts ($\geq$ 90mm; 1+)

CMF: Chum Fry (YOY)

COS: Coho Smolts ($\geq$ 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

NVOS: 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 ($\geq$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: NVOS 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

NVOS: North Vancouver Outdoor School

VIE: Visible Elastomer Tag

WSC: Water Survey of Canada

WUP: Water Use Planning

YOY: young of the year

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