Cheakamus Project Water Use Plan

Cheakamus River Juvenile Outmigrant Enumeration

Implementation Year 7

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Cheakamus River Juvenile Salmonid Outmigration Enumeration Assessment Annual Data Report 2013

Study Period: 2013

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Prepared for BC Hydro

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Executive Summary

In 2000 a juvenile outmigration salmonid monitoring program was initiated by the Cheakamus Water Use Plan Consultative Committee to evaluate anadromous fish productivity in the Cheakamus River under the Interim Flow Agreement. This report details information collected during a continuation of this monitoring program as decided by the CC in September 2012. Juvenile outmigration of anadromous fish is now monitored (CMSMON1a) as part of the evaluations of flow changes implemented under the Water Use Plan, and the flow regime initiated on this river in February of 2006. This includes yield evaluations of smolt and fry outmigrants for five species of salmonids: coho salmon (*Oncorhynchus kisutch*), chum salmon (*O. keta*)[1], chinook salmon (*O.tshawytscha*), pink salmon (*O. gorbuscha*) and steelhead trout (*O.mykiss*).

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

In 2013, 340,834 chinook fry, 83,707 coho smolts, and 4,455 steelhead smolts were produced in the area of the Cheakamus River upstream of the monitoring site at the North Vancouver Outdoor School (NVOS) property. No estimate was formed for chinook smolts or pink fry as catches were too low. Ranking of production years evaluated indicates that in 2013 across the thirteen years of data collection, steelhead smolt production ranked 8th, coho smolts 5th, chinook fry 4th.

Side-channel production estimates were obtained for coho smolts and chum fry[1]. Coho and chum fry production was within the range observed in all other years of the study.

[1] Reported in Monitor 1b. Fell et al 2013.

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1.0INTRODUCTION

1.1 Background History of Study and Watershed

The Cheakamus River is a major tributary of the Squamish Watershed and drains upstream of Brackendale gauging station (WSC 08GA043), an area totaling 1010 km^2 of the Coastal Mountain range in south-western British Columbia. River discharge is affected by BC Hydro through operation of Daisy Reservoir and the Cheakamus Generating Station, 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 2013.

The CC held its last meeting in January, 2002 and was unable to reach consensus on a new operating alternative. The CC recognised that it was essential to address critical scientific uncertainties that could affect future decision making, and to comprehensively assess the response of the system to the operating alternative implemented. The FTC developed a comprehensive monitoring plan to address the critical points of scientific uncertainty and disagreement within the CC. The CC agreed that the highest priority ecological indicator was salmonid spawning and juvenile production (Mamorek and Parnell, 2002).

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

Under the implemented WUP, the discharge rules for operations were varied from the existing IFA, which specified that the greatest of 5 m^3/sec or 45% of the previous days' inflows to the reservoir be released from Daisy Dam (within a daily range of 37% to 52% and within 45% of the previous 7 days' average), to a required minimum measured flow at the following two locations:

1) Minimum required flow below Daisy Lake Dam:

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

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

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

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

1.1.1 Management Questions

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

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

1. What is the relation between discharge and juvenile salmonid production, productivity, and habitat capacity of the mainstem and major side-channels of the Cheakamus River?
2. Does juvenile salmonid production, productivity, or habitat capacity change following implementation of the WUP flow regime?

The outmigration data will also be used in conjunction with data collected as part of the Chum Salmon Adult Escapement Monitor #1b (McCubbing et al, 2012) 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).

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

- Chum fry production and egg to fry survival will be reported in the Monitor 1b (Fell et al, 2013),
- Steelhead smolt production as it relates to stock recruitment will be reported in Monitor 3 (Korman et al,, 2013),
- Chum fry production as it relates to groundwater in sidechannels will be reported in Monitor 6 (Pottinger Gaherty 2010).

A report summarizing results of this study from 2001 through 2012 as they related to the two key management questions in Section 1.1.1 was completed in the fall if 2012 (Melville et al, 2012) and an interim review meeting of the Consultative Committee was held to discuss the results. It was decided by the committee in 2012 to continue Monitor 1a for a further five years of data collection to increase the analytical scope of data analysis and to better inform a future final synthesis report and flow related decisions thereafter. Here we present a further year of data, 2013. This has been added to the data set and we provide a brief update the status of analysis as it relates to the management questions.

1.2 Study Area and Trapping/Enumeration Locations

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

1.3 Hatchery Releases

Releases of hatchery fish are undertaken annually into the Cheakamus River by various organizations. Species that have been augmented include chinook, coho, pink, steelhead and chum.

Due to observed losses of chinook adults following the caustic soda spill in 2005 (McCubbing et al. 2006), a hatchery enhancement program targeting Cheakamus River chinook was implemented in the fall of 2005. Chinook salmon adults are captured in the river and placed in Tenderfoot Hatchery (TH) where they are spawned and their progeny raised and released the following spring as young-of-the-year (YOY). These YOY are released to the Cheakamus mainstem at RK 12 to 15. This varies from hatchery practice prior to fall 2005 when all chinook brood collection and young release occurred in Howe Sound.

Coho 1+ smolts are released every spring directly from the hatchery into Tenderfoot Creek. These fish are marked with an adipose clip and can be easily identified. Commencing in 2007 additional unmarked coho smolts were also released at RK 12-15. As for chinook YOY, the upper river releases are being done to mitigate losses observed during the caustic soda spill in 2005 (McCubbing et al. 2006).

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

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

Commencing in fall 2005 in response to the observed mortality of pinks during the 2005 caustic soda spill a hatchery enhancement program targeting Cheakamus River pinks was implemented. Pink salmon adults are captured at smolt trap Site 1 on NVOS side channel and placed in Tenderfoot Hatchery (TH) where they are spawned and their progeny released downstream of the RSTS the following spring as young-of-the-year (YOY).

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

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

1.4 2003 Flood and 2005 NaOH Spill

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

On August 5th 2005, the second event occurred; 41,000 litres of caustic soda (NaOH) was spilled into the Cheakamus River when a train derailed at approximately river kilometer (RK) 19. This chemical killed nearly all fish residing downstream in the mainstem (McCubbing et al 2006). Species affected were chinook, pink and coho salmon, steelhead, rainbow and cutthroat trout, char, cottids, lamprey, and stickleback (McCubbing et al., 2006).

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

1.5 Fish Restoration Projects

A number of restoration projects have been completed on the Cheakamus River since 2001. These included the addition of these projects upstream of the RST site (FWCP completion reports 2002-2006 and Triton Environmental 2008 & 2009):

- Cheakamus Gravel Recruitment (ground water): constructed in 2002; created 700m^2 of additional head pond area in the upper Kisutch channel. Target species: chum &coho salmon.
- Gorbuscha 1 (river intake): constructed in 2002; created 750m of channel and 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.
- Mykiss channel (river intake): constructed in 2006; created 1600m^2 spawning habitat and 3800m^2 of rearing habitat. Target species steelhead/rainbow trout and coho.
- Km 6.5 side-channel re-watering (river intake): constructed in 2007; created 1400m^2 habitat. Targeted species Chinook and rainbow trout.
- Large Wood Restoration Project (mainstem structures): constructed in 2007; created 900m^2 of habitat. Targeted species rainbow/steehead trout.

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

2.0 Methods Summary (Consistencies and Changes over sample years)

2.1 Fish Trapping Methods

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

1) partial traps, RSTs, fyke nets and minnow traps which rely on mark recapture methodology to evaluate fry and smolt outmigration,
2) complete channel traps, which allow for manual counting of all outmigrant smolts from a designated area,
3) resistivity counters in combination with trap boxes built into diversion weirs, which electronically enumerate outmigrant smolts 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).
Changes in trapping methods made in 2013 are described below; other changes made over the study period (2001-2012) are described in detail in Melville et al, 2012

2.1.2 Side-channel Fyke Net Traps

In 2013 assessment of chum fry production from Tenderfoot Creek was added to more accurately assess the contribution of this tributary to the chum population. Three fyke nets (F9, 10 and 11) were operated to evaluate fry production upstream of the fish fence where adult enumeration occurs and one at the confluence with the Cheakamus River to assess the entire creek contribution. Results are reported in the Cheakamus River chum salmon escapement and fry production monitoring 2001-2013 (Fell et al, 2013).

2.2 Population Estimate Methods

In 2008 with the technical advice of Dr. Carl Schwarz and Dr. Simon Bonner from the Department of Statistics and Actuarial Science at Simon Fraser University, marking techniques were altered to better assess some of the issues with meeting the assumptions made by Seber 2002. In particular to evaluate changing catchability as flows fluctuate during the spring, often at the same time as outmigration for some species is expected to peak (i.e. coho and steelhead). In the interim (2008 through 2011) as described fully in Bonner (2008), Schwarz et al. (2009), and Bonner and Schwarz (2011) we developed an alternate method (Bayesian spline model) for calculating population estimates that has many advantages over existing methods.

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

2.3 Discharge Data Collection and Analysis

Mean daily and weekly discharge (Q) is computed annually from the Water Survey of Canada (WSC) hourly discharge record for the Cheakamus River at 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) are primarily used for analysis in this study.

2.5 Bio-sampling and Age Data Collection

A sub-sample of all species captured has been sampled for lengths and weights at the RST site and at Upper Paradise side channel trap (Site 1 and 6) throughout the study (2001-2013) and methods are more fully described in Melville and McCubbing, 2011.

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

Coho, chinook and steelhead juveniles have varied freshwater life histories prior to migration to salt water. For the purpose of marking and enumeration estimates it is necessary to have straightforward criteria (length) to identify which life stage these species are at when captured during the spring migration period.

Length frequency data from 2000-2003 and in the case of steelhead juveniles age and length frequency data were used to identify length cut-offs for the various life stages (Table 1):

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

In all years of the study scale samples were taken for a stratified sub-sample of steelhead (1+, 2+ and 3+), coho (1+) and chinook (1+) juveniles by the methods detailed in Ward et al. (1989). All steelhead scale samples taken since 2001 have been aged once and corroborated independently by a second technician. Coho and chinook samples have not been analysed because length frequency data in all years of the study indicates that the majority of migrating coho are 1+ and Chinook are 0+ (Melville and McCubbing 2001-2011).

3.0 Results

3.1 Chinook

3.1.2 Chinook Fry Migration and Production

As in all years of the juvenile study the migration timing of early chinook fry in 2013 indicates that the migration was already under way when sampling began on February 15th. In 2013 based on estimated weekly abundance, 26% of the total yield was estimated to have migrated in the first two sampling strata (Figure 5). In comparison from 2001 through 2012 an average of 25% of the total yield was estimated to have migrated in these strata (Figure 4 & 5). In 2013, the out-migration did not appear to be fully completed when the RST drums were changed to larger mesh on May 6th, as 9% of the total yield was estimated to have occurred in the last strata assessed (Figure 5).

In three years, 2002, 2004 and 2009 where out-migration appears to be complete (nearly no fish captured in the final sample strata), the peak of migration occurred March 11th to 18th (35%), March 16th to 29th (26%) and February 24th to March 9th (30%) respectively. In 2013 out-migration was not completed when the drums were changed, but nevertheless, the peak of migration likely occurred between Feb 25th and March 11th which is similar to the migration timing observed throughout the study period. It does not appear that increased temperature or discharge affected the migration timing of chinook fry in 2013 (Figure 5) so it is likely that spawner timing in conjunction with water temperature during incubation drives the migration timing of early chinook fry.

Estimates of chinook fry production from the Cheakamus River have been calculated for nearly every year of the study (2001-2013). The exception being in 2006 when insufficient numbers (499) were captured to derive a mark-recapture estimate. The 2006 outmigration was in part affected by adult spawner mortality resulting from the chemical spill event in the summer of 2005.

In 2013 the estimated emigration of chinook fry was 352,356 (SD = 14,881). Estimated production of chinook fry from the mainstem of the Cheakamus River has ranged from 60,040 in 2010 to 874,946 in 2011. The average estimated production for all years (2001 to 2013) was 318,721, SD = 62,791 (Table 2 and Figure 6). There have been five IFA and seven WUP estimates of production. Average IFA and WUP abundance was 250,860 fry and 367,194 fry respectively, this equates to an average change in abundance of 116,334 or 46% increase. The 2013 estimate of 352,356 chinook fry ranks as the 4th highest during the years assessed; 2001-2013 (Table 2).

There are no estimates of early chinook fry production in the side channels as very few fish are captured. In 2013, 217 chinook fry were captured at F1 enumeration fyke on the NVOS side-channel complex compared to an average catch of 287 fish since 2007 (range of 99-598). As in other years no fish were captured at site F7 on the BC Rail side channel complex (Figure 3).

3.1.2 Chinook Smolt Migration and Production

In most study years, insufficient capture of fish has resulted in too few fish to mark for the derivation of an estimate for 1+ chinook smolts.

In the four years (2001-2003 and 2009) where weekly abundance estimates of chinook smolts were calculated it appears that the peak migration timing is between April 20th and May 10th. Chinook smolts appear to begin their peak outmigration period when average daily water temperatures reach 7^{0}C, (Figure 7 & 8).

In 2013 a total of 49 chinook smolts were captured at the RST traps and so, as in other years with the exception of four years (2001-2003 and 2009) an estimate of chinook abundance was not calculated. In the years where an estimate was derived chinook smolt abundance has ranged from 6,020 to 14,439 (Table 2 & Figure 9)

In 2013, 7 chinook smolts were captured at Site 1 fish trap at the NVOS side channels (Figure 3). Since 2009, an average of 12 (range: 3-37) chinook smolts have been captured at this location.

3.1.3 Chinook Length and Age Data

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

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

In 2013 length frequency for all chinook juveniles captured at the RST was bi-modal with the first mode generally falling between the 30 and 60mm 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 2013. 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 in 2013 was 39 mm and ranged from 27-62 mm (Table 3). The majority (83%) of fish sampled were in the size range spanning 35-44mm. In general the majority (average 78%) for all years analysed (2002-2013) chinook fry fall within this size range (Figures 10 & 11).

There was a statistically significant observed difference in mean length of chinook fry between the thirteen sample years 2001 to 2013 (ANOVA, $p<0.001$, $F=25.2$, $df=12$). 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, $p=0.001$,$df=762$, $F=2.2$), 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+) in 2013 was 102mm, 12.0g, and 1.1 respectively. This falls within the range of all previous years sampled (2002-2012) when mean length, weight and condition factor (K) ranged from 101-111mm, 10.6-15.1g and 0.98-1.12 respectively. Note: 2005 and 2006 were excluded due to a sample size of 1 in those years and 2001 as it contained hatchery fish (Table 3).

There was a statistically significant difference observed in mean length of chinook smolts between the sample years 2002, 2003 and 2007 through 2013 (ANOVA, $p<0.001$, $F=5.7$, $df=8$). 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.

3.2 Pink Fry

One hundred and sixteen pink fry were captured at the RSTs and one in the side channels in 2013. These numbers are low as 2013 was an off-year for adult migration to the Cheakamus River and few spawners were observed (Table 2).

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 (2001-2013) 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 12 & 13).

In 2013 the migration timing was similar to all years of the study. Migration commenced in early April with 20% of the run having migrated by April 15th. The peak of migration occurred between April 29th and May 12th (weekly strata 11 & 12) when 48% of the estimated migration occurred. By June 2nd, 98% of the fish had migrated (Figure 13). Peak outmigration abundance occurred when average daily water temperatures reached 7^{0}C. Discharge does not appear to determine when migration occurs on this river (Figure 12 & 13).

Estimates of coho smolt production from the Cheakamus River at the RST site were calculated for every year of the study (2001-2013). In 2013 the estimated emigration of coho smolts was 83,707 (SD = 3,321). Estimated annual production of coho smolts derived at the RST site on the mainstem has varied from 60,686 in 2009 to 118,161 in 2003 smolts excluding 2006 data (Table 2 and Figure 14). In 2006 the estimated abundance of 35,444 smolts was directly affected by fish mortality caused by the chemical spill event in the summer of 2005 (McCubbing et al 2006).

There have been six IFA and six WUP estimates of coho smolt production. The 2007 estimate has been excluded from analysis of changes in abundance (IFA vs. WUP) due to being partially affected by both flow regimes having been spawned (2005 brood year) and partially rearing under IFA conditions. Average abundance of IFA years excluding 2006 (lowest estimate due to spill effects) was 85,261 (76,958 if 2006 is included) and 76,138 smolts in WUP years, this equates to an average change in abundance excluding 2006 data of -9,123 smolts or a 11% decrease (reduced to -821 or a 1% decrease if 2006 data are included). The average estimated production for all years (2001 to 2013) was 78,185, SD = 9,190 (Table 2 and Figure 14). The 2013 estimate of 83,707 coho smolts ranks 5th highest during the years assessed; 2001-2013 (Table 2 and Figure 14).

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 2013. In 2013 15,420 coho smolts were produced from these two channels representing 18.5% of the total production estimated at the RST site. The 2013 count ranks 3rd highest among years evaluated.

An average production of 14,860 smolts, ranging from 8,691 to 24,137 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 20% of the estimated coho population. The largest contribution to the estimated population occurred in 2001 when 36% of the fish originated from the NVOS and BCR channels. Since 2009 the contribution of these two channels appears to be slightly less; ranging from 11-24% of the estimated upper river population (Table 2).

3.3.2 Coho Length and Age Data

Length frequency for all coho smolts (≥70mm) captured and sampled at the RST and side channel sites is uni-modal in all years (2001-2013) indicating that the majority of migrating coho smolts are 1+ with a small percentage of larger fish likely 2+ (Figures 15 &16). Scales have not been aged for coho but have been taken and archived.

Mean length, weight and condition factor (K) for coho smolts in 2013 was 87 mm, 7.8g and 1.15 respectively. This falls within the range of all previous years sampled (2001-2012) when mean length, weight and condition factor (K) ranged from 86-95mm, 7.1-10.7g and 1.0-1.2 respectively (Table 3). Coho smolt length frequency in 2013 peaked between the 80 and 99mm range, with a majority (69%) of the fish sampled falling within this range. This is similar to all other years (2001-2012) when on average 66% of fish sampled fell in 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 66% during the WUP (Figure 15 & 16).

There was a statistically significant observed difference in mean length of coho smolts between the thirteen sample years 2001 to 2013 (ANOVA, $p<0.001$, $F=104$, $df=12$). 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 un-equal variance (F test, $p=0.01$, $df=6$, $F=0.055$), and a statistical difference was evident as larger fish were generally observed prior to the introduction of the WUP (T test equal variance, $df=7$, $F=3.14$, $p=0.01$).

3.4 Steelhead

3.4.1 Steelhead Smolt Migration and Production

Estimates of steelhead smolt (aged 2 to 4 years) population abundance have been calculated in nine of the thirteen study years; 2001-2003 and 2008-2013. 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 7 of the 9 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) and no recaptures and 1 capture respectively.

Steelhead smolt migration has generally started in the week of April 15th to 22nd (weekly strata 10) in the 7 years of the study when a migration curve was evident (2001-2002, 2008 and 2010-2013) on average 7% of the run have migrated by the third week of April. The peak of migration generally occurs between May 5th and May 20th (weekly strata 12-14) when on average 53% of the estimated abundance migrates. On average 90% of the run has migrated by May 31st (Figure 17 & 18).

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

In 2013 the migration timing varied slightly compared to other years, appearing to peak approximately one week earlier than the average of all years. Migration commenced in early April, with 17% of the run having migrated by April 15th (10% higher than the average of all years assessed). The peak of migration occurred between April 22nd and May 12th (Strata 10-12) when 52% of the estimated migration occurred. By June 2nd, 98% of the fish had migrated (Figure 18). As in other study years peak outmigration occurred when average daily water temperatures reached 7^0 C. Discharge does not appear to determine when migration occurs on this river. (Figure 17 & 18).

Estimated production of steelhead smolts from the mainstem have been calculated in 9 years of the study with two of those years appearing to be biased high by inaccurate estimates of late migration strata as described above. In an effort to compare annual abundance of steelhead smolt migration from 2003 and 2009 with the other seven years where the migration curve trended downward at the end of the study sample period we undertook two adjustments. First we removed strata data calculated for dates ending after May 31st as these appeared un-realistically high. Then we expanded the partial BTSPAS estimate by 10% as in years where a complete estimate was derived approximately 10% of the steelhead out-migration was derived annually from these later strata. This resulted in a comparative estimated steelhead smolt abundance in 2003 of 8,516 fish and in 2009 of 7,197 fish, rather than the estimates of 63,591 and 11,088 respectively when the final strata in 2003 and 2009 are included.

Steelhead smolt estimated abundance has ranged from an estimated abundance of 2,208 to 14,223 (including adjusted BTSPAS estimates in 2003 and 2009). The average estimate of abundance of all years assessed (2001-2003, 2008-2013) is 6,857. Large variances in production of steelhead smolts likely related to the 2003 flood and the 2005 spill are evident in the estimates derived in years following the events (2004-2007) when very few steelhead smolts were captured; range 9-21. This resulted in no abundance estimates being calculated for these cohorts (Table 2 and Figure 19).

There have been three IFA and five WUP estimates of steelhead smolt production. In addition, to the years (2004-2007) where no abundance estimate was calculated the 2008 estimate has been excluded from analysis of changes in abundance (IFA vs. WUP) due to being partially affected by both flow regimes having 3+ smolts rearing under IFA conditions. Average IFA and WUP abundance was 7,712 and 6,429 smolts respectively. This equates to an average change in abundance of fish of -1,283 fish or a decrease of 16%. The 2013 estimate of 4,455 steelhead smolts ranks 8th highest during the years assessed; 2001-2003, 2008-2013 (Table 2 and Figure 19).

Full trap counts of steelhead smolt production from the NVOS sidechannels and BC Rail side channel (Site 1 & 4) have been produced in 2001 and 2009 through 2013 with an average production of 180 steelhead smolts, ranging from 35 to 403. In 2013, 132 steelhead smolts were produced from these two channels. The 2013 estimate ranks 5th highest among years evaluated.

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

3.4.2 Steelhead Parr

The steelhead parr (1+) population is not estimated as it is assumed that these fish are not actively migrating from freshwater during the spring migration. The range of fish captured at the RSTs between 2001 and 2012 is 6 to 832. In 2013 1012 steelhead parr were captured at the RSTs this ranks 1st amongst all years of the study (Table 2).

3.4.3 Steelhead Length and Age Data

Mean length, weight and condition factor (K) for steelhead smolts in 2013 was 167mm, 50.9g and 1.1 respectively. This falls within the range of all previous years sampled (2001-2012) when mean length, weight and condition factor (K) ranged from 162-177mm, 50.2-69.0g and 1.0-1.1 respectively (Table 3). In 2013 the 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 (age-1 parr) representing 55% of the fish sampled, and 130-190mm (age 2 through 4 year old smolts) representing 17% of the fish sampled (Figure 21).

There was a statistically significant observed difference in mean length of steelhead smolts between the thirteen sample years 2001 to 2013 (ANOVA, $p<0.002$, $F=3.5$, $df=12$). 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 an equal variance (F test, $p=0.1$, $df=5$, $F=3.1$), but no difference was statistically evident (T test equal variance, $df=11$, $F=0.6$, $p=0.54$).

3.5 Biophysical Monitoring

Discharge (measured at WSC 08GA043) at the Cheakamus River near Brackendale (Figure 2) ranged from an average daily value of 15.02 to 214.32 over the period February 15th to June 15th, 2013 (Figure 22).

Average daily water temperature at the RST data logger (Figure 2) during the juvenile migration period of Feb 15th to June 15th, 2013 ranged from 3.6 to 10.2 ^{0}C (Figure 23).

4.0 Discussion

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

In September 2012 the CC was presented with a summary of data and analyses on juvenile population estimates from 2001 through 2012 (Melville et al, 2012). The summary report examined the mean and variance of annual fish production for migratory salmonids, and the power to detect a significant change based on these data. It was decided in September 2012 based on the analyses performed that the ability to detect changes in fish production in relation to the flow change (IFA vs WUP) had generally not been achieved and additional data were yet required to evaluate a statistical variance between treatments. The CC recommendation was that this study (CMSMON1a) should be continued for a further five years with annual reporting on fish production until 2017 when further statistical analysis will be undertaken to assess the effects of the flow change on productivity.

Analysis of the power to detect significant change in productivity 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 (Fell et al 2013 in prep, Korman et al 2013 in prep).

Based on juvenile data collected from the RST site at RK 5.5, three 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 and compared to the IFA affected years. These changes ranged from 25% in chum fry, 46% for 0+ chinook fry and a nearly 500% increase in pink fry abundance. Coho smolts indicated a slight decrease in average annual production; of 11% or 1% if 2006 (affected by CN related fish kill is used in the analysis). Steelhead trout smolts annual production decreased by16% when using the adjusted estimates in 2003 and 2009 but pre WUP data are limited to three years. No comparison of chinook smolt (1+) abundance was attempted due to only calculating population abundance in four of the thirteen years of study.

Data in 2013 as in all other years of the study indicate that for chinook salmon the juvenile outmigrant population is annually dominated by 14-60 day (from emergence) outmigrants and that yearling smolts numerically represent typically less than 5% of the outmigrants. Thus the population can be characterized predominantly as an ocean rearing type. Migration timing in 2013 followed the pattern of a number of the years where an unknown portion of the population had out migrated prior to sampling being underway (i.e. 2003, 2005, and 2010). The BTSPAS model has difficulties with this type of data (Bonner and Schwarz 2011) so evaluating how much migrated before the study started is difficult to ascertain. Reasons for the observed high variance in fry outmigration timing are most likely related to spawning timing and associated ATU's on egg incubation which may be affected by river discharge (natural or regulated) and seasonal variances in air temperatures. Other factors such as spawner abundance on which there is a shortage of accurate data (Golder, 2009), the impacts of the CN caustic soda spill fish mortality (McCubbing at el 2006), changes in the hatchery program intensity and methods (DFO data on file) and the effect of the 2003, 1 in 50 year flood are all likely contributing to the high variance observed in chinook productivity.

Coho smolt migration has followed the timing pattern observed at other study sites where full river fences or partial traps have been operated in British Columbia (McCubbing and Johnston 2012, Ladell and McCubbing 2011) with peak smolt outmigration occurring in May. In addition the majority of the run is sampled prior to increases in discharge which can make trap operation inefficient. In 2013 this pattern continued with peak migration occurring in the same strata as all other years assessed. As coho salmon juveniles are known to rear in the river for at least one year (some fish migrate as 2 year olds, circa 5-20%, DFO data on file) we may expect that migration timing is not driven by spawning and incubation timing but other environmental factors (Spence and Dick 2013).

Productivity of coho smolts on the Cheakamus with the exception of the spill effected 2006 migration has been relatively stable (SD=18%) with only a slight decrease in productivity observed between IFA and WUP years. 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 at Tenderfoot Creek 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 which we have sampled are clearly significant contributors, with 14-24% of the total RST estimate being derived from the two channels sampled (BC Rail and NVOS), although in recent years BC Rail channel appears to have declined in importance, perhaps related to beaver activity and spawner access. In 2013 the production from the side channels fell within the range of years assessed contributing 18.5% of the total RST estimate.

Steelhead smolt migration has generally followed the timing pattern observed at other study sites where full river fences or partial traps have been operated in British Columbia (McCubbing et al 2012, McCubbing and Ramos-Espinoza 2011) with peak smolt outmigration occurring in May. In general the entire sampling period has been captured throughout the study although data in 2003 and 2009 were corrected due to the perception of an inflated estimate due to high numbers of fish estimated in the final strata as river levels increased. The 2013 estimate was the second lowest estimate generated (the lowest being 2012) since the study commenced. Further discussion on steelhead production numbers can be found in Korman et al, 2013 in prep.

5.0 Recommendations and Conclusions

The data collected from 2001-2013 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 functionally attributed to changes in treatment discharge. In coho salmon, the additional data being collected should within 5 years allow for assessment of the likelihood of statistically greater variance than 50% in smolt production which is less than the CC originally intended (25%).

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

The linkage between side channel production and mainstem production of fry and smolts has been examined but presents several obstacles to complete analysis. For coho smolts the inability to derive a defensible estimate of production in Tenderfoot and the addition of new channels upstream of the RST site, confound the ability to clearly define mainstem versus sidechannel production in its entirety. For chum fry production, it was recently identified that an estimate from Tenderfoot Creek is required to better establish this linkage (McCubbing et al. 2012). This year provides the first of these estimates and this work will be continued through 2017.

The following recommendations are provided for ongoing studies of juvenile salmonid production:

1) Continued improvement to chum fry assessment to include Tenderfoot Creek
2) Due to the very large returns of adult pink salmon in 2013, a sub-sampling regime for fry at the RSTs will be developed in 2014 to allow for reasonable labour expenditures while maintaining confidence in the ability to compare estimates with previous years.

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

Table 2. Thirteen-year summary (2001-2013) of fish caught and marked at the rotary screw trap and side-channels on the Cheakamus River. Bold = WUP estimates
Relative sd. >0.3 = Poor precision.

Species	**Year**	**Total Caught**	**Total Marked**	**Total Recap**	**BTSPAS EST.**	**SD.**	**Rel. SD**
Chinook Fry	2001	8,578	3,109	207	241,913	39,688	0.18
Chinook Fry	2002	7,567	1,486	91	137,254	18,966	0.14
Chinook Fry	2003	5,859	2,376	77	400,964	98,652	0.25
Chinook Fry	2004	1,232	415	4	236,717	159170	0.67
Chinook Fry	2005	1,107	386	4	237,454	154,692	0.65
Chinook Fry	2006	499	n/a	n/a	n/a	n/a	n/a
Chinook Fry	**2007**	**8,737**	**2,904**	**141**	**238,180**	**27,475**	**0.12**
Chinook Fry	**2008**	**5,127**	**2,036**	**45**	**564,313**	**132,302**	**0.23**
Chinook Fry	**2009**	**8,039**	**3,172**	**193**	**157,151**	**21,335**	**0.14**
Chinook Fry	**2010**	**3,649**	**1,082**	**73**	**60,040**	**7,799**	**0.13**
Chinook Fry	**2011**	**31,933**	**10,127**	**435**	**874,946**	**46,220**	**0.05**
Chinook Fry	**2012**	**8,787**	**4,127**	**189**	**323,375**	**32,315**	**0.10**
Chinook Fry	**2013**	**22,248**	**11,556**	**943**	**340,834**	**14,405**	**0.04**
Chinook Smolt	2001	404	304	31	8,439	5,120	0.61
Chinook Smolt	2002	94	61	2	13,439	16,034	1.19
Chinook Smolt	2003	94	55	3	6,020	5,213	0.87
Chinook Smolt	2004	4					
Chinook Smolt	2005	2					
Chinook Smolt	2006	1					
Chinook Smolt	2007	47					
Chinook Smolt	**2008**	**52**					
Chinook Smolt	**2009**	**417**	**128**	**11**	**14,439**	**10,165**	**0.28**
Chinook Smolt	**2010**	**83**					
Chinook Smolt	**2011**	**56**					
Chinook Smolt	**2012**	**50**					
Chinook Smolt	**2013**	**49**					

Table 2. continued

Species	Year	Total Caught	Total Marked	Total Recap	BTSPAS EST.	SD.	Rel. SD
RST Pink Fry	2001[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	2002	27,038	5,301	113	1,673,795	286,619	0.17
RST Pink Fry	2003[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	2004	2,742	1,415	53	82,834	13,474	0.16
RST Pink Fry	2005[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	2006	41,336	10,870	1,567	303,488	9,817	0.03
RST Pink Fry	2007[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	**2008**	**41,873**	**19,291**	**848**	**2,060,948**	**89,979**	**0.04**
RST Pink Fry	2009[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	**2010**	**238,730**	**57,124**	**3,942**	**6,157,377**	**606,896**	**0.1**
RST Pink Fry	2011[1]	n/a	n/a	n/a	n/a	n/a	n/a
RST Pink Fry	**2012**	**1,447,749**	**91,694**	**6,964**	**29,314,436**	**630,824**	**0.02**
RST Pink Fry	2013[1]	n/a	n/a	n/a	n/a	n/a	n/a
SC Pink Fry	**2008**	**36,066**	**26,084**	**867**	**1,172,050**	**43,524**	**0.04**
SC Pink Fry	2009[1]	n/a	n/a	n/a	n/a	n/a	n/a
SC Pink Fry	**2010**	**35,946**	**31,330**	**2,197**	**627,542**	**16,615**	**0.03**
SC Pink Fry	2011[1]	n/a	n/a	n/a	n/a	n/a	n/a
SC Pink Fry	**2012**	**246,536**	**84,937**	**7,892**	**3,127,546**	**41,406**	**0.01**
SC Pink Fry	2013[1]	n/a	n/a	n/a	n/a	n/a	n/a

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

Table 2. continued

Species	Year	Total Caught	Total Marked	Total Recap	BTSPAS EST.	SD.	Rel. SD
RST Steelhead Smolt	2001	231	162	14	6,101	8,726	1.4
RST Steelhead Smolt	2002	116	76	2	8,520	7,152	0.84
RST Steelhead Smolt	2003	379	286	11	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**
RST Steelhead Smolt	**2013**	**597**	**524**	**94**	**4,455**	**910**	**0.20**
SC Steelhead Smolt	2001	151	n/a	n/a	n/a	n/a	n/a
SC Steelhead Smolt	**2009**	**403**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
SC Steelhead Smolt	**2010**	**217**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
SC Steelhead Smolt	**2011**	**153**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
SC Steelhead Smolt	**2012**	**35**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
SC Steelhead Smolt	**2013**	**132**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

Table 2. continued

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

Table 2. continued

Species	Year	Total Caught	Total Marked	Total Recap	BTSPAS EST.	SD.	Rel. SD
RST Coho Smolt	2001	3,696	30,613	2,731	74,537	12,713	0.29
RST Coho Smolt	2002	2,549	17,879	810	100,653	26,972	0.27
RST Coho Smolt	2003	5,823	25,601	1,818	118,161	9,833	0.11
RST Coho Smolt	2004	1,048	8,727	191	71,481	15,437	0.25
RST Coho Smolt	2005	1,609	3,355	139	61,472	8,316	0.14
RST Coho Smolt	2006	1,165	4,578	174	35,444	3,744	0.12
RST Coho Smolt	2007	7,237	7,422	675	97,832	5,882	0.07
RST Coho Smolt	**2008**	**3,036**	**5,972**	**196**	**81,624**	**11,367**	**0.15**
RST Coho Smolt	**2009**	**6,614**	**8,764**	**1,035**	**60,686**	**8,239**	**0.13**
RST Coho Smolt	**2010**	**10,681**	**14,857**	**2,030**	**101,271**	**3,687**	**0.04**
RST Coho Smolt	**2011**	**5,238**	**5,720**	**499**	**62,593**	**4,359**	**0.09**
RST Coho Smolt	**2012**	**6,194**	**6,870**	**918**	**66,944**	**5,599**	**0.08**
RST Coho Smolt	**2013**	**7,244**	**11,184**	**2,109**	**83,707**	**3,322**	**0.04**
SC Coho Smolt	2001	26,828	n/a	n/a	n/a	n/a	n/a
SC Coho Smolt	**2009**	**13,437**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
SC Coho Smolt	**2010**	**24,408**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
SC Coho Smolt	**2011**	**8,691**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
SC Coho Smolt	**2012**	**12,799**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
SC Coho Smolt	**2013**	**15,240**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

Table 3. Summary of mean fry lengths (mm) 2001-2013 from the Cheakamus River.

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

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

Table 3. continued

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

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

Species	Year	N	Mean Length	Mean Weight	Mean K
Steelhead Smolts	2001	179	175	69.0	1.0
	2002	136	176	56.3	1.0
	2003	193	174	59.0	1.0
	2004	27	162	n/a	n/a
	2005	60	176	66.2	1.1
	2006	23	177	58.9	1.0
	2007	50	172	54.4	1.0
	2008	192	170	52.1	1.0
	2009	**217**	**171**	**50.2**	**1.0**
	2010	**87**	**176**	**52.9**	**1.0**
	2011	**142**	**172**	**54.2**	**1.0**
	2012	**89**	**175**	**57.5**	**1.0**
	2013	**137**	**167**	**50.9**	**1.1**

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

Table 3. continued

Species	Year	N	Mean Length	Mean Weight	Mean K
Coho Smolts	2001	2280	89	8.0	1.1
	2002	2151	91	9.3	1.2
	2003	2667	91	9.0	1.1
	2004	1606	93	n/a	n/a
	2005	1648	95	9.5	1.1
	2006	1333	94	10.0	1.2
	2007	1689	91	8.5	1.1
	2008	**845**	**90**	**8.4**	**1.1**
	2009	**1566**	**89**	**7.5**	**1.0**
	2010	**2521**	**95**	**9.3**	**1.0**
	2011	**2215**	**88**	**7.7**	**1.1**
	2012	**2335**	**86**	**7.1**	**1.1**
	2013	**2734**	**87**	**7.8**	**1.15**

7.0 FIGURES

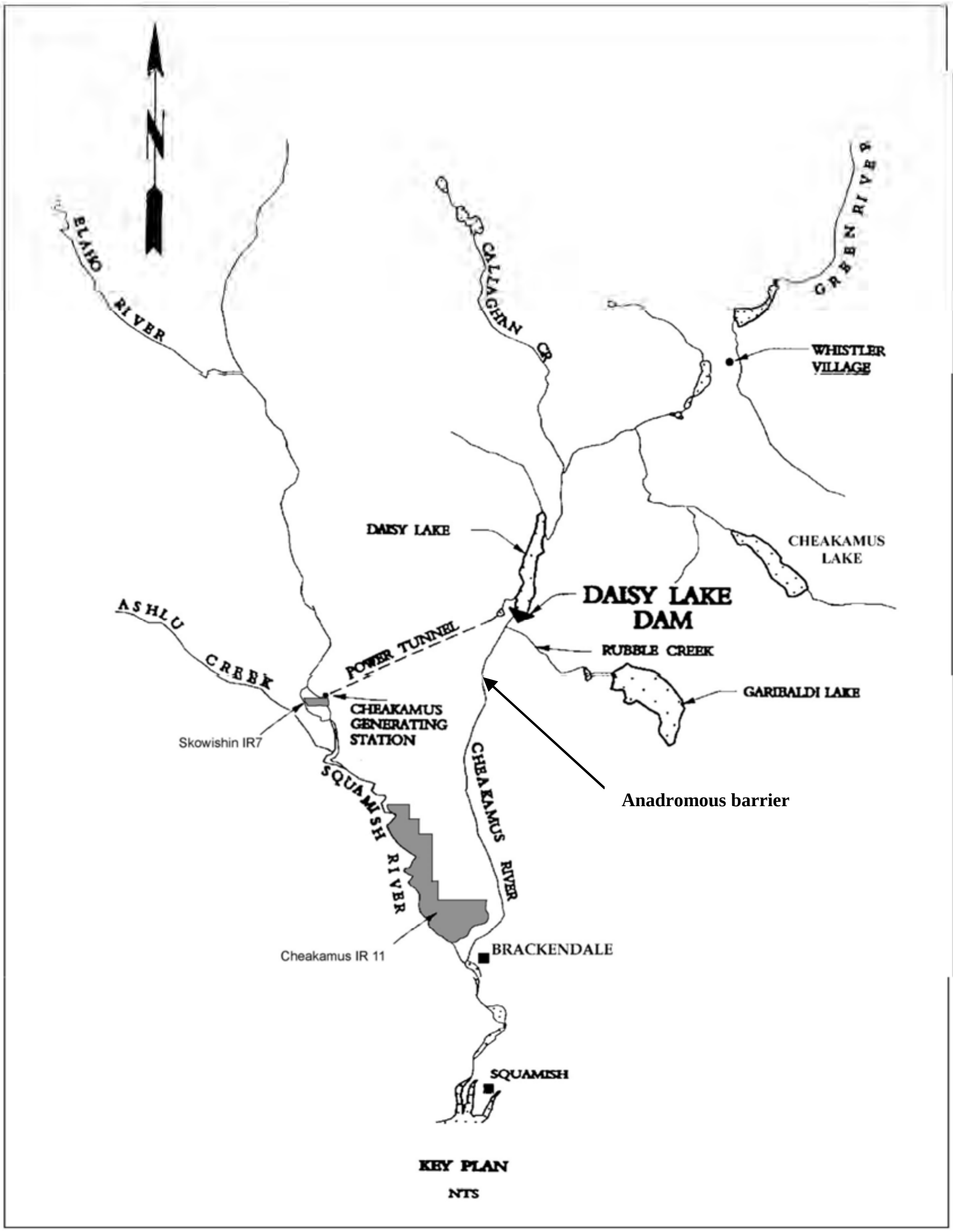


Figure 1: Map of Cheakamus Watershed indicating location of Daisy Dam and diversion tunnel.

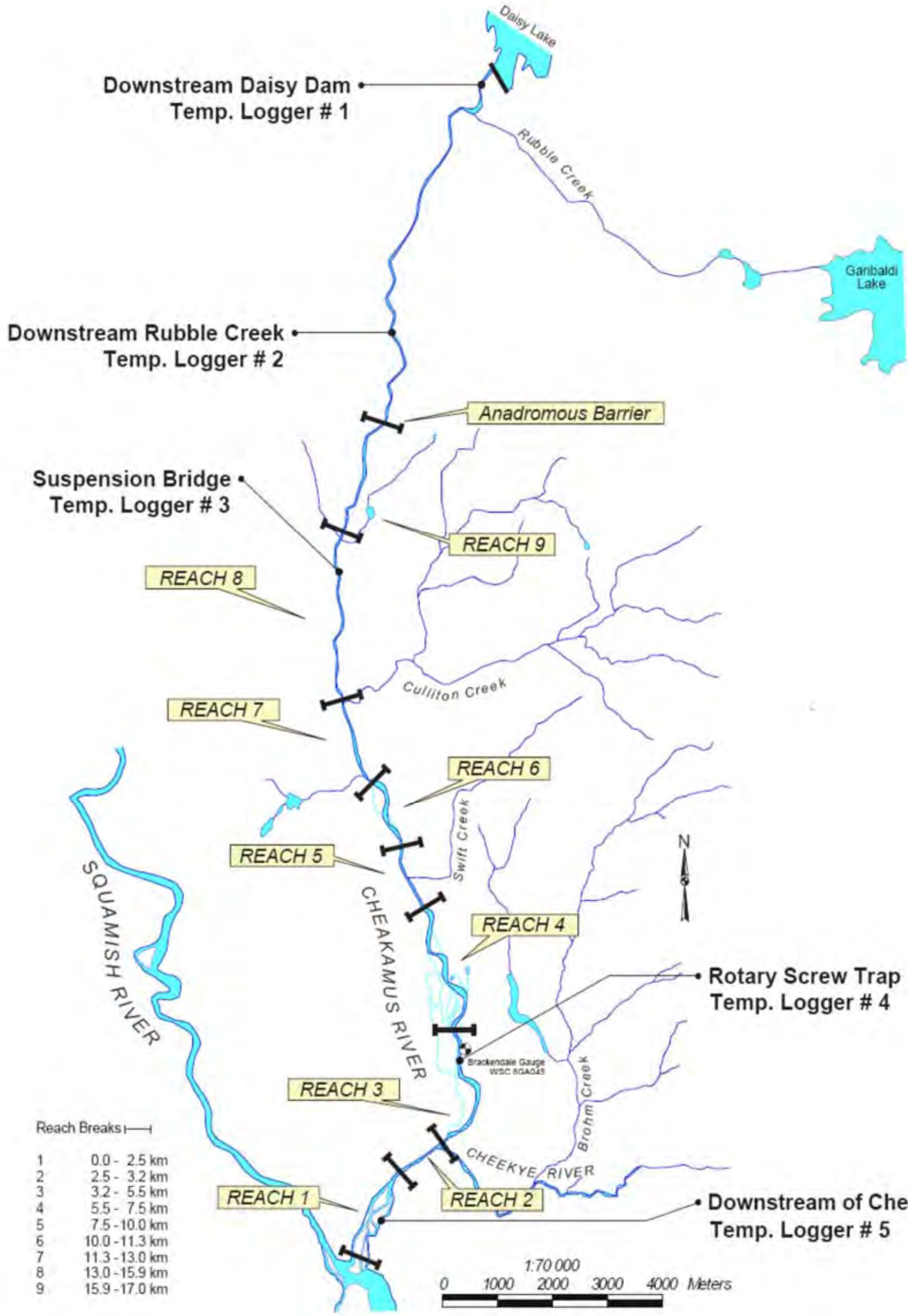


Figure 2. Cheakamus River watershed indicating Reaches 1 through 9, WSC gauging station, temperature loggers, and RST trap location.

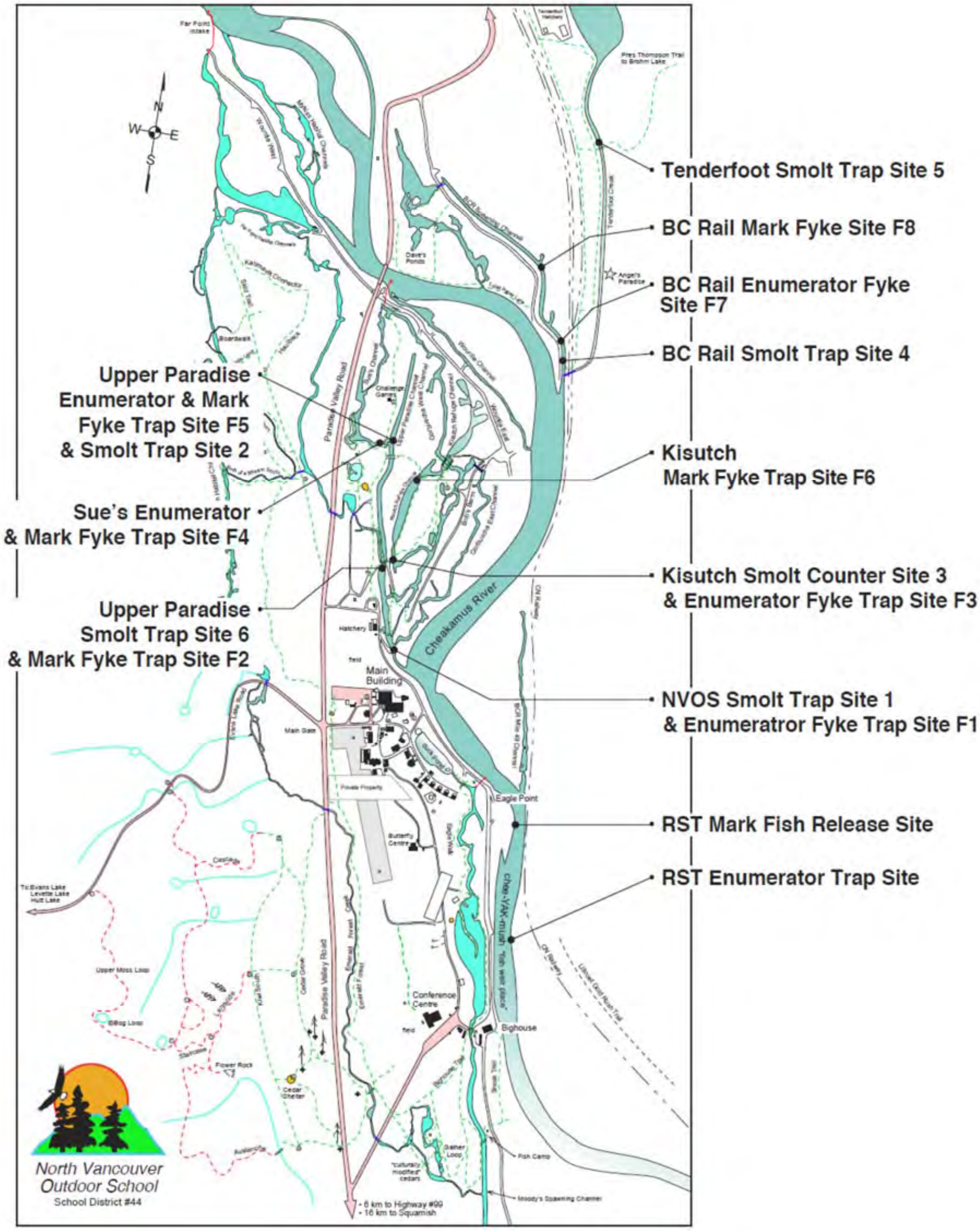


Figure 3.Site Map indicating trap sites utilized for the Cheakamus River Juvenile Outmigration Monitor 1a.

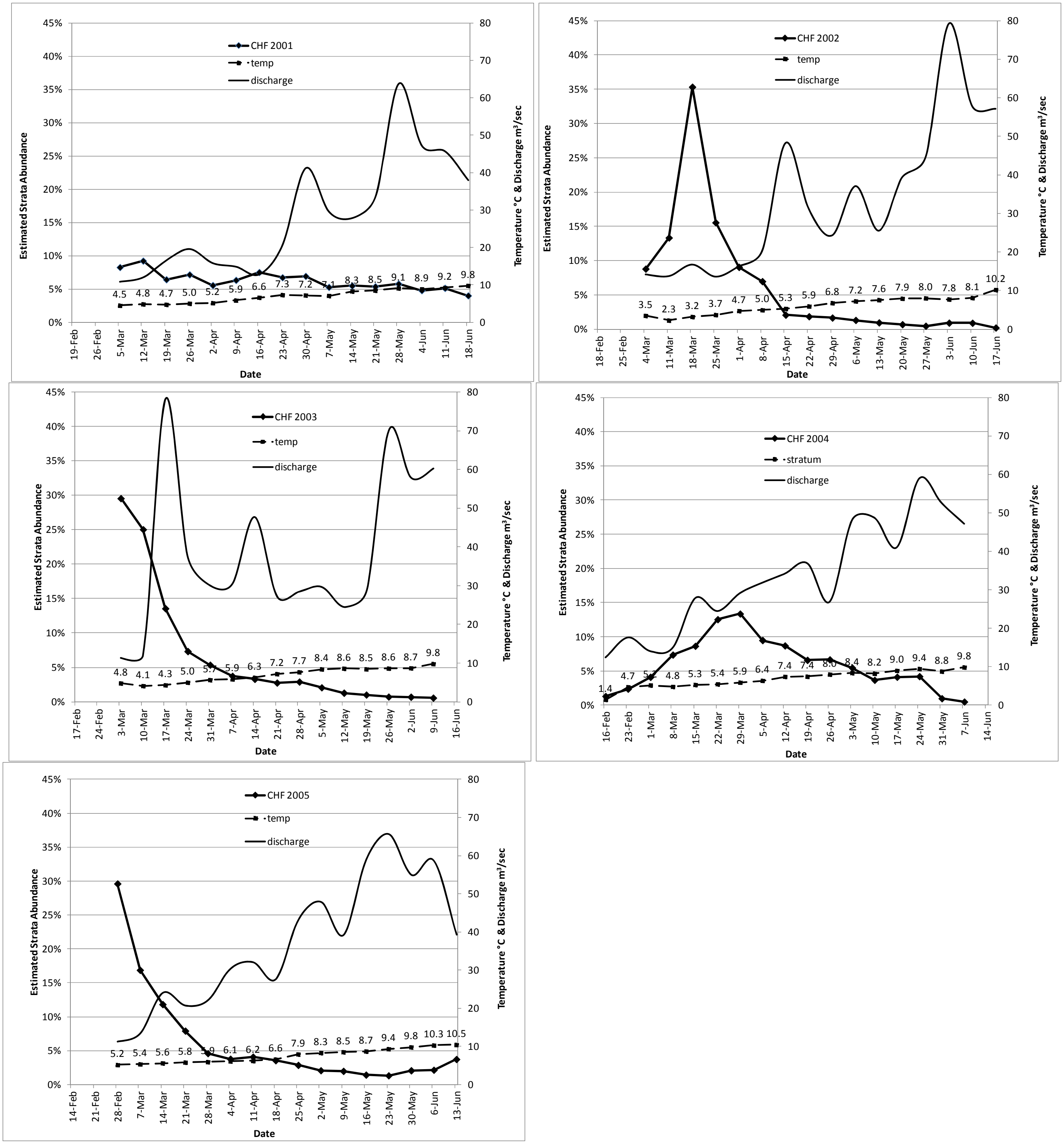
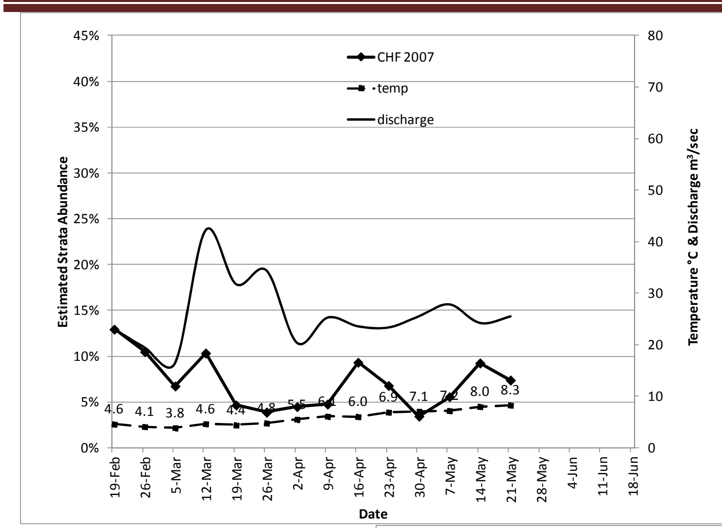
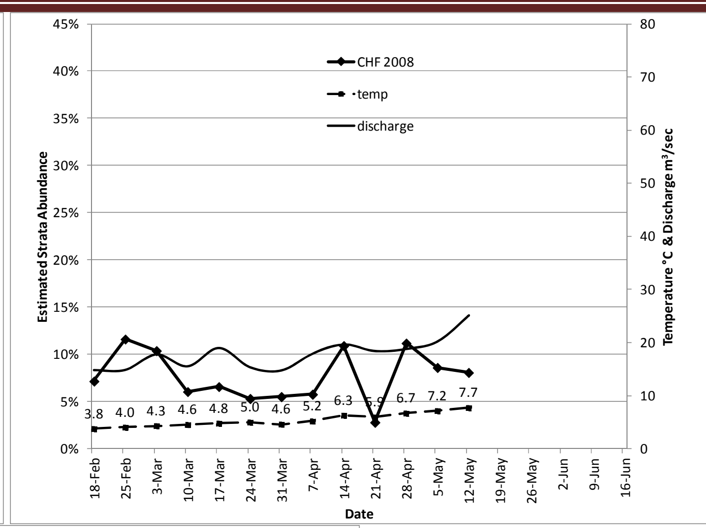
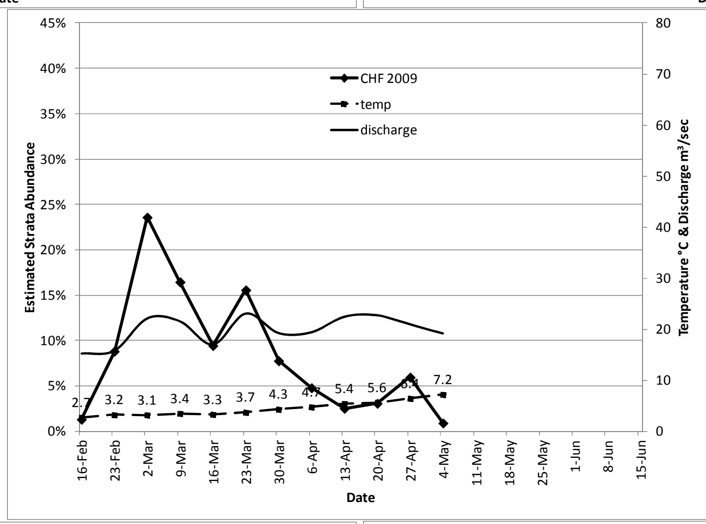
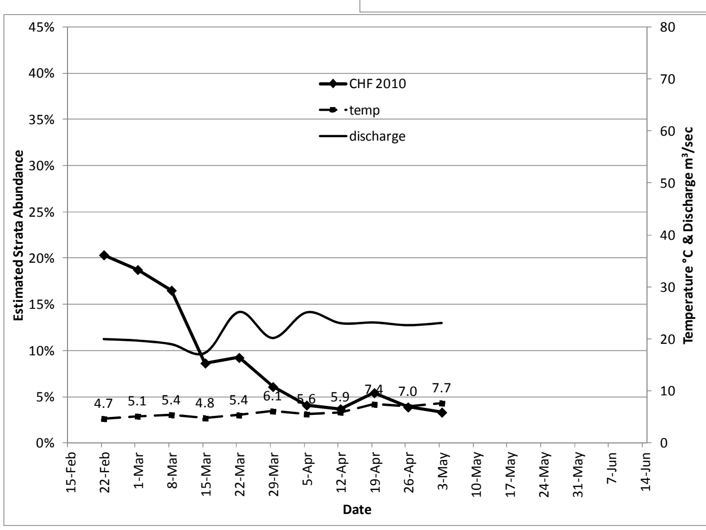


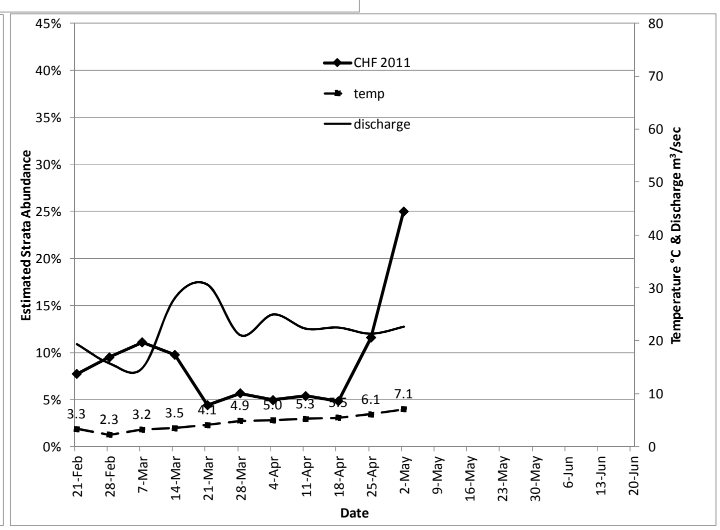
Figure 4. IFA Weekly abundance estimates of chinook fry (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.


CHF 2007
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date
4.6 4.1 3.8 4.6 4.4 4.8 5.5 6.1 6.0 6.9 7.1 7.2 8.0 8.3


CHF 2008
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date
3.8 4.0 4.3 4.6 4.8 5.0 4.6 5.2 6.3 5.9 6.7 7.2 7.7


CHF 2009
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date
3.2 3.1 3.4 3.3 3.7 4.3 4.7 5.4 5.6 6.4 7.2


CHF 2010
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date
4.7 5.1 5.4 4.8 5.4 6.1 5.6 5.9 7.4 7.0 7.7


CHF 2011
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date
3.3 2.3 3.2 3.5 4.1 4.9 5.0 5.3 5.5 6.1 7.1

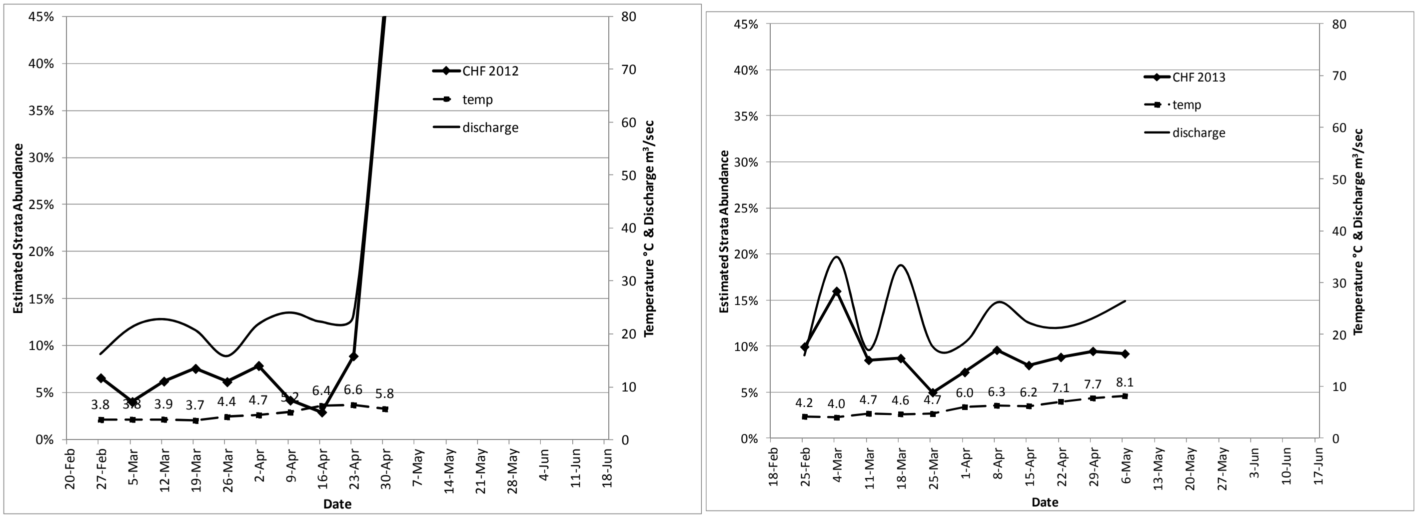


Figure 5. WUP Weekly abundance estimates of chinook fry (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

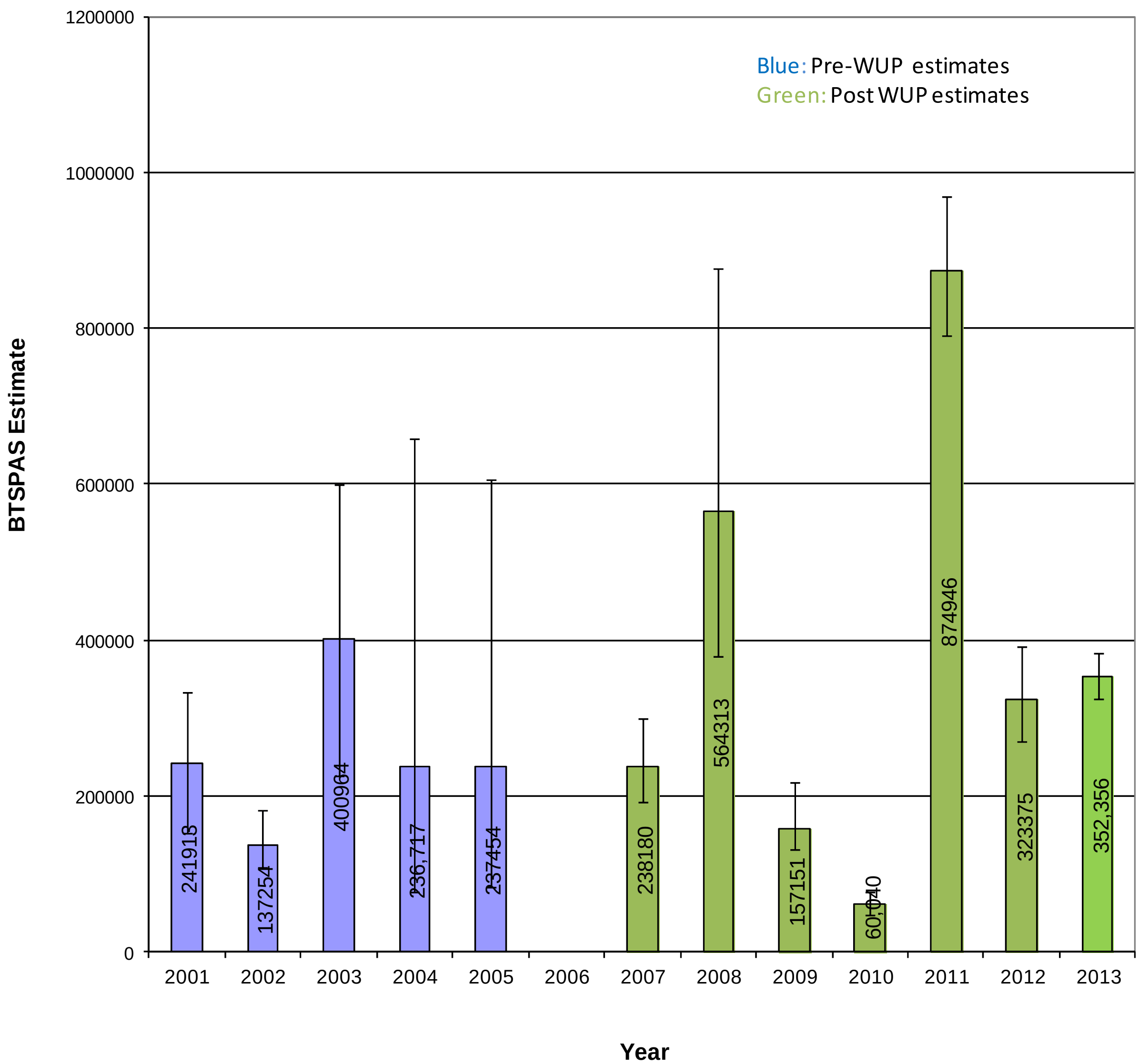


Figure 6. RST derived BTSPAS estimates of chinook fry from Spring 2001 to 2013, including 95% confidence limits.

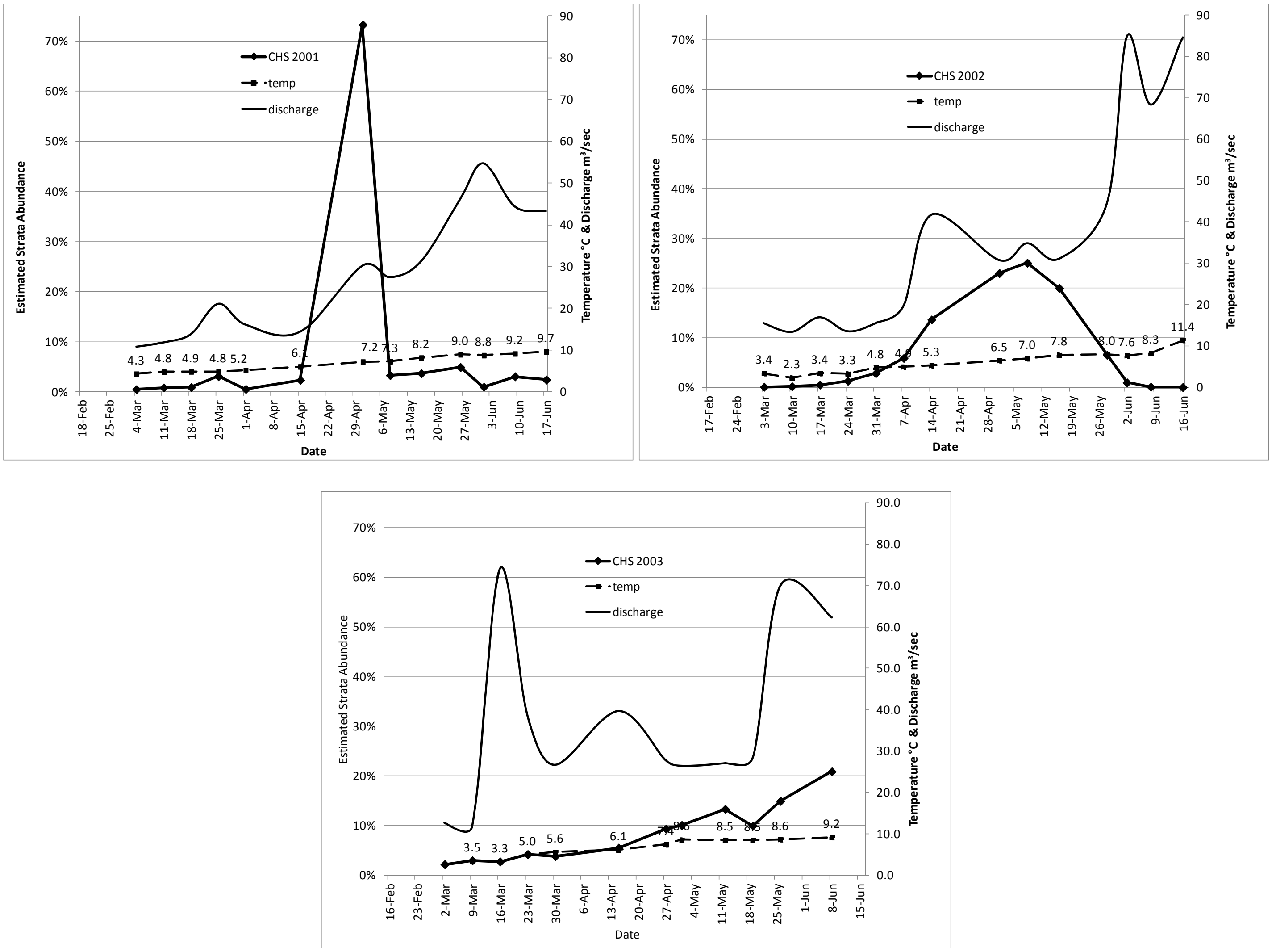


Figure 7. IFA weekly abundance estimates of chinook smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

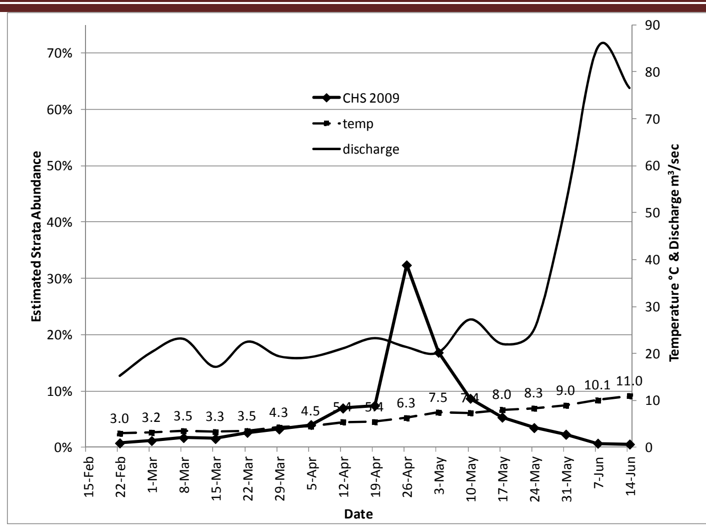


Figure 8. WUP Weekly abundance estimates of chinook smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

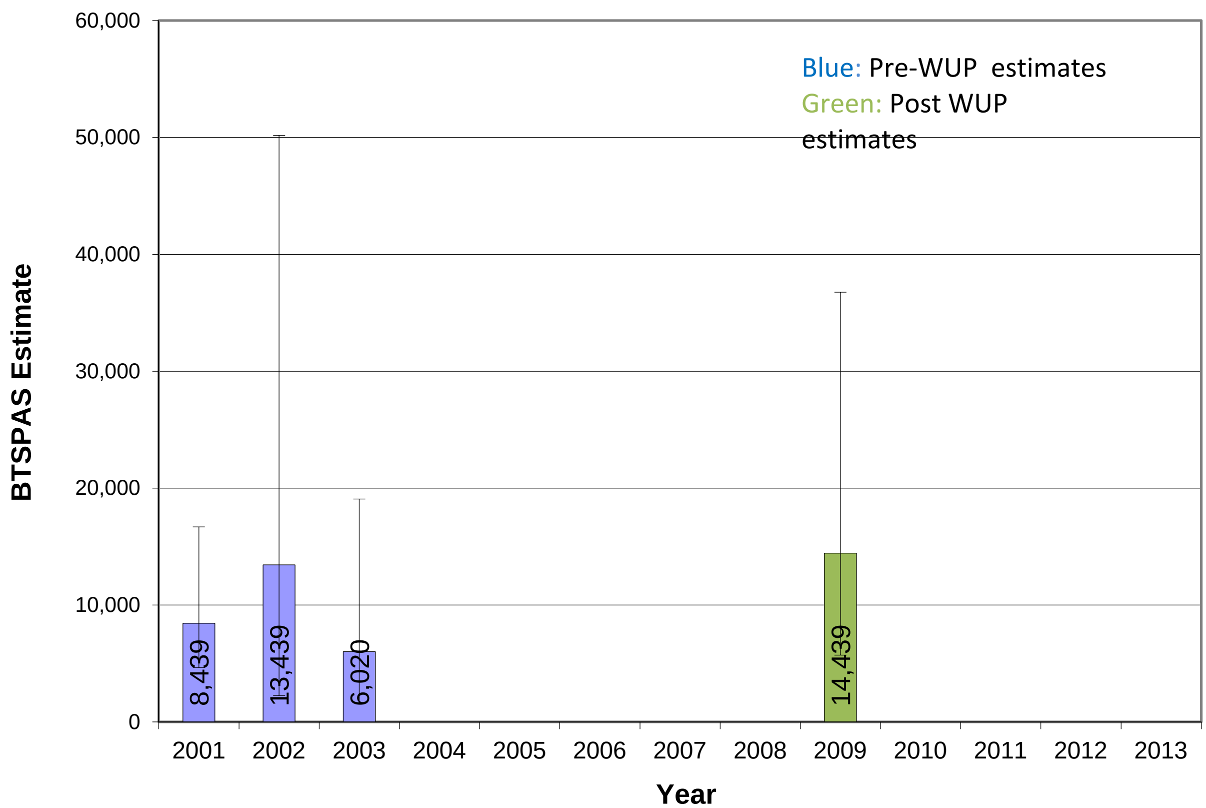


Figure 9. RST derived BTSPAS of chinook smolts from Spring 2001 to 2013, including 95% confidence limits.

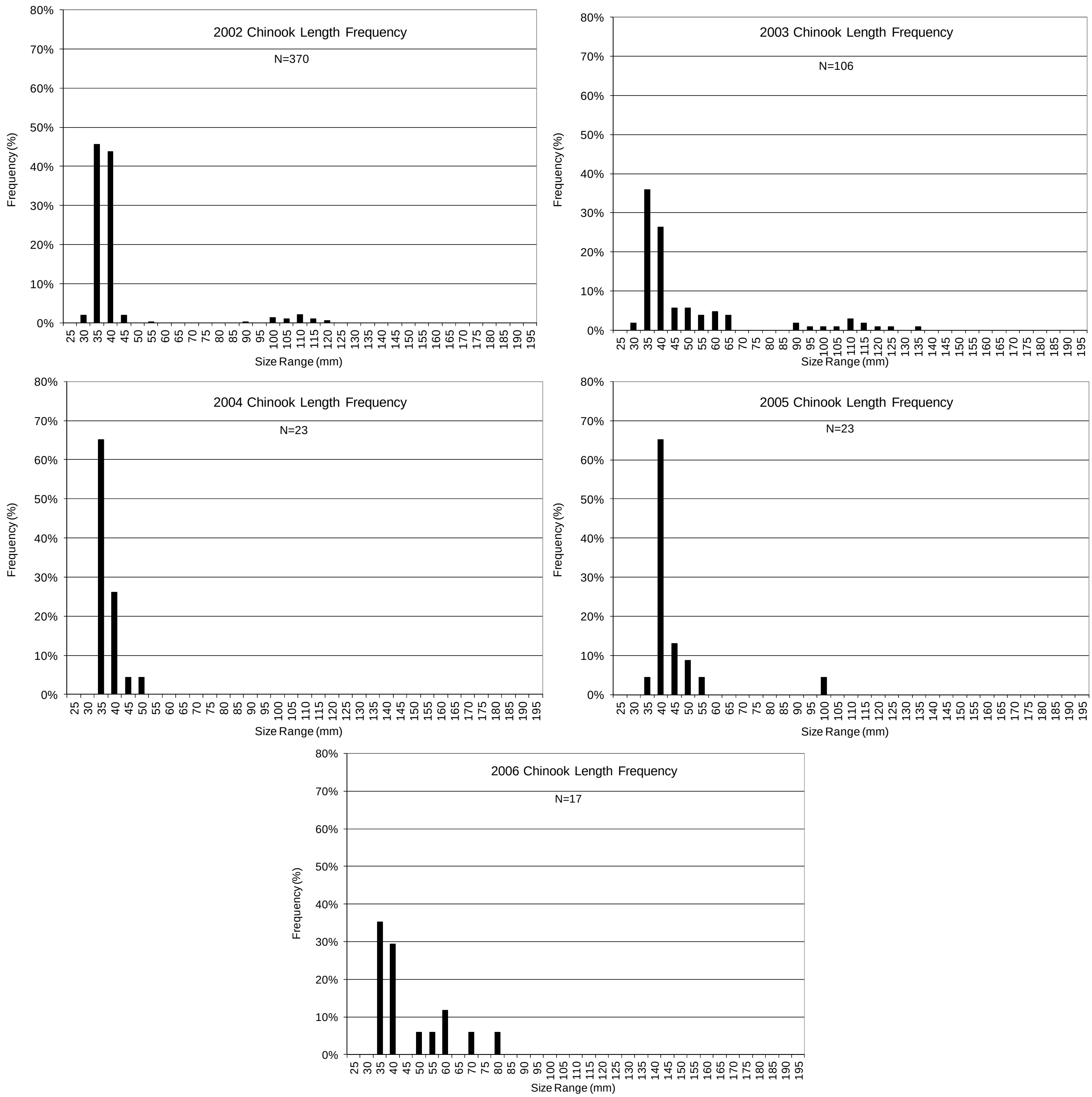
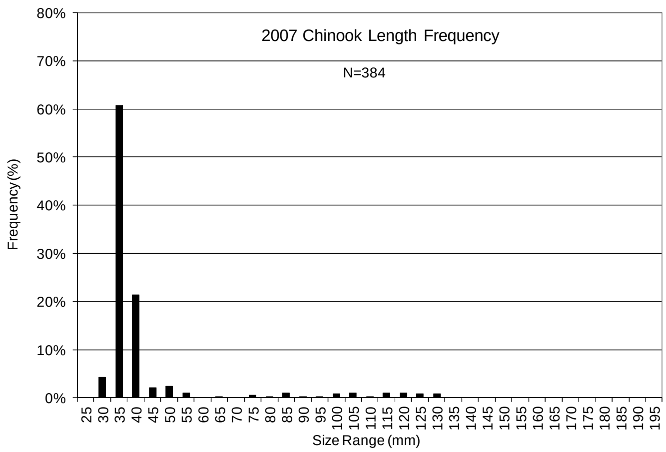
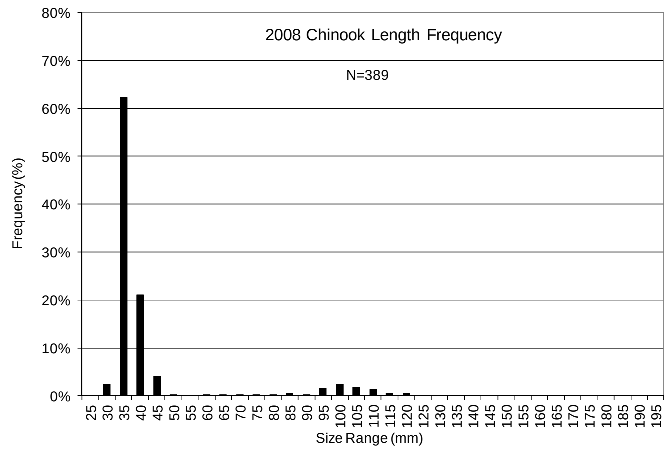
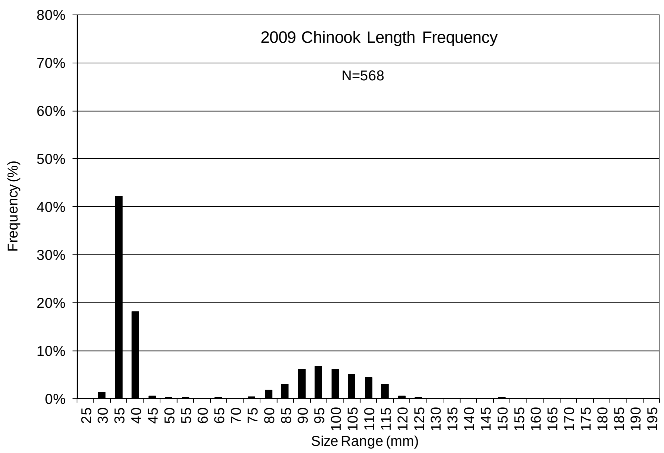
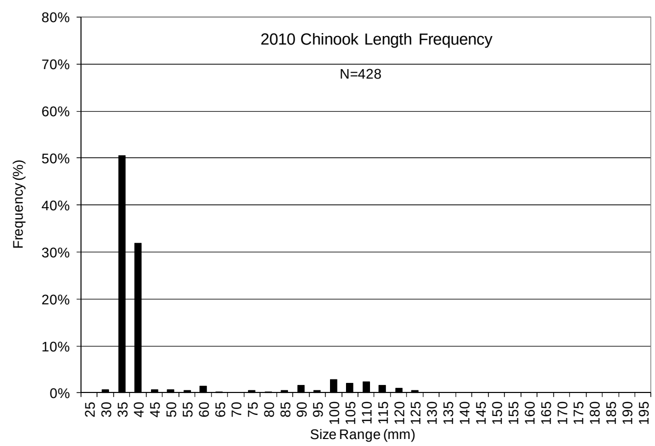


Figure 10. IFA length frequency distribution of chinook juveniles from the Cheakamus River.


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)

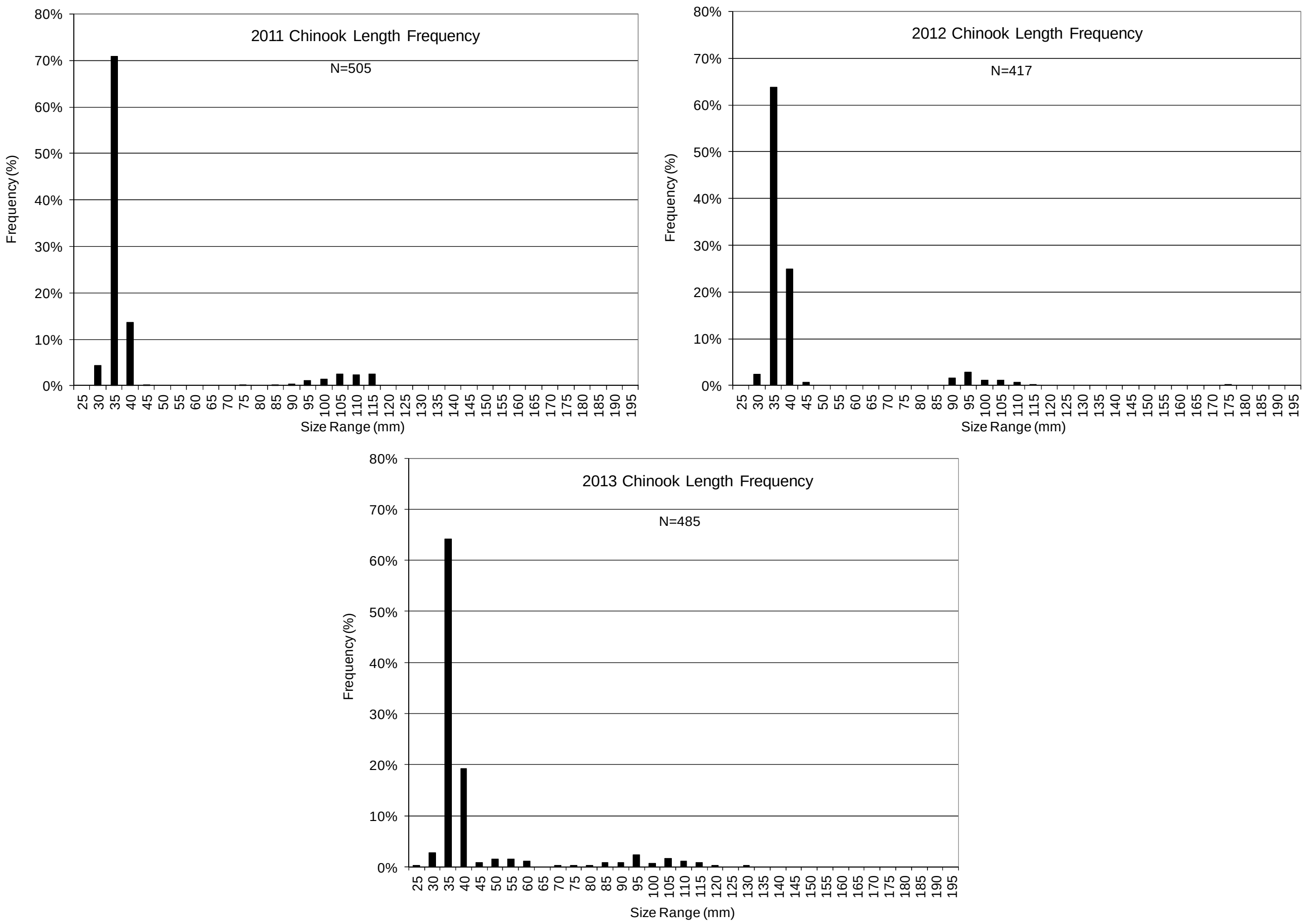
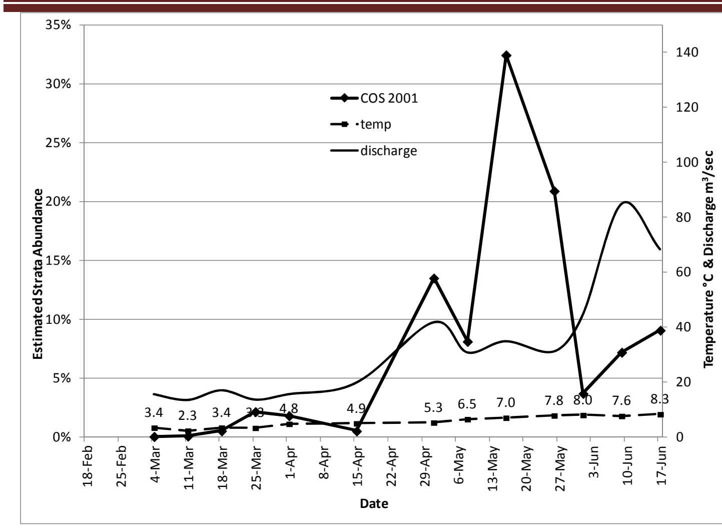
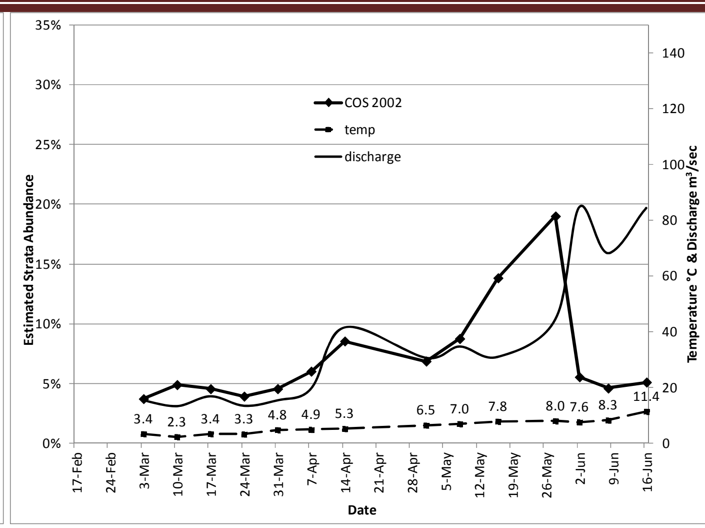
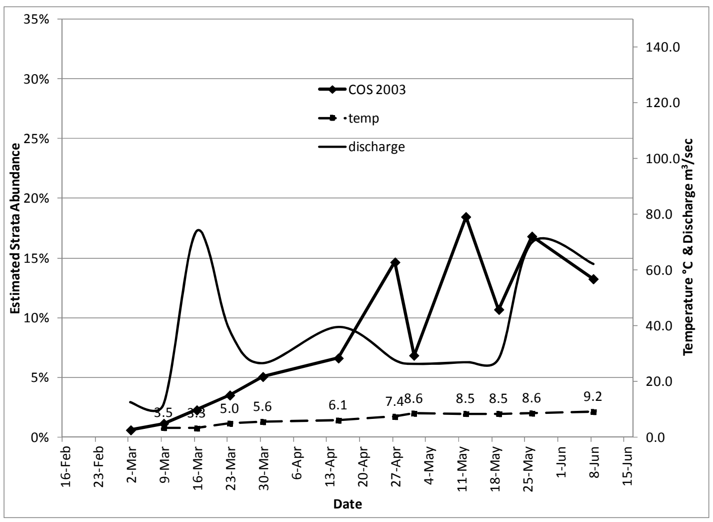
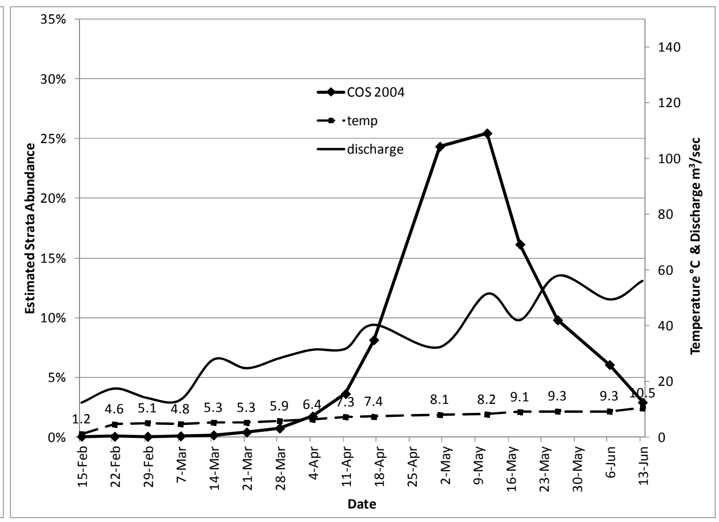


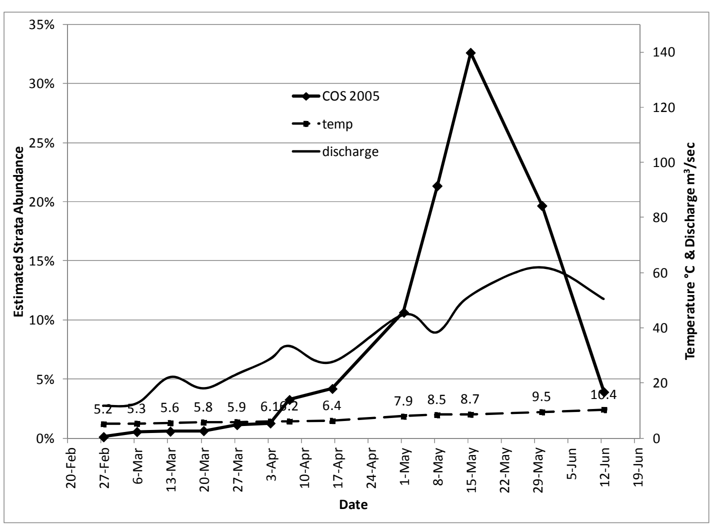
Figure 11. WUP length frequency distribution of chinook juveniles from the Cheakamus River chinook length frequency (%)

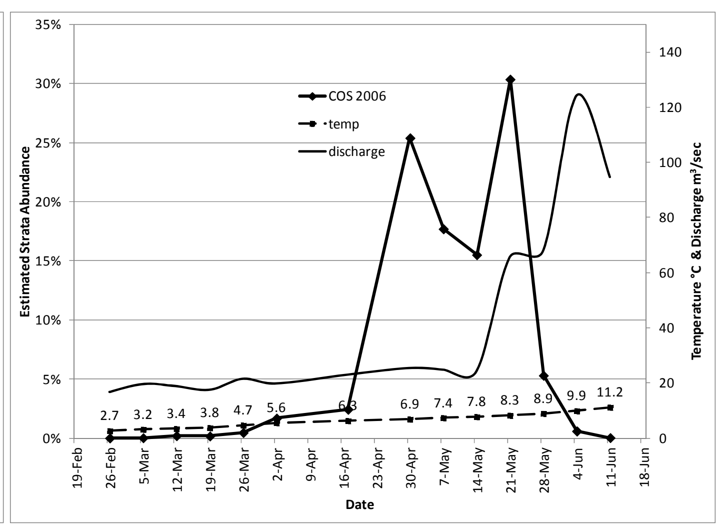

COS 2001
temp
discharge
Estimated Strata Abundance
Temperature °C & Discharge m³/sec
Date


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

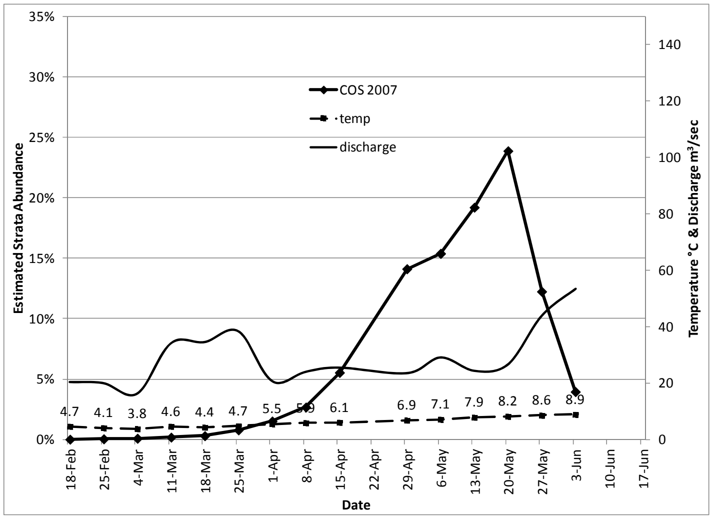


Figure 12. IFA weekly abundance estimates of coho smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

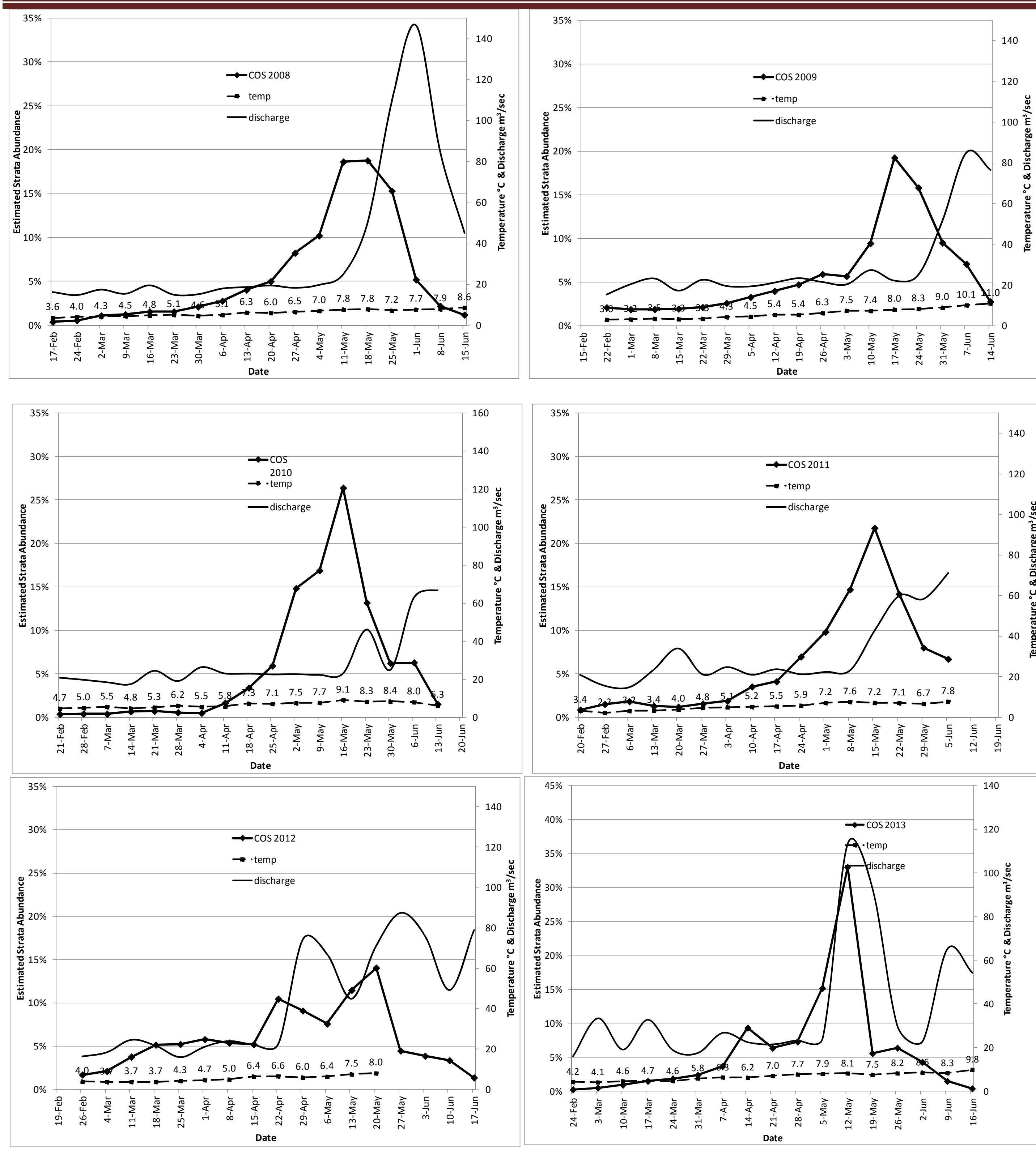


Figure 13. WUP weekly abundance estimates of coho smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

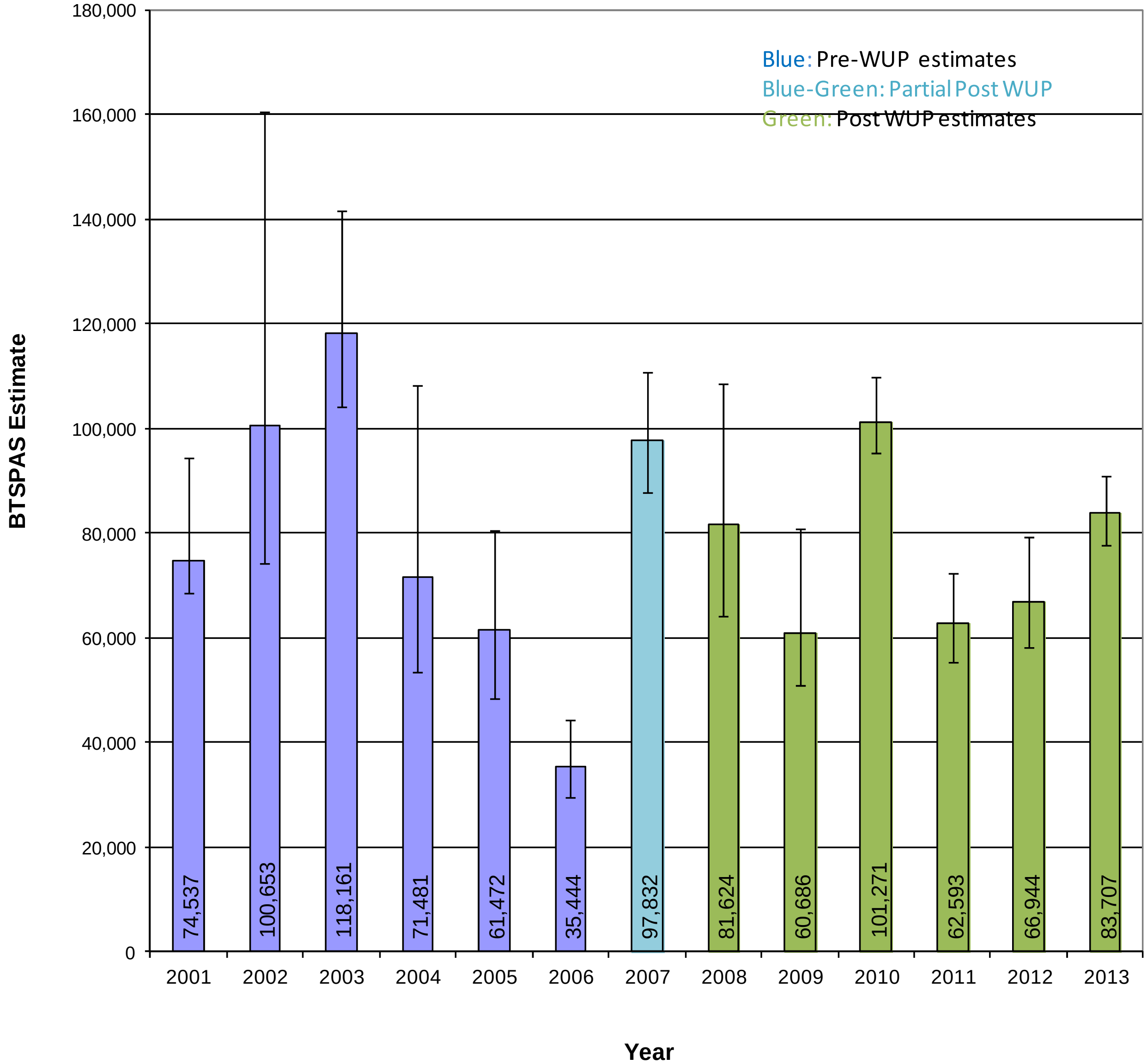
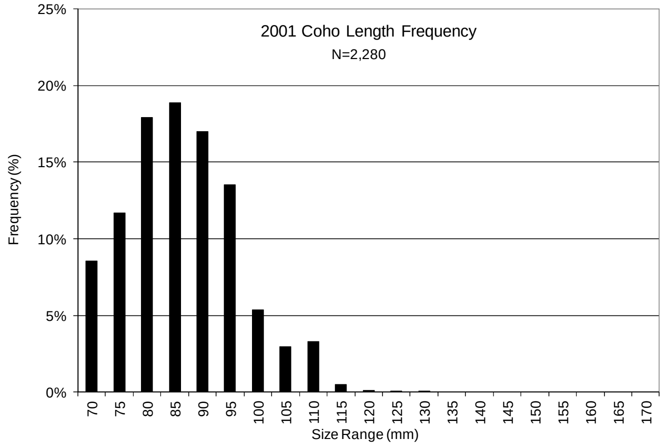
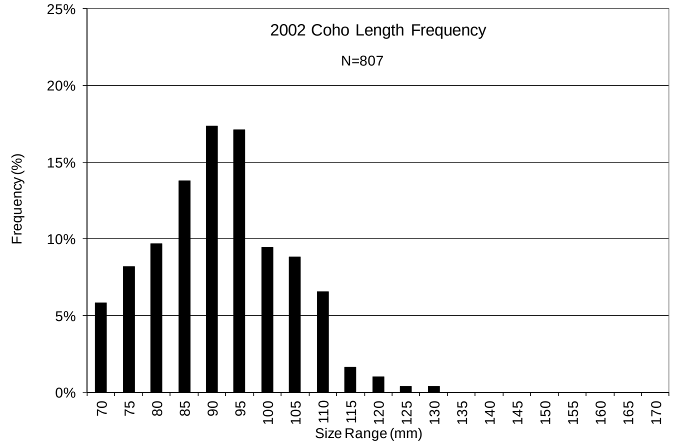
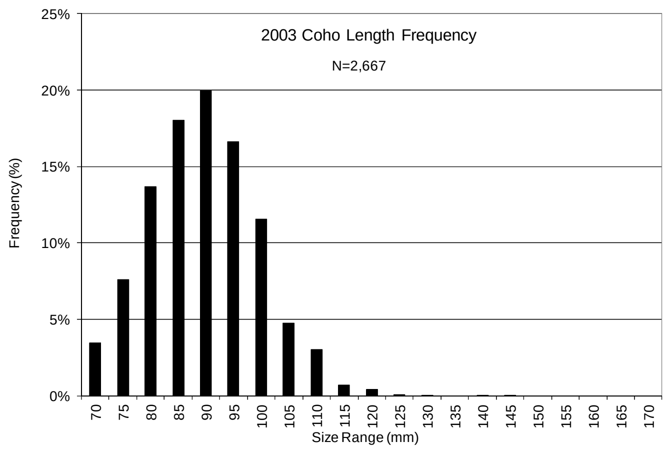
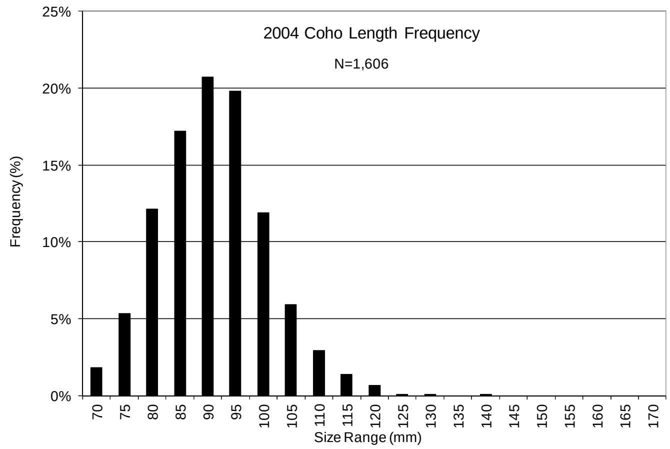


Figure 14. RST derived BTSPAS estimates of mainstem coho smolts outmigration, from Spring 2001 to 2013


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)

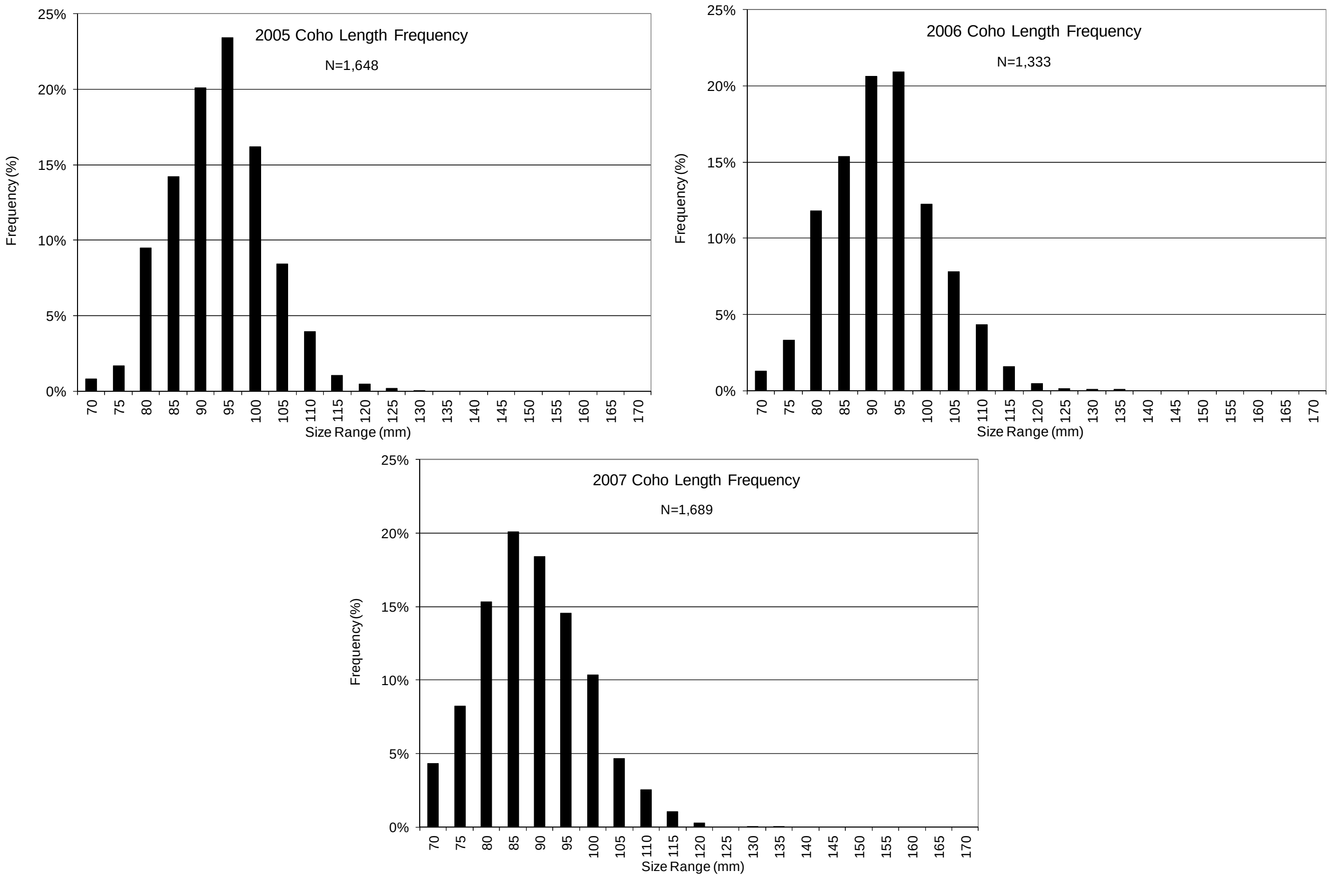


Figure 15. IFA length frequency distribution of coho smolts from the Cheakamus River.

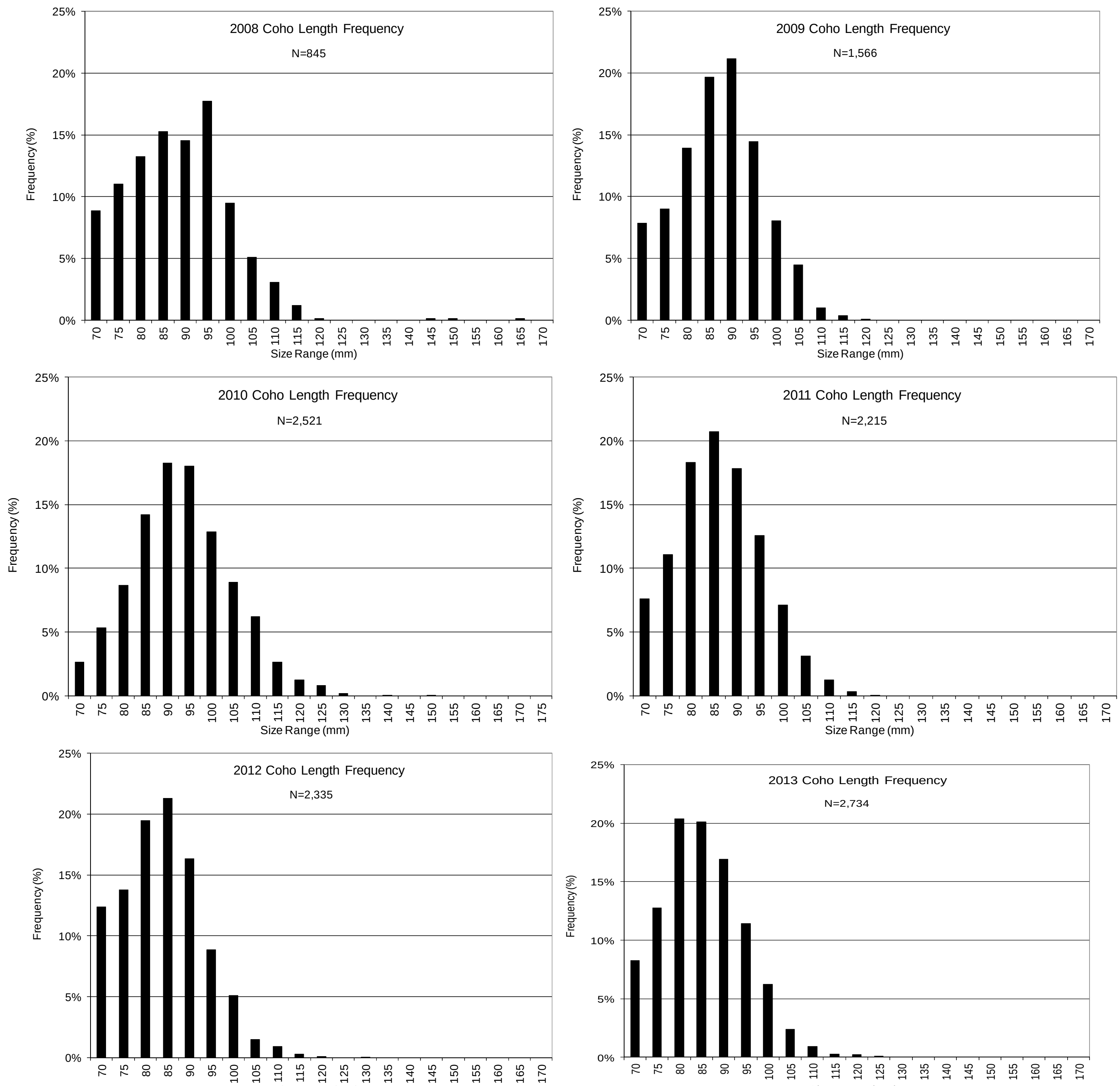


Figure 16. WUP length frequency distribution of coho smolts from the Cheakamus River.

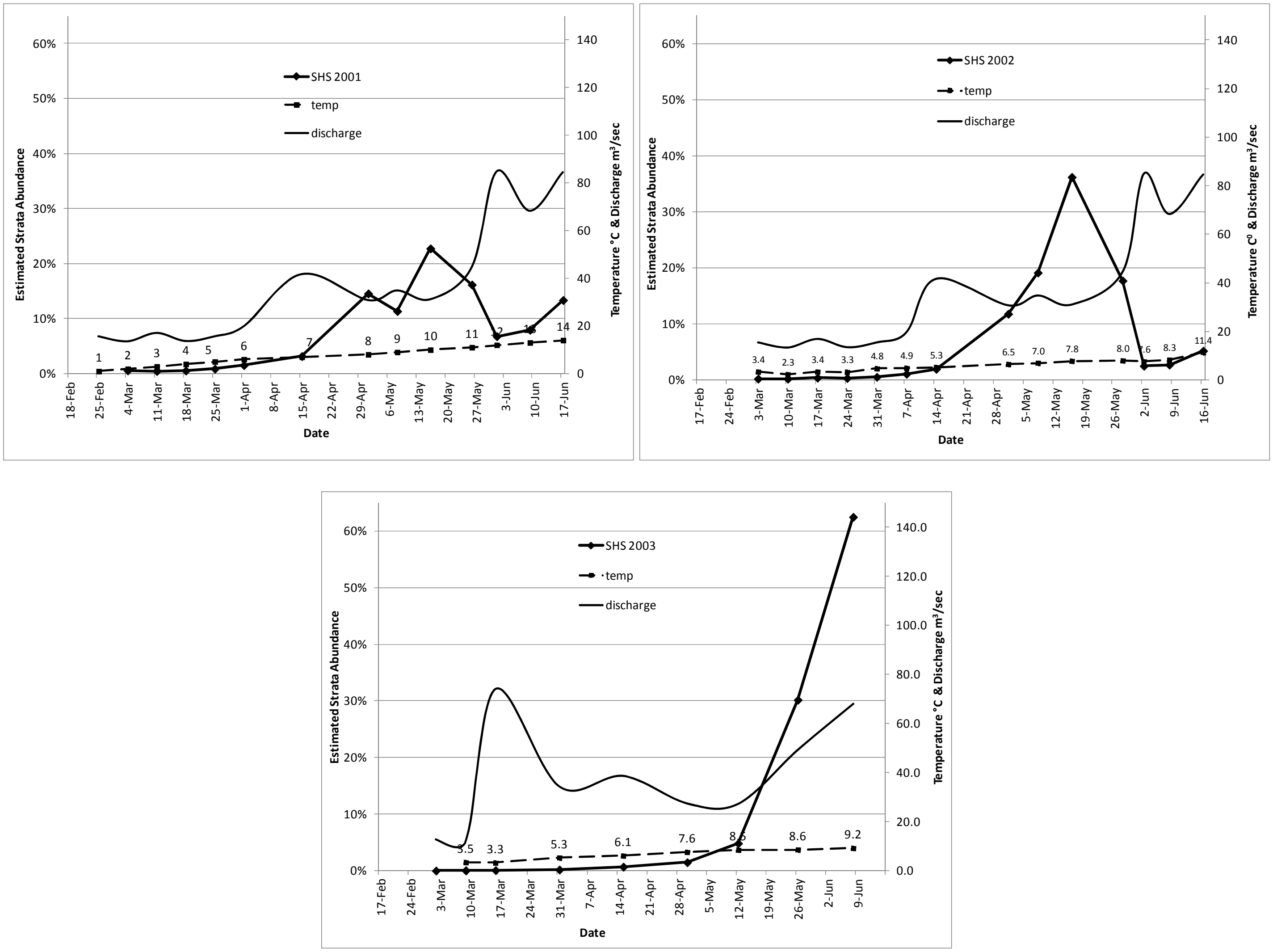


Figure 17. IFA weekly abundance estimates of steelhead smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River.

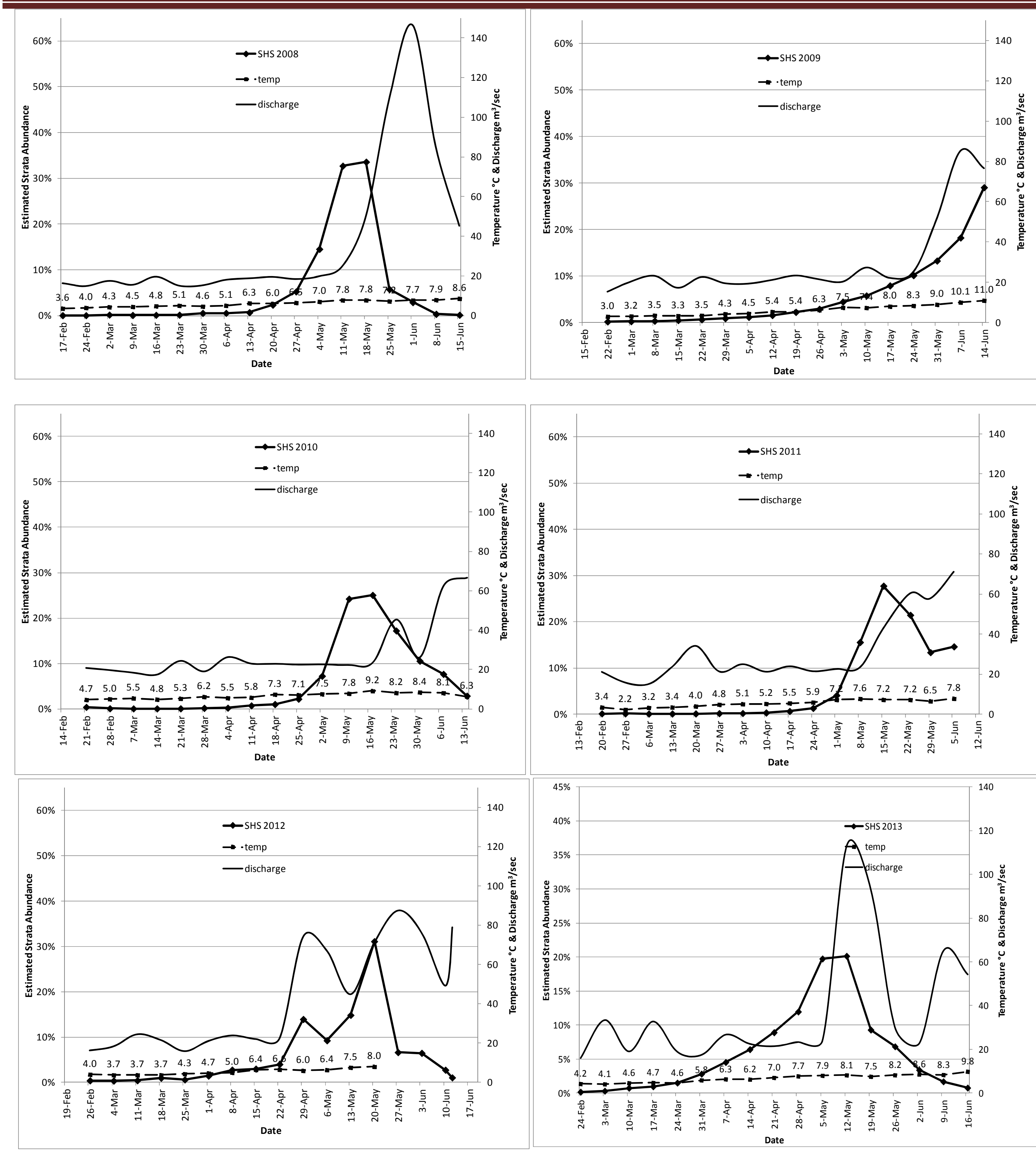


Figure 18. WUP weekly abundance estimates of steelhead smolts (solid line, diamonds) related to temperature in ^{0}C (broken line, squares) and discharge (solid line) from the Cheakamus River

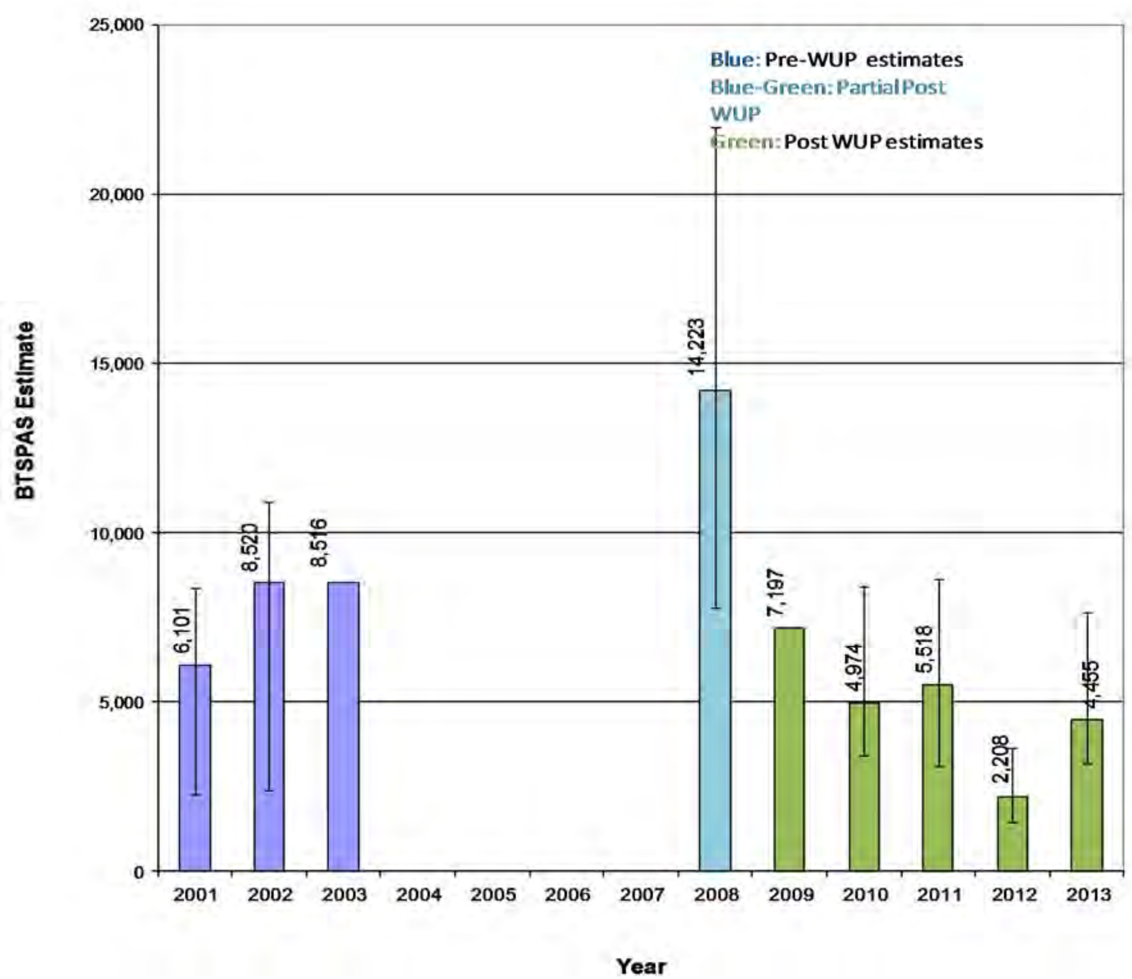
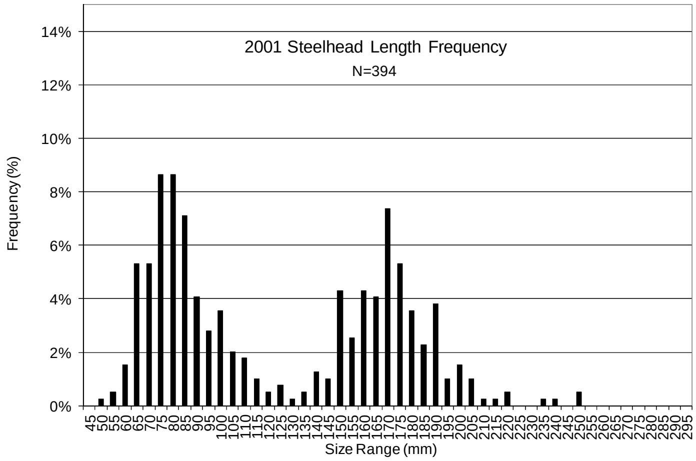
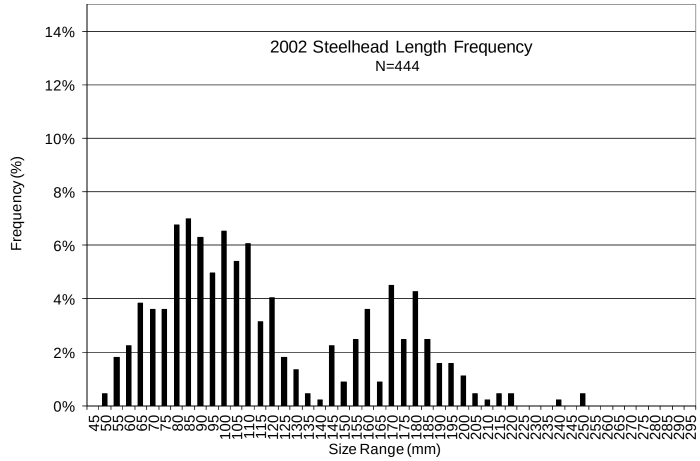
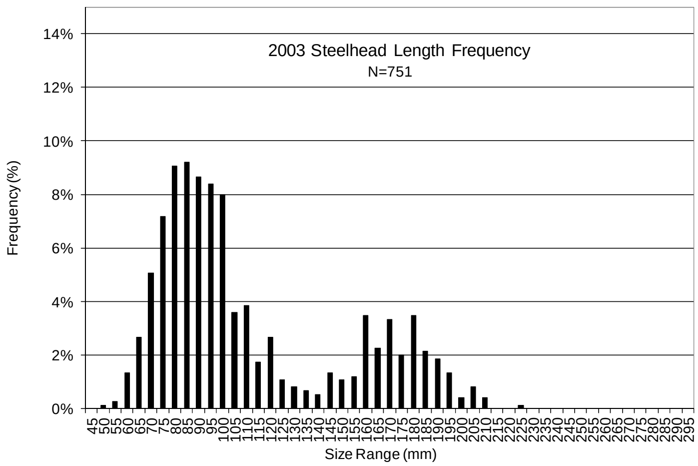
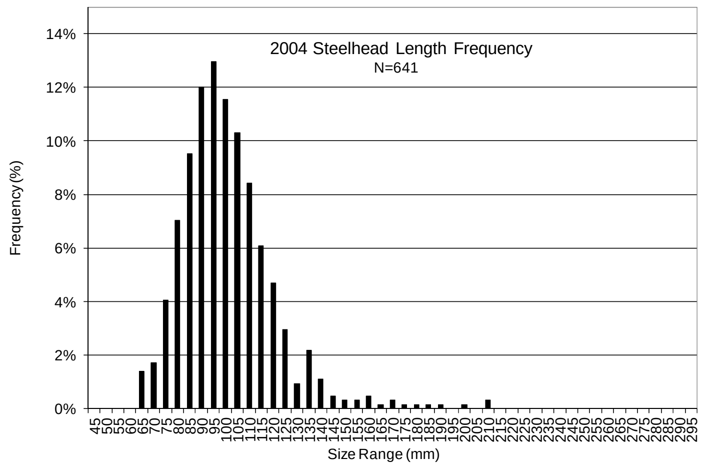


Figure 19. RST derived BTSPAS estimates of steelhead smolts from Spring 2001 to 2013, including 95% confidence limits.


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)

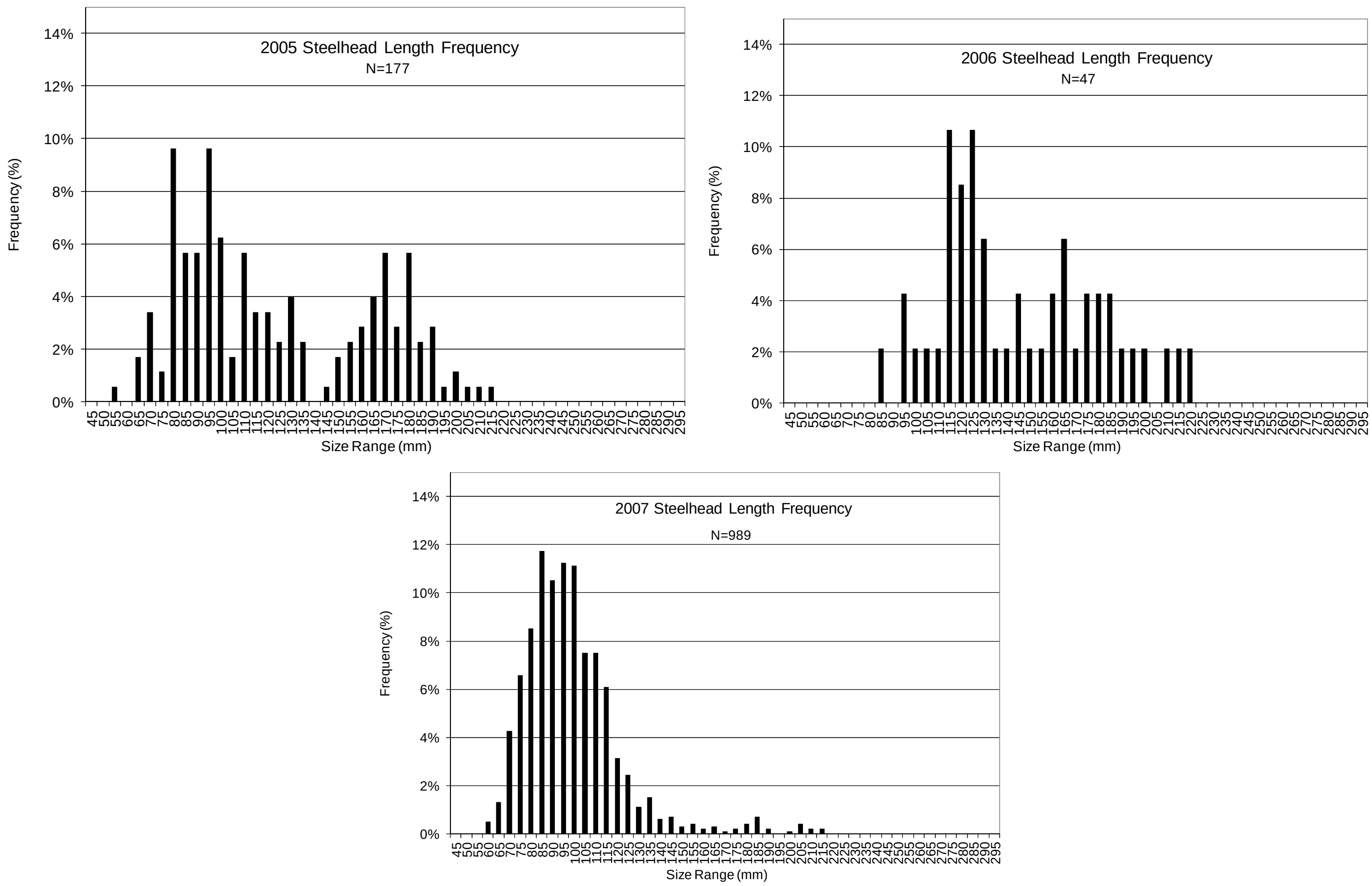


Figure 20. IFA length frequency distribution of steelhead juveniles from the Cheakamus River.

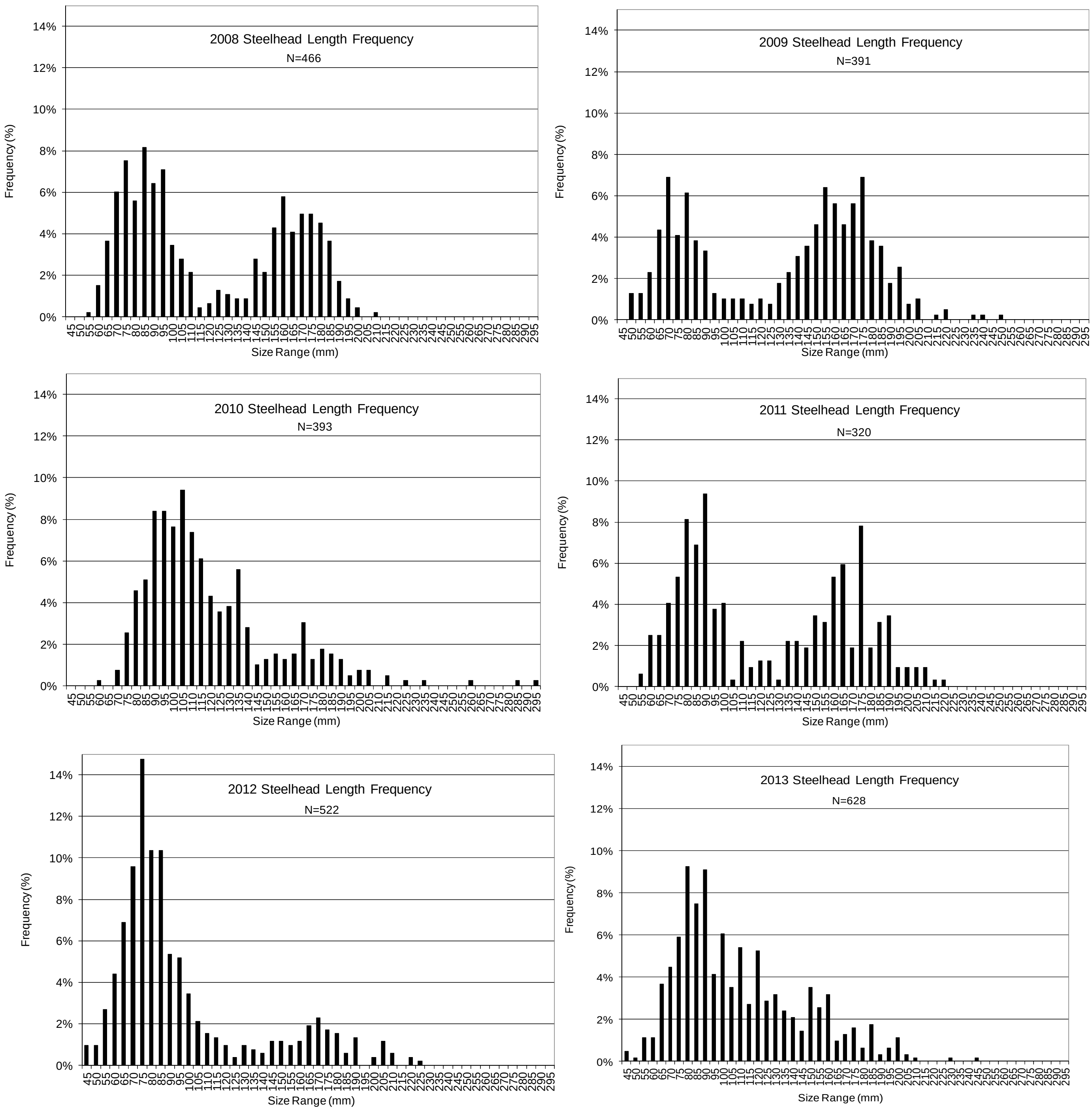


Figure 21. WUP length frequency distribution of steelhead juveniles from the Cheakamus River.

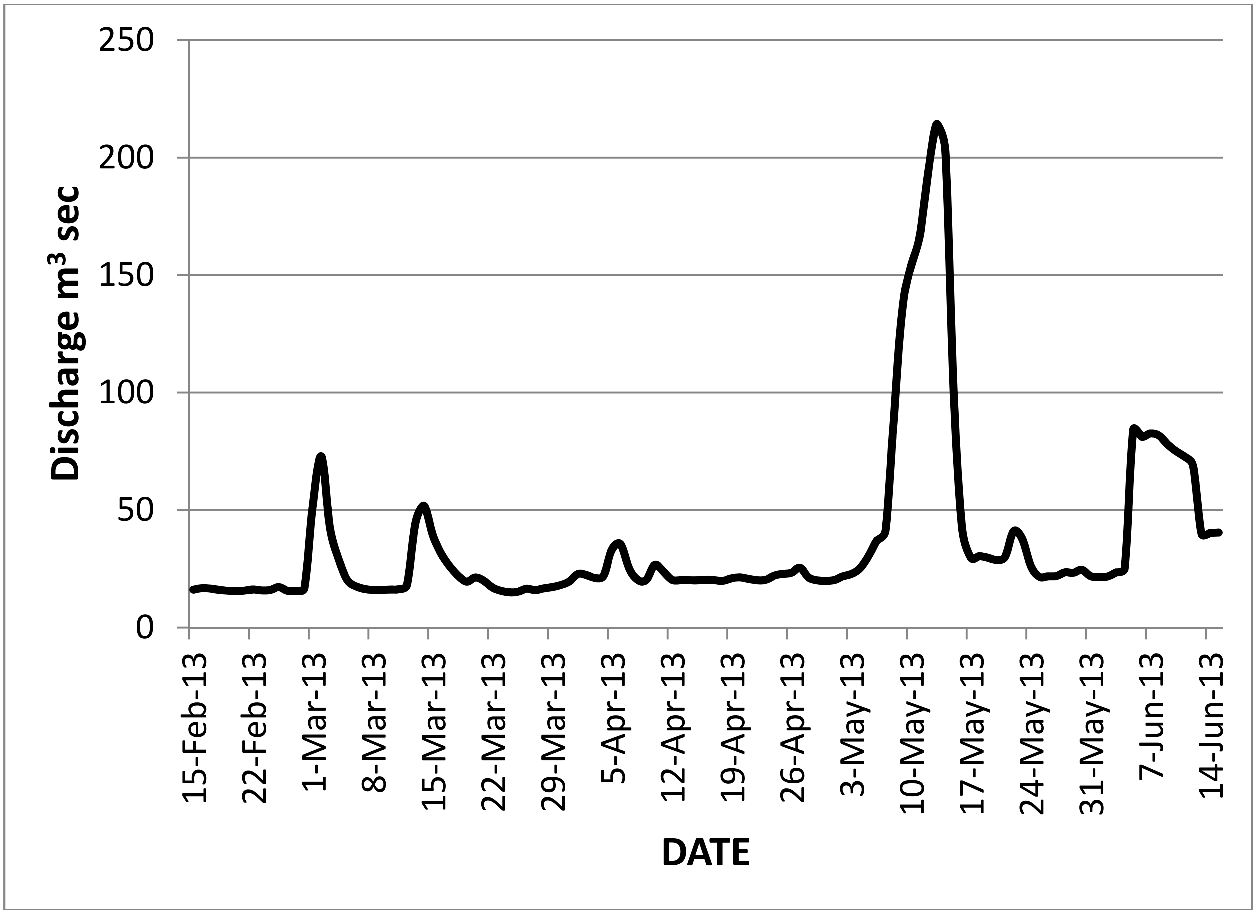


Figure 22. Mean daily discharges from Cheakamus at Brackendale WSC Gauge 08GA043, Spring 2013.

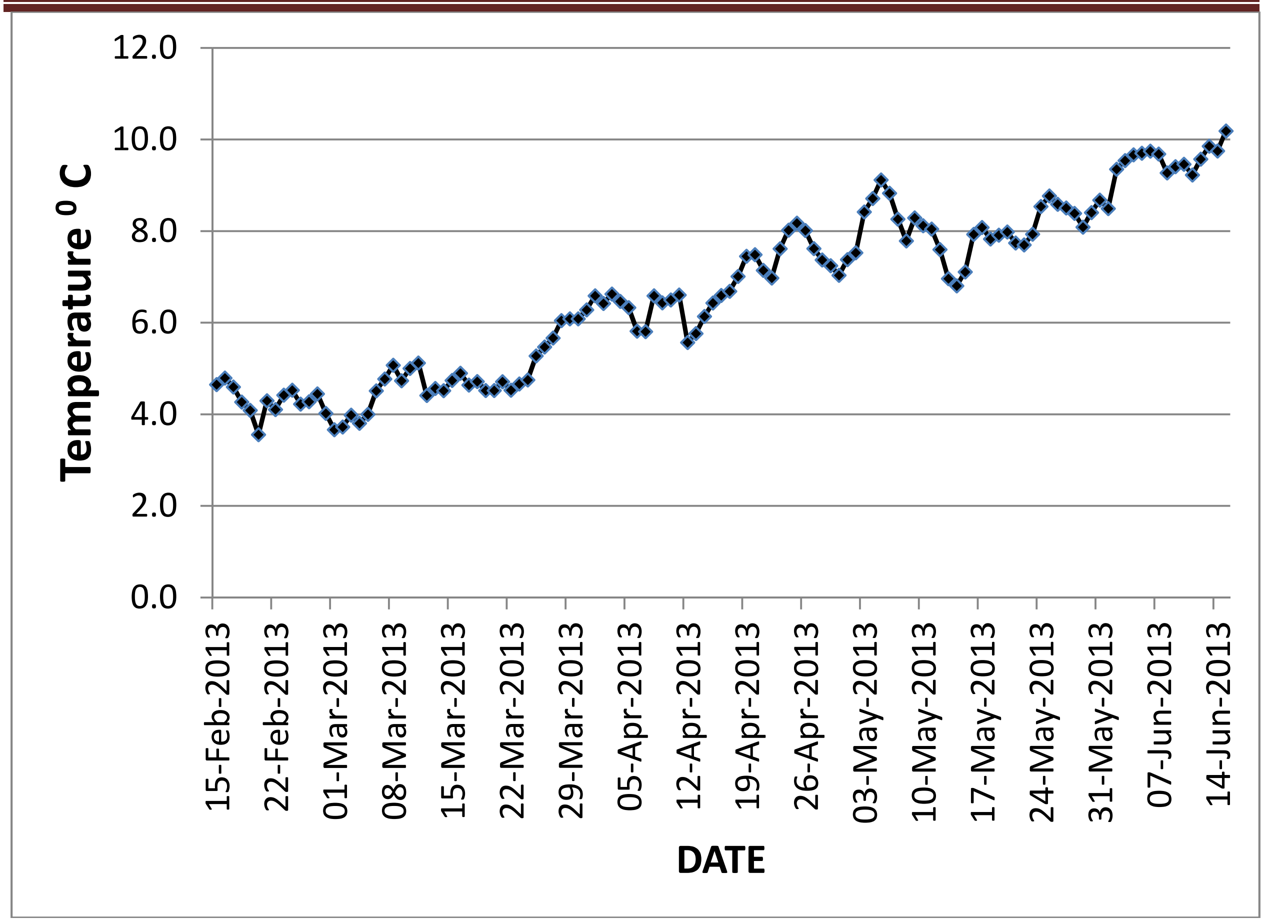


Figure 23. Mean daily temperature from Cheakamus River at the RST site, Spring 2013.

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 Kilometre from confluence

RST: Rotary Screw Trap

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

TH: Tenderfoot Hatchery

UC: Upper Caudal Clip

UP: Upper Paradise channel

NVOS: North Vancouver Outdoor School

VIE: Visible Elastomer Tag

WSC: Water Survey of Canada

WUP: Water Use Planning

YOY: young of the year

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