Cheakamus Project Water Use Plan

Cheakamus River Juvenile Outmigrant Enumeration

Implementation Year 6

Reference: CMSMON-1A

Cheakamus River Juvenile Salmonid Outmigration Enumeration Assessment Summary Report 2001-2012

Study Period: 2012

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Enumeration Assessment
Summary Report 2001-2012

Prepared for BC Hydro

By

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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. Juvenile outmigration of anadromous fish is 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*), chinook salmon (*O.tshawytscha*), pink salmon (*O. gorbuscha*) and steelhead trout (*O.mykiss*).

The primary goal of this study is to evaluate if there is any change in the productivity of salmonid juveniles in the Cheakamus River in response to the change in flow regime as created by the Water Use Plan. Results presented in this report examine the mean and variance of annual fish production for migratory salmonids, and also the power to detect a significant change based on these data. This analysis is of critical importance as it describes whether any observed changes in fish abundance are statistically significant and could be related to flow changes or if they may be within the natural variance of the population as observed under Interim Flow Agreement conditions.

This monitor 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 review reports, i.e. chum fry production (Monitor 1b), steelhead smolt production as it relates to stock recruitment (Monitor 3), and chum fry production as it relates to groundwater in side channels (Monitor 6) This report summarizes and reviews the methods and results, from 2001 through 2012. In addition recommendations are made as to potential study modifications for the next five years of the monitor.

Primary results from the study so far indicate: insufficient data are available to evaluate the trends in Pink and Chinook salmon juvenile production as they relate to flow due to high variance in the years prior to WUP implementation. However for Pink salmon current abundances are nearly 5 fold higher on average post WUP, thus current discharges appear not to be a significant impediment to fry yield. Coho smolt production remains largely unchanged through the pre and post study period, although 3 addition years of data are yet required to determine a 50% variance in yield with an 80% detection probability for a 0.05 Type 1 error.

TABLE OF CONTENTS

LIST of TABLES

LIST of FIGURES

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 & 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 2012.

The CC held its last meeting in January, 2002 and was unable to reach consensus on a new operating alternative. 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 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 and the Cheakamus River Steelhead Adult and Juvenile Abundance Monitor #3 (Korman et al, 2012) 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 (Pottinger Gaherty, 2010) 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).

This report will summarize and review the methods and results, from 2001 through 2012 as they relate to the two key management questions in Section 1.1.1. In addition recommendations will be made as to potential study modifications for the next five years of the monitor.

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 review reports, i.e.:

- Chum fry production and egg to fry survival will be reported in the Monitor 1b (McCubbing et al, 2012),
- Steelhead smolt production as it relates to stock recruitment will be reported in Monitor 3 (Korman et al, 2012),
- Chum fry production as it relates to groundwater in sidechannels will be reported in Monitor 6 (Pottinger Gaherty 2010).

Mainstem juvenile production data collected in 2000 and side-channel data collected in 2007 is not included in this review. These data were collected in the inaugural year for those components of the study and both a late start due to logistical reasons (approx. March 15th in each year) and unrefined operational methods rendered these data incomparable to the other years of data .

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 done 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 Tenderfoot Hatchery releases hatchery chum fry each spring into the NVOS channels and Tenderfoot Creek. Depending on release numbers, RST and/or fyke net operations are occasionally 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 is not suspended chum fry catch for the day after the release is removed from the data set, thus eliminating these fish from being included in wild 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 smolt trap Site 1 on the 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 can be found in the annual Cheakamus River Juvenile Monitor Reports (Melville and McCubbing 2001-2011).

1.4 2003 Flood and 2005 NaOH Spill

Two events that have had effects 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 event 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 resulting in the peak discharge not being measured. The previous highest mean daily discharge was 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 river kilometer (RK) 19. This chemical killed nearly all fish residing downstream in the mainstem. Species affected were chinook, pink and coho salmon, steelhead, rainbow and cutthroat trout, char, cottids, lamprey, and stickleback (McCubbing et al., 2006).

The effects of the 2003 flood and the 2005 NaOH spill on this time series of data, as it relates to the objective of monitoring the effects of flow regulation, is discussed briefly 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 the following 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 4600m2 habitat Target species: pink &Chinook salmon.

- Gorbuscha 2 (river intake): constructed in 2003; created 478m channel and 3225m2 habitat. Target species: pink salmon

- Sue's Channel (river intake): constructed in 2006; created 380m channel and 2400m2 habitat. Targeted species pink, Chinook, chum, and coho salmon, and rainbow/cutthroat trout.

- 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.

2.0 Methods Summary (Consistencies and Changes over sample years)

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 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 whilst 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).

2.1.1 Rotary Screw Traps

Mainstem RST trapping methods for the Cheakamus in all years of operation have followed those outlined in Melville &McCubbing, 2001 & 2002a. Briefly, emigrating salmonid juveniles are captured in the mainstem of the Cheakamus River at RK 5.5 using two six-foot diameter rotary screw traps during the sampling period from February 15th to June 15th.

In 2007, a change to operational procedures was placed in effect in an effort to increase trap operating efficiency in May and early June. With lengthening days and increased sunlight, conditions are typically dominated by higher discharges due to high elevation snowmelt and also by increased algal growth which clogs screens during this time period. This results in a reduced ability to operate traps with small mesh drums (Melville &McCubbing, 2006). As a result5/32” mesh (fry) screen drums were replaced by larger 1/4” mesh in order to reduce screen surface area and thereby reduce resistance to water flow as well as minimize clogging due to algal and debris build up. Although this improved the capture of smolts, the larger mesh size does not capture chum, pink or chinook fry. Therefore, to minimize the reduction in precision of yield estimates as a result of reduced capture efficiencies for fry, the date change for drum mesh size was selected as on or after May 1st, after which, in the majority of years (2001 through 2012), $\leq$10% of estimated fry abundance occurs (data on file).

A new cableway/anchoring system was installed in the spring of 2008. The old cable way system was replaced to improve safety margins and allow trap operation under higher discharges. This cableway has allowed for more consistent operation of the traps at discharges between 50-90 m^3/sec at Brackendale gauge, thus improving mark-recapture data particularly in May.

2.1.2 Side-channel Fyke Net Traps

Since 2007 estimates of fry production, from channels with only ground water sources and river augmented flow-through channels (which may or may not have groundwater influences) in the Cheakamus River, have been provided by operating fyke nets (Figure 3).The fyke nets (1/8” mesh) have openings of 1m by 1m tapering down to a 6” tube which is attached to a capture box. These fry estimates assist in the assessment of mainstem vs. side-channel production and also inform Monitor 1b and 6.

Methods for the operation of the fyke net traps are described in detail in Melville and McCubbing 2008 & 2009. In general upstream capture nets were used to obtain fish for marking. These fish were released at the site of marking with a portion being captured in downstream traps, allowing a population estimate to be derived for the area upstream of the enumerator traps using mark-recapture methods.

In 2008 the locations of two marking traps were changed to increase capture of fish for marking. Sites in Big and Little Gorbuscha channel (site E and G; Melville and McCubbing 2008) were replaced with Site F2 and F4 (Figure 3).

In addition in 2008 estimation of fry production from BC Rail channel (Site F7 & F8) was added. This ground water channel was added to replace Site F5 (Upper Paradise Ground water) as the physical geography of Upper Paradise groundwater channel was altered after the study was designed and, as a result, the area available for groundwater production evaluation was much reduced in size. Attempts to get an accurate population estimate at Site F5 were continued through 2010 but the site failed to capture sufficient fish for marking purposes and to provide a reliable yield estimate and operation of this trap site was suspended in 2011 (Melville and McCubbing 2010). In addition the “Ground Water in Side-Channels Monitor 6” also moved its focus from Upper Paradise to BC Rail channel to better assess the relationships between ground water changes and chum fry production (PGL, 2009).

2.1.3 Complete Channel Traps/Resistivity Counters

A juvenile smolt trap was operated from 2001 through 2009 on the Upper Paradise channel (Trap Site 6; Figure 3). The primary objective of this trap was to provide a large sample of coho smolts for marking to derive mark-recapture estimates at the RST site. It has also provided a count of all out-migrating smolts from the Upper Paradise channel and the portion of Farpoint channel which is diverted into Upper Paradise, but not the entire smolt production from the NVOS restoration channel complex.

In 2007 as part of the expanded study plan (side-channel fish production) enumeration of smolts from Upper Paradise (Site 2), Kisutch (Site 3) BC Rail (Site 4), and Tenderfoot (Site 5) was conducted using a combination of complete channel traps and resistivity counters, as described in Melville and McCubbing 2008.

In 2008 an additional complete capture trap (Trap Site 1; Figure 3) was completed and operated at the downstream end of Upper Paradise channel complex. This trap captures all coho and steelhead smolts migrating from the Upper Paradise channel complex, providing total production numbers from the NVOS restoration channel complex and smolts to mark for mainstem mark-recapture estimates.

In the original study it was planned to use Upper Paradise (Site 2) to evaluate coho smolt production in ground water channels to inform Monitor 6. The reduction of area available to assess due to the addition of the river-augmented Sue's channel after the study was designed, resulted in very few coho being captured in 2007. Thus it was decided to not continue with assessing this channel for smolt production (Melville and McCubbing 2008).

From 2008 through 2010 to ensure that the large sample of marked fish (steelhead and coho) was maintained, fish trapped at Site 6 were marked and combined with fish trapped and marked at Site 1, and released at Site 1. Based on good capture rates at Site 1 supplying sufficient and consistent smolts for marking, and producing total smolt production numbers for the NVOS restoration channel complex it was decided in 2011 that operation of the Site 6 trap would be suspended.

From 2007 through 2009 enumeration of smolt outmigration from Kisutch and BC Rail ground water channels and Tenderfoot Creek (Sites 3, 4 & 5; Figure 3) was undertaken through the operation of full river span weirs that directed fish to electronic counters and subsequently trap boxes. The Logie 2100C electronic counter (Aquantic Ltd, Scotland) is a resistivity counter. Briefly, the counter operates by detecting the passage of a fish across an array of three electrodes which the counter continually monitors (Nicholson et al., 1995). It was hoped that development of this technology would reduce handling of fish and staff time to manually count fish. The technology has proven effective at the enumeration of adult salmonids on the Cheakamus (McCubbing 2011). Ultimately after three years of counter validation using manual counts from trap boxes, the technology proved to be inaccurate and inconsistent when enumerating small juvenile fish and operation of the counters ceased in 2010 and the sites are counted manually from trap boxes.

Full creek trapping efforts to assess the coho migration were not attempted at Tenderfoot Creek (Site 5, Figure 3) post 2008 as problems with hatchery releases and high discharge made full span continuous trapping impossible. In an attempt to generate an improved estimate of the contribution that Tenderfoot Lake and Creek wild coho juveniles make to the total smolt outmigrant population, a mark-recapture assessment of pre-smolts was undertaken in 2009 through 2011 utilizing minnow trapping in early April just prior to migration. The estimates of coho yield from Tenderfoot have been varied in the three years (since 2009). The estimates derived by this method exhibited relatively broad confidence limits a result of low recapture efficiencies, thus the data was deemed too uncertain to make any conclusions about the contributions of Tenderfoot to the coho populations of the Cheakamus. In 2011 it was recommended to the CC that this component of the study be terminated.

2.2 Population Estimate Methods

In 2002 the CC recognized that it is 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. To achieve this, the importance of refining statistical and sampling methods was identified as the highest priority within the monitoring plan (Mamorek and Parnell, 2002). Therefore the Terms of Reference for Monitor 1a included a component to develop improved statistical models for estimating fish production (Cheakamus Water Use Plan Monitoring Program Terms of Reference, Feb 2007).

Historical population estimates (Melville and McCubbing 2001-2011) from Cheakamus outmigrant data have been calculated using unstratified Petersen and/or the temporally-stratified Darroch methods as implemented in SPAS (Arnason et.al. 1996). Population estimates were derived by applying the proportion of the total marked fry and smolts recaptured to the total unmarked catch also known as the total estimated catch efficiency (ECE_T). This estimate makes a number of assumptions as outlined in Seber 2002:

1) the population is closed such that the population is constant,
2) all untagged fish during the sample period have the same probability of being captured at the rotary traps,
3) marking and clipping fish and releasing them upstream does not affect, their subsequent catchability in the rotary screw traps,
4) sampling at the rotary trap for marks is a simple random sample where each of the possible combinations of tagged and untagged fish have an equal probability of occurring,
5) fish do not lose their marks between the release site and the recapture site,
6) all marks are reported on recovery in the second sample.

As well, we assume that:

7) marked and unmarked fish have similar movement patterns from the release site to the rotary trap,
8) fish can pass the rotary trap only once and all marked smolts pass trap the traps by the end of the study, i.e., none of the fish remain above the rotary trap,
9) there is no mortality and no fish leave the system without passing trap.

A key challenge in meeting these assumptions (in particular 2 & 4) has been 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). For example, the Pooled-Petersen estimator will simply pool all releases, all recaptures of marked fish, and all captures at the relevant locations and use these pooled values in the simplest capture-mark-recapture estimator (Seber, 1982). This estimator makes a crucial assumption of homogeneity of catchability (among others) and can be biased if the assumption of homogeneity is not valid. More importantly estimates of precision from the Pooled-Petersen estimator in the presence of heterogeneity of catchability, will tend to understate the actual uncertainty in the estimate i.e. the results from the Pooled-Petersen method will appear more precise than they should be (Seber, 2002).

In order to address the heterogeneity in catchability throughout the study population estimates calculated using capture efficiency estimates over shorter time periods (strata) are likely to be more accurate than population estimates calculated using average capture efficiency over the entire migration period (Seber, 1982). This requires a planned marking regime where individual strata can be differentiated based on separation of mark groups. The estimator for Stratified-Petersen studies was introduced by Darroch (1961) with further work by Seber (1982, Chapter 13), Plante et al. (1998), Schwarz and Taylor (1998), Arnason et al. (1996), and Bjorkstedt (2000). While these methods are theoretically justified, there are several practical problems that prevent their simple usage. When the data from the study are stratified, the resulting matrix of recoveries can be sparse with small counts. Consequently, the resulting estimates are often very unreliable and can often not be computed because they rely upon the inversion of this sparse recapture matrix with small counts. As well, these methods do not take into account the temporal stratification in the study where the abundance in one stratum is likely to be similar to that in adjacent strata and the movement pattern of a release group is also likely to be similar to the movement pattern in adjacent release groups. Because of sparse data, extensive pooling of strata is often required. But there is no defensible method to decide which strata to pool, and the pooling decisions are not incorporated into the estimates of uncertainty (Schwarz and Bonner, 2012, Appendix A).

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 discussed above. In general:

- Fry (chum, chinook and pink) marking protocols remained the same as described in Melville and McCubbing, 2011. In general fry are marked using immersion dye for four days in each 7 day strata and then a 3 day break occurs to allow all the fish to migrate past the trap. This procedure was developed as there are limited individual marking techniques available for fish this size.

- Coho smolt marking protocols were changed as described in Melville and McCubbing 2008. In general the mark (combination of caudal fin mark(s) and the sub-dermal injection of a coloured dye using a jet inoculator) was changed from 7 day strata to daily strata (mark changed each day). This change in methodology was instituted to evaluate the effects of daily variations in trap efficiency on yield estimates.

- In addition marking of coho smolts from the RST and moving them upstream was suspended and all coho smolts were marked and released at the NVOSS trap site, as less precise estimates were generally calculated by this method due to lower number and inconsistent numbers of fish available at the RST for marking and subsequent recapture.

In the interim (2008 through 2011) as described fully in Bonner (2008), Schwarz et al. (2009), and Bonner and Schwarz (2011) developed an alternate method (Bayesian spline model) for calculating population estimates that has many advantages over existing methods. It takes into account the temporal stratification and shares information among neighboring strata to help alleviate problems caused by small counts. The key features of this method are the use of splines to model the general shape of the run and Bayesian hierarchical methods to share information on catchability and the shape of the spline among strata. 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 and so it is relatively simple to also estimate derived quantities such as the time at which50% of the run has passed, or the time needed to reach a pre-specified target number of fish. In the past; 2001-2011 run-timing has been reported as actual strata catch, which is likely not always a true indication of abundance through time. The features of the model also deal with problems (such as no sampling in some strata) in a straightforward fashion – the spline curve for the run is used to “interpolate” for the missing data. These last two features are difficult to obtain from the previous methods.

Despite its complexity, the spline model is not a panacea to solve all potential problems encountered in capture-mark-recapture studies. There are a number of caveats that apply to this and potentially to other stratified models (Schwarz and Bonner, 2012). These potential problems are more fully described in Schwarz and Bonner, 2012 (Appendix A).

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 and appended in Appendix A. Briefly; in 2011 all years (2001-2011) and for all species, mark-recapture data was prepared for analyses using the BTSPAS model. This analysis was completed in early 2012. In addition to calculating annual population estimates and run timing, the covariates of discharge and temperature were plotted against the estimated catchability in mainstem estimates to determine if these parameters had any observed effect on estimated catchability. This analysis was not undertaken for side channel estimates as discharge and temperature data for these locations is unavailable.

2.3 Discharge Data Collection and Analysis

Mean daily and weekly discharge (Q) over the study period was computed 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.

2.4 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 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 Rotary Screw Trap (Temperature Logger 4) were used for analysis in this study.

2.5 Bio-sampling and Age Data Collection

A sub-sample of all species captured was sampled for lengths and weights at the RST site and at Upper Paradise side channel trap (Site 1 and 6) throughout the study (2001-2012) 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 migration.

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 small 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).

2.6 Power Analysis

A power analysis based on a t-test of mainstem production estimates which include side channel production (BTSPAS) was undertaken to test the statistical power and probability of the available data to find statistical change between IFA and WUP periods.

Each year’s estimate (2001-2012) was considered IFA or WUP affected based on life history. A WUP year class was identified as all freshwater life stages for the species occurring during the WUP flow regime. i.e. coho smolts are not considered WUP affected until 2007 (even though the WUP was instituted in Feb 2006) as 2006 smolts would have been spawned in the fall of 2004 and spent their incubation and rearing under the IFA. In addition some estimates were excluded as data used to derive estimates was weak (i.e. few fish to mark and/or few recaptures). From this initial data set the number of IFA and WUP years, the change in abundance and the relative change in abundance was summarized. The power analysis was calculated using R and the power T-test function which requires the standard deviation in the population estimates and a specified Type I error level, (0.05 was used). Based on these statistics 3 power-related statistics were computed:

1) The statistical power given the available data. That is, what is the probability of finding a significant change in post-WUP compared to pre-WUP given the sample size, variance, and difference in average abundance between pre- and post-WUP periods?

2) Relative change in abundance required to achieve a power of 0.8 given the sample size and inter-annual variance in population estimates.

3) Number of years to detect a 50% change in abundance during the post-WUP period (relative to pre-WUP) given the variation in population estimates across years and a power of 0.8.

3.0 Results

3.1 Chinook

3.1.2 Chinook Fry Migration and Production

The run-timing of early chinook fry based on estimated weekly abundance at the RST site, indicates that in the majority of years the run is already under way when sampling commences. In particular in 2003, 2005 and 2010, a range of 39-55% of the total yield was estimated to have migrated in the first two sample strata (Figure 4 & 5). In three years, 2002, 2004 and 2009 where the curve of migration appears to be complete, the peak of migration occurred March 11th to 18th (35%), March 16th to 29th (26%) and February 24th to March 9th (30%) respectively. It does not appear that increased temperature or discharge affected the migration timing of chinook fry (Figure 4 & 5). It is likely spawner timing in conjunction with water temperature during incubation that drives migration timing of early chinook fry.

Estimates of chinook fry production from the Cheakamus River were calculated for every year of the study (2001-2012). The exception being 2006 when insufficient numbers (499) were captured to derive a mark-recapture estimate. The 2006 outmigration was affected by adult spawner mortality caused by the chemical spill event in the summer of 2005. Estimated production of chinook fry from the mainstem of the Cheakamus River ranged from 60,040 in 2010 to 874,946 in 2011. The average estimated production for all years (2001 to 2012) was 315,664, SD = 229,794 (Table 2 and Figure 6).

There have been five IFA and six WUP estimates of production. Average IFA and WUP abundance was 250,860 fry and 378,926 fry respectively, this equates to an average change in abundance of 128,066 or 51% increase. Several power analyses were undertaken on the data to establish if the null hypothesis of a change of 25% in production could be determined based on the length of the study and the mean and variance of IFA and WUP years production. These analyses indicate that with the data collected a 25% change in population size, with a 0.05 Type I error and power of detection of 0.8, would take 233 years of data collection in each group to detect such a difference. A greater change in population size of 75% would still take 27 years of data in each group based on this analysis (Table 3).

There are no estimates of early chinook fry production in the side channels as very few fish are captured. Since 2007 the average catch being 300 with a range of 99-598 fish at F1 enumeration fyke on the NVOS side-channel complex, and no fish captured at F7 on the BC Rail side channel complex.

3.1.2 Chinook Smolt Migration and Production

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 7 & 8)

Estimates of chinook smolt production have been calculated for 2001-2003 and 2009. Insufficient capture of fish in most years to mark has resulted in the inability to calculate an estimate. In the years where an estimate was derived chinook smolt abundance has ranged from 6,020 to 14,439 (Table 2 & Figure 9). As for chinook fry several power analyses were undertaken on the data to establish if the null hypothesis of a change of 25% in production could be determined based on the length of the study and the mean and variance of IFA and WUP years production. These analyses indicate that with the data collected a 25% change in population size, with a 0.05 Type I error and power of detection of 0.8, would take 48 years of data collection in each group to detect such a difference. A greater change in population size of 75% would still take 6 years of data in each group based on this analysis (Table 3). As we currently only have three years of IFA and one year of WUP estimates, further data are yet required to determine any change in smolt production.

Since 2009 an average of 14 (range: 3-37) chinook smolts have been captured at Site 1 fish trap at the NVOS sidechannels.

3.1.3 Chinook Length and Age Data

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

No early chinook fry were sampled for lengths or weights at the sidechannels and the small numbers of chinook smolts sampled (<5 annually) were included with the fish sampled at the RST.

Length frequency for all chinook juveniles captured at the RST site was bi-modal with the first mode generally falling between the 30 and 69mm range, representing 0+ fry, and a much less frequent second mode (80-134mm), representing 1+ smolts. This is similar in all sample years, 2002 to 2012. Note: 2001 was not included in the analysis of chinook length frequency as hatchery chinook smolts were included in the sample (Figure 10 & 11).

Mean length for early chinook fry from 2001 to 2012 ranged from was 38-46mm(Table 4). In general the majority (78%) for all years analysed (2002-2012) of chinook fry fall within the two modes spanning 35-44mm (Figures 10 & 11).

There was a statistically significant observed difference in mean length of chinook fry between the twelve sample years 2001 to 2012 (ANOVA, $p<0.001$, $F=26.3$, $df=11$). Largest fish were observed in 2005 and smallest in 2011. A statistical test was conducted to compare the mean lengths of IFA and WUP chinook fry which had unequal variance (F test, $p=0.003$,$df=5$, $F=17.1$), and a statistical difference was evident (T test equal variance, $p=0.01$, $df=6$, $F=2.98$) with smaller fish being sampled since 2007. 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.

Mean length, weight and condition factor (K) for chinook smolts (1+) 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 4).

There was a statistically significant observed difference in mean length of chinook smolts between the sample years 2002, 2003 and 2007 through 2012 (ANOVA, $p<0.001$, $F=6.3$, $df=7$). Insufficient fish were sampled in 2004-2006 and 2001 data contained an unknown number of hatchery fish. Fish were largest in 2003 and smallest in 2009. No comparisons of IFA and WUP mean length or condition factor values were evaluated as there were only two IFA sample years with sufficient data.

3.2 Pink Fry

3.2.2 Pink Fry Migration and Production

The run-timing of pink fry based on estimated weekly abundance at the RST site, indicates that the run is just starting or has not yet started when sampling commences. On average only 6% (6-11%) of the total yield was estimated to have migrated by the fourth weekly strata (Figure 12 & 13). The peak of migration for pink fry in 2001-2011, which was effectively uni-modal generally occurs between March 25th and April 10th (weekly strata 6-9) when on average 61% of the outmigration occurs. In comparison in 2012 it appears from model output data that a second peak of migration could have been in process when high water suspended fry capture mid strata (weekly strata 11), although it is likely that this stratum estimate is biased high (Schwarz 2012).

It appears that increased river temperature (4.5 to 7 C^0) but not discharge has an effect on the migration timing of pink fry (Figures 12 & 13). It is likely spawner timing in conjunction with water temperature during incubation and emergence is what drives migration timing of pink fry.

Estimates of pink fry production from the Cheakamus River were calculated for every on-year (even years) of the study 2001-2012. Estimated production of pink fry from the mainstem has generally been increasing since 2002 when an estimate of 1.7 million fry was calculated to a high of 29 million pink fry being estimated in 2012, this estimate is 5- fold higher than the previous highest estimate of 6 million in 2010 (Table 2 and Figure 14).

There have been three IFA and three WUP estimates of pink fry production. Average abundance was 686,706 fry and 4,109,163 fry respectively, this equates to an average change in abundance of 3,422,457 or 498% increase. Several power analyses were undertaken on the data to establish if a change of 75% in production could be determined based on the length of the study and the mean and variance of IFA and WUP years production. These analyses indicate that with the data collected a 75% change in population size, with a 0.05 Type I error and power of detection of 0.8, and would take 357 years of data collection in each group to detect (Table 3).

Estimates of pink fry production have been derived in 2008, 2010 and 2012 from Site F1 at the NVOS channel. The estimates range from 627,542 to 3,127,546. The 2012 estimate is 3-fold higher than the next highest estimate of 1.2 million fry in 2008. In the three years that both mainstem and side-channel estimates have been calculated for pink fry the production from the NVOS side-channel complex represents a range of 10-57%, with 2010 and 2012 being 11% and 10% respectively (Table 2).

3.2.3 Pink Fry Length Data

Mean length for early pink fry sampled at the RSTs in even years from 2001 to 2012 ranged from 27-44mm, and the average length has been 34mm in all years except 2010 when it was 33mm (Table 4).Weight data for pink fry was not analysed as it is very difficult to get accurate weights of fish this size in the field. No length data was taken for pink fry captured at site F1 at the NVOS side channel.

There was a statistically significant observed difference in mean length of pink fry between the six years of pink fry capture (ANOVA, $p<0.001$, $F=11.3$, $df=5$) but this difference was less than 1mm and is thus within the likely range of observer error, as such no further statistical tests were conducted.

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. outmigration does not begin until after trap operations commence and the majority of fish have migrated before trap operations are suspended in June. Coho smolt migration commences in early April in all years of the study (2001-2012) with on average 15% of the run migrating by April 15th. The peak of migration generally occurs between May 1st and May 25th (weekly strata 11-14) when on average 55% of the estimated abundance migrates. On average 90% of the fish have migrated by May 31st (Figure 15 & 16).

Coho smolts followed the same migration pattern observed above in all years since the study commenced in 2001 on the Cheakamus River, beginning their peak outmigration period when average daily water temperatures reached 7^{0}C. Discharge does not appear to determine when migration occurs (Figure 15 & 16).

Estimates of coho smolt production from the Cheakamus River at the RST site were calculated for every year of the study (2001-2012). Estimated production of coho smolts from the mainstem has varied from

60,686 to 118,161 smolts annually (Table 2 and Figure 17). The exception is 2006 (estimated abundance of 35,444) which was affected by fish mortality caused by the chemical spill event in the summer of 2005.

There have been seven IFA and five WUP estimates of coho smolt production. Average abundance including 2006 was 79,940 (excluding 2006 average abundance 81,569) and 76,544 smolts respectively, this equates to an average change in abundance of -3,397 or a 4% decrease if 2006 data are included. Several power analyses were undertaken on the data to establish if a change of 25% in production could be determined based on the length of the study and the mean and variance of IFA and WUP years production. These analyses indicate that with the data collected a 25% change in population size, with a 0.05 Type I error and power of detection of 0.8, and would take 24 years of data collection in each group to detect. To evaluate a greater change in population size will take fewer years, with a 50% change requiring only 7 years of data in each group. At least three more years of data are required to evaluate a 50% change in production, in particular if 2006 data are excluded from the analysis as it was affected to some extent by the fish mortality event in 2005 (Table 3).

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 then again in 2009 through 2012. Between 2001 and 2009 the location and amounts of channel area evaluated at NVOS has changed substantially (section section 1.4). An average production of 14,800 smolts, ranging from 8,691 to 26,828 has been observed in the years of evaluation. In the five years that both mainstem estimates and side-channel production have been calculated the contribution from the side channels has averaged 23% (sd. 8%) 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 14-24% of the estimated upper river population (Table 2).

3.3.2 Coho Length and Age Data

Length frequency for all coho smolts (≥70mm) captured and sampled at the RST and side channel sites is uni-modal in all years (2001-2012) indicating that the majority of migrating coho smolts are 1+ with a small percentage of larger fish likely 2+ (Figures 18 &19). Scales have not been aged for coho but have been taken and archived.

Mean length, weight and condition factor (K) for all coho smolts ranged from 86-95mm, 7.1-10.7g and 1.0-1.2 respectively (Table 4). Coho smolt length frequency peaks between the 80 and 99mm range, with a majority (66%) of the fish sampled each year (2001-2012) falling within this range. There does not appear to be any detectable shift in the length frequency of coho with 67% of smolts within this size range during the IFA and 65% during the WUP.

There was a statistically significant observed difference in mean length of coho smolts between the twelve sample years 2001 to 2012 (ANOVA, $p<0.001$, $F=123$, $df=11$). Largest coho smolts were observed in 2005 and 2010, with smallest in 2012. A statistical test was conducted to compare the mean lengths of IFA and WUP affected coho smolts which had equal variance (F test, $N=6$, $df=5$, $F=1.89$), but no difference was statistically evident (T test equal variance, $df=10$, $F=1.71$, $p=0.06$). We also examined mean condition factor between groups with equal variance (F test, $N=6$, $df=5$, $F= 1.92$) and found that fish which were sampled post 2006 had a slightly lower condition factor than those sampled in 2001-2006 (T test, $df=9$, $F=1.87$, $p=0.047$).

3.4 Steelhead

3.4.1 Steelhead Smolt Migration and Production

Estimates of steelhead smolt population abundance have been calculated in eight of the twelve study years; 2001-2003 and 2008-2012. In 2004 through 2007 insufficient steelhead smolts were captured, range: 9-21 to mark (Table 2).

The migration timing of steelhead 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. the run does not begin until after trap operations commence and in 6 of the 8 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 and so the final strata estimates which are also the largest in the study likely bias the estimate high[1]. This is particularly troublesome when sparse data occur in these strata. For example the last strata (week ending June 8th) in 2003 had no steelhead captures or recaptures and the last two strata in 2009 had few marks (23), no recaptures and 1 capture.

Steelhead smolt migration has generally started in the week of April 15th to 22nd (weekly strata 10) in the 6 years of the study when a migration curve was evident (2001-2002, 2008 and 2010-2012) on average 10% 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 20 & 21).

Steelhead smolts followed the pattern observed in all years since the study commenced in 2001 on the Cheakamus River, beginning their peak outmigration period when average daily water temperatures reached 7^0C. Discharge does not appear to determine when migration occurs. (Figure 20 & 21).

Estimated production of steelhead smolts from the mainstem has been calculated in 8 years of the study with two of those years appearing to be biased high by inaccurate estimates of late strata as described above. In an effort to more accurately compare annual abundance of steelhead smolt migration from 2003 and 2009 with the other six years where the migration curve trended downward at the end of the sample period, the strata ending after May 31st (estimated 90% of run has passed) were removed from the total BTSPAS estimate and the resulting partial estimate was then expanded by 10%, this resulted in an comparative estimated abundance of 8,516 and 7,197 in 2003 and 2009 respectively, rather than the 63,591 and 11,088 estimated 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 (excluding BTSPAS estimates in 2003 and 2009). The average estimate of abundance in these years (2001,2002, 2008, and 2010-2012) is 6,402. Data following the 2003 flood and the 2005 spill are evident in the years following the events (2004-2007) when very few steelhead smolts were captured; range 9-21 thus no abundance estimates were calculated. (Table 2 and Figure 22).

There have been three IFA and four WUP estimates of steelhead smolt production (with 2008 being partially affected having 3+ smolts rearing under IFA conditions) but only 2 IFA and 4 or 5 WUP (depending in use of 2009 data) estimates are evaluated of high accuracy. Average IFA and WUP abundance was 6,101 and 8,951smolts respectively (including BTSPAS estimate of 2009). This equates to an average change in abundance of 3,636 fish or an increase of 47%.Several power analyses were undertaken on the data to establish if a change of 25% in production could be determined based on the length of the study and the mean and variance of IFA and WUP years production. In these analyses 2003 data were excluded as the estimate is clearly incorrect as it is 10 times the average production for the reasons explained. Data from 2009 were initially included as despite there being concerns with the model output, the number generated is within the range of estimates in other years. These analyses indicate that with the data collected a 25% change in population size, with a 0.05 Type I error and power of detection of 0.8, and would take 90 years of data collection in each group to detect. To evaluate a greater change in population size will take less years, with a 50% change requiring 23 years of data in each group (Table 3).

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 2012 with an average production of 190 steelhead smolts, ranging from 35 to 403. In the five years that both mainstem estimates and side-channel production have been calculated the contribution from the side channels has averaged 3% (2-4%) of the estimated steelhead population (Table 2).

3.4.2 Steelhead Length and Age Data

Mean length, weight and condition factor (K) for all steelhead smolts ranged from 162-177mm, 50.2-69.0g and 1.0-1.1 respectively (Table 2). Length frequency for all steelhead juveniles captured at the RST and side channels was bi-modal with the first mode generally falling between the 70 and 114 mm range, representing age-1 parr, and 130-190mm representing age 2 through 4 year old smolts. Weighted age proportions varied annually in years that sufficient data were collected to describe the smolt outmigrant population. Age 2 smolts contributed 54, 74, 49, 56 and 33% of annual smolt emigrants in 2008-2012 respectively. The bulk of the rest of the fish were estimated to be aged-3, 45, 23, 44, 43 and 60% with the remainder 4 years or older. Smolt length at age also varied annually from a low of 159mm in age 2 fish in 2010 to a high of 165mm in 2009, while age 3 fish varied from a low of 179mm in 2012 to a high of 189 in 2009 (Table 5). These variances in proportions of smolt ages and size at age are likely the result of the 2003 flood and 2005 spill events, as well as varied year class strengths and will be described in more detail in the steelhead monitor (Korman et al, 2012, Figure 23 & 24).

There was a statistically significant observed difference in mean length of steelhead smolts between the eleven sample years 2001 to 2012 (ANOVA, $p<0.002$, $F=2.6$, $df=11$). Largest steelhead smolts were observed in 2002 and 2006, with smallest in 2004. A statistical test was conducted to compare the mean lengths of steelhead smolts pre and post WUP which had equal variance (F test, $df=5$, $F=3.6$), but no difference was statistically evident (T test equal variance, $df=10$, $F=1.5$, $p=0.44$). We also examined mean condition factor between groups with equal variance (F test, $df=7$, $F=3.5$) and found no difference in condition factor between than those sampled in 2001-2007 and those sampled in 2008-2012 (T test, $df=10$, $F=0.25$, $p=0.4$).

[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).

3.5 Discharge

Discharge (measured at WSC 08GA043) at the Cheakamus River near Brackendale (Figure 2) during IFA years of the study (Jan 1st, 2001 to Dec 31st, 2005) ranged from an average daily value of 6.0 m^3/s to 709.0 m^3/s, in comparison to WUP years (Jan 1st 2007 to Dec 31st, 2011) ranged from 13.0 m^3/s to 287.9 m^3/sec (Figure 25 & 26). In an effort to compare differences in average daily discharge under the two regimes the 10th, 50th and 90th percentile were plotted and the values were compared statistically using a T-test, IFA and WUP. In the winter months, January through March and in October, mean daily discharge were increased significantly (p=0.01) for the lower 10th percentile of measurements, although only by between 1.8 and 2.5 m^3/s in the January to March period and by 5 m^3/s in October. In May, July, August and November flows were significantly reduced (p=0.01 except in August when p=0.05). Differences in mean daily discharge were decreased by between 3 to 6 m3/s (Figure 27). On statistical analysis of the 50 percentile data a significant decrease (p=0.01) in the discharge was evident in 7 of 12 months. These were January, April, June through August, November and December. Decreases in discharge ranged from a low of 5 to 30 m3/s in December and July respectively (Figure 28). Perhaps surprisingly the 90 percentile discharge was also significantly different in eight months of the year. It was significantly lower in January, June, July, September, October and December (all at 0.01 level, except October at 0.05). Reductions in flow ranged from 22 to 84 m3/s in December and July respectively. Increased river discharge was observed in two months, April and August with a mean daily increase of 23 and 21 m3/s respectively (Figure 29).

3.6 Temperature

Average daily water temperature at the RST low only data logger (Figure 2) during the juvenile migration period of Feb 15th to June 15th during IFA years of the study (2001-2005) ranged from 2.7˚C to 10.3˚C (sd: 2.1), in comparison to WUP (2006-2012) temperatures ranged from 3.3˚C to 9.4˚C; sd: 1.8 (Figure 30 and 31).. In an effort to compare differences in average daily temperature under the two discharge regimes the 10th, 50th and 90th percentile were plotted and the IFA and WUP values were compared statistically. Statistical evaluation by T-test for significant differences in river temperature indicates that

IFA river temperatures were generally higher than recent post 2006 data (Table 6). However data for IFA years is limited to two years (2001 and 2005), except during the spring period, thus summer temperatures could be affected greatly by variation in the annual size of snow pack and melt run off patterns which may not be fully captured in pre 2006 data. Spring temperatures i.e. March through May have however significantly changed within the data collected and analysed with cooler conditions dominating. The reasons for this change are unclear as flows are generally lower in this time period

4.0 Discussion (Has Monitor Answered Management Questions?)

The primary goal of this study was to evaluate if there was change in 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). Our results presented here examine not only the mean and variance of annual fish production for migratory salmonids, but also the power to detect a significant change based on these data. This analysis is of critical importance as it describes whether any observed changes in fish abundance are statistically significant and could be related to flow changes or if they may be within the natural variance of the population as observed under IFA conditions. Assuming that a significant variance in any salmonid population is observed, it may still be difficult in some species to equate this directly to variance in river discharge as other factors such as hatchery programs (Schroeder et al 2008), changes in ocean survival of smolts (McCubbing et al 2011), spawner distribution within the watershed and natural flood events may also affect watershed production. For this reason, in chum salmon and steelhead trout additional data on adult escapement, habitat use and spawner distributions are collected to add weight to flow related impacts. Those results are discussed in the related monitors (1b & 3) reports utilizing data in part from this study (McCubbing et al 2012 in prep, Korman et al 2012 in prep).

Based on juvenile data collected from the RST site at RK 5.5, five of the six species/age classes studied indicated moderate to large increases in mean outmigrant population size in the 6 years since the WUP was implemented compared to the IFA years. These ranged from 15% in chum fry to a near 500% increase in pink fry abundance. The others indicating increases in average annual production were chinook smolts and fry (51 and 55%), and steelhead trout smolts (47%). Coho smolts indicated a small reduction in production by 4%, or 12% if 2006 (affected by CN related fish kill) is removed from the analysis.

Data indicate that for chinook salmon the juvenile outmigrant population is annually dominated by 30-60 day out migrants and that yearling smolts numerically represent typically less than 5% of the outmigrants. Thus the population can be characterized predominantly an ocean rearing type where presumably changes in discharge would be most manifest on spawner and incubation habitat. As the adult spawners return to the river in July through September (McCubbing and Melville 2000, Golder, 2009) and spawn in August through October (McCubbing and Melville 2000), the key periods that may be affected by discharge are August through October for spawners and August through March for incubation. Discharge data indicate that daily mean flows are significantly reduced in July, August and November at the 10th & 50th percentile but higher in October, and January through March at the 10th percentile level. Thus, there is less water in the river for early spawners but greater amounts of water during incubation. A power analysis however indicates that while we may have observed a change in mean productivity of both chinook fry and chinook smolts, it is not possible to be sure with any confidence that the changes observed (~50%) are linked to WUP conditions and not just within the annual and large variance previously observed in the population in the IFA regime. Examination of outmigration timing indicates that at least in some years, an unknown portion of the population will likely have out migrated prior to sampling being underway (i.e. 2003, 2005 and 2010) although the BTSPAS model has difficulties with this type of data (Bonner and Schwarz 2011) so evaluating how much is difficult to describe. Reasons for the observed high variance in fry outmigration timing are most likely related to spawning timing and associated ATU's on egg incubation. 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) and the effect of the 2003, 1 in 50 year flood are all likely contributing to the high variance observed in chinook productivity.

Additional juvenile data collection is unlikely to determine confidence in a statistically significant result in the assessment of productivity of chinook juveniles within the next 5 years, as to accept or reject a change of 75% in abundance for fry (at the 0.8 level) is calculated to require 27 additional years of data collection, not to mention the need for many more years of IFA data, which is not available. Chinook smolt monitoring potentially requires just 6 years of additional data (although IFA data are also sparse) to provide a statistically significant result, but as we have only generated an estimate of smolts in one of the last six years of data collection due to low fish abundance, the opportunity to test this hypothesis seems unlikely in the near future.

Factors which have and are affecting chinook juvenile production in the Cheakamus River are most likely complex and the ability of the juvenile fish monitoring program to identify real change in the population appears limited without a long timescale (>20 years) and then only if evaluating for a large population change (75% or greater) is the desired result. Studies that evaluate the potential for redd stranding following river ramp down in August, evaluations of hatchery contribution to productivity and a study to better understand adult escapement may be of equal or greater benefit to our understanding of chinook productivity in this regulated watershed.

Pink salmon fry numbers have varied greatly in the six years where they have been observed. 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.

As pink salmon juveniles do not rear in the river presumably changes in discharge would be most manifest on spawner and incubation habitat. Adult spawners return to the river in August and September (McCubbing 2005) and spawn in the same months. Fry emerge in late February and outmigration is completed by mid-April. The key periods that may be affected by discharge are August and September for spawners and August through April for incubation. Discharge data indicate that daily mean flows are significantly reduced in July, August and November at the 10^{th} & 50^{th} percentile level but higher in October, and January through March at the 10^{th} percentile level. As for chinook juveniles, there is less water in the river for spawners but greater amounts of water during incubation. A power analysis undertaken on the outmigration indicates that we have clearly observed a very large change in mean productivity of pink fry, but due to the very large annual (on year) variance in productivity estimates before and after the WUP implementation it would take a considerable period of time of pre and post monitoring (over 300 years!) to establish a statistical difference. In reality the pink fry outmigrant population has increased annually from between 3 and 6 fold since 2006 and at 29 million fry in 2012 now exceeds the highest IFA outmigration estimate by over 17 fold.

Examination of outmigration timing indicates that in all but one year the majority of the population will likely have out migrated during the sampling period. In 2012 the final strata contributes 23% of the estimate. The BTSPAS model has difficulties with this type of data (Bonner and Schwarz2011) and thus the population is likely overestimated, but even removing this entire stanza, which will then likely underestimate the population, results in an outmigration estimate of over 20 million fry.

Additional juvenile data collection is unlikely to determine confidence in a statistically significant result in the assessment of productivity of pink fry juveniles within the next 5 years, as to accept or reject a change of 75% in abundance for fry (at the 0.8 level) is calculated to require 300 additional years of data collection, not to mention the need for many more years of IFA data, which is not available. However the data do not lend themselves to such an analysis due to the paucity of IFA data and the high variation of spawner numbers typically associated with pink salmon (Beamish 2012, Irvine and Fukuwaka 2011), a function of small changes in marine survival on very high numbers of juveniles (Beamish 2012). For this reason pink salmon fry are a less than ideal species to use when evaluating salmonid production values in this regulated river. 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 2012 fry outmigrants from above the RST site would result in excess of 200,000 returning adults in 2013. It is important at these higher spawner densities that the chosen date of discharge ramp down from 38 m^3s to 20 m^3s occurs early in August. 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 2013, a potential high adult escapement year are perhaps warranted.

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 an Johnston 2012, Ladell and McCubbing 2011) with peak smolt outmigration occurring in May. In general the entire sampling period was captured although data in 2003 may result in a slightly inflated estimate due to high numbers of fish estimated in the final strata as river levels increased. As coho salmon juveniles are found rearing in the river for at least one year (some fish migrate as 2 year olds, circa 5-20%, DFO data on file) the flow regime created in the WUP affects these fish throughout the entire year and thus we may expect these fish to be more sensitive to flow changes than fry outmigrants. Coho spawners may be affected by fall discharge in the spawning period, which can be extended from November through January and eggs may be affected during incubation, November through April: fry are typically seen emerging in April and captured at the RST and sidechannel traps. Unlike the majority of chinook and pink fry, coho juveniles rear from April through May of the following year prior to leaving for the ocean. Thus habitat for rearing may be as important to smolt outmigration numbers.

The CC indicated that it was concerned that the 2D model which predicted no net change in habitat for stream rearing salmonids based on the RUA method, may not be sensitive enough to detect smaller changes (25%) in the potential productivity of coho salmon juveniles on the Cheakamus River. We examined the 12 years of coho data that we have collected at the RST utilizing power analysis techniques and we conclude that at this time insufficient data is available to determine a change of less than 75% in total river production. The observed annual mean production change of -4% does indicate we have high confidence that large (>75%) variance in production has not occurred but an additional 2 or 3 years of data are required to evaluate a change of greater than 50%. The target change of 25% may not be achievable without a very long data time series, due to highly varied smolt output annually which may be related to river discharge, marine survival affecting spawner escapement (Irvine and Fukuwaka 2011, Shaul et al 2007) or other factors. Given the lack of statistical confidence in the observed level of change in productivity, it is inappropriate at this time to attempt to categorize the reasons for population fluctuations. Instead additional years data are required to establish a reasonable level of confidence in both the magnitude of any change and its relationship to the IFA and WUP discharge regimes.

An additional goal of this study was to establish the relationship between mainstem and sidechannel production of coho smolts on an annual basis to evaluate how discharge variance may affect the proportional productivity. Unfortunately due to problems with full or partial creek trapping: a function of very large hatchery releases to the creek, and broad confidence limits on alternate mark recapture estimates it is only possible to evaluate in part the importance of the various side-channels. The channels are clearly significant contributors, with 14-24% of the total RST estimate being derived from the two channels (Tenderfoot excluded), although in recent years BC Rail channel appears to have declined in importance, perhaps related to beaver activity and spawner access. The variance on an annual basis in production has been relatively small (SD = 8%) when compared with RST estimates, perhaps indicating that the within channels variance which is high (3 fold, ~8k to 25k) is more determined by spawner escapement, a key factor in smolt production (Bradford et al 2000) than by other variables. As there is only one year of IFA channel estimates, additional WUP regime data is required to evaluate potential productivity variance as it relates to discharge and even then the outcome is uncertain. At the NVOS channel this can be combined with the capture of coho smolts required for marking to derive RST estimates.

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 was captured although data in 2003 and 2009 may result in a slightly inflated estimate due to high numbers of fish estimated in the final strata as river levels increased. As steelhead trout juveniles are found rearing in the river for at least two year (some fish migrate as 2 year olds others through age 4) the flow regime created in the WUP affects these fish throughout the entire year and thus we may expect these fish to be more sensitive to flow changes than fry outmigrants. Steelhead spawners may be affected by spring discharge in the spawning period, which can be extended from April through June and eggs may be affected during incubation, from April through August: fry are typically observed emerging in late July and through August (McCubbing et al 2006).

The CC indicated as for coho salmon smolts that it was concerned that the 2D model which predicted no net change in habitat for stream rearing salmonids based on the RUA method, may not be sensitive enough to detect smaller changes (25%) in the potential productivity of steelhead juveniles on the Cheakamus River. We examined the 8 years of data that we have collected at the RST utilizing power analysis techniques and we conclude that at this time insufficient data is available to determine a change of 75% or greater in total river production. The observed annual mean production change of 47% between treatments is not statistically defensible as we have only 3 years of IFA data one of which is of very poor precision and unrealistically high, and 5 years of WUP data again one of which is of some concern. Power analysis indicates 11 years of IFA and WUP data would be required to evaluate a statistical difference in production of 75% given the variance in population size. Given the lack of statistical confidence in the observed level of change in productivity, it is inappropriate at this time to attempt to categorize the reasons for population fluctuations. Smolt estimates are therefore currently utilized in conjunction with other steelhead data to establish possible relationships to flow regime changes (Korman et al 2012).

As for abundance data, growth data as length and condition factor were examined across all species. Fry data indicated that recent years, post 2006 have indicated a significant reduction in the size of outmigrant fry. The reasons for this change may relate to temperature variance restricting growth for chinook and pink fry which have a brief period of river residence as WUP river temperatures have been significantly lower in the out-migration period in March and April than IFA conditions. Determining the reason for the temperature difference is beyond the scope of this monitor. Steelhead smolt size at age is unavailable for IFA years due to low fish capture rates, so a before and after comparison is not particularly relevant with age structure changes very likely to affect average fish length on an annual basis as observed in 2009-2012 data. Length data of coho smolts indicate no significant change between IFA and WUP periods, although data have not been examined for changes in age class structure. Condition factor in smolts was unchanged in steelhead and slightly lower in coho juveniles. The statistically significant difference in coho smolts might be related to the lack of opportunity post 2006 for smolts to feed on co-captured chum fry in the RST trap box during holding in May as few were captured once the drum mesh was swapped out. Alternatively changes to annual temperature budgets may be restricting spring growth immediately prior to fish capture. In general changes to fish size and condition appear limited although further investigation of coho condition factor may be warranted if the temperature changes persist over the next 5 years and are defined as related to the WUP discharge regime.

5.0 Recommendations and Conclusions

The data collected from 2001-2012 indicate that for the majority of species and or age classes of salmonids, we do not have as yet sufficient data to evaluate a statistical variance in watershed production between the IFA and the WUP flow regimes. In some cases, Chinook smolts and fry, steelhead smolts and arguably pink fry, it is unlikely that we will be able to evaluate a statistical difference between treatments using only juvenile data at least in a reasonable timeframe (<20 years) or if at all. This is due to a variety of reasons including: low numbers of sample years of IFA data, high variance in observed population levels across years and poor precision of juvenile estimates in some years. For other species, chum fry and coho smolts we have either established a statistically acceptable result (see Chum Monitor report 1b, McCubbing et al 2012) or are within a few years of doing so.

The data collected from 2001-2012 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 salmon) even large variance in population levels (75% or greater) may not be statistically defensible. The expanded studies on steelhead trout and to a lesser extent on chum salmon have provided a more confident evaluation of the changes in watershed production and how these may relate to discharge, although many questions remain un-answered. In these cases the data collected perform a supporting role as well as the primary role of evaluating pre and post treatment changes. In coho salmon, additional data should within 5 years allow for assessment of the likelihood of a slightly coarser change in productivity (50%) than the CC originally intended (25%).

The linkage between side channel production and mainstem production of fry and smolts has been examined but presented several obstacles to complete analysis. For coho smolts the inability to derive a defensible estimate of production in Tenderfoot and the addition of new channels upstream of the RST site, confound the ability to clearly define mainstem versus sidechannel production. In chum fry, a production estimate from Tenderfoot Creek is required to establish this linkage (McCubbing et al. 2012)

The following recommendations are provided for ongoing studies of juvenile salmonid production, excluding chum fry which are addressed in Monitor 1b (McCubbing et al 2012):

1) Steelhead smolt data should be collected on an ongoing basis to assist the steelhead monitor (#3) evaluations, but the CC should be aware that direct assessment of a population change through smolt monitoring only even at a relatively broad level (75%) is very unlikely.
2) Coho smolt monitoring should be continued at the mainstem RST site for an additional 5 years as it is likely that the additional data will assist in being able to evaluate the likelihood of a moderate population change (>50%) with a high degree of statistical significance (p=0.8).
3) Only one IFA year of side channel data exists for coho smolts, so variance in channel production as it pertains to discharge is restricted to variance within the current WUP flow regime. The requirement to further assess channel production as it relates to discharge is open for discussion, but coho smolt monitoring at the side channels could be suspended if the data are only used for proportional production evaluation (channels to mainstem), as the lack of a reliable estimate from Tenderfoot Creek (2007-2012) confounds these evaluations.
4) Pink fry monitoring should be continued if chum fry monitoring (see Monitor 1b) is continued as the incremental cost of undertaking this work is very small and the data allow for an assessment of overall watershed health.
5) Chinook juvenile salmonid monitoring may be continued but without the addition of a broader suite of monitoring goals (adults and hatchery evaluations) the ability of juvenile fry and/or smolt data to determine flow related changes will be highly unlikely from data collected through 2017.

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
Early Chinook Fry (Feb. & March)	0+ (YOY)	CHF	< 70mm	Cheakamus length frequency data (2000-2006)
Late Chinook Fry (April & May	0+ (YOY)	CHF	70-90mm	Cheakamus length frequency data (2000-2006)
Chinook Smolts	1+	CHS	>90mm	Cheakamus length frequency data (2000-2006)

Table 2. Eleven-year summary (2001-2012) 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 (live)	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 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**					

Table 2. continued

Species	Year	Total Caught (live)	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**	**29,314,436**	**630,824**	**0.02**
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**

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

Table 2. continued

Species	Year	Total Caught (live)	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	35,44	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**	**94,629**	**17,950**	**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**	**81,335**	**5,458**	**0.07**
RST Coho Smolt	**2012**	**6,194**	**6,870**	**918**	**66,944**	**5,599**	**0.08**
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**

Table 2. continued

Species	Year	Total Caught (live)	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	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**	**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**
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**

Table 2. continued

Species	Year	Total Caught (live)	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**
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**

Table 3. Power Analysis Table

	Years of Data		Average Abundance					
Sp.	**IFA**	**WUP**	**IFA**	**WUP**	**Change in Abundance WUP-IFA**	**Change in Abundance (%)**	**Average SD.**	**Average relative error (CV)**
CHF	5	6	250,860	378,926	128,066	51%	242,209	0.77
CHS	3	1	9,299	14,439	5,140	55%	4,018	0.38
PKF	3	3	686,706	4,109,163	3,422,457	498%	2,446,021	1.19
COS	7	5	79,940	76,544	-3,397	-4%	23,967	0.30
SHS	2	5	6,101	8,951	2,850	47%	3,646	0.43
CMF	6	6	3,795,110	4,109,163	569,086	15%	1,600,026	0.39

			Years per Group to Detect:				
Sp.	**Power at Type I=0.05**	**Rel. Change in Abundance achieve Power=0.8**	**+1% Power=0.8**	**+25% Power=0.8**	**+50% Power=0.8**	**+75% Power=0.8**	**Power with 5 additional WUP years**
CHF	0.13	184%	156,978	233	59	27	0.17
CHS	0.12	244%	29,675	48	13	6	0.43
PKF	0.26	1094%	1,744,192	3,204	801	357	0.59
COS	0.06	54%	14,416	24	7	4	0.06
SHS	0.15	176%	54,318	90	23	11	0.23
CMF	0.09	76%	27,254	46	12	6	0.11

Table 4. Summary of mean fry lengths (mm) 2001-2012 from the Cheakamus River.

Species	Year	N	Mean Length	Range
Chum Fry	2001	352	40	31-50
	2002	414	39	30-53
	2003	276	41	33-55
	2004	223	39	32-50
	2005	200	39	31-55
	2006	224	39	30-54
	2007	**425**	**38**	**30-54**
	2008	**459**	**39**	**31-49**
	2009	**400**	**39**	**34-57**
	2010	**400**	**38**	**31-48**
	2011	**465**	**39**	**35-45**
	2012	**405**	**37**	**30-41**

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**

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**

Table 4. 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**

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**

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**

Table 4. continued

Species	Year	N	Mean Length	Mean Weight	Mean K
Coho Smolts	2001	2280	89	8.0	1.1
	2002	807	93	10.7	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**

Table 5. Steelhead proportions of length at age 2008-2012 from the Cheakamus River

2008	Age 1	Age 2	Age 3	Age 4	Age 5	sum	Average Age	Pop. Mean (mm)
N	0	7,562	6,259	72	0	13,893	2.46	169.5
%	0	54.4	45.1	0.5	0	100		
Mean (mm)		160.0	183	0	0			

2009	Age 1	Age 2	Age 3	Age 4	Age 5	sum	Average Age	Pop. Mean (mm)
N	0	9,247	2,866	282	0	12,395	2.28	167
%	0	74.6	23.1	2.3	0	100		
Mean (mm)		165	189					

2010	Age 1	Age 2	Age 3	Age 4	Age 5	Sum	Average Age	Pop. Mean (mm)
N	0	2,454	2,177	143	200	4,974	2.6	177
%	0	49.3	43.8	2.9	4.0	100		
Mean (mm)		159	184	244	263			

2011	Age 1	Age 2	Age 3	Age 4	Age 5	sum	Average Age	Pop. Mean (mm)
N	0	3,084	2,348	85	0	5,518	2.46	173
%	0	55.9	42.6	1.5	0			
Mean (mm)		162	186	193				

2012	Age 1	Age 2	Age 3	Age 4	Age 5	sum	Average Age	Pop. Mean (mm)
N	0	738	1346	124	0	2,208	2.7	176
%	0	33.4	60.9	5.6	0	100		
Mean (mm)		164	179	214				

Table 6. Comparison of IFA and WUP Temperatures by Month

	10 Percentile	50 Percentile	90 Percentile	Mean
January	No data	No data	No data	No data
February 15-28	No difference	No difference	No difference	No difference
March	No difference	Pre > Post*	Pre > Post*	Pre > Post*
April	Pre > Post*	Pre > Post*	Pre > Post*	Pre > Post*
May	Pre > Post*	Pre > Post*	Pre > Post*	Pre > Post*
June	Pre > Post*	Pre > Post*	Pre > Post*	Pre > Post*
July	Pre > Post*	Pre > Post*	Post > Pre*	Pre > Post*
August	Pre > Post*	Pre > Post*	Post > Pre**	Pre > Post*
September	Pre > Post*	Pre > Post**	No difference	Pre > Post*
October	No difference	No difference	Post > Pre*	No difference
November 1-10	Pre > Post*	Post > Pre*	Post > Pre*	Post > Pre*
December	No data	No data	No data	No data

*p value = 0.01
**p-value = 0.05

7.0 FIGURES

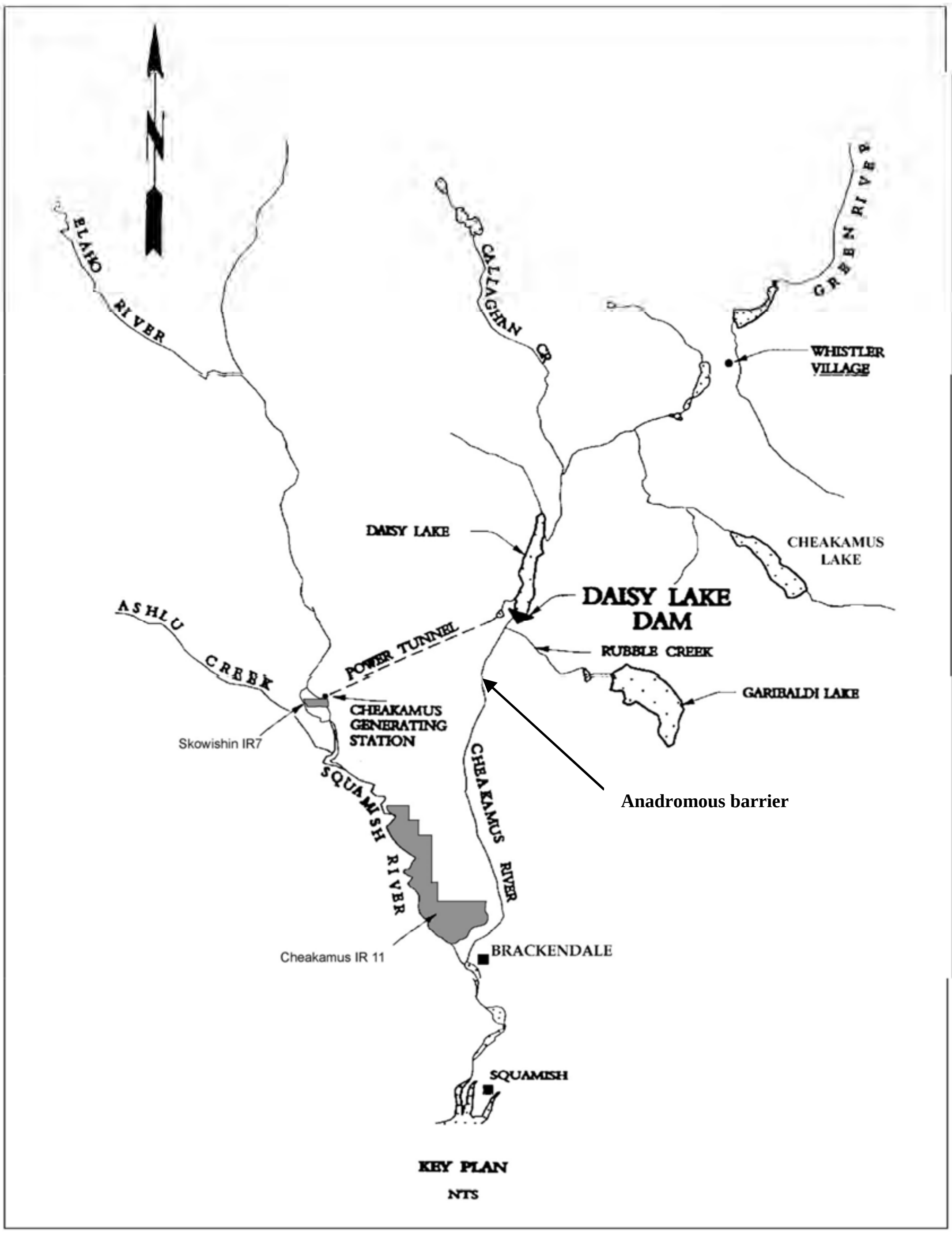


Figure 1: Map of Cheakamus Watershed indicating location of Daisy Dam and diversion tunnel.

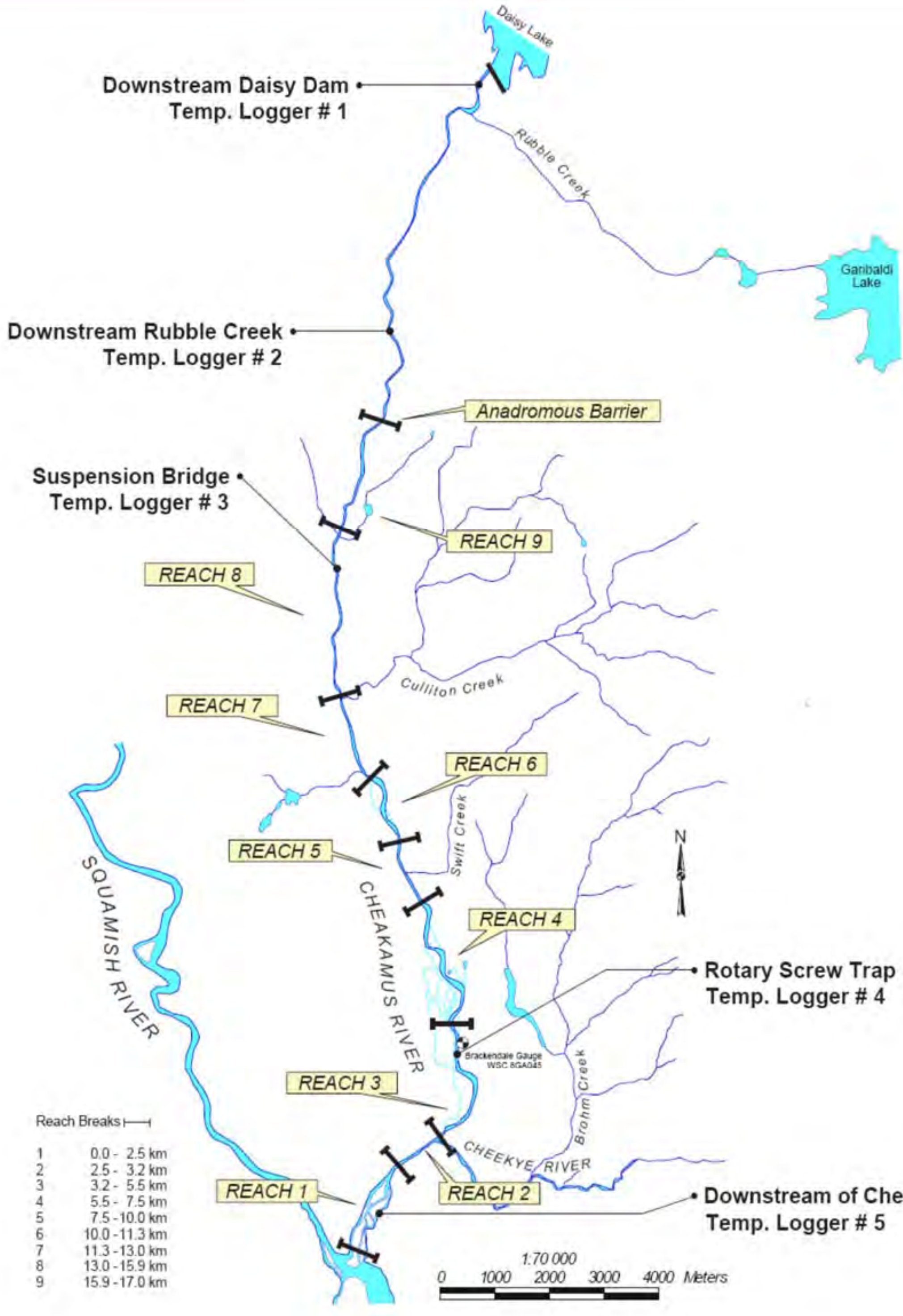


Figure 2. Cheakamus River watershed indicating Reaches 1 through 9, WSC gauging station, temperature loggers, and RST trap location.

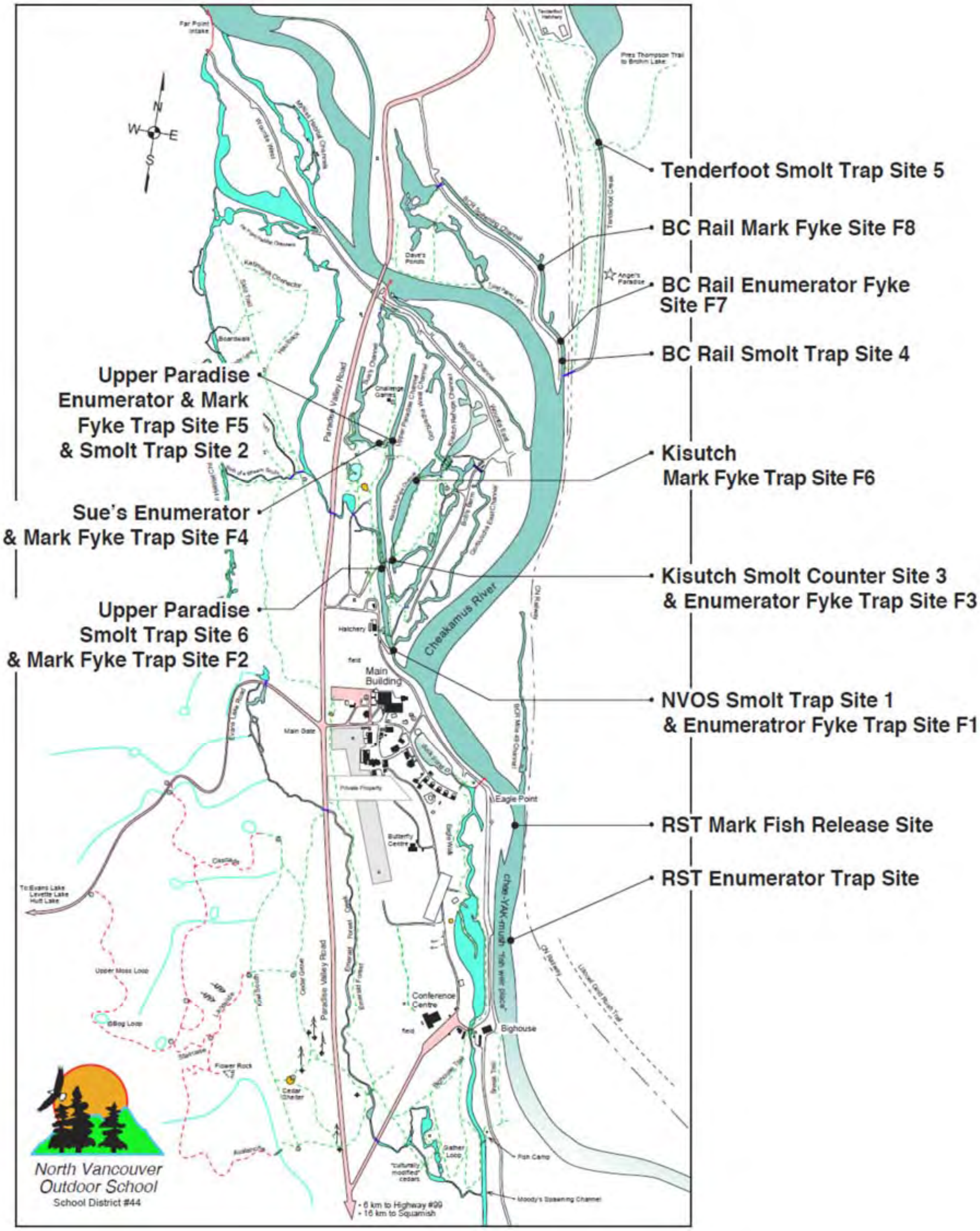


Figure 3.Site Map indicating trap sites utilized for the Cheakamus River Juvenile Outmigration Monitor 1a.

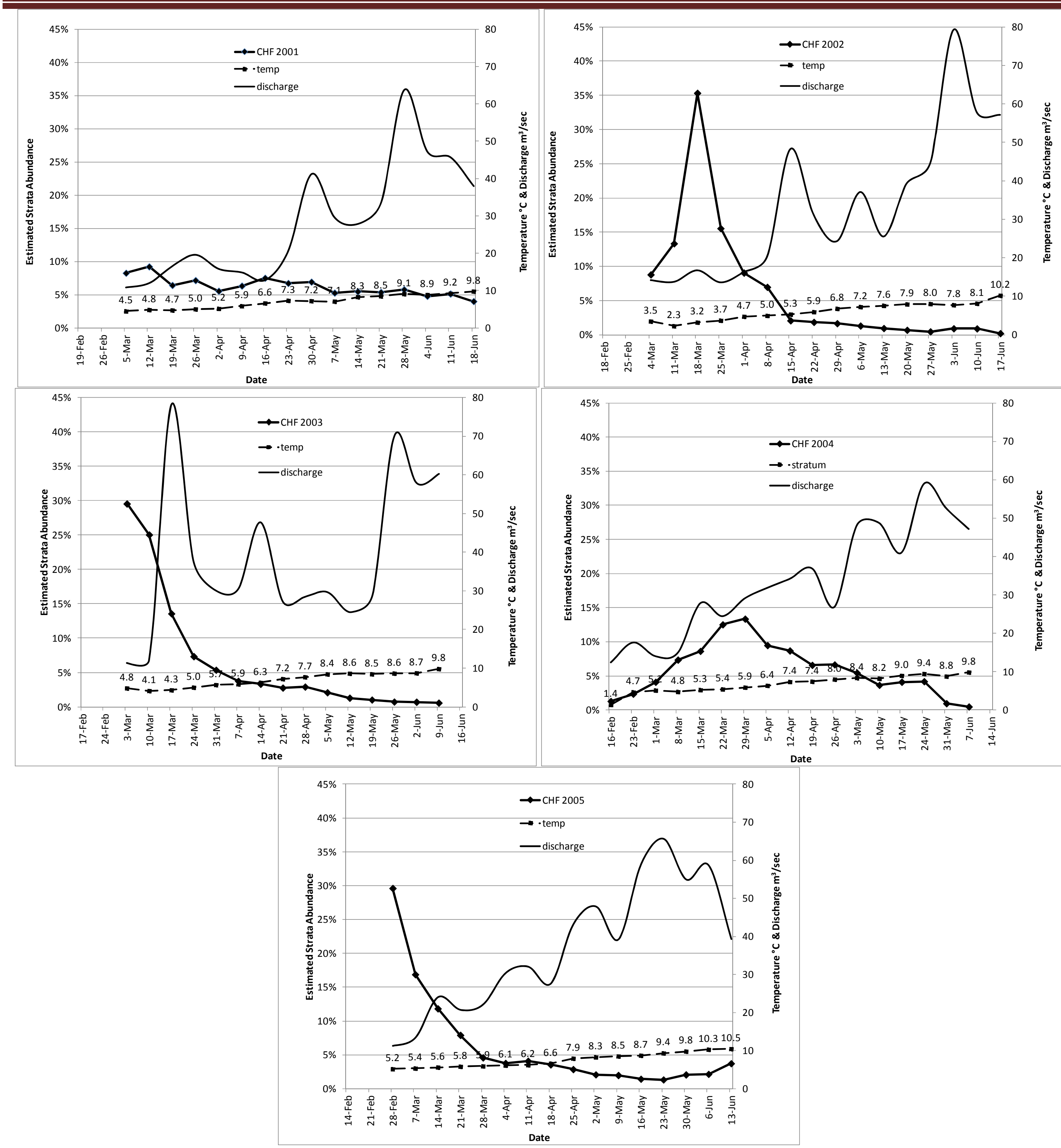


Figure 4. IFA Weekly abundance estimates of chinook fry (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River

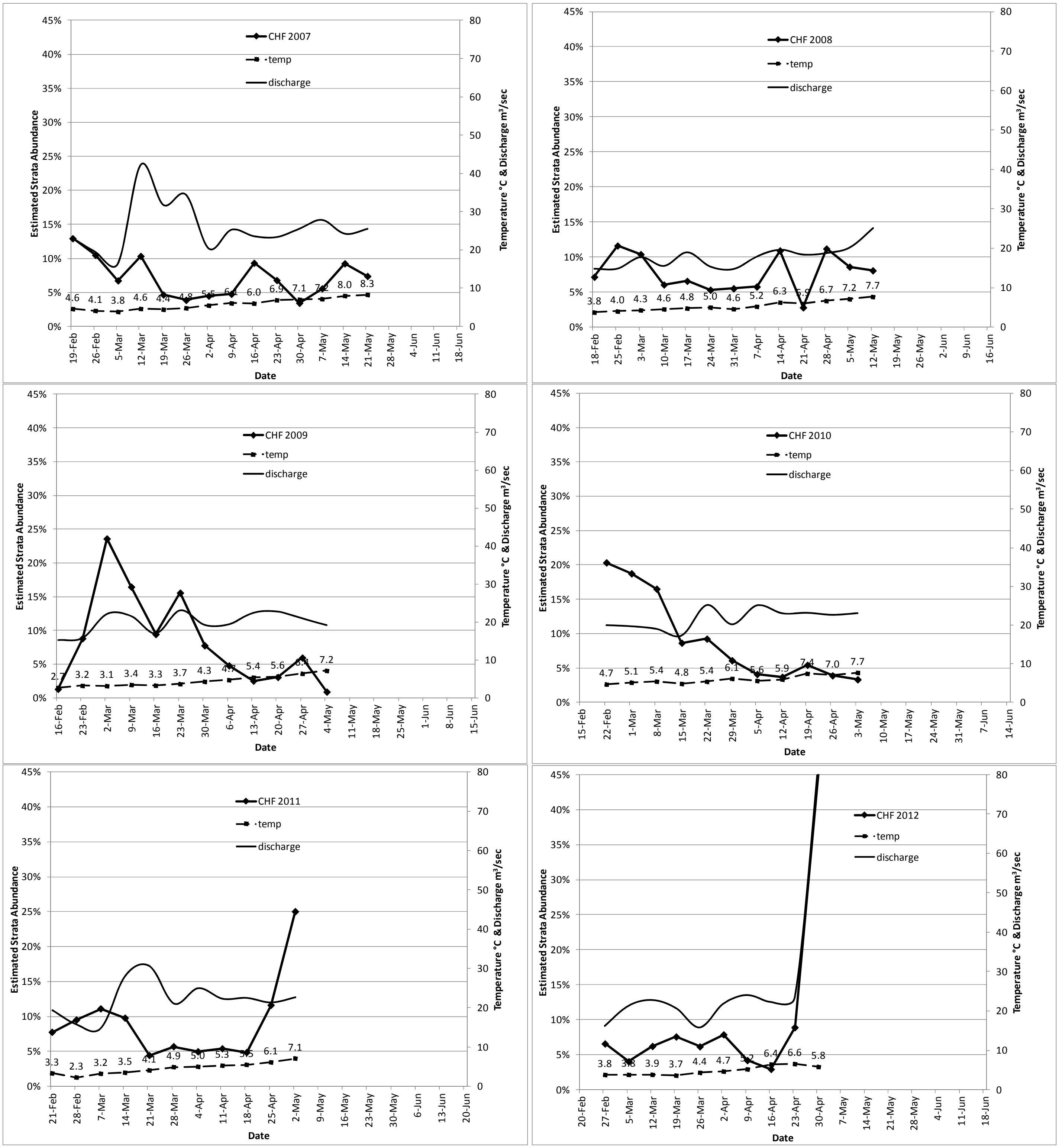


Figure 5. WUP Weekly abundance estimates of chinook fry (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

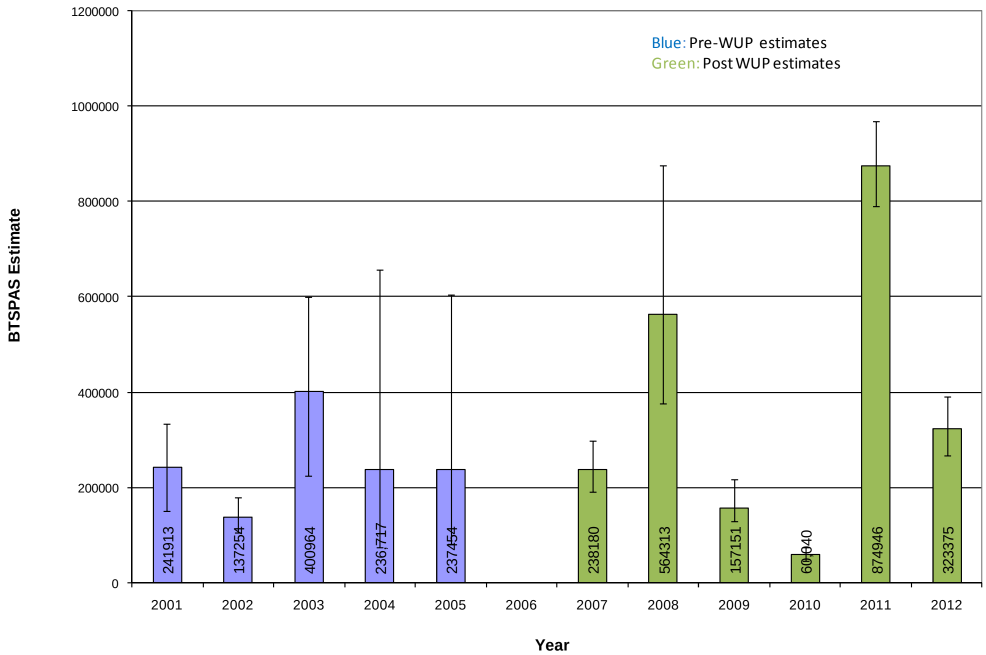


Figure 6. RST derived BTSPAS estimates of chinook fry from Spring 2001 to 2012, including 95% confidence limits.

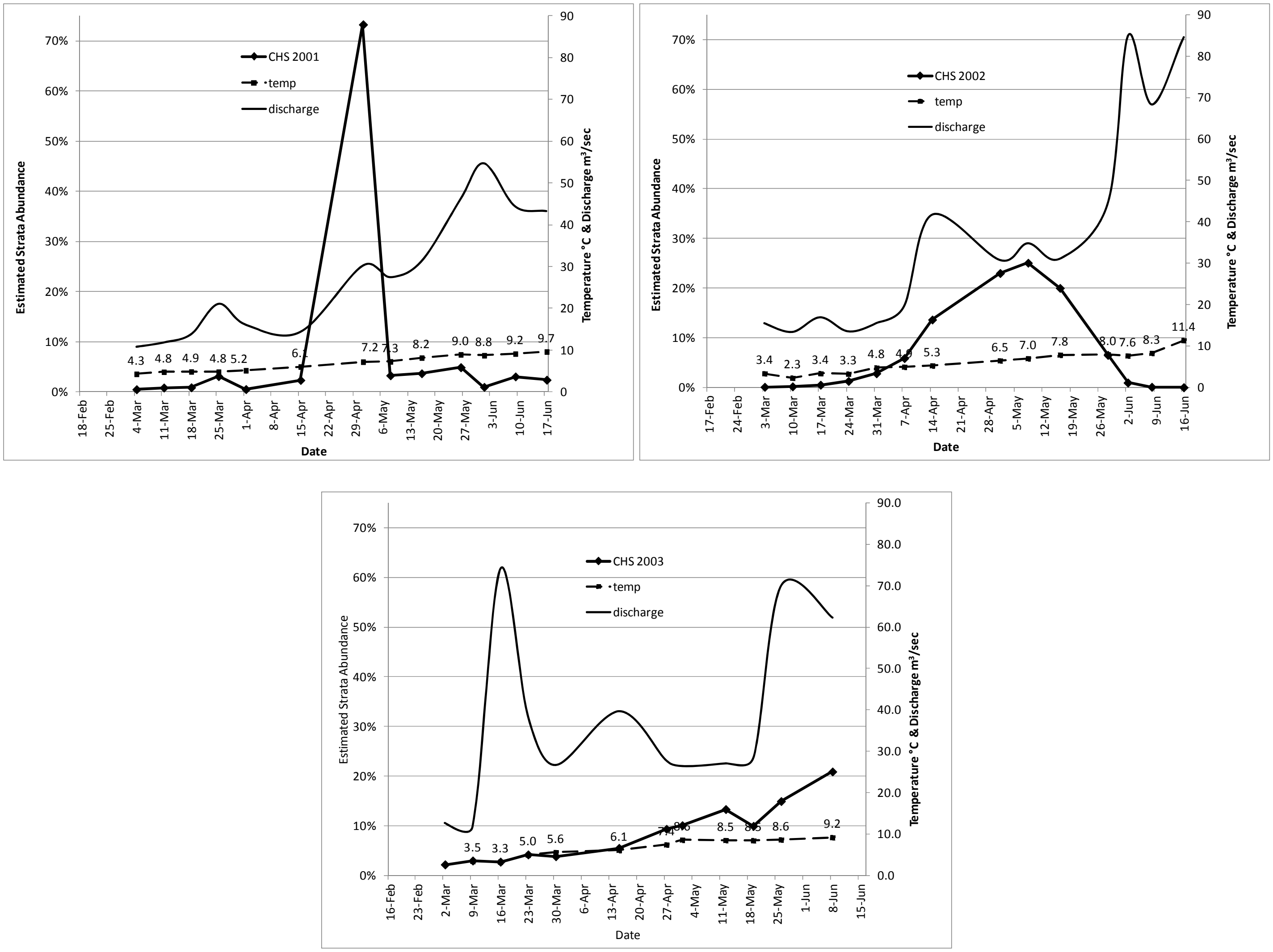


Figure 7. IFA weekly abundance estimates of chinook smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

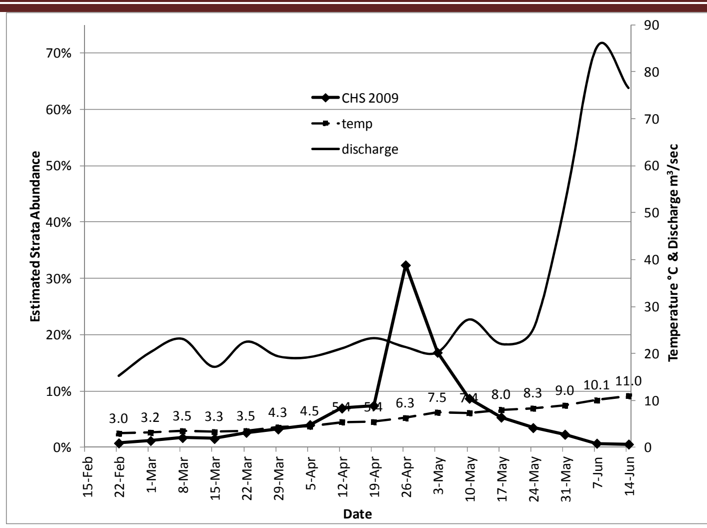


Figure 8. WUP Weekly abundance estimates of chinook smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

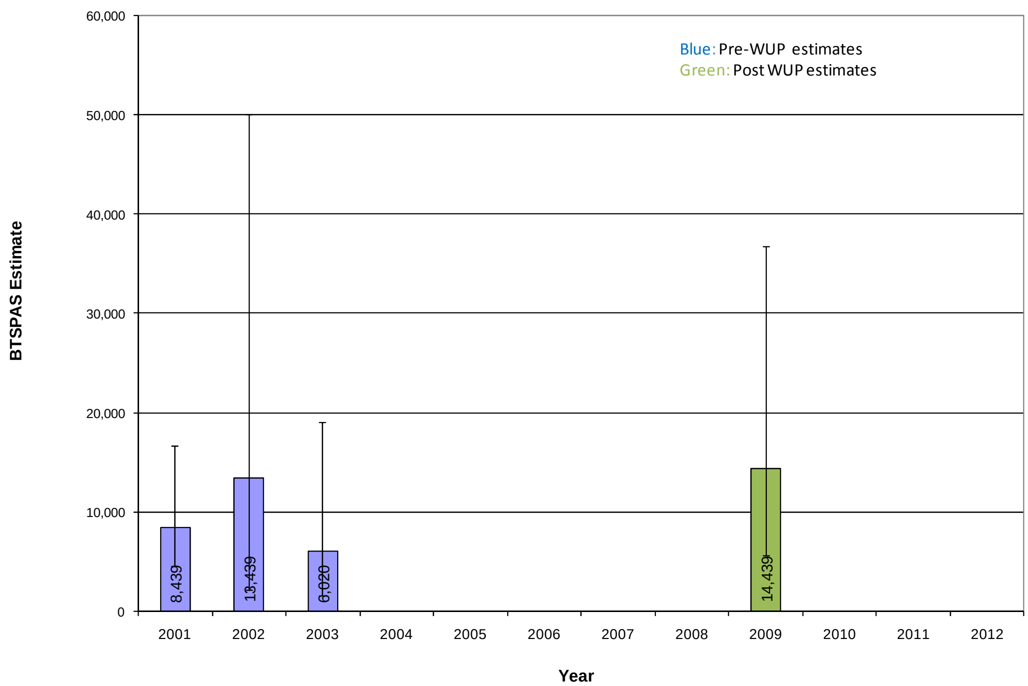


Figure 9. RST derived BTSPAS of chinook smolts from Spring 2001 to 2012, including 95%

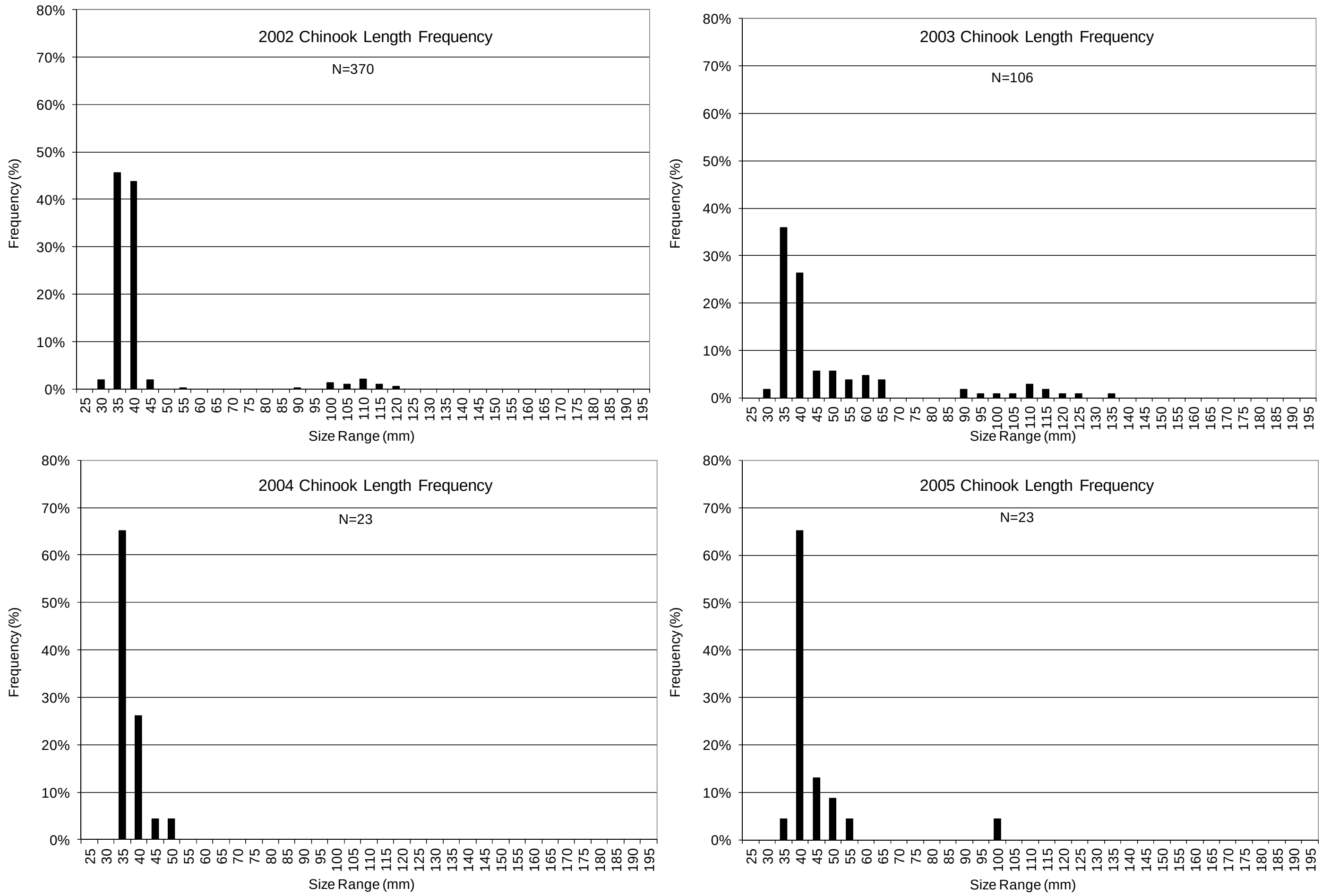
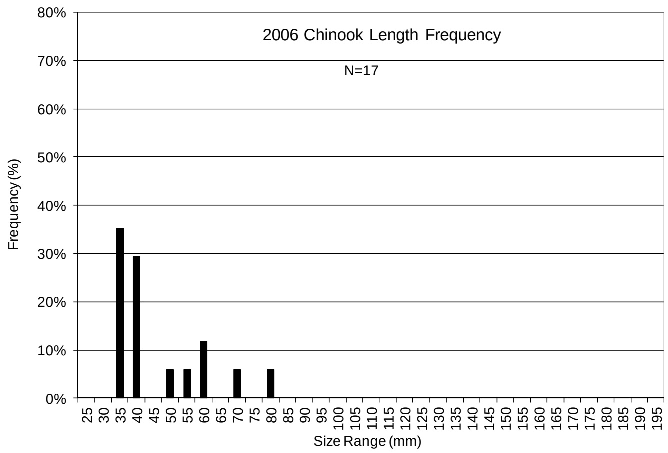
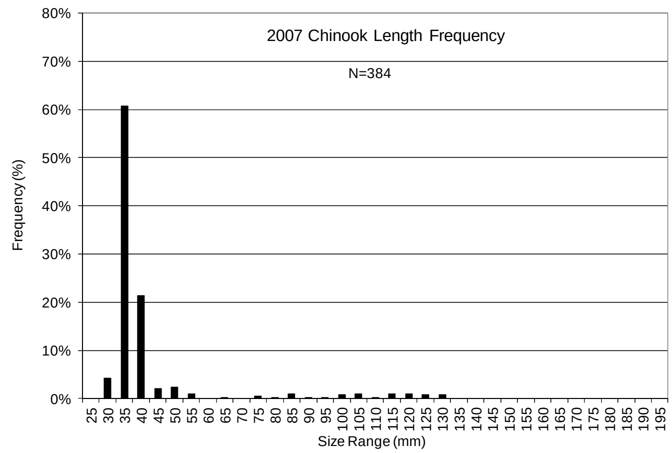
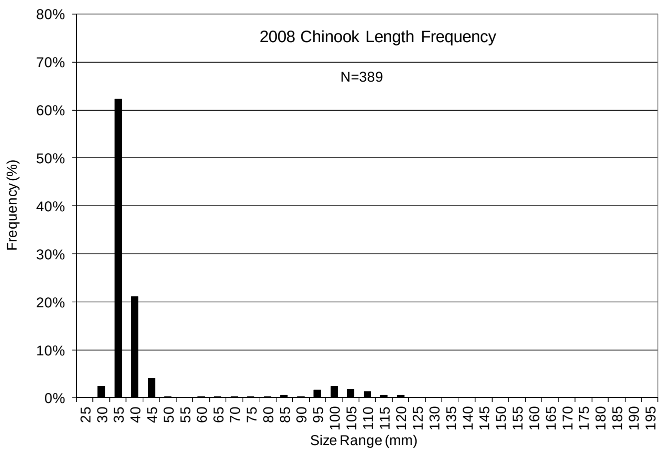
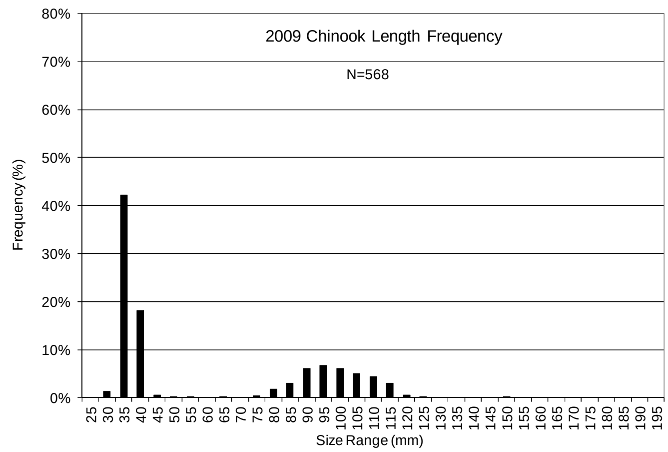


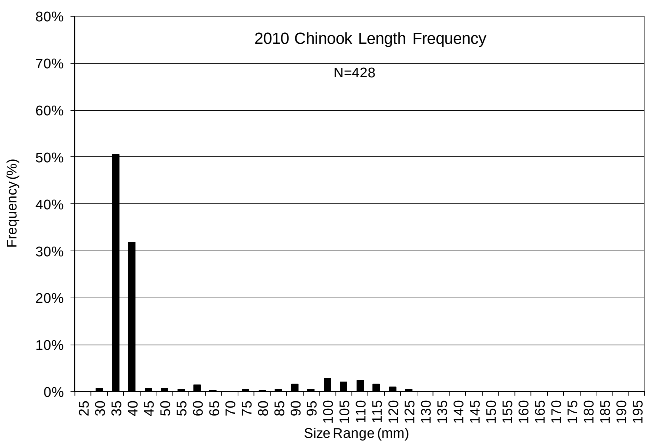
Figure 10. IFA length frequency distribution of chinook juveniles from the Cheakamus River.

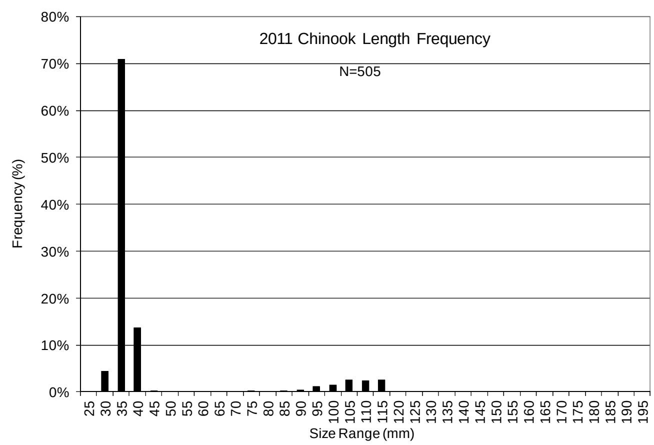

2006 Chinook Length Frequency
N=17
Frequency (%)
Size Range (mm)


2007 Chinook Length Frequency
N=384
Frequency (%)
Size Range (mm)


2008 Chinook Length Frequency
N=389
Frequency (%)
Size Range (mm)


2009 Chinook Length Frequency
N=568
Frequency (%)
Size Range (mm)


2010 Chinook Length Frequency
N=428
Frequency (%)
Size Range (mm)


2011 Chinook Length Frequency
N=505
Frequency (%)
Size Range (mm)

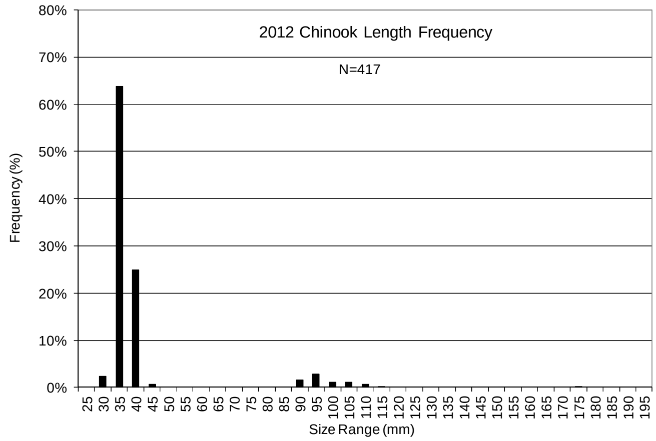


Figure 11. WUP length frequency distribution of chinook juveniles from the Cheakamus River.chinook length frequency (%)

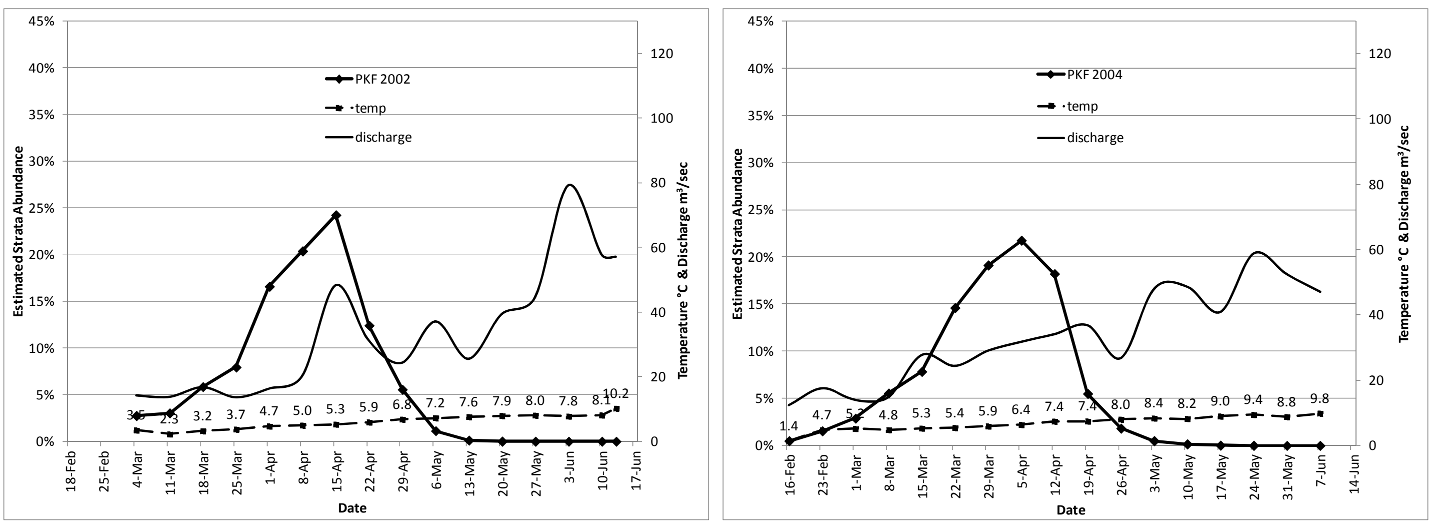


Figure 12. IFA weekly abundance estimates of pink fry (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

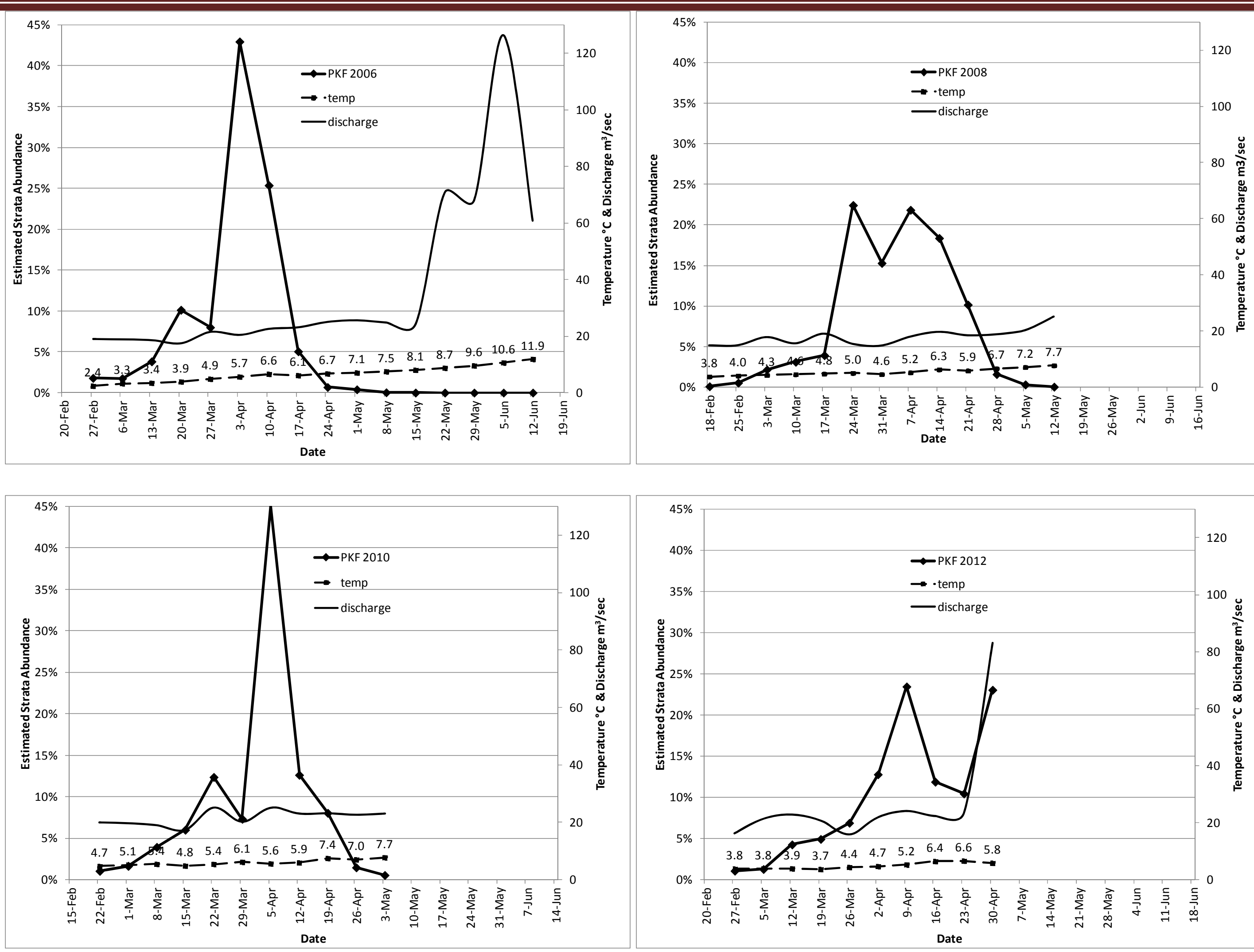


Figure 13. WUP weekly abundance estimates of pink fry (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

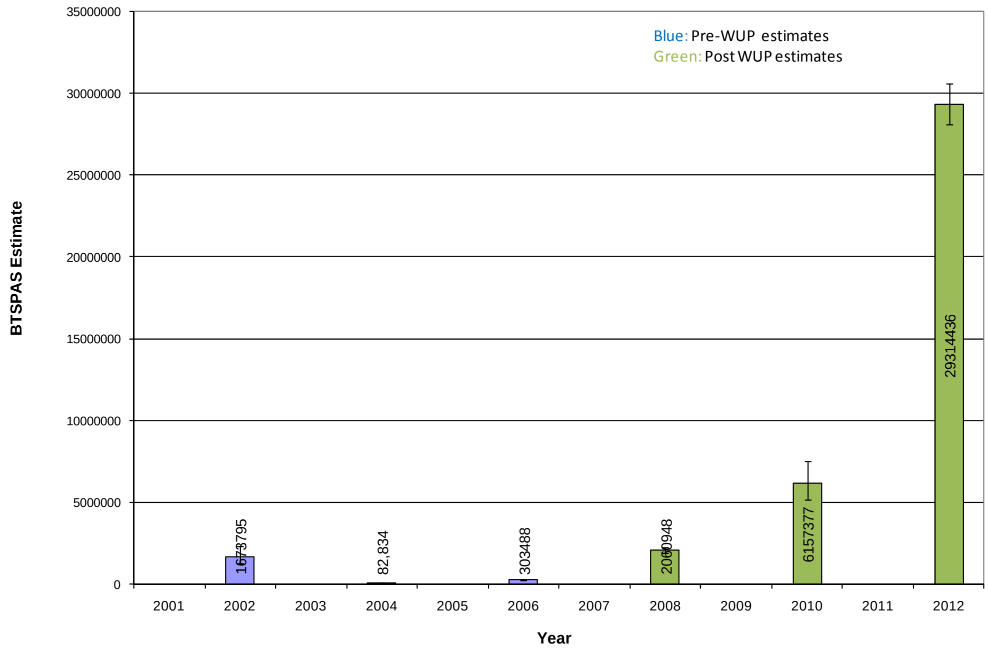
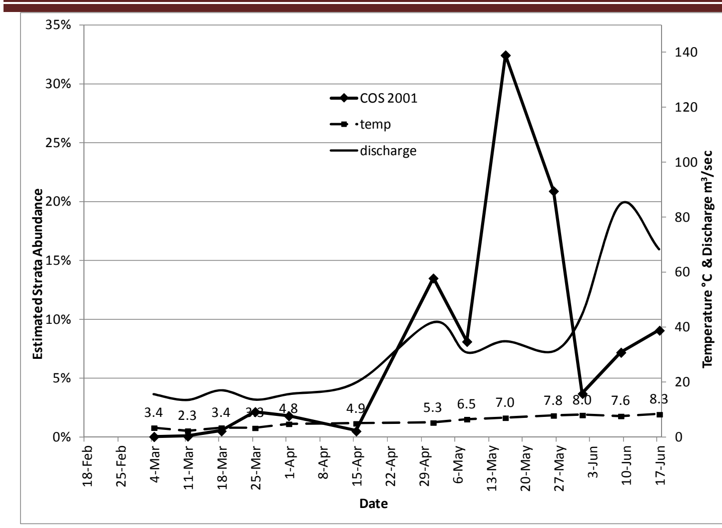
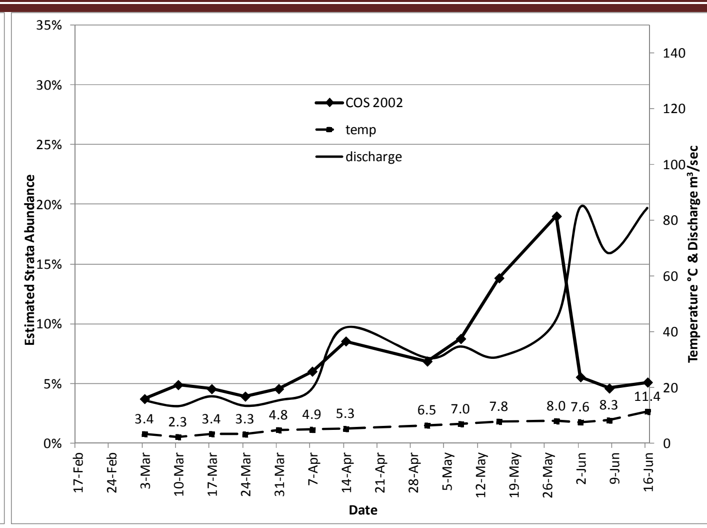
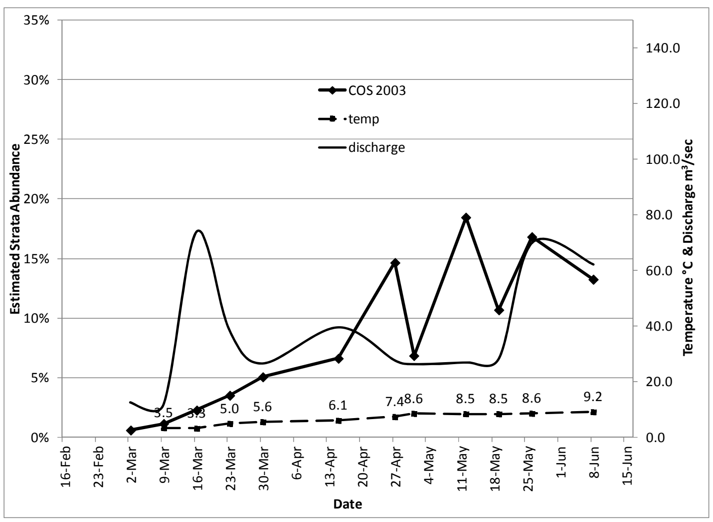
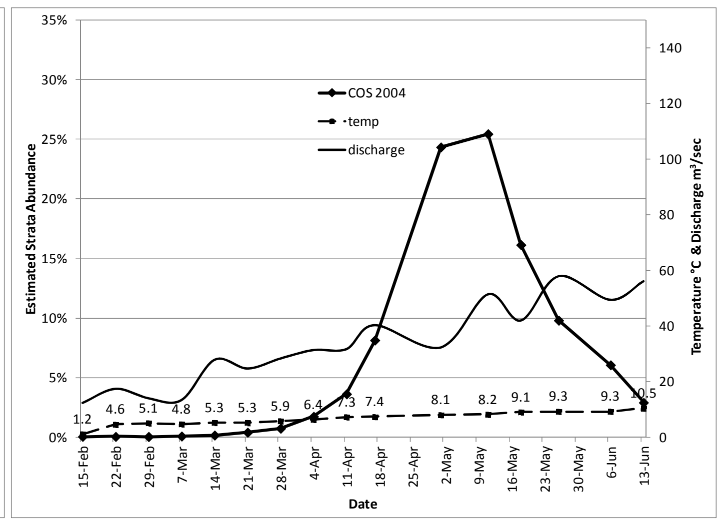


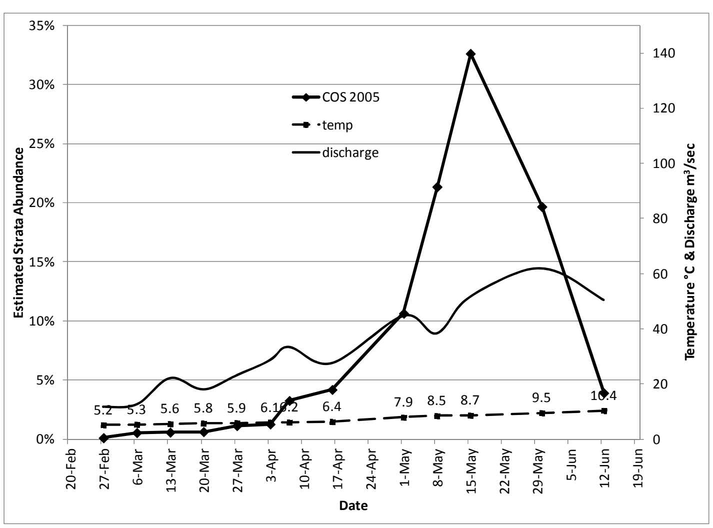
Figure 14. RST derived BTSPAS estimates of pink fry from Spring 2001 to 2012, including 95% confidence limits.

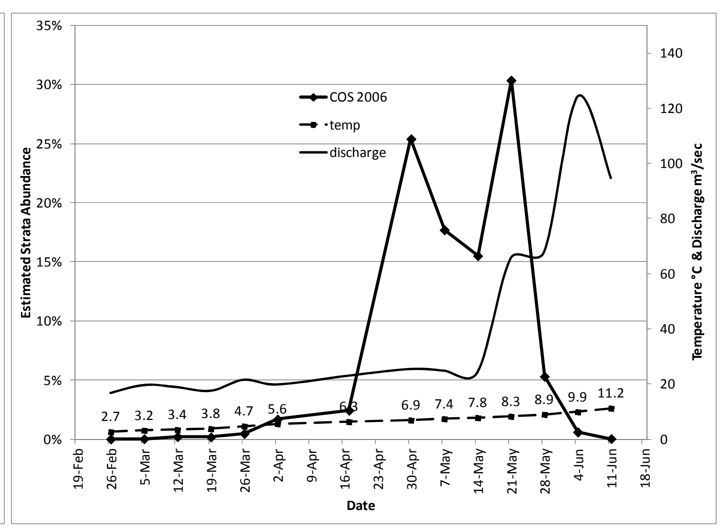

COS 2001
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date


COS 2002
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date


COS 2003
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date


COS 2004
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date


COS 2005
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date


COS 2006
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date

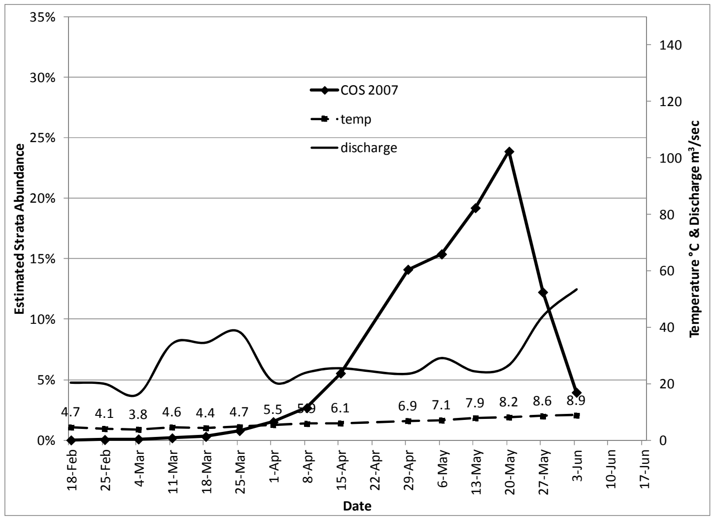


Figure 15. IFA weekly abundance estimates of coho smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

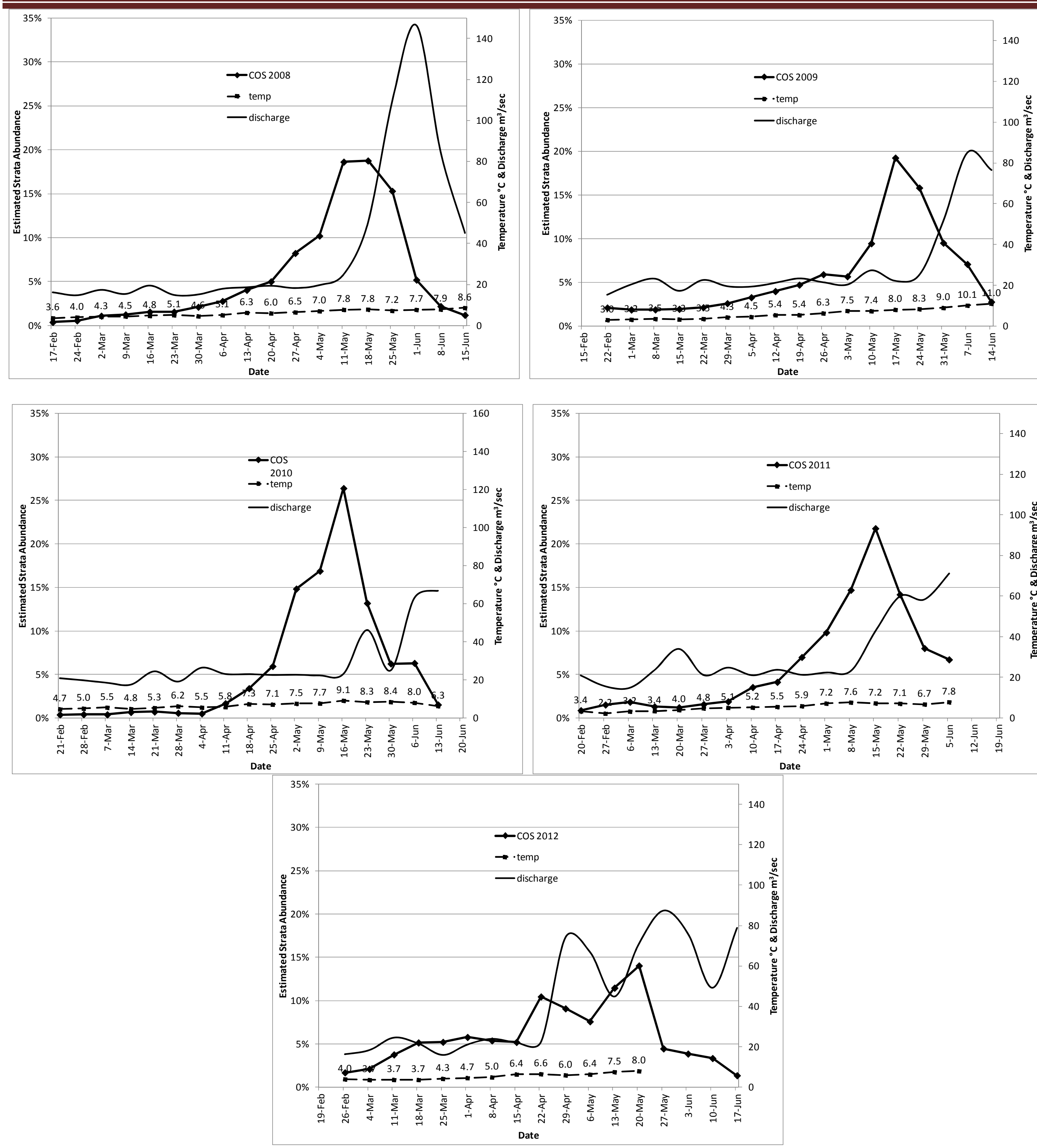


Figure 16. WUP weekly abundance estimates of coho smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

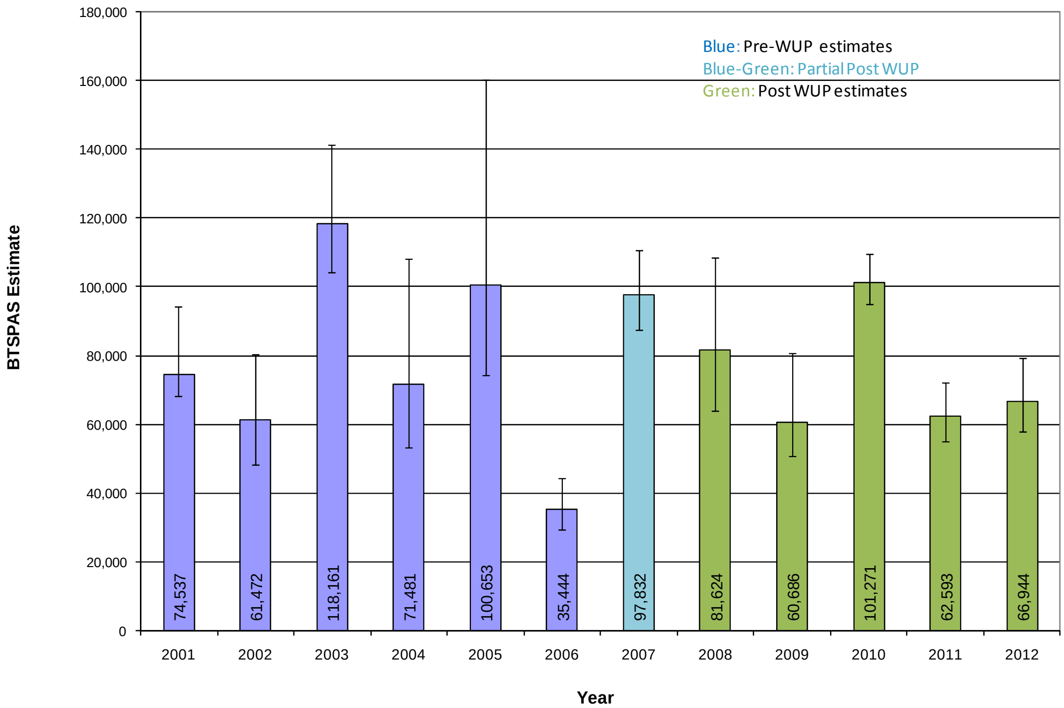
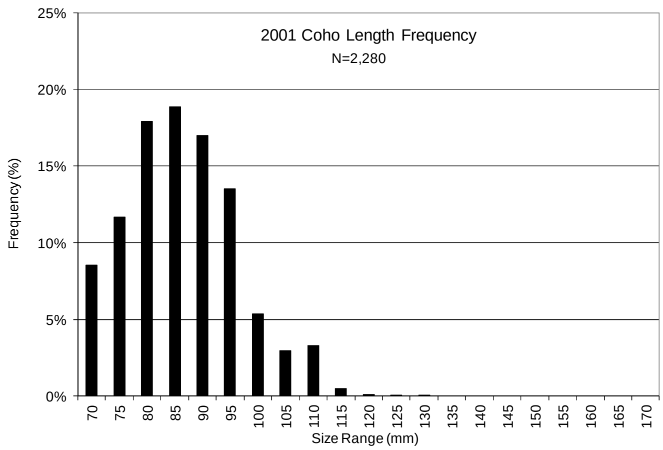
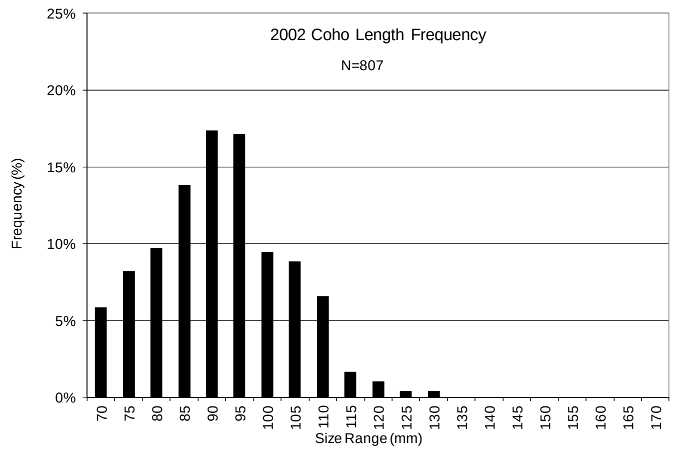
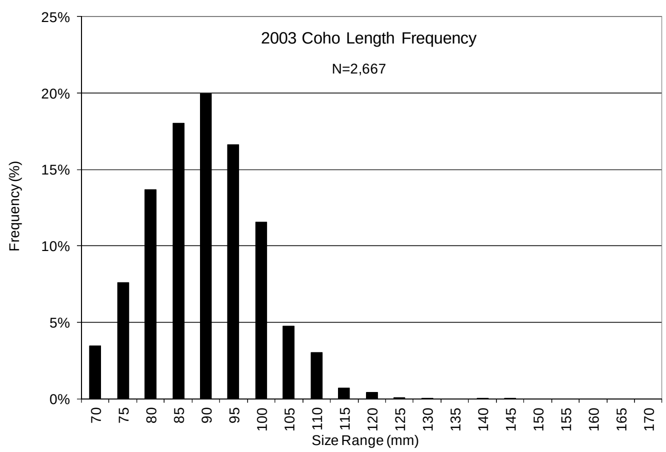
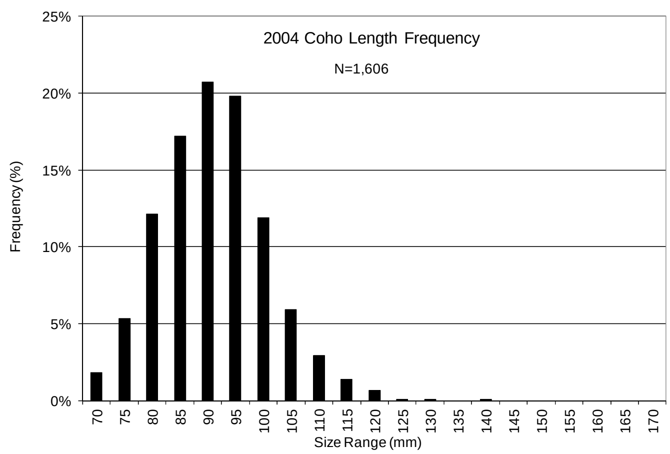


Figure 17. RST derived BTSPAS estimates of mainstem coho smolts outmigration, from Spring 2001 to 2012


2001 Coho Length Frequency
N=2,280
Frequency (%)
Size Range (mm)


2002 Coho Length Frequency
N=807
Frequency (%)
Size Range (mm)


2003 Coho Length Frequency
N=2,667
Frequency (%)
Size Range (mm)


2004 Coho Length Frequency
N=1,606
Frequency (%)
Size Range (mm)

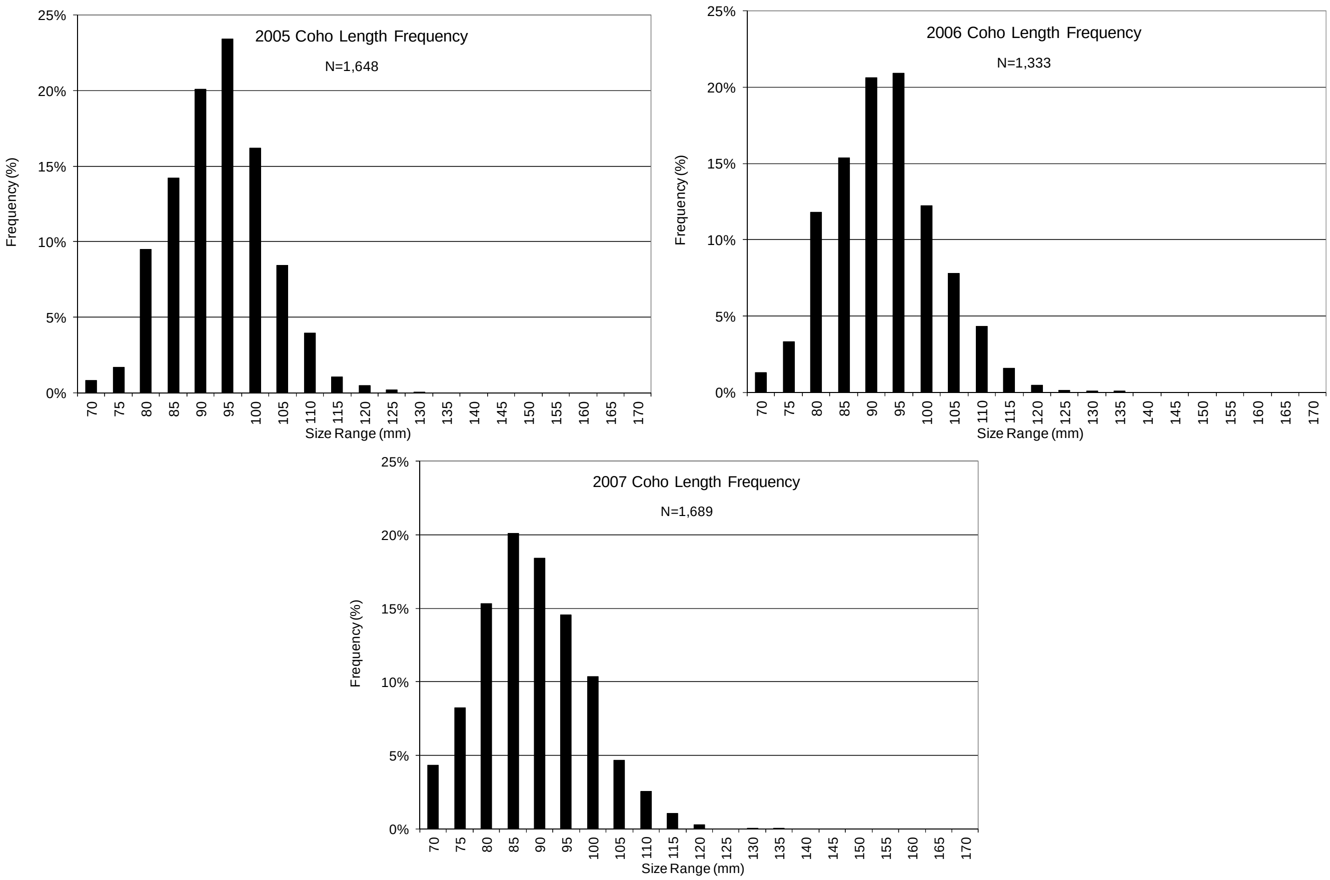


Figure 18. IFA length frequency distribution of coho smolts from the Cheakamus River.

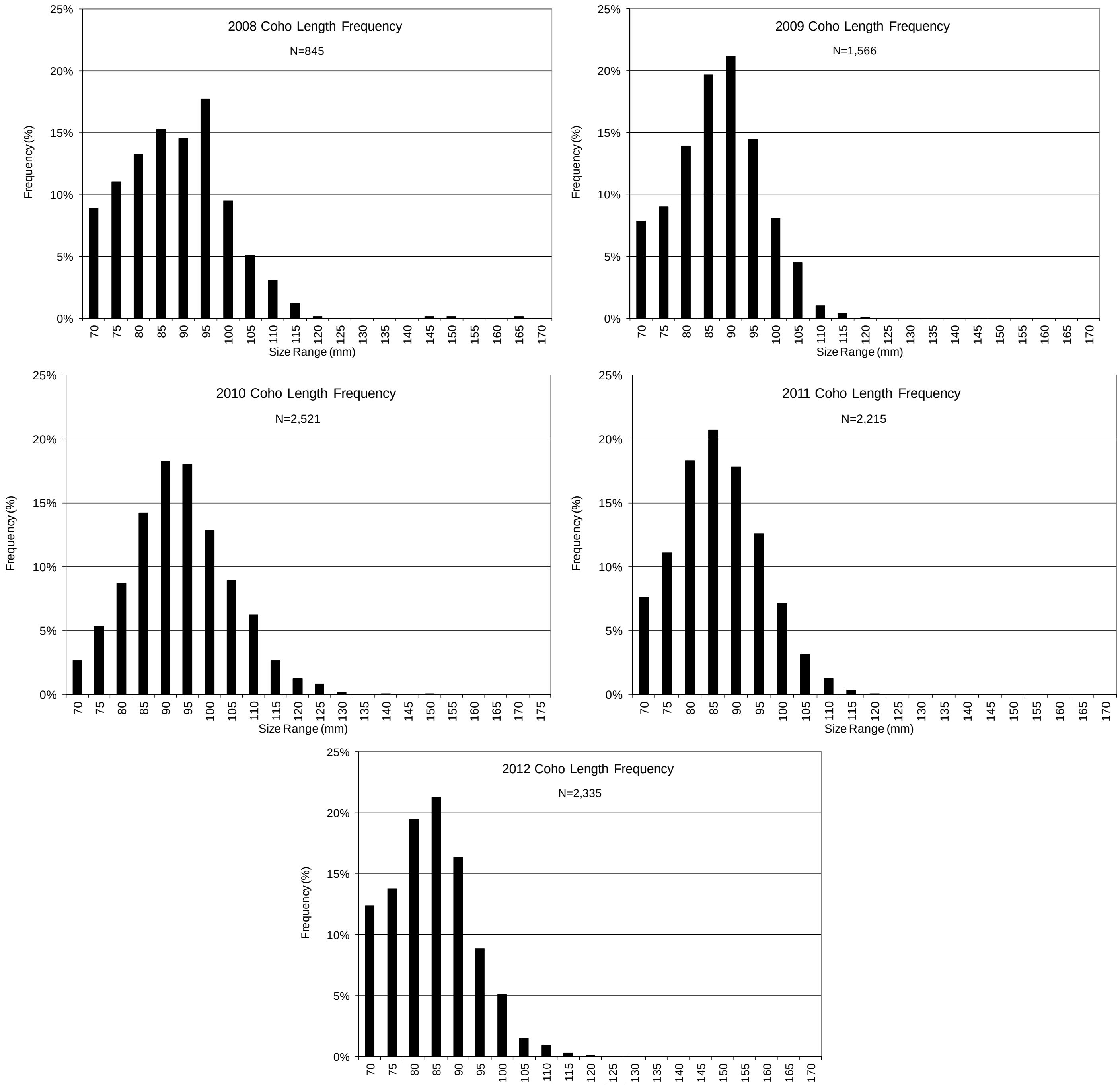


Figure 19. WUP length frequency distribution of coho smolts from the Cheakamus River.

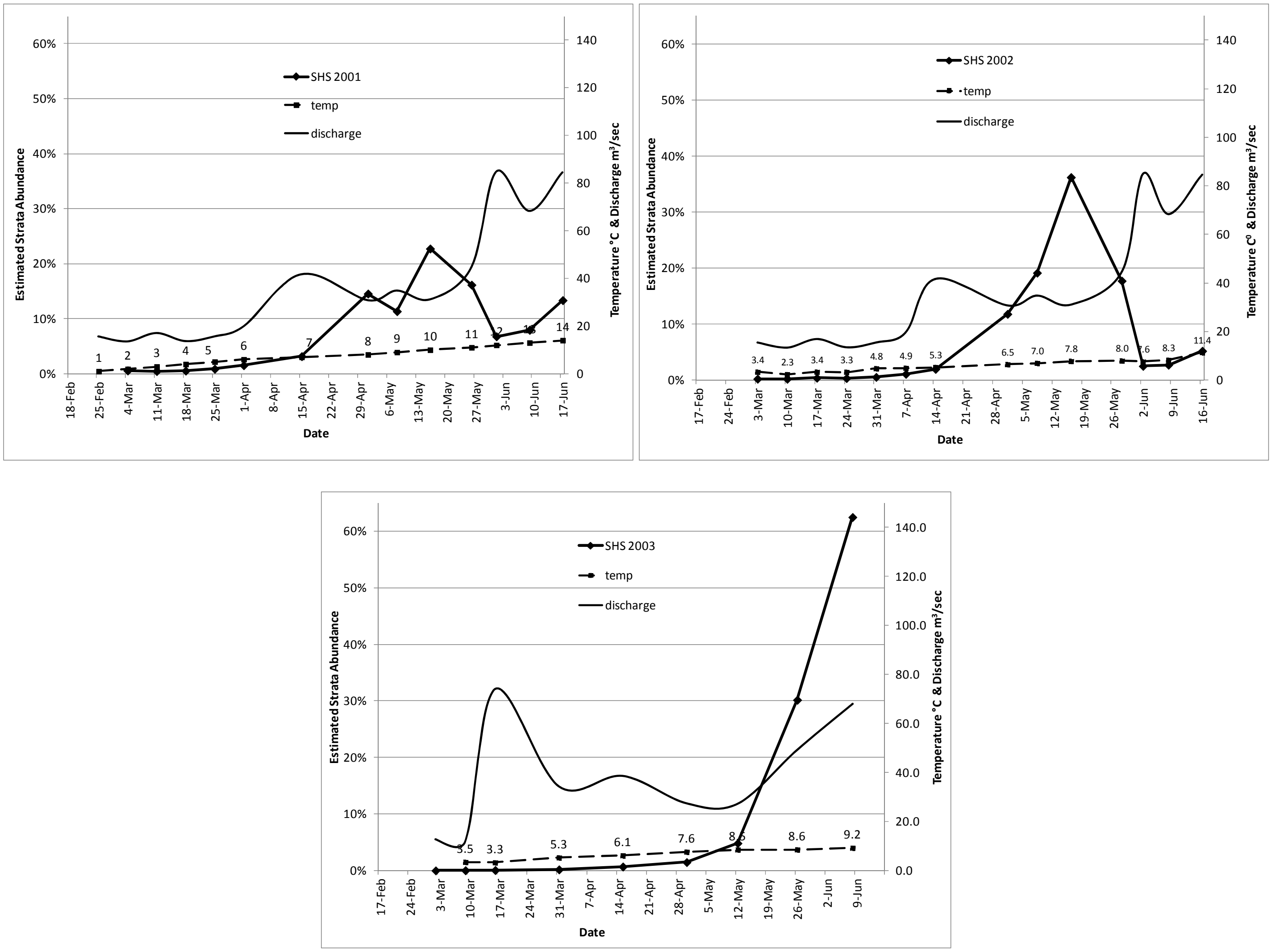


Figure 20. IFA weekly abundance estimates of steelhead smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

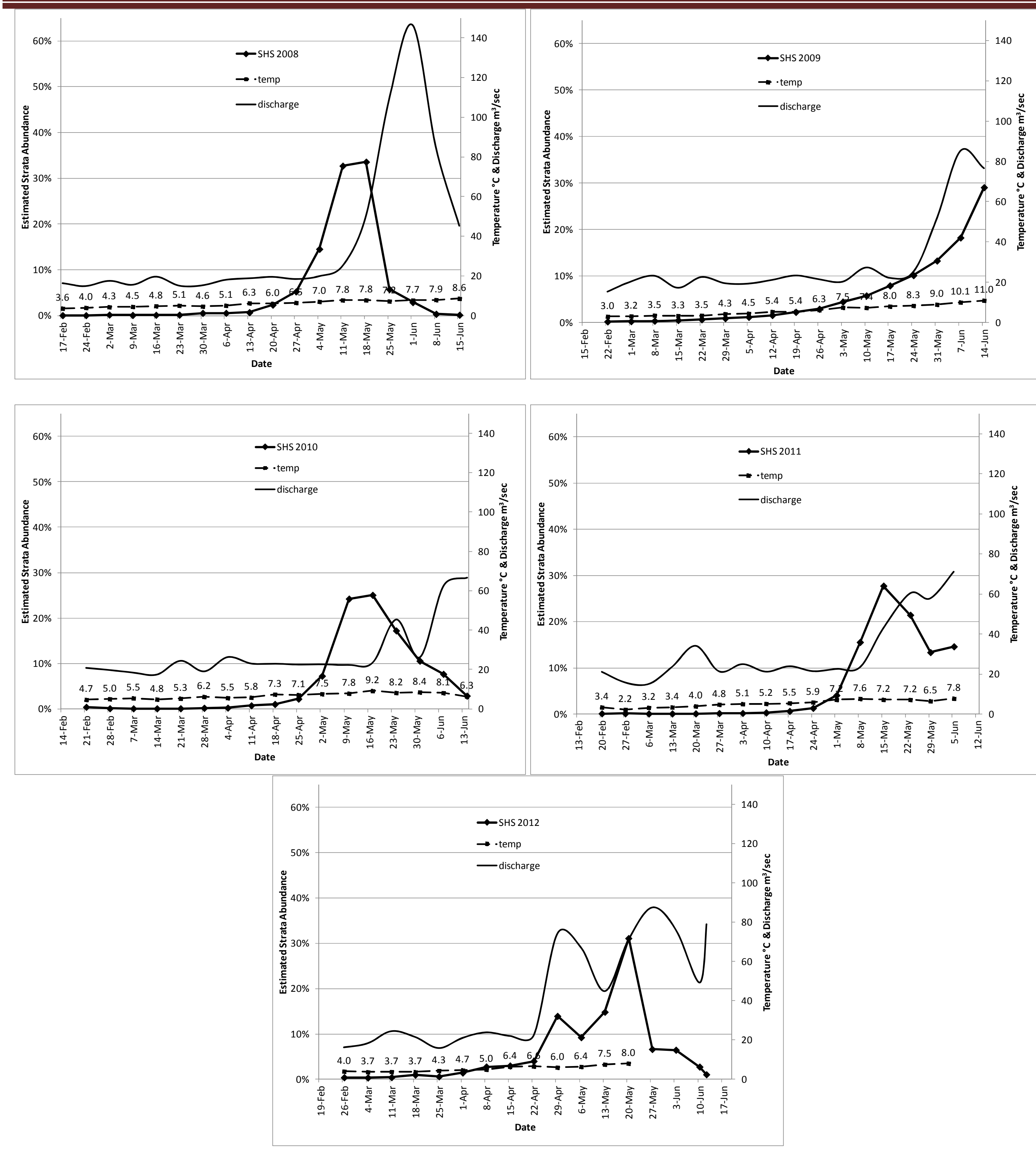


Figure 21. WUP weekly abundance estimates of steelhead smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River

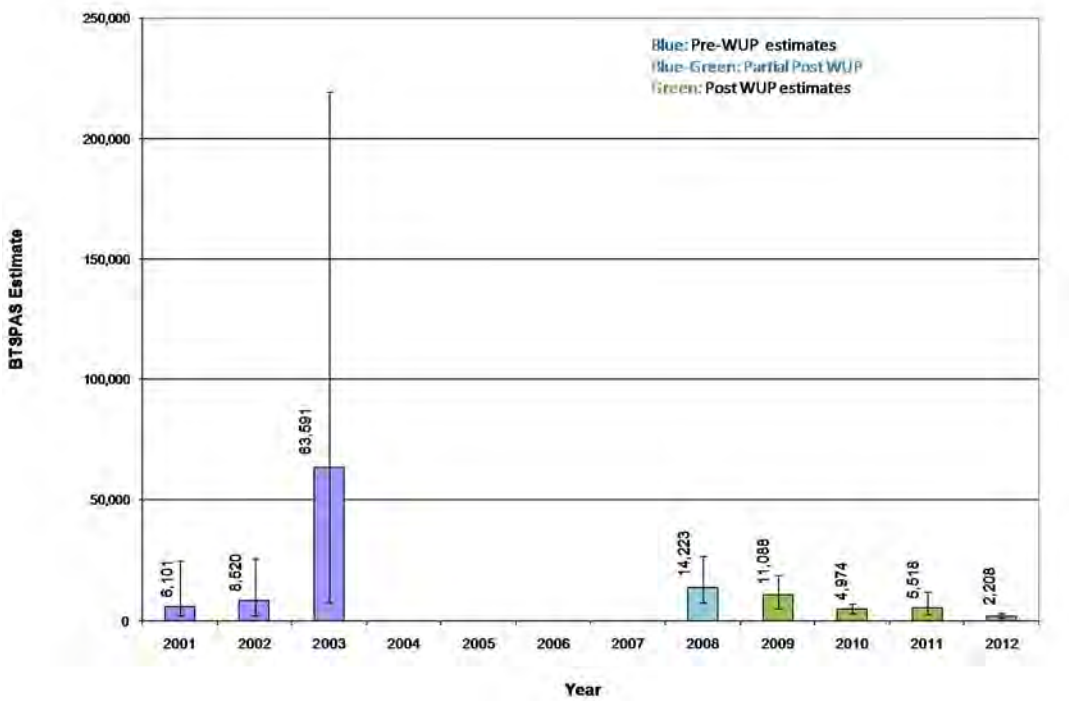
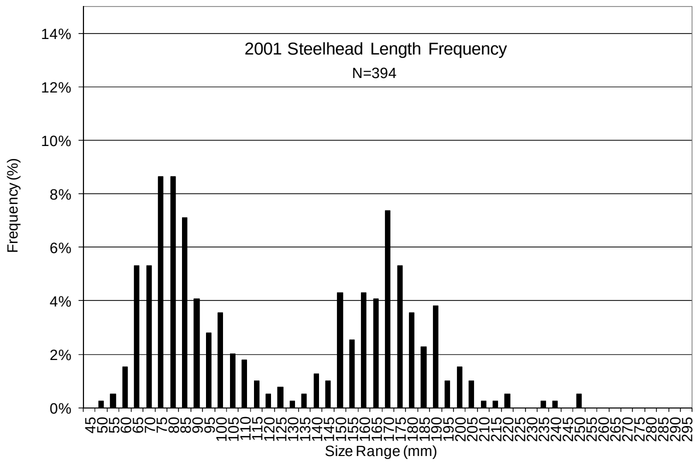
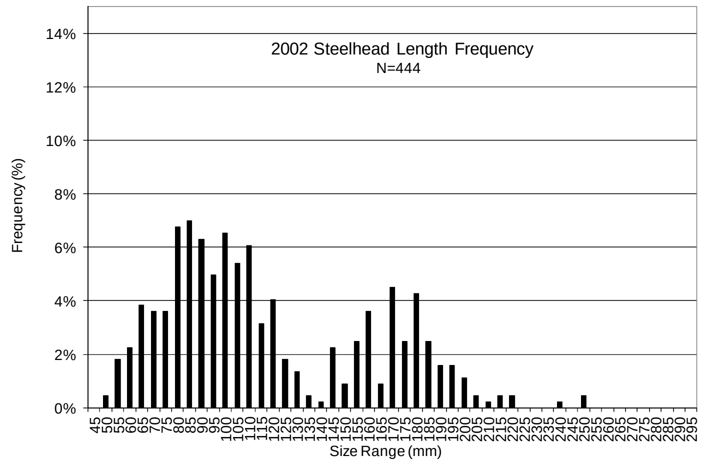
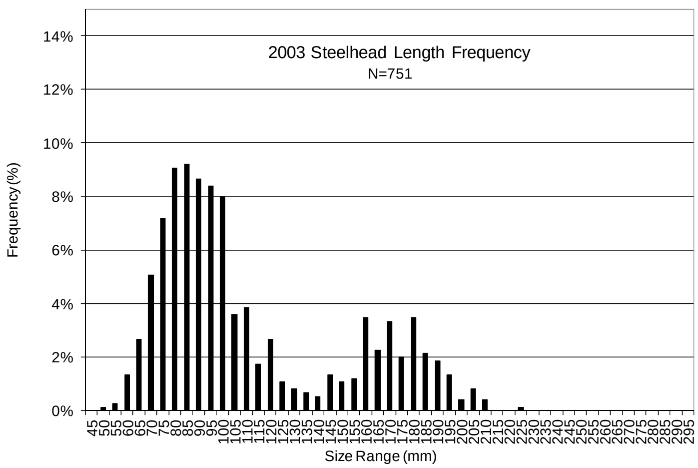
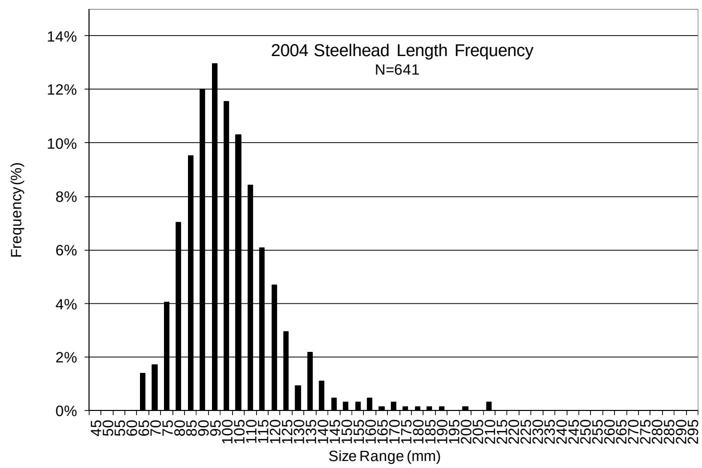


Figure 22. RST derived BTSPAS estimates of steelhead smolts from Spring 2001 to 2012, including 95% confidence limits.


2001 Steelhead Length Frequency
N=394
Frequency (%)
Size Range (mm)


2002 Steelhead Length Frequency
N=444
Frequency (%)
Size Range (mm)


2003 Steelhead Length Frequency
N=751
Frequency (%)
Size Range (mm)


2004 Steelhead Length Frequency
N=641
Frequency (%)
Size Range (mm)

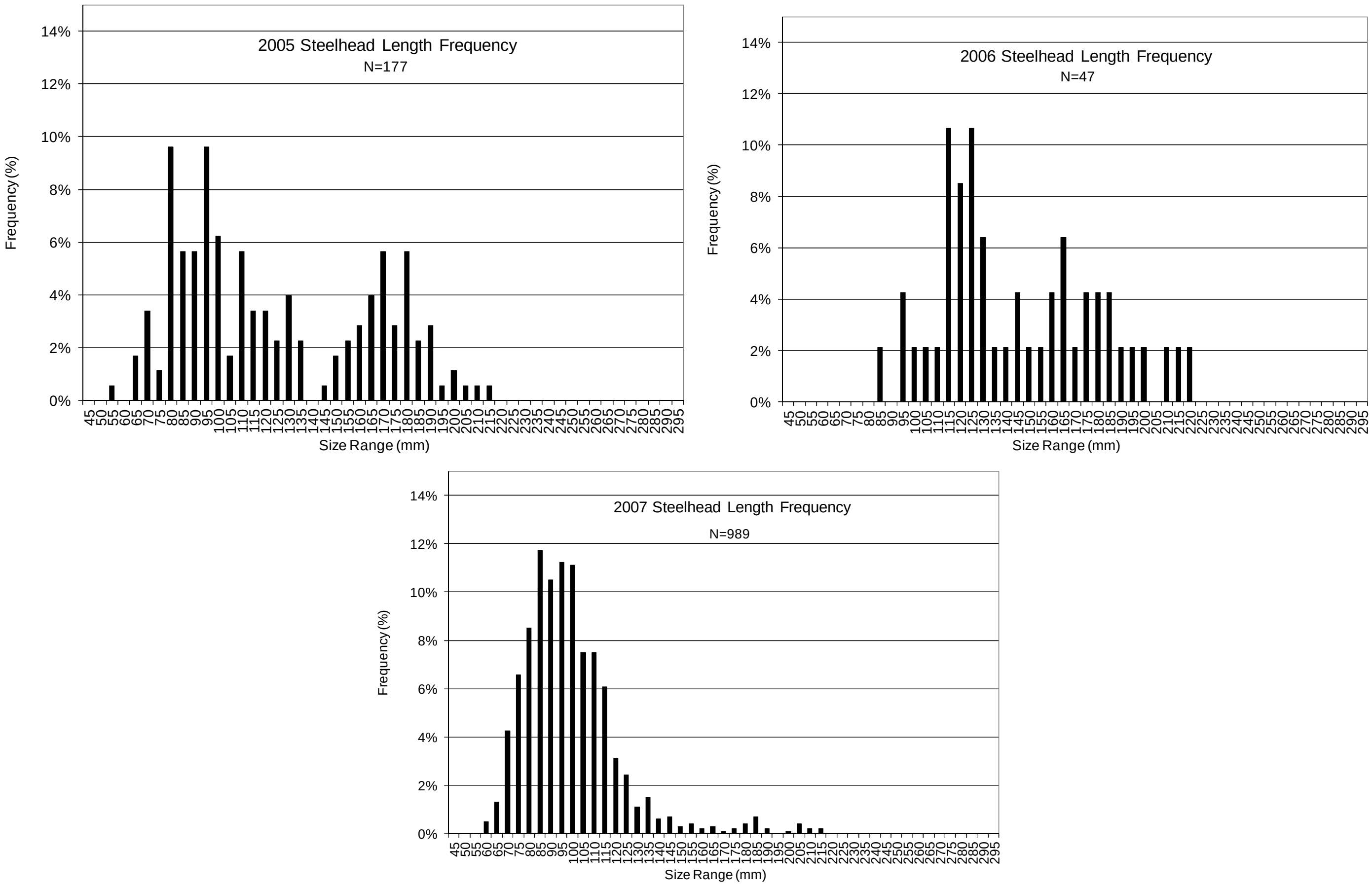


Figure 23. IFA length frequency distribution of steelhead juveniles from the Cheakamus River.

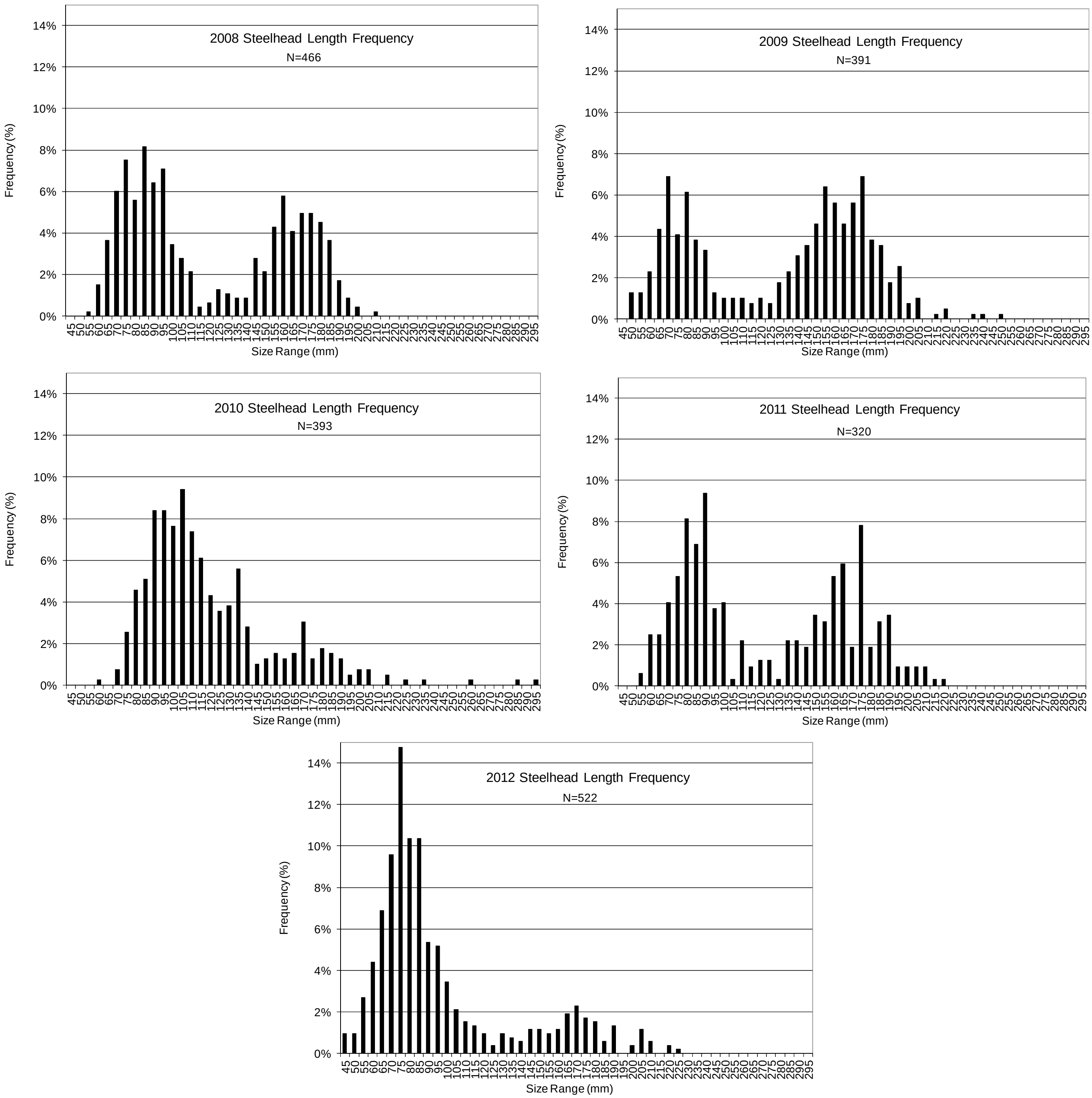


Figure 24. WUP length frequency distribution of steelhead juveniles from the Cheakamus River.

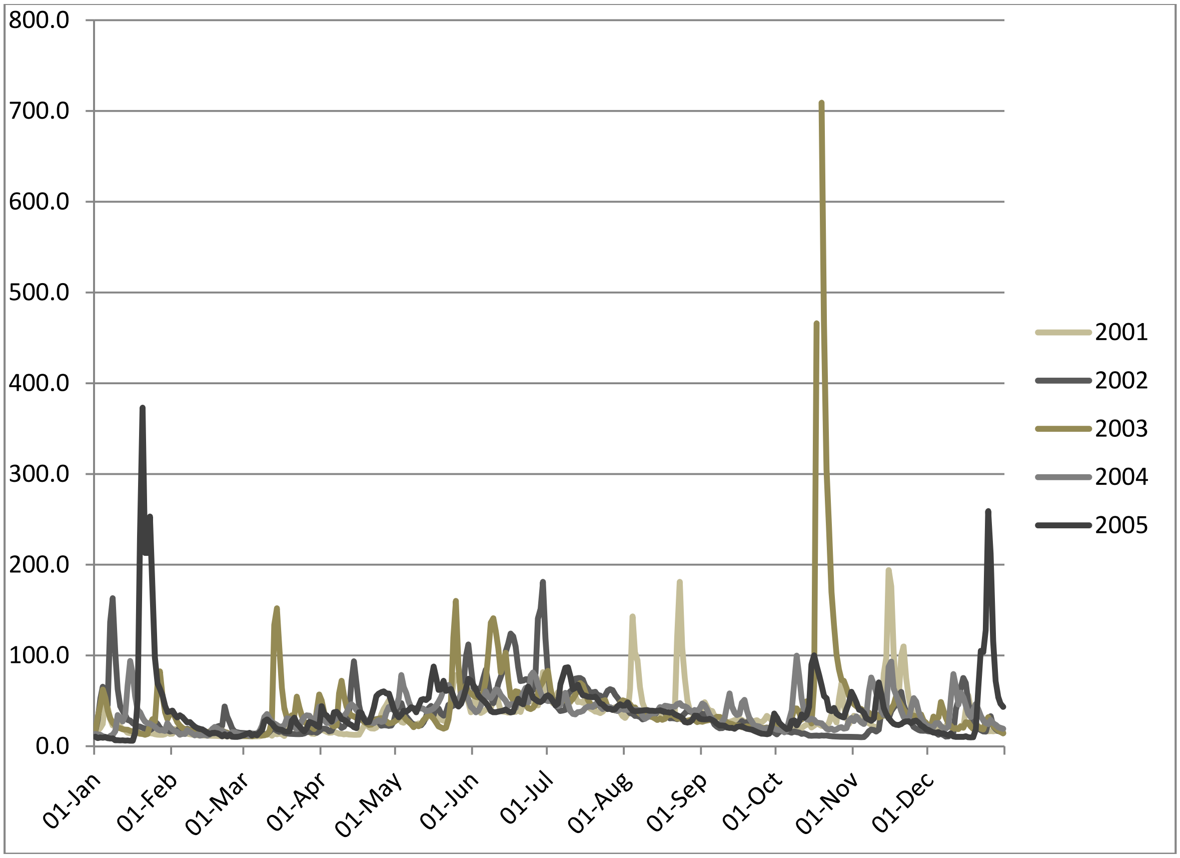


Figure 25. Mean IFA daily discharges (2001-2005) from Cheakamus at Brackendale WSC Gauge 08GA043.

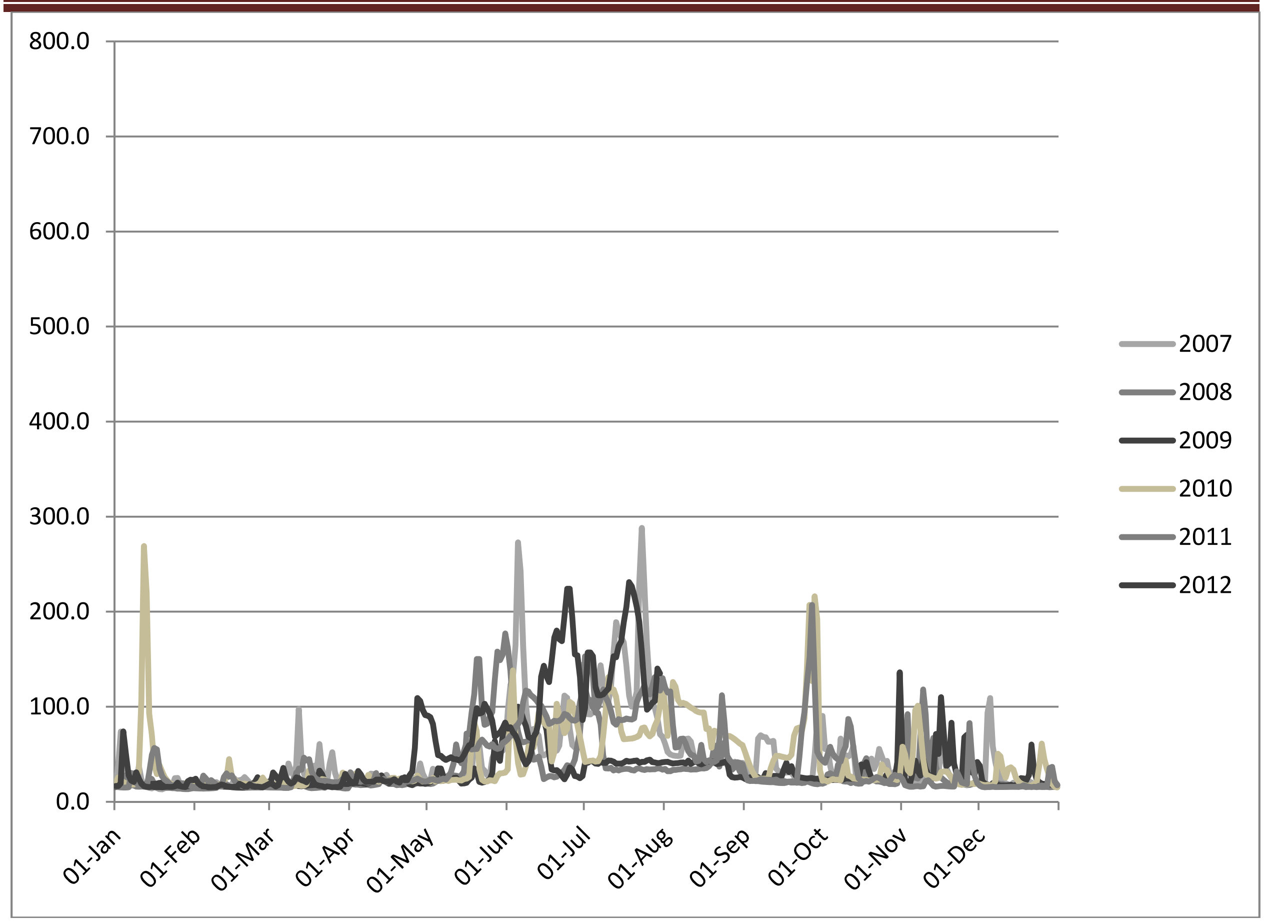


Figure 26. Mean WUP daily discharge (2006-2012) from Cheakamus at Brackendale WSC Gauge 08GA043.

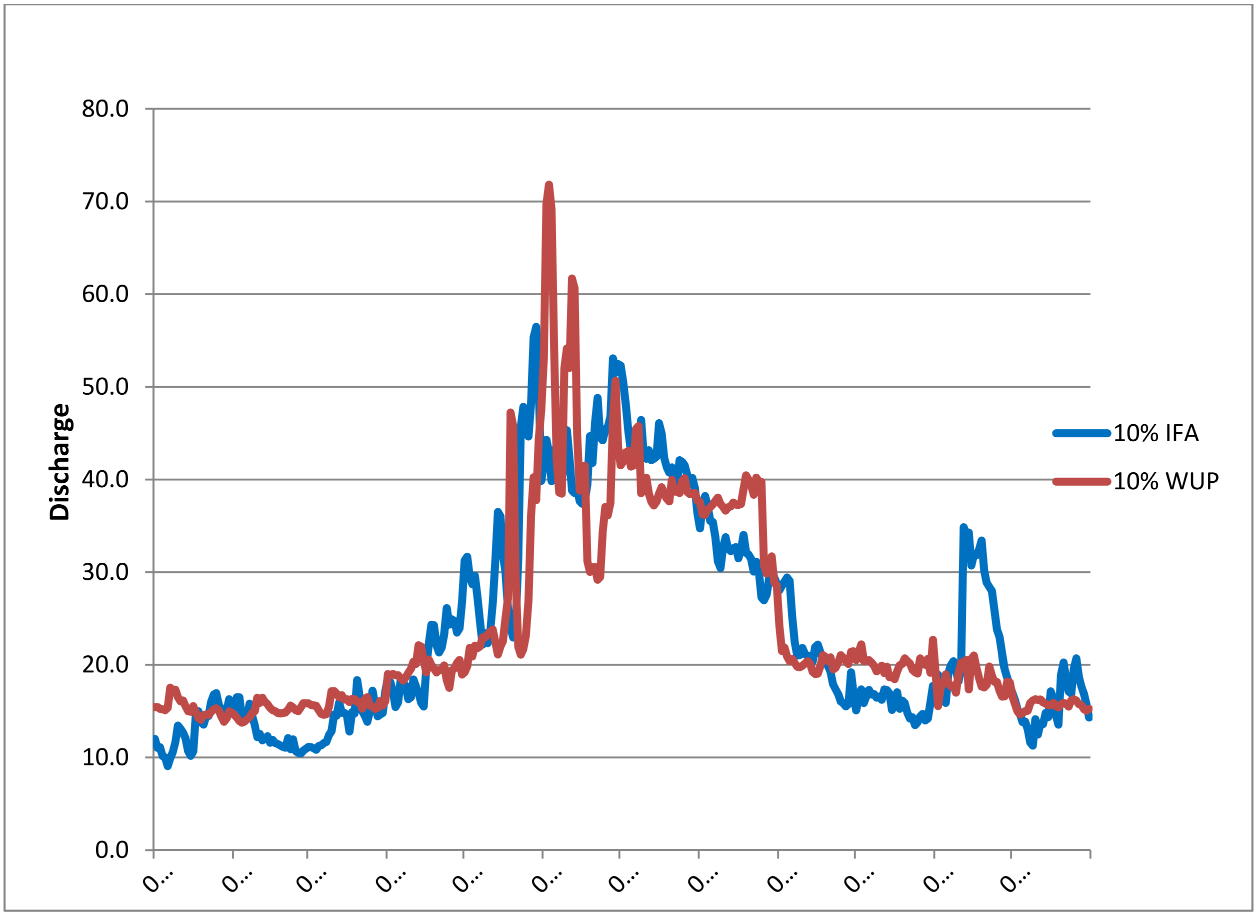


Figure 27. Comparison of the 10th Percentile of Discharge at Brackendale Gauge (08GA043) IFA and WUP.

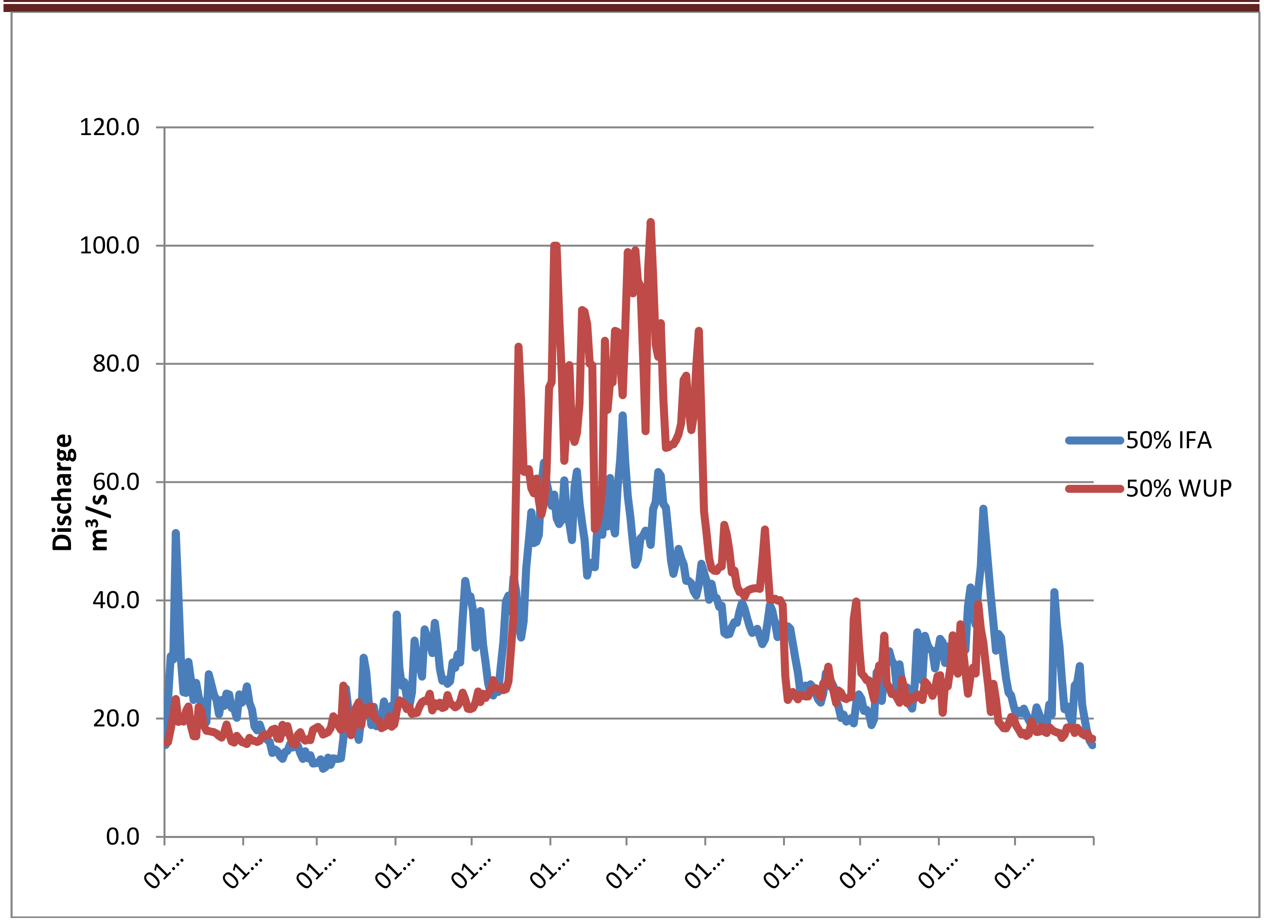


Figure 28. Comparison of the 50th Percentile of Discharge at Brackendale Gauge (08GA043) IFA and WUP.

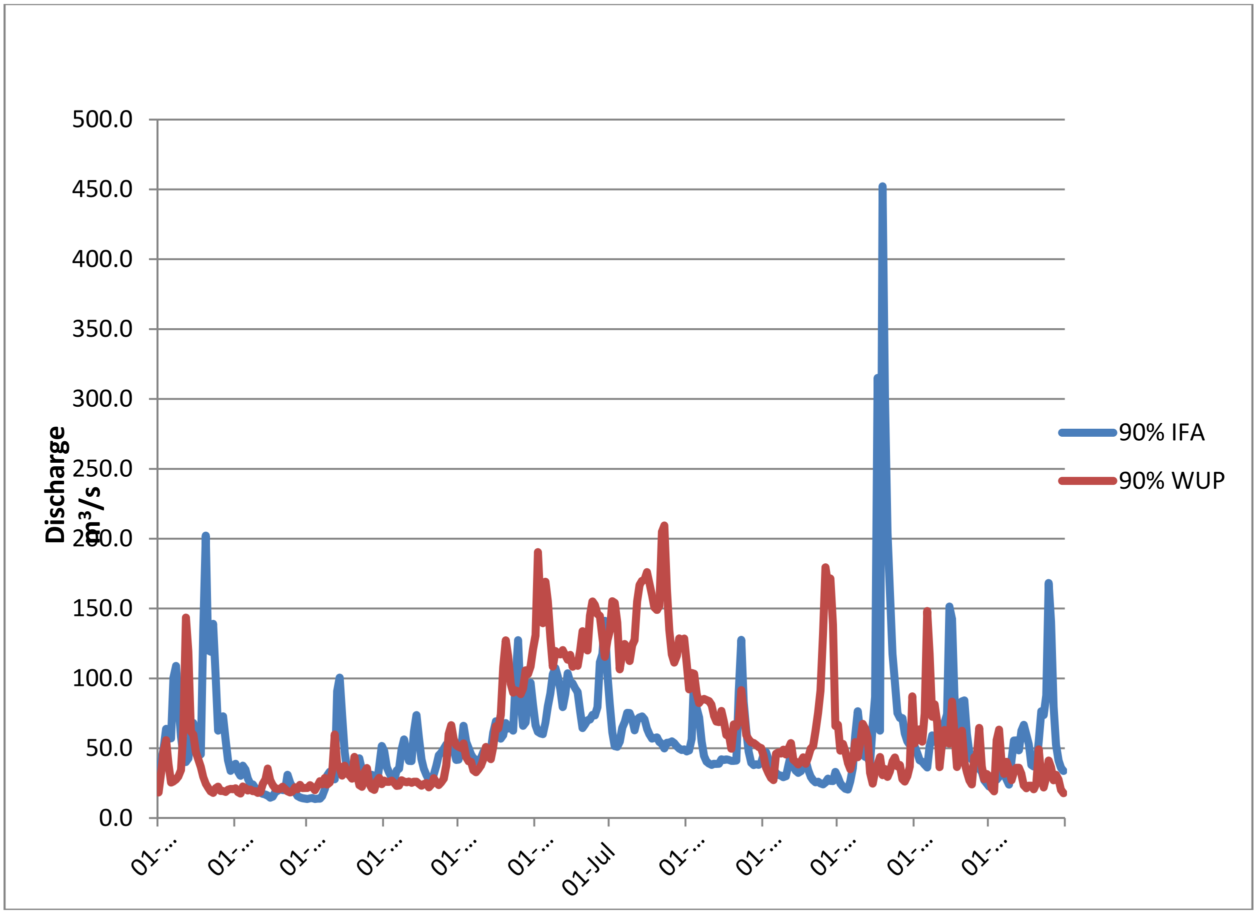


Figure 29. Comparison of the 90th Percentile of Discharge at Brackendale Gauge (08GA043) IFA and WUP.

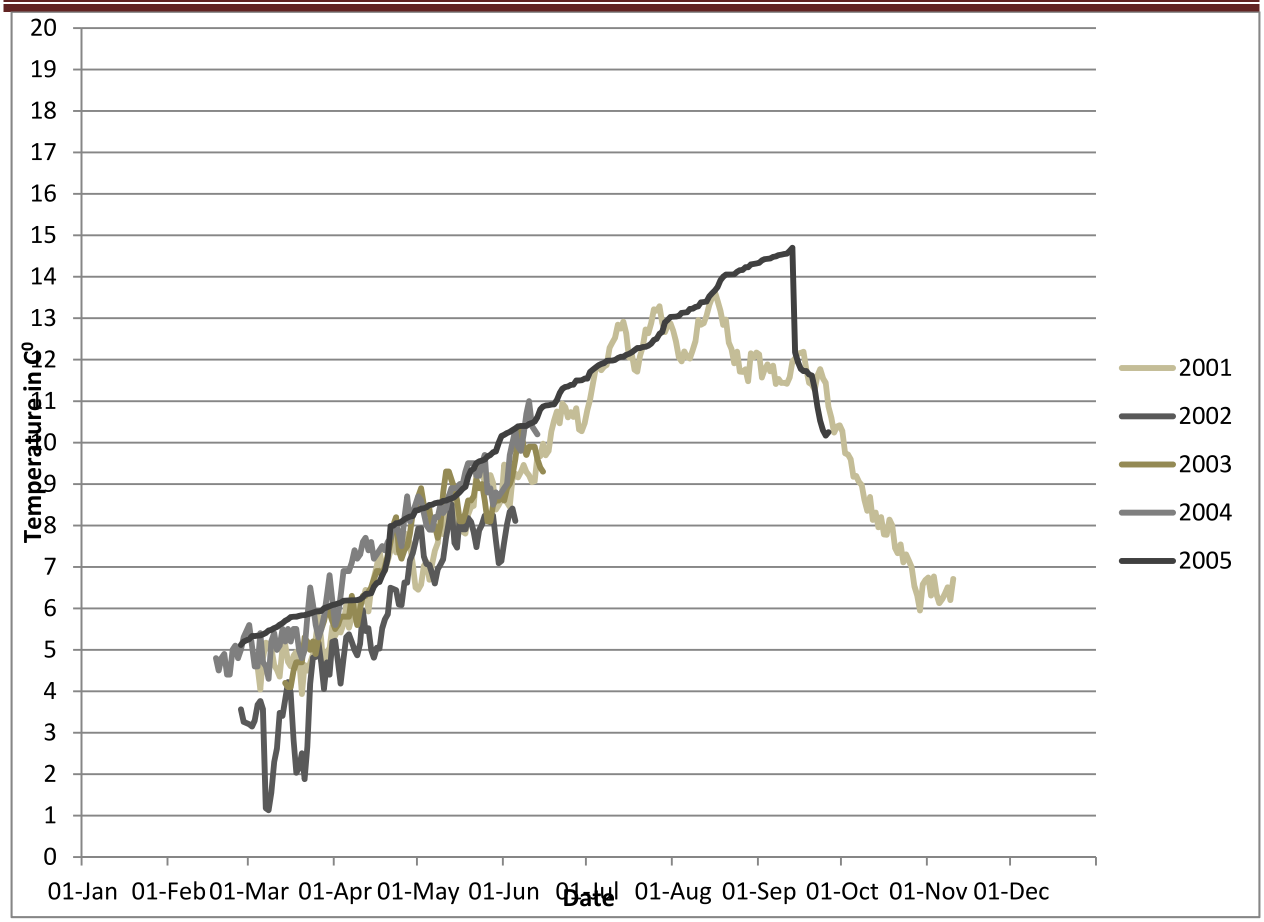


Figure 30. Mean IFA daily temperature (2001-2005) from Cheakamus River at the RST site.

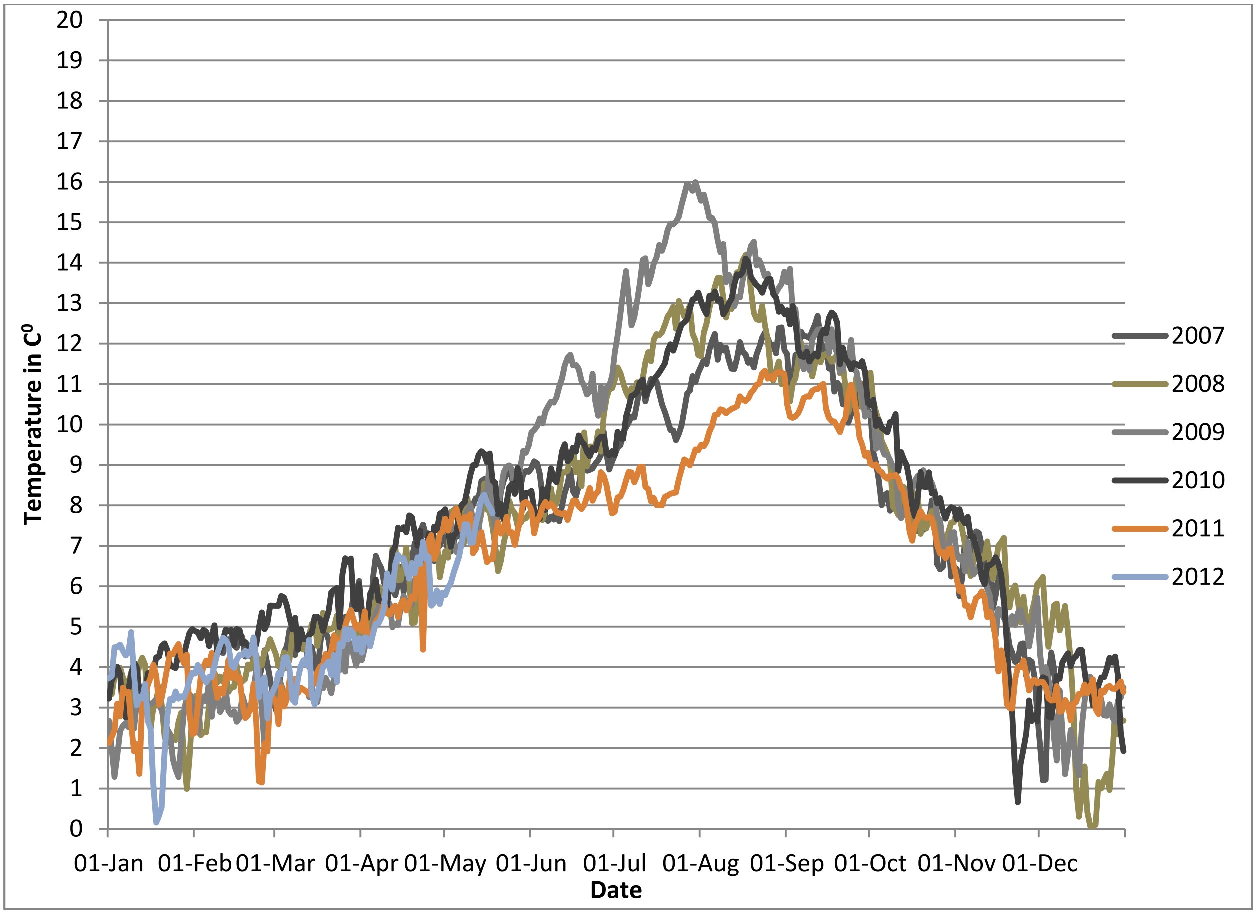


Figure 31. Mean WUP daily Temperatures (2007-2012) from Cheakamus River at the RST site.

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

NVOS: North Vancouver Outdoor School

PKF: Pink Fry (YOY)

PPE: Pooled Petersen Estimate

Q: discharge

RK: River Kilometer 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.

<u>Site 6:</u> 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.

<u>Site F1:</u> NVOS sidechannel Enumerator Fyke Net; recapture trap for chum & pink fry to obtain productivity of side channels.

<u>Site F2:</u> Upper Paradise Marking Fyke; capture chum & pink fry to mark for productivity estimate at Site F1.

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

<u>Site F4:</u> Sue's Marking Fyke; capture chum & pink fry to mark for productivity estimate at Site F1.

<u>Site F5:</u> 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.

<u>Site F6:</u> Kisutch Marking Fyke Net; to obtain chum fry to mark for productivity estimate at Site F1 & F3.

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

<u>Site F8:</u> BC Rail Marking Fyke; capture chum fry to mark for productivity estimate at Site F7.

<u>TH:</u> Tenderfoot Hatchery

<u>UC:</u> Upper Caudal Clip

<u>UP:</u> Upper Paradise channel

<u>NVOS:</u> North Vancouver Outdoor School

<u>VIE:</u> Visible Elastomer Tag

<u>WSC:</u> Water Survey of Canada

<u>WUP:</u> Water Use Planning

<u>YOY:</u> young of the year

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APPENDIX