

**Assessment of the 2006 Juvenile Salmon Migration  
in the Cheakamus River, using Rotary Traps.**

**FINAL**

Prepared for BC Hydro

By

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## 1.0 INTRODUCTION

The Cheakamus River watershed is a major tributary of the Squamish River and drains an area totaling 1010km<sup>2</sup> (upstream of Brackendale gauging station) of the Coastal Mountain range in south-western BC. River flow 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 28m high, 680m 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. The Cheakamus River downstream of the reservoir extends 26km to its confluence with the Squamish River. Only the lower 17km of this river are accessible to anadromous salmon as a number of natural barriers preclude further upstream migration (Figure 1).

As part of the Water Use Planning (WUP) process and future monitoring of the effects of the flow agreement for the Cheakamus River, a juvenile salmon emigration study utilizing rotary screw traps was implemented in the Spring of 2000 (Melville & McCubbing, 2001). The WUP process identified the need to determine the response in juvenile salmonid populations to the Interim Flow Order (IFO) in 1999.

The primary objectives of this study are to assess annual juvenile salmonid abundance and to assess how operations affect abundance over time. Based on data collected over the past seven years, this report recommends improvements to the study design in order to refine and strengthen population estimates to meet the objectives of the monitoring plan.

On August 5<sup>th</sup> 2005, 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, trout char, cottids, lamprey, and stickleback (McCubbing et al., 2006). The effects of the 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. More information of the effect of this event on the time series will be available in future years.

The new flow order for the Cheakamus River was implemented on February 26<sup>th</sup>, 2006. Simply, the discharge from Daisy Lake Dam was changed from 45% of previous day inflows to a minimum measured flow at the following two locations:

1) Minimum flow below Daisy Lake Dam:

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

2) Minimum flow at the Brackendale gauge:

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

## **2.0 METHODS**

### **2.1 Spring Trap Operation**

Trapping methods followed those outlined in Melville & McCubbing, 2006. Emigrating juveniles were captured in the Cheakamus River at RK 5.5 using two six-foot diameter rotary screw traps (RSTs); the only exception was from February 23<sup>rd</sup> to March 30<sup>th</sup> when a four-foot diameter trap was used in location #2 (river left) due to shallow depths that precluded the use of the larger trap. The rotary traps were fished continuously from February 23<sup>rd</sup> to June 7<sup>th</sup>, 2006, except during periods of high debris laden water (>50 CMS) when traps were normally brought to shore and fishing was suspended until water receded to a level where risk of trap loss was minimized. Traps were monitored continuously when flows were at or near the threshold of 50 CMS and when flows were relatively stable at this discharge. Frequency of trap maintenance increased when flow and fish numbers warranted, minimizing trap-induced mortality and insuring optimal trap operation.

The two traps were installed approximately 20m apart with Trap# 1 situated slightly upstream of Trap #2. When both traps were operated, Trap #2 was situated to the left side (looking

downstream) of the thalweg (Location 1), while Trap #1 sampled the right side of an area of concentrated river flow in the deeper area of the thalweg (Location 2). These locations were selected to maximize sampling of the thalweg and, at lower flows during fry migration, the adjacent area of reduced velocity. These areas of the river have been observed through this time series of data to be the most efficient for the capture of out-migrating smolts and fry. When only one trap was operated (because of high water), Trap # 2 was utilized on the right side of the river (Location 2), thus avoiding the requirement to winch it across the high velocity of the main flow (thereby reducing risk of failure of the anchoring system) whilst still allowing sampling in an area of good water velocity. The traps were anchored to shore using a pulley system which allowed them to be winched to shore for cleaning and sampling. The pulley system also allowed adjustment of sampling location to best capture the main current of the river.

As in previous study years, a juvenile trap was operated on the Upper Paradise channel (Figure 2) to increase the number of coho smolts available for mark-recapture estimates, as reported in 2001 through 2005 (Melville & McCubbing, 2002a & b, 2003, 2004, and 2006, data on file). The Upper Paradise trap is a full weir trap that captures all out-migrating smolts (no fry) from the Upper Paradise channel and a portion of Farpoint channel which is diverted into Upper Paradise (Figure 2). The objective of this trap is to obtain coho smolts for marking. As the majority of chum and chinook fry, indicated by run timing data of this time series, have emigrated prior to trap operations, any fry captured are released downstream without enumeration or sampling. The trap was fished from April 2<sup>nd</sup> to June 8<sup>th</sup>. The trap was checked once daily when coho smolts were marked and bio-sampled. Steelhead smolts and parr were sampled for lengths and released unmarked. Other species including chum, pink, chinook and coho fry were not sampled or marked and were released immediately downstream. During high discharge the trap was cleaned often to avoid debris build up.

## **2.2 Biophysical Sampling**

Temperature data from a data logger installed in Big Gorbushca (flow through channel) was used for data analysis as the temperature logger at the RST site had failed (Figure 2). Temperature data only covers the period of February 15<sup>th</sup> to May 15<sup>th</sup>, 2006. Mean daily and weekly discharge (Q) over the survey period was computed from the Water Survey of Canada (WSC) hourly discharge record for the Cheakamus River at Brackendale (WSC 08GA043, Figure 1), located 100m upstream of the RST trap site (Figure 2).

A manual water level gauge was installed at the RST site and water levels were recorded at trap checks; this allowed for instantaneous monitoring of river level fluctuations. These readings are not reported as they were used only for operation of the traps and were not related to discharge or water levels recorded at the WSC gauge.

### **2.3 Catch Monitoring**

Traps were sampled in the morning after sunrise as the majority of fish capture on the Cheakamus River occurs during the hours of darkness (data on file). Fish were removed from the traps and transferred to aerated 20 litre buckets for enumeration, sampling and marking. Coho and steelhead smolts, for the purpose of marking and enumeration estimates, were defined by the following fork lengths: >70 mm for coho smolts, <70mm for coho fry, and >140 mm for steelhead smolts, <140mm for steelhead parr, and <70mm for steelhead fry. In order to verify the length partitioning of steelhead smolts and parr on the Cheakamus, juvenile scale samples from 2000 to 2003 and adult scale samples from 2000 to 2001 and 2003 to 2004 were analyzed and previously reported (Melville & McCubbing, 2005). The three components of the chinook migration were classified by fork lengths as follows: 0+ (2005 brood year) early spring (February & March) fry with <70mm in length, 0+ (2005 brood year) late spring (April & May) fry with 70-90mm, and spring 1+ (2004 brood year) spring smolts with >90mm. An examination of scale data and length frequency histograms from previous years were undertaken in 2004 for chinook, steelhead, and coho juveniles. These data were used for in-season size-based classification rather than classification based on other systems' data as has been utilized in the past (Melville & McCubbing, 2004).

All fish caught and not marked were released 300m downstream of the RST site (Figure 2). Each day's migration is defined as the fish caught in a 24-hour period (8am to 8am).

### **2.4 Bio-sampling**

Every second day, 25 coho smolts or the total day's catch (if less than 25) and 20% of steelhead and chinook smolts (up to 25 individuals) were sampled. In order to reduce handling stress, fish were anaesthetized with a diluted solution of clove oil, dissolved 1:10 in ethanol. Fork lengths (to the nearest mm) were recorded for each fish sampled; weights were recorded bi-weekly. Scale samples were taken for steelhead juveniles. Chum, chinook, coho and pink fry were sampled bi-weekly for lengths and weight throughout the sampling period.

## **2.5 Hatchery Releases**

Hatchery coho and 0+ chinook were released by Fisheries and Oceans Canada (FOC, Tenderfoot Hatchery) into the Cheakamus River during the period of trap operations. Due to observed losses of chinook adults following the caustic soda spill (McCubbing et al., 2006), a hatchery enhancement program targeting Cheakamus chinook was implemented in the fall of 2005. Chinook salmon adults were captured in the river and placed in Tenderfoot Hatchery where they were spawned and their progeny raised to YOY. These YOY were released to the Cheakamus in the spring of 2006 at RK 12 to 15. This varies from normal FOC hatchery practice in this watershed where chinook brood collection and young release both occur in Howe Sound.

The North Vancouver Outdoor School Hatchery (Figure2) releases a small number of chum fry each spring. Depending on release numbers, trapping will either be suspended (if greater than 20,000) for one day or continued (if less than 20,000). This operational protocol has been established based on observed behavior throughout this time series of chum fry that normally migrate quite quickly (overnight) past the traps (C. Melville, pers. obs.)

Trap operation was suspended for two days following coho releases, allowing them to bypass the traps as immediately following release their abundance is too great to facilitate sampling. The few hatchery coho smolts caught at the RSTs during other trapping periods were easily identified from wild coho by an adipose clip (all hatchery coho were marked). The hatchery coho were separated from wild coho while brailling out the trap boxes and were released downstream. In order to reduce handling stress, hatchery coho caught in the traps were not counted.

No alteration of trap operation was initiated after the chinook fry releases as no increase in catch was observed after the release. Identification of hatchery chinook is largely based on appearance, as hatchery chinook tend to be larger than wild fish with average weight 7g vs. 4g, respectively (data on file).

## **2.5 Mark-recapture Trials**

Mark recapture methods were used to assess capture efficiency of the RSTs and calculate population estimates of outmigrants. Since capture efficiency is known/expected to vary over the migration period based on flow conditions, migratory patterns, fish abundance and other factors,

population estimates calculated using capture efficiency estimates over shorter time periods (strata) can be more accurate than population estimates calculated using average capture efficiency over the entire migration period (Seber, 1982). To facilitate a stratified estimate a portion of the daily catch of were marked.

Smolt marks (unique to a release group) refer to a combination of caudal fin mark(s) and the sub-dermal injection of a coloured dye using a jet inoculator (Hart & Pritcher, 1969). The fin mark was varied during the migration period to determine the efficiency of the traps through time (temporal stratification). Dates for each release group are determined at the start of the study based on previous years' run timing. The marking strategy is adaptive in nature and can be altered within the field season based on changes in capture numbers, migration timing, and/or events such as high flow that precipitate a change in trap operation as explained in Section 2.1.

Prior to marking, smolts were anaesthetized in a bath of diluted clove oil dissolved in ethanol. Caudal fin clips were of two types, upper caudal (UC) and lower caudal (LC). The caudal fin was cut dorso-ventrally at a point approximately one-fourth the distance from the tip of the lobe to the caudal peduncle. Blue (alcian blue) or Red (neutral red) coloured dye was applied either to the upper or lower caudal peduncle, the pectoral fin, the ventral fin or the anal fin with a jet inoculator. The mark was a line on the fin ray approximately 3-4 mm long. Efforts were made to minimize the stress on smolts during the marking process. Temperature stress was minimized by marking as fast as possible in the morning and in a shady area. The holding, anesthetic and recovery water were changed frequently during the procedure. The holding and recovery buckets were also aerated using battery-operated pumps. Generally, fish sampled for length, weight and/or scale samples are not used for marking as the added stress could affect their migration behavior. When the marking process was completed, the marked RST origin smolts were transported upstream 500m to Eagle Point (Figure 2), placed in a holding box, and subsequently released at dusk. Steelhead and chinook smolts were not marked in 2006 due to the low numbers captured.

Coho smolts were also marked (utilizing a different mark than RST captured fish) at the trap located on Upper Paradise restoration channel (Figure 2). These fish are more abundant than those available at the RST site and may offer the opportunity for increased confidence in population estimates derived from MR methods. The majority of smolts captured at the restoration channel trap each day were marked in the morning and held until dusk in a holding

box immediately downstream of the Upper Paradise trap site. This differed from 2001 to 2004 when fish were released immediately after recovery from marking. The new procedure was implemented in 2005 to minimize potential predator related mortality on these marked fish.

Chum and pink fry marking procedure at the RSTs in 2006 followed the same protocol implemented in 2004, prior to which a slightly altered procedure was followed in 2001 through 2003 (Melville & McCubbing, 2001-2003). Unlike smolts, fry collected in the RST trap boxes overnight were not sampled in the morning of capture but held during the day in the RST trap boxes. Thus, fry daily catches represent the period 5pm to 5pm (differs from smolts) although visual observations indicate few fry are captured during daylight hours. These fish were subsequently enumerated and marked late in the afternoon and immediately released at Eagle Point (Figure 2). Marking and enumeration were timed in order to coincide each release of marked fry with dusk. This procedure was undertaken for four days each week. The three-day break between marking periods has been assessed as sufficient to allow all marked fry from each four-day marking period to pass by the RSTs prior to each new group being marked, thus requiring only one mark type. Historical recapture of marked fry has consistently approached zero within 48 hours after release in all years of this time series (data on file). These methods allowed for calculations of weekly capture efficiency to be developed. A maximum of 3,000 fry were marked in each batch by immersion in Bismark Brown Y dye (BB) at a concentration 1:100,000 for 1 hour in 50 litres of dye solution aerated with medical grade oxygen. The marking strategy was developed to minimize stress related mortality due to the marking/holding process on fry and at the same time reduce safety concerns relating to staff working at night (Melville & McCubbing, 2002). Marking was restricted to the peak fry migration period (February 28<sup>th</sup> to May 3<sup>rd</sup>) as recaptures of low numbers of marked fish (<100 per day) are too few to provide a robust efficiency estimate. Chinook fry were not marked in 2006 as numbers caught were the lowest observed since 2000.

## **2.6. Mark Recapture Methodology**

Assumptions made for mark-recapture studies as outlined by Seber (1982) include:

- the population is closed such that the population is constant;
- all untagged fish (smolts) have the same probability of being captured at the enumerator trap;
- marking and clipping the smolts does not affect their catchability in the rotary trap;
- smolts do not lose their marks between the release site and the recapture site;

- all marks are reported on recovery in the enumerating trap.

As well, we assume that:

- marked and unmarked smolts have similar movement patterns from the release site to the rotary trap;
- smolts can pass the rotary traps only once and all marked smolts pass Traps 1 & 2 by the end of the study, i.e., none of the smolts remain above the rotary traps;
- there is no mortality and no smolts leave the system without passing the lower trap.

Given that these assumptions are met, the Peterson estimate gives a population estimate in most cases from the equation (Ricker, 1975):

$$N = \frac{(M+1)*(C+1)}{(R+1)} + (\text{mortalities})$$

Where N = population estimate

C = total catch

R = number of marked fish recaptured

M = number of marks released

Analysis was carried out utilizing the SPAS computer program (Arnason et al., 1996) which reports the pooled Peterson estimate (PPE) and its standard error by using the Chapman hypergeometric model, as described in Seber (1982). The term pooled refers to pooling of mark strata. Actual daily out-migrations have been observed to violate a number of the above assumptions in some cases (Decker, 1998; Schubert et al., 1994). Recapture rates may vary between groups as a result of differential tagging stress, temporal variances in recapture rate through release date and river discharge, and/or residulization and mortality. To overcome bias created by using average trap efficiency through the whole study period, data may be stratified into different marked groups. This stratified data utilizes the different marked groups and their recapture efficiencies as sampled over time to create an estimate. It is not always clear what criteria are best for stratifying the data and subsequent pooling of strata. In this case, temporal groups (of seven days) were used. Strata were then pooled together based on the maximum likelihood Darroch (ML Darroch) estimator developed by Plante (1990). It is an iterative process and uses initial values calculated by least squares methods. These calculated stratum values are

compared to the predicted values from the fitted model and a goodness of fit test is used to assess the deviation of the observed from the predicted. Such a method can be applied to remove bias that can occur in complete pooling (Seber, 1982).

## 2.7 Estimated Catch Efficiencies (ECE)

Estimated catch efficiencies of the traps were recorded by marked group and indicate trap efficiency through specific time periods. Variations in observed recapture rates amongst different life stages indicated differential susceptibility of smolts and fry to being recaptured at the RST trap site. These varied statistically (see Results) within and between species, across the sample period, and between trap locations; and may be related to changes in trap efficiency at varied flows, loss of marks through mortality or predation, and trap avoidance. Examination of this data may allow for improved study design in future years, resulting in improved precision and accuracy of population estimates.

Catch efficiency can be calculated from the equation:

$$ECE_G = [(MRG + 1)/(MRLG + 1)] * 100$$

Where  $ECE_G$  = estimated catch efficiency of marked group  
 $MR_G$  = total number of marked fish recovered from that group  
 $MRL_G$  = total number of marked smolts released from that group

Furthermore, an average ECE for all marked groups (by species) can be calculated from both traps from the equation:

$$ECE_T = [(MRT + 1)/(MRLT + 1)] * 100$$

Where  $ECE_T$  = average estimated catch efficiency of all marked fish  
 $MR_T$  = total number of marked fish recovered  
 $MRL_T$  = total number of marked smolts released

## 3.0 RESULTS

### 3.1. Spring Trap Operation

The rotary traps were operated from February 23<sup>rd</sup> until June 7<sup>th</sup>, 2006, a total of 106 days. Due to low flows, only Trap #1 was in operation (Location 2) during the first two days, February 23<sup>rd</sup> and 24<sup>th</sup>, after which a smaller, 4-ft diameter trap was put in Location 1. Both traps fished until March 7<sup>th</sup> when higher flows allowed Trap #2 to replace the smaller, temporary RST in Location 1. Until mid-May, flows were very stable with no trapping days lost to high discharge. During the second half of May and early June 2006, high flows were experienced that resulted in sporadic operation of the RSTs and the subsequent termination of trapping prior to the target of June 15<sup>th</sup>. The highest discharge experienced during trap operation since the program began in 2000 occurred on June 2<sup>nd</sup> when discharge peaked at 302.2 CMS and averaged 267 CMS for the day (Figure 3).

During the period of February 23<sup>rd</sup> to May 16<sup>th</sup>, two traps were utilized for 93% of the potential 83 trapping days. No days were lost due to high flow during this time. On two days, February 23<sup>rd</sup> and 24<sup>th</sup>, only one trap was operating due to low flows. There were only four days where no RSTs were operated: February 27<sup>th</sup> due to a large snowfall that limited access to the trap and increased risk of trap sinking, and April 30<sup>th</sup>, May 5<sup>th</sup> and 6<sup>th</sup> in response to hatchery releases. In comparison, after May 16<sup>th</sup> and until trapping was terminated on June 7<sup>th</sup>, two traps were in operation for 3 days or 14% of the 22 potential trapping days. One trap was in operation all night on 7 days or 32% of the time and one trap was in operation on a limited basis with continuous monitoring from 3pm to 2am on 2 days representing 9% of the time period (Table 1). The majority of lost trapping days during this time was due to high flows, with the exception of May 17 and 18 (prior to flow increase) when the traps became inoperable due to excessive algae build-up (Figure 4). We have assumed that not fishing a trap at any given time should not greatly affect population estimates (but may result in higher variance) because the strata with the missed fishing days would have an associated lower ECE, and hence, theoretically, generate the same population estimate as if they had been fished.

### 3.2 Hatchery Releases

Three of six lost trapping days prior to May 16<sup>th</sup> were lost due to hatchery releases from the NVOS hatchery and from the Tenderfoot Creek Hatchery operated by FOC. North Vancouver Outdoor School Hatchery undertook one main release of chum fry on the evening of April 29<sup>th</sup>, totaling 29,000 fish. Trapping was suspended until the afternoon of April 30<sup>th</sup> to allow these fish to pass. FOC undertook one release of 131,750 adipose clipped coho smolts (average 19g) on May 4<sup>th</sup>, 2006 (FOC, data on file). On the afternoon of the release (May 4<sup>th</sup>) both RSTs were brought in and trapping was suspended until the evening of May 6<sup>th</sup>.

The first release of juvenile chinook which occurred on May 2<sup>nd</sup> was similar to previous years when an unknown number of 0+ chinook juveniles (estimated as <1000) which cannot be captured from raceways when fish are being removed for release transportation to Howe Sound, are volitionally released from Tenderfoot Creek Hatchery (RK 6.5). Unlike previous years, in 2006 releases of chinook juveniles to the mainstem of the Cheakamus at RK 12 to 15 occurred on three different dates: May 5<sup>th</sup> with 403,307 fish, May 10<sup>th</sup> with 311,577 fish and May 11<sup>th</sup> with 7378 fish. The growth of 0+ chinook is accelerated in the hatchery compared to their wild counterparts thus making them easily identified from wild chinook by size and appearance. Hatchery chinook averaged 7g while wild 0+ chinook fry captured after April 15<sup>th</sup> historically have averaged 3g and 1+ chinook smolts have historically average 10g (data on file). A total of 307 chinook young of the year (YOY) assessed as hatchery origin by size were enumerated on May 3<sup>rd</sup> and 4<sup>th</sup>. No hatchery chinook juveniles were identified after May 5<sup>th</sup>. This brief migration period has been exhibited during all previous hatchery releases that have been observed at the RST site over the previous six years of study. There was no observed increase of chinook capture at the RST traps following the three releases to the Cheakamus mainstem May 5<sup>th</sup> to 11<sup>th</sup> (Figure 8).

There were three releases of coho fry by Tenderfoot Creek Hatchery during trap operations. On March 8<sup>th</sup> and March 14<sup>th</sup>, 5,776 and 3,294 fish, respectively, were released in BC Rail channel, and on May 29<sup>th</sup> 10,995, 13,636, and 8,086 were released at Big Gorbushca channel, Farpoint channel and Road's End (RK 15 of mainstem), respectively (Figure 2). The North Vancouver Outdoor School hatchery had no releases of coho fry during trap operations (FOC, data on file). Catch of coho fry did not increase post releases.

### 3.3. Biophysical Monitoring

Discharge (measured at WSC 08GA043) at the Cheakamus River near Brackendale during trap operation ranged from an average daily value of 16.34 m<sup>3</sup>/s to 266.94 m<sup>3</sup>/s over the period of February 23<sup>rd</sup> to June 7<sup>th</sup> (Figure 3).

Average daily water temperature at the Gorbushca channel data logger ranged from 5.1<sup>0</sup> C to 10.5<sup>0</sup> C from February 26<sup>th</sup> to June 11<sup>th</sup> (Figure 5).

### 3.4 Chum Fry Migration

Chum fry migration was underway as RST operations began on February 23<sup>rd</sup>, with fish captured on the first day of operation. The majority of observed fish were sampled between March 12<sup>th</sup> and April 8<sup>th</sup>; a total of 57% of chum fry captures (Figure 6). The dates of 10%, 50% and 90% migration were March 13<sup>th</sup>, April 1<sup>st</sup>, and April 30<sup>th</sup>, respectively. As in previous years, the observed peak of chum fry migration coincided with an increase in water temperature from an average weekly temperature of 3.7<sup>0</sup> to 6.3<sup>0</sup>C and daytime water temperatures approaching or exceeding 7<sup>0</sup>C. Based on diminished captures, ninety-nine percent of the chum fry were estimated to have migrated prior to notable flow increases beginning the week ending May 20<sup>th</sup> (Figure 6).

The total number of chum fry caught at the RST site was 354,337, including mortalities (Appendix 1). This is approximately twice the highest capture of chum fry since the study began in 2000, the range of which is 54,527 to 173,924 (Table 2). Eleven mark groups totaling 94,285 fish were re-released upstream. A total of 7,798 of these marked fish were recaptured at the traps, giving an average ECE of 8.5%, and an individual mark group recapture rate that ranged from 3.0% to 16.9% (Appendix 2-A).

Based on the combined mark and recapture data (i.e., pooled Peterson estimator) the total chum fry emigration past the trap site was estimated to be 4,270,934 fish with a 95% confidence interval of 4,182,395 and 4,359,472. However, the assumption of complete mixing was not met as the percentage of marks recovered differed significantly between release periods (chi-square, df = 10,  $X^2=1511$ ,  $p < 0.001$ ). This indicates that the trap efficiency and/or the migration pattern of fish varied over the sampling period as can be seen in Appendix 2-A. The assumption of equal proportions of marked versus unmarked fish among recovery strata was also not met (chi-square,

df = 14,  $X^2 = 432$ ,  $p < 0.001$ ). These tests indicate that pooling may create bias in the population estimate. In an attempt to examine the bias, we dropped recovery strata 1 and 13 through 15 (no recaptured chum fry), pooled columns 1 with 2 and pooled row 1 with 2 (low numbers of recaptured and marked fish, respectively). A ML Darroch estimate of 4,379,297 chum fry with 95% confidence limits of 4,270,066 to 4,488,529 was calculated. The low  $G^2$  value associated with this estimate ( $G^2 < 0.27$ , df = 1,  $p = 0.6$ ) indicates a good fit to the data (Arnason et al., 1996). An estimated 9,907 chum fry passed the RST site before February 27<sup>th</sup> and after May 16<sup>th</sup>. This figure was derived using the delta method: total number of fish in recovery strata 1 and 13-15 divided by the mean efficiency for all release strata (8.6). Thus a total estimate of yield upstream of the RST site was 4,389,204. The pooled estimate appears to be biased low from these analyses.

A total of 1,881 chum fry mortalities were incurred between the two traps. This represented approximately 0.04% of the estimated chum fry emigration, or 0.5% of the chum fry caught in the traps (Appendix 1).

#### *3.4.1 Chum Fry Length*

Mean length and weight for chum fry in spring 2006 was 39mm and 0.7g (Table 3). A statistically significant observed difference in mean fry length was found between the seven sample years, 2000 to 2006 (ANOVA,  $p = 0.001$ ,  $F = 32$ ,  $df = 6$ ). Largest fry were captured in 2001 and 2003, with smallest fish captured in 2004 to 2006 (Table 4).

### **3.5 Pink Fry Migration**

Pink fry migration had commenced as trap operations began on February 23<sup>rd</sup>, as indicated by fish captured on the first day of operation. The peak of observed migration occurred between March 26<sup>th</sup> and April 8<sup>th</sup> when 77% of pink fry were captured (Figure 7). The dates of 10%, 50% and 90% migration were March 22<sup>nd</sup>, April 1<sup>st</sup>, and April 9<sup>th</sup>, respectively. Similar to chum, the observed peak of pink fry migration coincided with an increase in water temperature from an average weekly temperature of 4.4<sup>o</sup> to 6.4<sup>o</sup>C and daytime water temperatures approaching or exceeding 7<sup>o</sup>C. It was estimated that all emergent pink fry had migrated by the start the week ending May 20<sup>th</sup>, based on zero catch prior to notable flow increases (Figure 7).

The total number of pink fry caught in both traps was 41,418, including mortalities (Appendix 1). This is approximately twice the highest capture of pink fry since the study began in 2000, the

range of which is 1,281 to 26,876 (Table 2). Eleven mark groups totaling 10,811 fish were re-released upstream. A total of 1,567 of these marked fish were recaptured at the traps giving an average ECE of 14.5% and an individual mark group recapture rate ranging from 4.8% to 18.0%. Thus the high capture in 2006 also corresponds with by far the highest average ECE to date (2.1% and 3.5%, respectively, in “on” years 2002 and 2004, Table 2).

Based on the combined mark and recapture data (i.e., pooled Peterson estimator), the total pink fry emigration past the trap site was estimated to be 296,405 fish with 95% confidence interval of 283,093 and 309,716. However, the assumption of complete mixing was not met as the percentage of marks recovered differed significantly between release periods (chi-square,  $df = 8$ ,  $X^2=134.38$ ,  $p < 0.001$ ). This indicates that the trap efficiency or the migration pattern of fish varied over the sampling period as can be seen in (Appendix 2-B). The assumption of equal proportions of marked versus unmarked fish among recovery strata was met (chi-square,  $df = 14$ ,  $X^2 = -nan$ ,  $p < 1.0$ ). These tests indicate that pooling may create bias in the population estimate. In an attempt to examine the bias, we dropped recovery strata 1 and 11 through 16 (no recaptured pink fry). A ML Darroch estimate of 309,758 pink fry with 95% confidence limits of 289,808 to 329,716 was calculated. The low  $G^2$  value associated with this estimate ( $G^2 < 0.0$ ,  $df = 0$ ,  $p = 2$ ) indicates a good fit to the data (Arnason et al., 1996). An estimated 5,106 pink fry passed the RST site prior to February 22<sup>nd</sup> and after May 2<sup>nd</sup>. This figure was derived using the delta method: total number of fish in recovery strata 1 and 11-15 divided by the mean efficiency for all release strata (11.3%). Thus a total estimate of yield upstream of the RST site was 314,864.

A total of 316 pink fry mortalities were incurred between the two traps. This represented approximately 0.01% of the estimated pink fry emigration, or 0.7% of the pink fry caught in the traps (Appendix 1).

### **3.6 Chinook Fry and Smolt Migration**

#### *3.6.1 Chinook Fry*

Three chinook fry (0+) were captured on February 23<sup>rd</sup>, the first day of trap operations. During the sampling period emigration peaked between April 9<sup>th</sup> and 29<sup>th</sup> when 57% of the total sample was caught. Chinook fry were caught in small numbers prior to the peak and after (Figure 8). This single later peak differs from previous years' migration patterns when the migration timing has been mostly bi-modal with the majority of fish migrating in March (Figure 9; 2000 data is not included as trap operation did not start until March 17<sup>th</sup> in that year). When the migration pattern

has not been bi-modal, as in 2002 and 2003, there has been a well established peak in March. This differs from the migration pattern of 2006 when very low numbers of fish migrated in March (Figure 8). The last chinook fry was captured on the last day of trap operation on June 7<sup>th</sup>. The dates of 10%, 50% and 90% migration were February 28<sup>th</sup>, April 19<sup>th</sup> and May 11<sup>th</sup>, respectively. It does not appear that increased temperature or flow affected the migration timing of chinook fry (Figure 8).

The total number of chinook fry caught in both traps was 499, including mortalities (Appendix 1). This is the lowest catch since the study commenced in 2000 with the lowest previous catch occurring in 2004, the range of which was 733 to 8,558 (Table 2). Only 165 early chinook fry were captured prior to April 15; thus, due to their apparent low abundance, no marking of chinook fry was undertaken.

A total of 3 chinook fry mortalities were incurred at the traps. This represents 0.6% of the chinook fry caught in the traps (Appendix 1).

### *3.6.2 Chinook Smolts*

A total of one chinook smolt (1+) was captured, with no mortalities (Appendix 1). Insufficient smolts were available for marking, thus no mark recapture estimate nor runtime analysis were possible in 2006.

### *3.6.3 Chinook Length and Age Data*

Mean length and weight for early chinook fry in spring 2005 was 42mm and 0.7g (Table 3). There was a statistically significant observed difference in mean length of chinook fry between the seven sample years 2000 to 2006 (ANOVA,  $p < 0.001$ ,  $F = 124$ ,  $df = 6$ ). Fry were significantly smaller in 2004 than in all other years by nearly 10mm and larger in 2005 by about the same margin (Table 4).

The one chinook smolt captured was measured with a length of 95mm and weight of 8.4g (Table 3). No statistical comparison could be undertaken due to low sample size in 2006.

Length frequency for all chinook juveniles was bi-modal with one mode in the 40 to 49mm range, representing early migrant fry (Figure 10), while the second peak was in the 65 to 79mm range,

representing late migrant fry. This is similar to six of the seven sample years, 2000 to 2006 (Melville & McCubbing, 2005).

### **3.7 Steelhead Smolt and Parr Migration at RST Site.**

#### *3.7.1 Steelhead Smolts*

In 2006, a total of 5 steelhead smolts were captured, with no mortalities (Appendix 1). This is the lowest annual catch of steelhead smolts since 2000, the range of which is 9 to 429 (Table 2). No pattern of migration was evident (Figure 11). Insufficient smolts were available for marking, thus no mark recapture estimate or runtime analysis were possible in 2006.

#### *3.7.2 Steelhead Parr*

In total 6 steelhead parr were captured, with no mortalities (Appendix 1). This is the lowest annual capture to date since the study started in 2000, the range of which is 36 to 256 (Table 2). No migration pattern of steelhead parr was evident (Figure 12). Steelhead parr were not marked and population estimates were not attempted.

#### *3.7.3 Side Channel Steelhead*

In 2006 13 steelhead smolts and 14 steelhead parr were captured at the Upper Paradise trap (Table 2). To date steelhead captured at Upper Paradise have not been used for mark groups to derive population estimates.

#### *3.7.3 Steelhead*

Mean steelhead smolt length and weight in spring 2006 was 177mm and 58.9g; while steelhead parr mean length and weight was 88mm (Table 3). Samples of steelhead juveniles from the Upper Paradise trap were included in the sample. Due to low capture and sample rates in 2004 through 2006, data was insufficient to make comparisons of size between years.

Length frequency for all steelhead juveniles (parr and smolts) was bi-modal in 2006, likely representing 1+ parr (non-migratory) in the 120 to 129mm range and 2 and 3+ smolts in the 165 to 229mm range (after Melville and McCubbing, 2004; Figure 13). Scale samples were collected and are archived for subsequent analysis to confirm these classifications

### **3.8 Coho Smolt and Fry Migration at RST Site.**

#### *3.8.1 Coho Smolts*

Coho smolt migration peaked between April 23<sup>rd</sup> and May 13<sup>th</sup> when 68% of the total sample was caught. The last coho smolt was captured on June 1<sup>st</sup> (Figure 14). Reduced captures coincided with an increase in discharge that precluded efficient operation of both traps from May 17<sup>th</sup> through to removal on June 7<sup>th</sup> (Figure 3, Table 1). The RSTs were fished as discussed in Section 3.1 following the Tenderfoot Hatchery release of 131,750 fish on May 4<sup>th</sup>. The hatchery release appeared to be during the peak of coho smolt migration on the Cheakamus (Figure 14). The dates of 10%, 50% and 90% of emigration were April 17<sup>th</sup>, May 2<sup>nd</sup>, and May 15<sup>th</sup>, respectively. Coho smolts followed the pattern observed in all years since the study commenced in 2000 on the Cheakamus River, beginning their peak migration period when water temperatures reached 7<sup>0</sup>C (Figure 14).

Coho juvenile migration on the Cheakamus River is primarily made up of 1+ smolts, based on length frequency data. In 2006, as in other years, a small component of emigrants (19 or 1.4%), were classified as (1+) coho parr. These fish were caught primarily in February and March and had not yet achieved the size (>70mm) and appearance of smolts. A final component of coho juvenile monitoring in 2006 was the presence of 0+ coho fry, totaling 2,638 fish. These fish have been captured in varying numbers in all years of the study (Table 2). It is likely that these fish were dispersing downstream post emergence.

#### *3.8.2 RST Marked Coho*

In total 1,379 coho smolts were captured in the two RST traps (Appendix 1). This catch falls within the range of the three lowest catches to date (1,238 to 1,618), all occurring since 2004 (Table 2). A total of six marking rotations were planned; however, during the time period of May 21<sup>st</sup> to May 27<sup>th</sup>, an insufficient number were captured at the RST to mark fish, thus five mark groups totaling 757 fish were re-released upstream. A total of 49 of these marked fish were recaptured at the traps, giving an average ECE of 6.5% and an individual mark group recapture rate that ranged from 4.1% to 8.7% (Appendix 2-C). The average ECE is slightly higher than the last two years' with 4.0% in 2004 and 5.8% in 2005, but lower than the previous four years' (2000-2003) when a range of 8.1% to 20.5% was calculated (Table 2).

Based on the combined mark and recapture data (i.e., pooled Peterson estimator), the total coho smolt emigration past the trap site was estimated to be 21,602 fish with 95% confidence interval of 15,973 to 27,230. The assumption of complete mixing could not be calculated as the percentage of marks differed significantly between release periods (chi-square,  $df = 5$ ,  $X^2 = \text{--nan}$ ,  $p = 1$ ). The assumption of equal proportions of marked versus unmarked fish was met (chi-square,  $df = 6$ ,  $X^2 = 72.07$ ,  $p=0.00$ ) due to high variance between stratum and stratum with no recaptures. The later result may indicate the PPE was biased (Arnason et al., 1996).

In an attempt to examine any bias, we dropped recovery strata 1 through 7 and 14. We then pooled column 11 with 12 and 13. A ML Darroch estimate of 21,067 coho smolts with 95% confidence limits of 14,476 to 27,657 was calculated. The low  $G^2$  value associated with this estimate ( $G^2 < 0.66$ ,  $df = 1$ ,  $p=0.42$ ) indicates a reasonable fit to the data (Arnason et al., 1996). An estimated 2,685 coho smolts passed the RST site before the April 17<sup>th</sup> and after June 7<sup>th</sup>. This estimate was derived using the delta method: total number of fish in recovery strata 1-7 and 14 divided by the mean efficiency for all release strata (5.4%). Total estimate of coho smolt yield upstream of the RST site was 23,752.

### 3.8.3 Side Channel Marked Coho

In addition to marking and re-releasing groups of coho smolts upstream of the RSTs, coho smolts were marked at the Paradise trap location (Figure 2). All coho smolts (that were assessed as being in good condition) originating from the side-channel that joins the mainstem upstream of the RST trap locations were marked through time with a unique mark. A total of 5,472 coho smolts were captured at the Paradise trap (Appendix 1). Six mark groups totaling 4,578 fish were released at dusk of the day marked at the Upper Paradise trap site. Recapture rates ranged from 0.5% to 6.1%. A total of 173 of the side-channel marked fish were recaptured at the RST location, giving an average ECE of 3.8% (Appendix 2-D). The average ECE is slightly lower but similar to 2005 (4.1%).

Using ECEs for side-channel marked smolts, the combined mark and recapture data (i.e., pooled Peterson estimator) of total coho smolt emigration past the RST site was estimated to be 36,209 coho smolts with 95% confidence limits of 31,219 to 41,128. The low  $G^2$  value associated with this estimate ( $G^2 = 72.07$ ,  $df = 6$ ,  $p=0.00$ ) indicates a poor fit to the data (Arnason et al., 1996). The assumption of equal proportions of marked versus unmarked fish among recovery strata could not be calculated (chi-square,  $df = 12$ ,  $X^2 = 200.04$ ,  $p=0.001$ ) due to high variance between

stratum and several strata without recaptures. The later result may indicate the PPE was biased (Arnason et al., 1996).

In an attempt to examine any bias, we dropped recovery strata 1 through 6. A ML Darroch estimate of 37,962 coho smolts with 95% confidence limits of 26,903 to 49,012 was calculated. The low  $G^2$  value associated with this estimate ( $G^2 = 0.51$ ,  $df = 1$ ,  $p = 0.41$ ) indicates a reasonable fit to the data (Arnason et al., 1996). An estimated 3,452 coho smolts passed the RST site before the April 17<sup>th</sup> and after June 3<sup>rd</sup>. This estimate was derived using the delta method: total number of fish in recovery strata 1-7 plus strata 14, divided by the mean efficiency for all release strata (4.2%). Total estimate of coho smolt yield upstream of the RST site was 41,414.

#### *3.8.4 Coho Fry at RST*

A downstream movement of 0+ coho fry was observed in the Cheakamus River in 2006 as in all other years of trap operation. It commenced with newly emerged fry and increased as flows increased during the sample period and dropped off in late May likely as emergence ended. A total of 2,638 fry were captured of which 2,368 (90%) were caught prior to May 13<sup>th</sup> (Figure 15).

#### *3.8.4 Coho Lengths*

Mean length and weight of coho smolts caught in spring 2006 at the RST site was 96mm and 10.8g. Mean length and weight sampled at Paradise channel was 93mm and 9.6g (Table 3). There was a statistical difference between lengths of smolts captured at the RST (potentially mainstem or off-channel rearing, excluding Paradise channel) compared with those sampled in the trap at Paradise channel. Side-channel reared smolts were significantly smaller than main river captured counterparts (T-test un-equal variance,  $t = 3.7$ ,  $p = 0.001$ ). This was the opposite of typical observations. There was also a statistically significant difference in the mean length of coho smolts sampled at the RSTs between the six sample years 2000 to 2005 (ANOVA  $p < 0.001$ ,  $F = 10.3$   $df = 6$ ). Mean smolt length sampled at the RST site was greatest in 2006 and lowest in 2001 (Table 4).

The length frequency of all coho juveniles captured at the RSTs and Upper Paradise side-channel in 2006 was normally distributed with smolts peaking between 90mm and 109mm range, and fry between 35mm and 44mm (Figure 16). Scales were not taken in 2006.

### **3.9 Individual Trap Efficiencies**

During trap operation it has been observed in each of the six years of the study that the individual trap locations exhibit different capture quantities/efficiencies related to the species and age class of the target fish. In 2006 the traps exhibited similar capture rates for chum fry and coho smolts but differed for pink fry (Table 5).

## **4.0 DISCUSSION**

### **4.1 Spring Operations**

Trap operation this spring was characterized by stable flows February 15<sup>th</sup> to May 19<sup>th</sup>. This was likely a combined affect of the new flow order and a cool dry spring (Figure 3). As a result of these stable flows, algae growth was not “cropped” back by elevated flows as in previous years (pers. obs.), thus on May 17<sup>th</sup> and 18<sup>th</sup> (prior to a higher discharge event that occurred on May 19<sup>th</sup>) algae built up on the traps so quickly that they became inoperable (Table 1 and Figure 4). After May 19<sup>th</sup> an early snow melt freshet resulted in high flows that made operation of traps sporadic (Table 1). The inability to operate the traps in the later part of the season resulted in low ECEs and either a failure to create an out-migrant estimate or imprecise estimates for mark/recapture strata at this time. Improvements to trap design and increased tolerance to fish traps at high water would reduce this problem.

### **4.2 Chum Fry Migration**

The pooled Petersen estimate and 95% confidence limits for chum fry has varied over the seven study years from a high of 4,270,934 in 2006 to a low of 1,486,982 in 2001 (Figure 17).

The greatest number of fish captured and marked was coincident with the highest ECE and occurred this study year (Table 2). In 2006, average recapture rates (8.5%) for chum fry were similar to 2001 (8.2%) and 2005 (7.1%) but substantially higher than 2002 and 2004 (4.6% and 4.4%, respectively) and 2000 and 2003 (1.3% and 1.6%, respectively). Changes from day marking to evening/night marking undertaken in 2001 may be responsible for higher ECEs in 2001, 2002, and 2004 through 2006, but do not explain the low trap efficiency in 2003. In 2003, fewer fish were caught and marked (12,239) – a result of varied flow conditions on a week to week basis which limited consistent operation of the traps both for chum fry marking and

recapture. Availability of fish to mark (highest in the four highest ECE years) appears to be the largest factor in determining a precise estimate of fry yield. As this is a function of trap efficiency, years of low fish abundance will thus tend to create imprecise estimates.

Run timing of chum fry in 2006 appeared to be similar to the three previous years (2003 through 2005) of observed migration patterns when trapping commenced in mid-February. In 2000 through 2002, migration likely started before trap operations commenced on March 1<sup>st</sup>. In 2006, as in the first six years of trap operation (2000-2005), peak fry captures occurred between the first and third weeks of April with out-migration virtually completed by the first week of May (Melville & McCubbing, 2001, 2002a & b, 2003, 2004, & 2005). The migration in all years (2000-2006) of operation appears to be linked to an increase in average weekly water temperature to 7<sup>o</sup>C. In 2006, the peak appeared to occur when average weekly temperatures were slightly lower (3.7-6.4<sup>o</sup>C), although daytime temperature was on an increase to near or exceeding 7<sup>o</sup>C during the afternoon. This lower weekly average temperature may be a function of the location of the temperature logger in Gorbushca channel.

#### **4.3 Chinook Juvenile Migration**

Chinook juvenile migration on the Cheakamus River appears to be made up of four migrant components: spring 0+ chinook fry (early), spring 0+ chinook fry (late), spring 1+chinook smolts, and fall 0+ smolts (Melville & McCubbing, 2001 & 2002). Spring 0+ early and late chinook fry accounted for 98% of the total estimated spring migration of chinook juveniles in all sample years (2000 to 2006).

No estimate for 0+ chinook fry was possible due to low captures of fish in 2006. The pooled Petersen estimate (PPE) and 95% confidence limits for chinook fry has varied over the 5 years that estimates were obtained. The PPE for chinook fry has ranged from a high of 212,796 in 2003 to a low of 44,426 in 2004. The widest confidence limits on estimates have been observed in the most recent sample years (2004 and 2005) where the estimate was derived from small numbers of fish that were available to mark and recapture (300 and 329 marked, respectively; Figure 18).

No estimate of chinook smolts was possible in 2006 due to low capture of smolts. The pooled Petersen estimate for chinook smolts has been less than 3,000 smolts in each of the four years that an estimate has been possible (2000-2003). Pooled Petersen estimates have ranged from a high of

2,984 in 2001 to a low of 1,189 in 2003. Ninety-five percent confidence limits have never exceeded an estimate of 4,000 smolts, although the low number of fish captured and marked each year has resulted in wide confidence limits around the estimate (Figure 19). The highest number of fish caught and the highest ECE occurred in 2000 (Table 2). The majority of adult chinook sampled on the Cheakamus River indicate that they migrated as fry to the ocean, perhaps suggesting that stream type fish are only responsible for a small proportion of total adult returns (FOC & InStream, data on file).

A difference in migration timing was observed in 2006 where the migration of early fry prior to April 15<sup>th</sup> was almost non-existent, whereas in all other years (2000-2005) the main peak of migration had already occurred by this time. Whether migration has been a single peak as had occurred in 2002 and 2003 or bi-modal as in 2000, 2001, 2004 and 2005 (Figure 9), peak of migration has always occurred between the start of trapping in late February/early March and April 15<sup>th</sup>. It is unlikely that the RST was experiencing low capture efficiency on early chinook fry as both chum and pink fry (with similar migration timing and behavior) exhibited the highest ECE to date in 2006 (Table 2). Stable flows through March and April also allowed for traps to be run consistently with no trapping days being lost between March 1 and April 30 (Table 1). Instead, it is most likely that this reduced component of the chinook juvenile migration is linked to the observed mortality of early run chinook adults during the NaOH spill on August 5<sup>th</sup> 2005. A loss of 50% of the adult population was estimated during the impact assessment (McCubbing et al., 2006; Table 6). Whether this translates to a direct loss of 50% of juvenile migration is difficult to assess as different components of the adult run most likely contribute different proportions to juvenile production.

It continues to be difficult to obtain good estimates of chinook juvenile out-migration (Melville & McCubbing, 2005). As such, chinook salmon may not be a useful species to monitor the effects of flow regulation given not only these challenges in obtaining population estimates, but also the diversity in life history, the effects of hatchery releases, and, more recently, the potential effects of the 2005 chemical spill (McCubbing et al., 2006).

### **4.3 Steelhead Juvenile Migration**

Spring steelhead juvenile migration on the Cheakamus River consists of two components: steelhead smolts and steelhead parr (scales archived). No young of the year steelhead fry were

captured in the spring, although autumn sampling in 2000 and 2001 indicated some downstream movement of fry (Melville & McCubbing, 2000 & 2001).

No population estimate was possible for steelhead smolts in 2006, as in 2004 and 2005, due to low numbers of fish captured for marking. As with chinook juveniles, the possible reasons for low captures of steelhead juveniles in 2004 and 2005 include mortality resulting from the 1 in 100 flood event in October 2003. This event would have had the greatest impact on 2003 young of the year (migrating as 2-year smolts in 2005 and 3-year in 2006) and 2003 1-year old parr (migrating as 2004 2-year smolts and 2005 3-year smolts). In 2006, the lack of steelhead juveniles captured was also likely related to the NaOH spill which occurred in August 2005 and the associated mortality of 90% of three resident age classes of steelhead in the river at that time: YOY, 1+ and 2+ (McCubbing et al., 2006; Table 6).

The pooled Petersen estimate for steelhead smolts has been less than 5,000 smolts in each of the four sample years where an estimate was possible (2000-2003). The 95% confidence limits have been similar each year except for 2002 when a low number of marked and recaptured fish resulted in a broader confidence limit. Estimates ranged from a high of 4,583 in 2003 to a low of 2,467 in 2001. The low number of fish captured and marked over the four years where an estimate was derived has resulted in broad confidence limits in each year (Figure 20). Efforts to improve trap efficiency in late May and early June are required to improve steelhead and chinook smolt estimates.

Due to the inability to consistently develop robust estimates of steelhead smolts at the RST site which could then be directly linked to adult estimates, a proposed new monitor assessing YOY recruitment and abundance of 1+ and 2+ parr will be initiated in 2007 (Cheakamus Water Use Plan: Monitoring Program Terms of Reference, DRAFT October 13<sup>th</sup>, 2006). This program will allow a better understanding of freshwater survival of steelhead juveniles in the Cheakamus River in future years. It will also provide information on linkages between the effects of events such as changes in the flow regime, the 2003 flood, and the 2005 NaOH spill on freshwater steelhead productivity.

#### **4.4 Coho Juvenile Migration**

The pooled Petersen estimate for coho smolts captured and marked at the RSTs has varied over the seven study years from a high of 66,911 in 2003 to a low of 21,602 in 2006. The 95%

confidence limits for each of the seven years has been fairly consistent, with the most precise estimate reported in 2000 (Figure 21). The highest number of fish caught and marked and the highest ECE occurred in 2000 (Table 2). The estimated number of out-migrant coho in 2006, post the NaOH spill, was 48% lower than the average of all study years (2000-2005) – a factor likely related to the estimated loss of 50% of all YOY coho fry in the summer of 2005 (McCubbing et al., 2006; Table 6).

The pooled Petersen estimate for coho smolts estimated from smolts captured and marked at the side-channels has also varied over the six study years where this procedure was undertaken. PPEs have ranged from a high of 127,974 in 2003 to a low of 36,209 in 2006. The 95% confidence limits for each of the six years has been consistent, with the narrowest confidence limits occurring in 2001 (Figure 22). The highest number of fish caught and marked and the highest ECE occurred in 2001. ECEs produced from coho marked at the side-channels have been consistently lower than those marked at the RSTs (Table 2). This has resulted in a consistently higher estimate of coho smolt yield based on side-channel data (Figure 22). Fish are handled in the same way but side-channel fish are released further upstream from the RSTs; therefore, reasons for this difference in ECE might include predation of marked fish released in the side-channels, differences in capture efficiency of mainstem marked fish through trap avoidance, or variances in the mixing of marked and unmarked fish between sample groups. As stated earlier, one study undertaken in 2004 has shown that the assumption of tagged fish losses through predation has had a confounding effect (Melville & McCubbing, 2004) but additional studies are required to satisfactorily address these differences.

As in the past five years (2001-2005), the PPE from side-channel marked fish is above the upper confidence limit for the PPE based on mainstem marked smolts re-released upstream. This difference has been reasonably consistent over the five years of marking mainstem and side-channel coho. In 2001, the mainstem estimate was 41% less than the side-channel estimate, while in 2002 and 2003 it was 48% lower. In 2004, comparative yields were estimated 51% lower from mainstem marking data. In 2005, the difference was reduced to 26% between methodologies – a factor initially attributed to reduced predation of marked fish following a switch to dusk releases for side-channel marked smolts (Melville & McCubbing, 2006). Marked fish losses would tend to skew the population estimate high as less fish would be available for recapture than assumed in statistical analysis. However, in 2006 the difference between methodologies is once again similar to that observed in the period 2001 through 2004 with the side-channel PPE being 42% higher

than mainstem derived estimates. As dusk releases were undertaken in 2006, results are inconclusive and differential predation of marked fish may not be the only factor affecting estimates.

Losses of fish after marking and prior to recapture are a probable cause of some of the yield estimates variance. Predation is a likely source of fish loss, as has been indicated by studies on the Keogh River that show that many migrant smolts (up to 70% annually) are lost to predation and other unknown causes during in-river migration (McCubbing & Ward, 2002 & 2003). In-river losses of coho smolts have also been documented in the Cheakamus River through acoustic tracking studies. Releases of acoustic tagged hatchery coho smolts in 2004 and 2005 from Tenderfoot Hatchery were tracked by a receiver located immediately upstream of the Cheekye confluence in 2004 (Figure 1) and approximately 200m downstream of the RST site in 2005. In 2004, 52 of 100 fish tagged were not observed on the lower Cheakamus acoustic receiver while in 2005, 18 of 100 fish were not detected. The reasons for these tag losses are as yet elusive (Melnychuk, pers. comm.).

The observed migration timing and pattern of coho smolts in 2006 in the Cheakamus River was characterized by a single peak of migration occurring between the last week of April and the third week of May, as observed in previous years. This is similar to the migration pattern and timing that has been observed on the Keogh River (Ward & McCubbing, 1998; McCubbing, 1998 – 2000; and McCubbing & Ward, 2002 & 2003.), Waukwaas River (Frith et al., 1995; Melville, 1996 & 1997), and Alouette Rivers (Cope, 1999). Migration of coho smolts is likely temperature and photoperiod driven, which may explain the similar run timing on geographically isolated systems.

#### **4.5 Individual Trap Efficiency**

Individual trap efficiencies varied again in 2006. For chum fry, trap location #2 (river right) caught the greatest proportion of unmarked fish in 2006 (53%). This catch ratio is only similar to 2004 when location #2 captured 47.8% of the fish. In 2000, 2002, 2003, and 2005, 80.1%, 84.7%, 68.8%, and 66.0%, respectively, of unmarked chum fry were captured in trap location #1 (river left). In 2001, the opposite was true when 93.7% of chum fry were captured in location #2 (river right). The ratio of marked to unmarked chum fry also differed between 2001 through 2006 (a comparison to 2000 is not possible due to the low number of recaptures in that year). In 2003,

2004 and 2006 the traps had similar ratios of marked and unmarked chum fry in each trap, while in 2001, 2002 and 2005 the ratios for fry differed (two-fold), with location #2 having the highest ratio. This could be a function of differing efficiencies year on year or variance in flow characteristics at the trapping locations and will require further examination through a time series of several years.

There were few discernible differences in trap efficiencies between the first five years in coho smolts; as in all cases trap location # 2 caught the higher proportion of unmarked fish. In 2005 and 2006 the higher proportion of unmarked fish were captured at location #1 (river left); however, this difference was not that large (approximately 40% in location #2 vs. 60% in location #1 in both years).

The differences in the proportion of mainstem marked to unmarked fish caught in location #1 and #2 in 2006 did not differ as much as in previous years (prior to 2004), although the ratio difference between locations was still greater for mainstem marked fish than that for side-channel marked fish. Coho smolts marked at the side-channels show the most consistent ratio of marked to unmarked fish sampled in the two traps over the six study years (2001-2006) that this methodology has been used. This may indicate that the assumption of complete mixing is being met in this group of fish, and thereby suggesting that a release site for mainstem marked smolts further up the mainstem might improve mixing although possibly at the risk of reducing overall recapture rates through increased predation. Any remaining bias in population estimates resulting from trap avoidance, as discussed in Melville & McCubbing, 2000, appear to remain consistent between years.

## 5.0 SUMMARY AND RECOMMENDATIONS

The objectives for the seventh year of trap operation in the Cheakamus River were largely attained, albeit not for all species and age classes. Reasons for being unable to provide robust population estimates for out-migrants included significant site changes and the continuing re-stabilization of the river morphology following a 1 in 100 year flood event in fall 2003, as well as reduced numbers of some species following the NaOH spill in August 2005 and the resulting fish mortality. In summary, data we obtained included:

- mark-recapture data for migrating juveniles with 95% confidence intervals on the estimates on chum and pink fry and coho smolts
- biological data of lengths and weights.
- a seventh year of baseline smolt and fry yield data with comparisons to previous sample years and to river discharge and temperature.

Juvenile out-migrant fish catch at the RST in 2006 indicated that the spill event likely had a detrimental effect on chinook, coho salmon and steelhead trout out-migration, with the lowest number of fish captured for each of these species to date in the seven year study period. Estimated smolt abundance was much reduced in coho salmon and no estimate could be derived for chinook salmon or steelhead trout because of low catch numbers. Whilst high discharge in late May and June may have been partly responsible for reduced coho and steelhead smolt catch, it does not explain the much reduced catch of chinook early migrant fry nor the apparent lack of chinook and steelhead smolts in the early part of May in 2006.

The methodology used for fry marking in 2006 was the same as was used in 2004 and 2005 and, with the highest ECE in the seven years of operation, appeared to be the methodology best suited to minimize stress mortality while maximizing crew safety. The dusk marking and release methodology differs from the previous three years when fry were marked at midnight and released.

Marking coho smolts at side-channels upstream of the RSTs should be continued as this has allowed significantly higher sample sizes, thereby providing narrower confidence limits on population estimates. It has also maintained consistent marked to unmarked catch proportion

between traps as well as having the potential to meet the objective of partitioning restoration channel production from mainstem production for coho smolts and chum, pink and chinook fry

Alterations to the NVOS restoration channels and coho release strategies at Tenderfoot Hatchery have occurred since the RST program began marking side-channel coho smolts in 2001, resulting in only Upper Paradise channel being utilized in 2004 and 2005 to capture coho smolts for marking. Increased flows to two new channels, Big Gorbushca and Little Gorbushca (Figure 2), back-watered the trap site on Kisutch making it inoperable. It is recommended that the new smolt (and possibly adult) enumeration facility proposed within the Cheakamus Water Use Plan: Monitoring Program Terms of Reference, DRAFT Oct 13 2006, be developed in 2007. This trap will capture all smolts originating from the entire channel complex entering the mainstem below Upper Paradise channel (see Counter Site on Figure 2.). This trap would increase the sample size of coho available for marking to meet or exceed the number of fish marked prior to alterations to channels and hatchery release strategies. It would also potentially capture sufficient numbers of steelhead smolts to develop robust population estimates for these species.

In April 2003, Tenderfoot Creek Hatchery (FOC) altered their release strategy of coho smolts to model a more natural migration pattern. This resulted in a high influx of hatchery smolts to Tenderfoot Creek over a period of several days, which resulted in the stoppage of trapping operations. When trapping was resumed, there was a notable decrease in the number of wild fish caught which may be the effect of wild fish being influence by the large emigration of hatchery fish. As the hatchery releases have made efficient marking of wild fish on this system impractical, other methods of enumeration need be considered. To quantify the yield of off-channel coho smolts compared to mainstem derived fish, consideration should be given to the development of remote (electronic counter) methods of enumerating coho smolts from BC Rail and Tenderfoot Creek side-channels as described in Cheakamus Water Use Plan: Monitoring Program Terms of Reference, DRAFT Oct 13 2006. These methods would eliminate the need to handle all fish and would provide, after a period of validation, a robust estimate of smolt production without the requirement of handling fish which is both labour intensive and stressful for the fish as previously described.

To quantify yield of mainstem compared with side-channel produced chum, pink and chinook fry, operation of side-channel fyke net configurations, as undertaken in 2004 (Melville & McCubbing,

2004) and outlined in the Cheakamus Water Use Plan: Monitoring Program Terms of Reference, DRAFT Oct 13 2006, should be installed.

Adult “snorkel counts” combined with a radio and/or visual tag currently provide the best opportunity to achieve robust adult estimation of steelhead adults on the Cheakamus River (Korman et al., 2005). The data collected in the 2000 through 2006 spawning seasons, and the proposed continuation of adult enumeration, should allow a measure of comparison of recruitment scenarios for future smolt production. Unfortunately, the low capture of steelhead juveniles at the RST site has typically resulted in steelhead smolt population estimates with wide confidence limits (or no estimate, as in 2004 and 2005) which may be further complicated by changes in age class structure (Ward et al., 2003).

While adult escapement monitoring should be continued as it offers an accurate census on steelhead abundance, it is unlikely that smolt monitoring will be able to detect anything other than gross changes in juvenile production (4-fold or greater) with the current methodology. Increased infrastructure including permanent moorings with increased cable tolerances will allow for operation of traps at elevated flows and in areas of increased water velocity which should result in increased trap efficiency in late May and June. A third trap should also be considered to increase trapping volumes.

An assessment of the utility of the RST data to establish real changes in smolt and fry production is increasingly required. Evidence for year on year confidence in methodology indicates the potential for the use of this data in assessing the causes of changes in production, but we must be certain they are real changes and not artifacts of data collection methods. The current time series of data is being used to ground truth modeling exercises which seek to examine the effects of run timing and river discharge on the confidence of smolt yield estimates (J. Korman, Ecometric Ltd, pers. comm.). Further analysis and summary of data is included as part of the Cheakamus Water Use Plan: Monitoring Program Terms of Reference, DRAFT Oct 13 2006, and should be undertaken as soon as the Terms of Reference are adopted.

## 6.0 TABLES

**Table 1. Trap dates for which trap operation was limited or suspended (1 day = 24 hrs).**

<i>Trap</i>	<i>Dates not in operation</i>	<i>Limited operation (continuous monitoring pulled ~2am)</i>	<i>Comments</i>
Trap #2-	Feb. 23 & 24 (2 days)		Low Flow
Trap #1 & 2	Feb. 27 (1 day)		Heavy snowfall
Trap #1 & 2	April 30 (1 day)		Hatchery Release
Trap #1 & 2	May 5 & 6 (2 days)		Hatchery Release
Trap #1 & 2		May 17 & 18	Algae build-up
Trap #1 & 2	May 19 to 21 (3 days)		High Flow
Trap #1	May 22 to 27 (6 days)		High Flow
Trap #1	May 29 (1 day)		High Flow
Trap #1 & 2		May 31 (1 day)	High Flow
Trap #1 & 2	June 1 to 5 (5 days)		High Flow
Trap #1 & 2		June 6 (1 day)	High Flow

**Table 2. Seven year summary of fish caught and marked at the rotary screw trap and side channels on the Cheakamus River.**

Species	Year	Total Caught	Total Marked	Total Recap	ECE%
Chum Fry	2000	54,527	8,415	109	1.3
Chum Fry	2001	120,742	43,520	3,557	8.2
Chum Fry	2002	103,932	23,685	1,101	4.6
Chum Fry	2003	65,505	12,239	193	1.6
Chum Fry	2004	135,372	63,005	2,775	4.4
Chum Fry	2005	173,924	62,283	4,425	7.1
Chum Fry	2006	354,337	94,285	7,798	8.5
Chinook Fry	2000	1,537	185	3	1.6
Chinook Fry	2001	8,558	3,111	220	7.1
Chinook Fry	2002	7,554	1,571	91	5.8
Chinook Fry	2003	5,758	2,435	75	3.1
Chinook Fry	2004	733	300	4	1.3
Chinook Fry	2005	917	329	4	1.2
Chinook Fry	2006	499	n/a	n/a	n/a
Pink Fry	2000	1,241	156	0	0
Pink Fry	2001 <sup>1</sup>	8	n/a	n/a	n/a
Pink Fry	2002	26,876	5,304	113	2.1
Pink Fry	2003 <sup>1</sup>	0	n/a	n/a	n/a
Pink Fry	2004	2,844	1,521	53	3.5
Pink Fry	2005 <sup>1</sup>	3	n/a	n/a	n/a
Pink Fry	2006	41,418	10,811	1,567	14.5
Coho Fry	2000	1,088	n/a	n/a	n/a
Coho Fry	2001	5,295	n/a	n/a	n/a
Coho Fry	2002	1,239	n/a	n/a	n/a
Coho Fry	2003	2,163	n/a	n/a	n/a
Coho Fry	2004	3,121	n/a	n/a	n/a
Coho Fry	2005	597	n/a	n/a	n/a
Coho Fry	2006	2,638	n/a	n/a	n/a

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

**Table 2. continued**

<b>Species</b>	<b>Year</b>	<b>Total Caught</b>	<b>Total Marked</b>	<b>Total Recap</b>	<b>ECE%</b>
Chinook Smolt	2000	348	158	28	17.7
Chinook Smolt	2001	313	254	33	13.0
Chinook Smolt	2002	89	62	2	3.2
Chinook Smolt	2003	81	55	3	5.5
Chinook Smolt	2004	4	n/a	n/a	n/a
Chinook Smolt	2005	2	n/a	n/a	n/a
Chinook Smolt	2006	1	n/a	n/a	n/a
RST Steelhead Smolt	2000	429	238	23	9.7
RST Steelhead Smolt	2001	207	154	12	7.8
RST Steelhead Smolt	2002	115	76	2	2.6
RST Steelhead Smolt	2003	373	287	23	8.0
RST Steelhead Smolt	2004	9	n/a	n/a	n/a
RST Steelhead Smolt	2005	21	n/a	n/a	n/a
RST Steelhead Smolt	2006	5	n/a	n/a	n/a
UP <sup>2</sup> Steelhead Smolt	2001	138	n/a	n/a	n/a
UP Steelhead Smolt	2002	125	n/a	n/a	n/a
UP Steelhead Smolt	2003	78	n/a	n/a	n/a
UP Steelhead Smolt	2004	54	n/a	n/a	n/a
UP Steelhead Smolt	2005	38	n/a	n/a	n/a
UP Steelhead Smolt	2006	13	n/a	n/a	n/a
RST Steelhead Parr	2000	136	n/a	n/a	n/a
RST Steelhead Parr	2001	238	n/a	n/a	n/a
RST Steelhead Parr	2002	143	n/a	n/a	n/a
RST Steelhead Parr	2003	256	n/a	n/a	n/a
RST Steelhead Parr	2004	36	n/a	n/a	n/a
RST Steelhead Parr	2005	42	n/a	n/a	n/a
RST Steelhead Parr	2006	6	n/a	n/a	n/a

**Table 2 continued.**

<b>Species</b>	<b>Year</b>	<b>Total Caught</b>	<b>Total Marked</b>	<b>Total Recap</b>	<b>ECE%</b>
UP <sup>2</sup> Steelhead Parr	2001	132	n/a	n/a	n/a
UP Steelhead Parr	2002	159	n/a	n/a	n/a
UP Steelhead Parr	2003	387	n/a	n/a	n/a
UP Steelhead Parr	2004	660	n/a	n/a	n/a
UP Steelhead Parr	2005	73	n/a	n/a	n/a
UP Steelhead Parr	2006	14	n/a	n/a	n/a
RST Coho Smolt	2000	11,177	7,222	1,478	20.5
RST Coho Smolt	2001	6,394	2,517	400	15.9
RST Coho Smolt	2002	3,120	1,382	112	8.1
RST Coho Smolt	2003	7,616	4,129	500	12.1
RST Coho Smolt	2004	1,238	755	30	4.0
RST Coho Smolt	2005	1,618	1,060	61	5.8
RST Coho Smolt	2006	1,379	757	49	6.5
SC Coho Smolt	2000	n/a	n/a	n/a	n/a
SC Coho Smolt	2001	30,616	29,883	2,851	9.3
SC Coho Smolt	2002	21,221	17,861	813	4.6
SC Coho Smolt	2003	28,666	24,606	1,812	7.4
SC Coho Smolt	2004 <sup>3</sup>	10,588	8,249	175	2.1
SC Coho Smolt	2005 <sup>3</sup>	4,580	3,355	138	4.1
SC Coho Smolt	2006 <sup>3</sup>	5,472	4,578	173	3.8

2. For side-channel steelhead numbers, only Upper Paradise trap catch is reported

3. Only Upper Paradise trap operated (in previous years Tenderfoot and Kisutch were used).

**Table 3. Summary of length & weight data from fish captured at the rotary screw traps on the Cheakamus River, Spring 2006.**

<b>Species</b>		<b>Length (mm)</b>	<b>Weight (g)</b>
<b>Chum Fry</b>	<b>N</b>	274	274
	<b>Range</b>	30-54	0.3-1.3
	<b>Mean</b>	39	0.7
	<b>SD</b>	2.7	0.2
<b>Chinook Fry (early prior to April 15)</b>	<b>N</b>	7	4
	<b>Range</b>	38-56	0.6-1.0
	<b>Mean</b>	42	0.7
	<b>SD</b>	6.4	0.2
<b>Chinook Fry (late after April 15)</b>	<b>N</b>	25	23
	<b>Range</b>	36-88	0.5-6.5
	<b>Mean</b>	60	3.1
	<b>SD</b>	16.7	1.9
<b>Pink Fry</b>	<b>N</b>	164	164
	<b>Range</b>	29-39	0.2-1.0
	<b>Mean</b>	34	0.5
	<b>SD</b>	2.1	0.2
<b>Coho Fry</b>	<b>N</b>	124	117
	<b>Range</b>	28-45	0.4-1.1
	<b>Mean</b>	34	0.7
	<b>SD</b>	2.5	0.2
<b>Steelhead Smolts (includes sample from side-channel traps)</b>	<b>N</b>	23	18
	<b>Range</b>	142-223	29.1-121.3
	<b>Mean</b>	177	58.9
	<b>SD</b>	22.5	23.3
<b>Steelhead Parr (includes sample from side-channel traps)</b>	<b>N</b>	24	17
	<b>Range</b>	88-138	7.1-35.2
	<b>Mean</b>	118	19.8
	<b>SD</b>	12.5	7.8
<b>Coho Smolts (RST)</b>	<b>N</b>	394	184
	<b>Range</b>	73-125	4.5-18.7
	<b>Mean</b>	96	10.8
	<b>SD</b>	9.1	2.7
<b>Coho Smolts (SC)</b>	<b>N</b>	939	347
	<b>Range</b>	70-138	4.4-17.1
	<b>Mean</b>	93	9.6
	<b>SD</b>	9.6	2.7

**Table 4. Summary of mean lengths 2000-2006 from the Cheakamus River.**

Species	Year	N	Mean Length
Chum Fry	2000	59	42
	2001	404	40
	2002	491	39
	2003	403	41
	2004	324	38
	2005	225	39
	2006	274	39

Species	Year	N	Mean Length
Pink Fry	2000	n/a	n/a
	2001	n/a	n/a
	2002	358	34
	2003	n/a	n/a
	2004	53	34
	2005	n/a	n/a
	2006	164	34

Species	Year	N	Mean Length
Chinook Fry (early)	2000	67	55
	2001	490	48
	2002	419	43
	2003	191	50
	2004	68	40
	2005	22	44
	2006	7	42

Species	Year	N	Mean Length
Chinook Smolts	2000	123	100
	2001 <sup>1</sup>	n/a	n/a
	2002	25	108
	2003	13	111
	2004	2	90
	2005	1	103
	2006	1	95

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

**Table 4. continued**

Species	Year	N	Mean Length
Steelhead Smolts	2000	138	170
	2001	110	176
	2002	43	175
	2003	90	178
	2004	5	156
	2005	57	176
	2006	23	177

Species	Year	N	Mean Length
Steelhead Parr	2000	63	79
	2001	169	84
	2002	104	82
	2003	194	81
	2004	38	88
	2005	53	88
	2006	24	118

Species	Year	N	Mean Length
RST Coho Smolts	2000	1180	94
	2001	893	91
	2002	818	93
	2003	1114	93
	2004	244	93
	2005	477	92
	2006	394	96

Species	Year	N	Mean Length
Side Channel Coho Smolts	2000	n/a	n/a
	2001	5416	90
	2002	3229	96
	2003	3334	95
	2004	1298	93
	2005	1187	96
	2006	939	93

Species	Year	N	Mean Length
Coho Fry	n/a	n/a	n/a
	2001	49	35
	2002	217	43
	2003	184	38
	2004	139	36
	2005	n/a	n/a
	2006	124	34

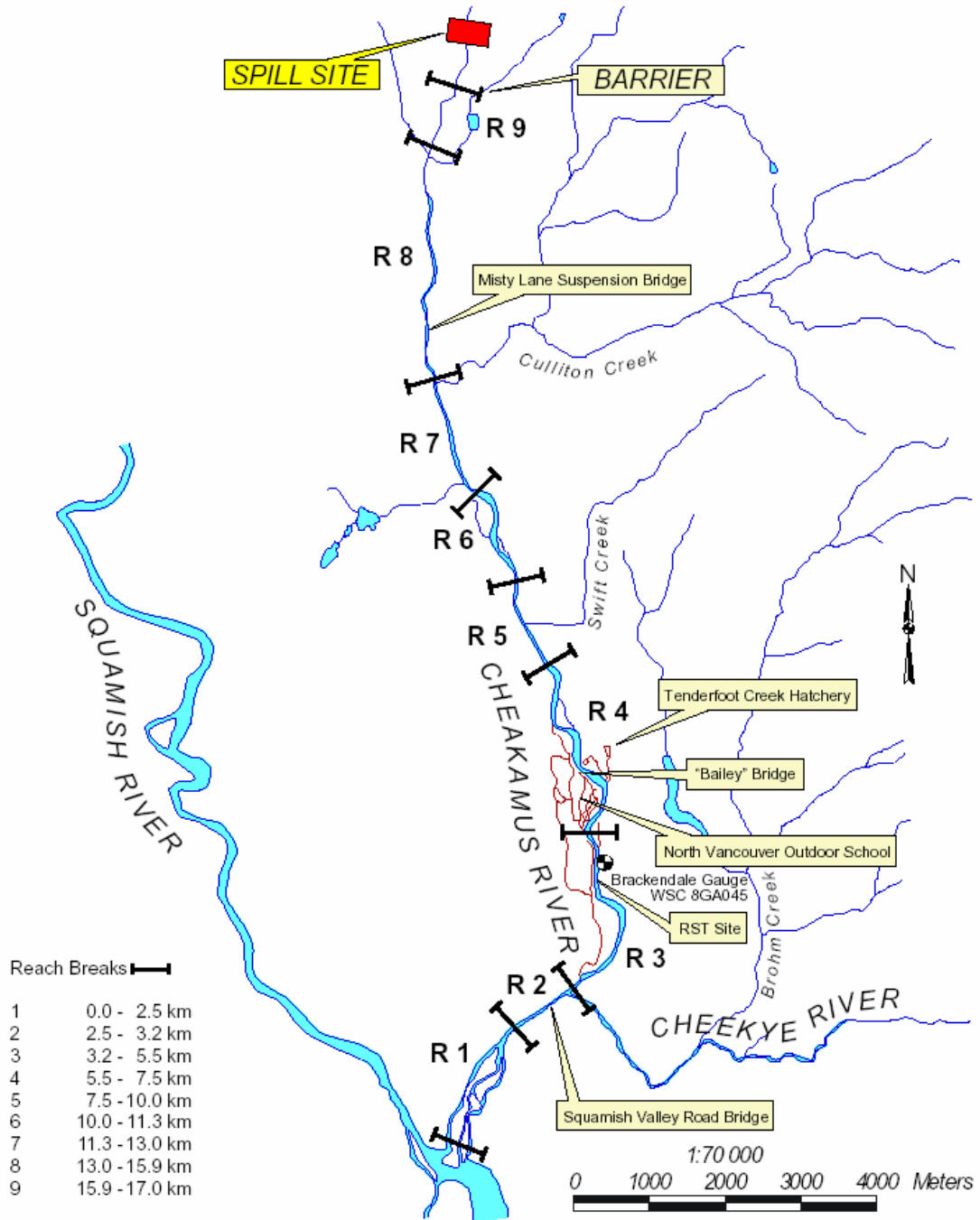
**Table 5. Proportion of fish caught in Location #1 and Location #2 on the Cheakamus River, Spring 2006.**

		<u>Location #2</u> (river right)	<u>Location #1</u> (river left)
<u>Chum Fry</u>	# Unmarked	187,189	167,148
	% Unmarked	53%	47%
	# Recaptured	4806	3192
	Ratio	1 in 39	1 in 52
<u>Pink Fry</u>	# Unmarked	14,175	27,286
	% Unmarked	34%	66%
	# Recaptured	782	785
	Ratio	1 in 18	1 in 35
<u>Coho Smolts</u> (mainstem)	# Unmarked	550	826
	% Unmarked	40%	60%
	# Recaptured	23	26
	Ratio	1 in 24	1 in 32
<u>Coho Smolts</u> (side-channel)	# Unmarked	550	826
	% Unmarked	40%	60%
	# Recaptured	45	128
	Ratio	1 in 12	1 in 6

**Table 6. Estimated magnitude of affected salmonid age classes by the August 5<sup>th</sup> sodium hydroxide spill on the Cheakamus River (McCubbing et.al., 2006).**

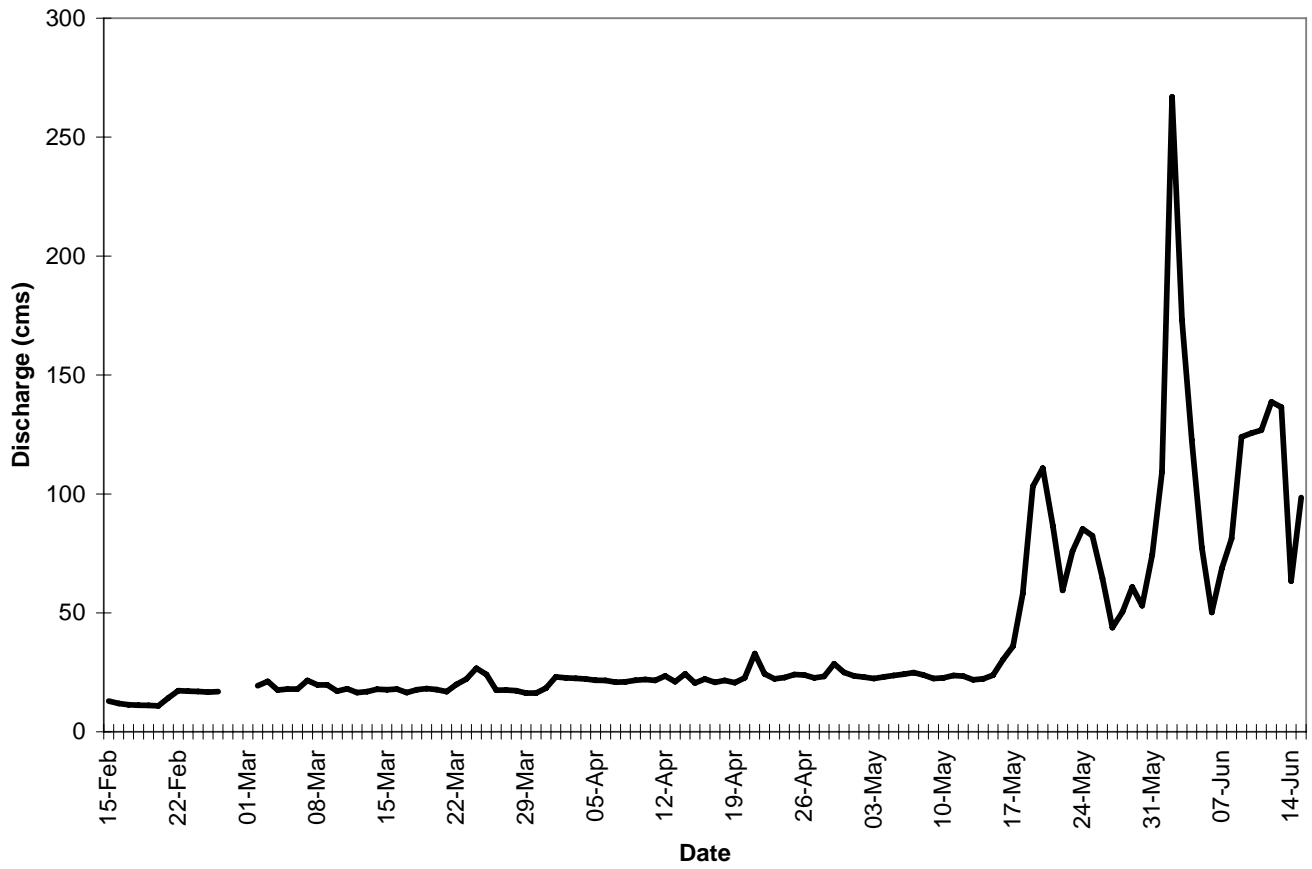
Species	Age Class and Impact			Impact as % Killed
	Adult	Parr	Fry	
<i>Chinook</i>	50	90	0	None Low Medium High Unknown
<i>Coho</i>	0	3	50	
<i>Pink</i>	10	0	0	
<i>Chum</i>	1	0	0	
<i>Steelhead</i>	0	90	90	
<i>Charr</i>	?	?	?	
<i>Cottid</i>	90	90	90	
<i>Lamprey</i>	90	90	?	

## 7.0 FIGURES



**Figure 1. Cheakamus River watershed indicating Reaches 1 through 9, WSC gauging station, temperature logger site, trap location and fish release site.**

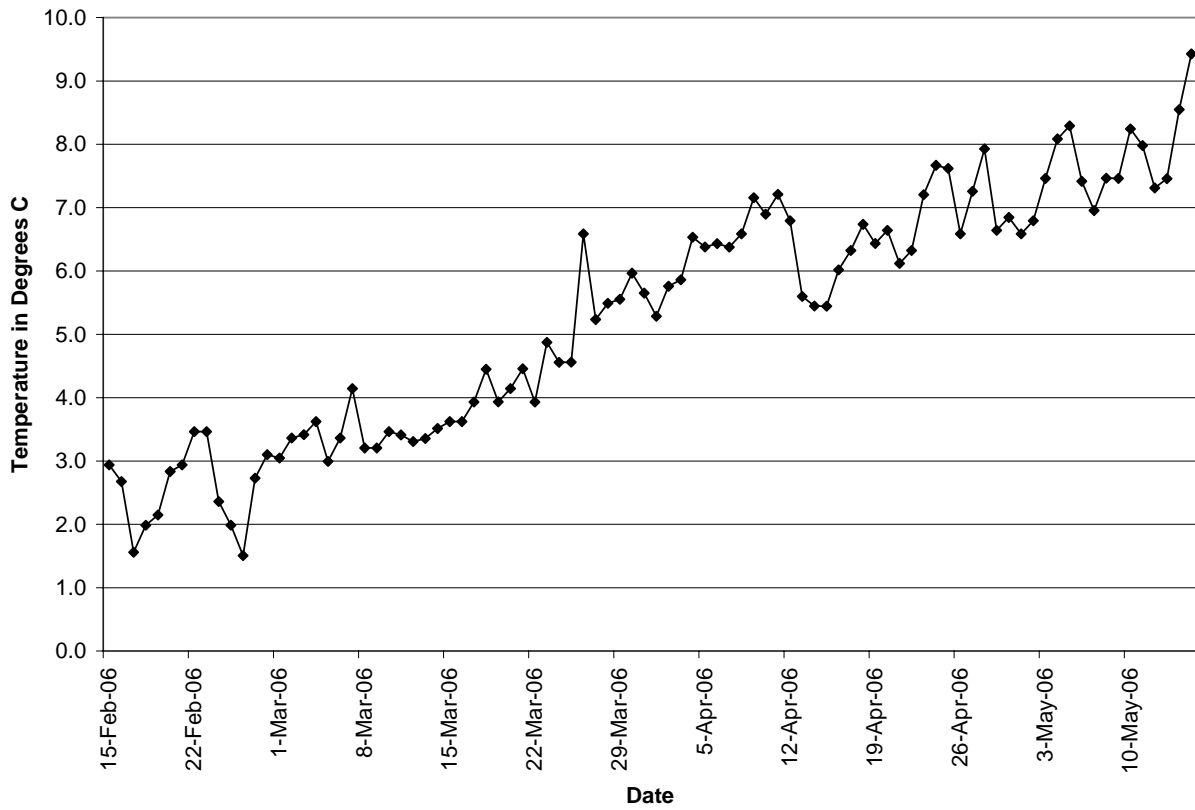




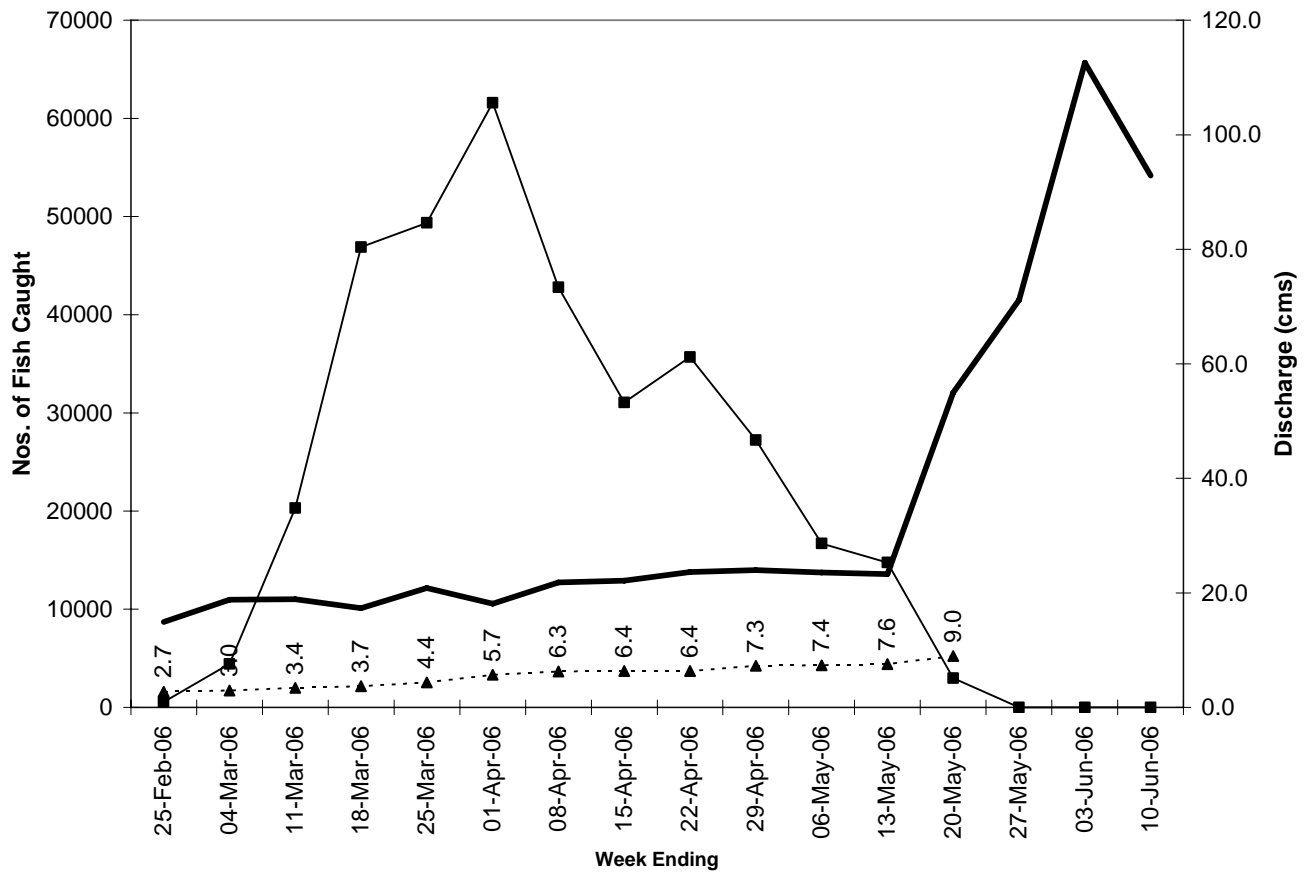
**Figure 3. Mean Daily Discharge from Water Survey of Canada Station 08GA043 Cheakamus at Brackendale. Spring 2006.**



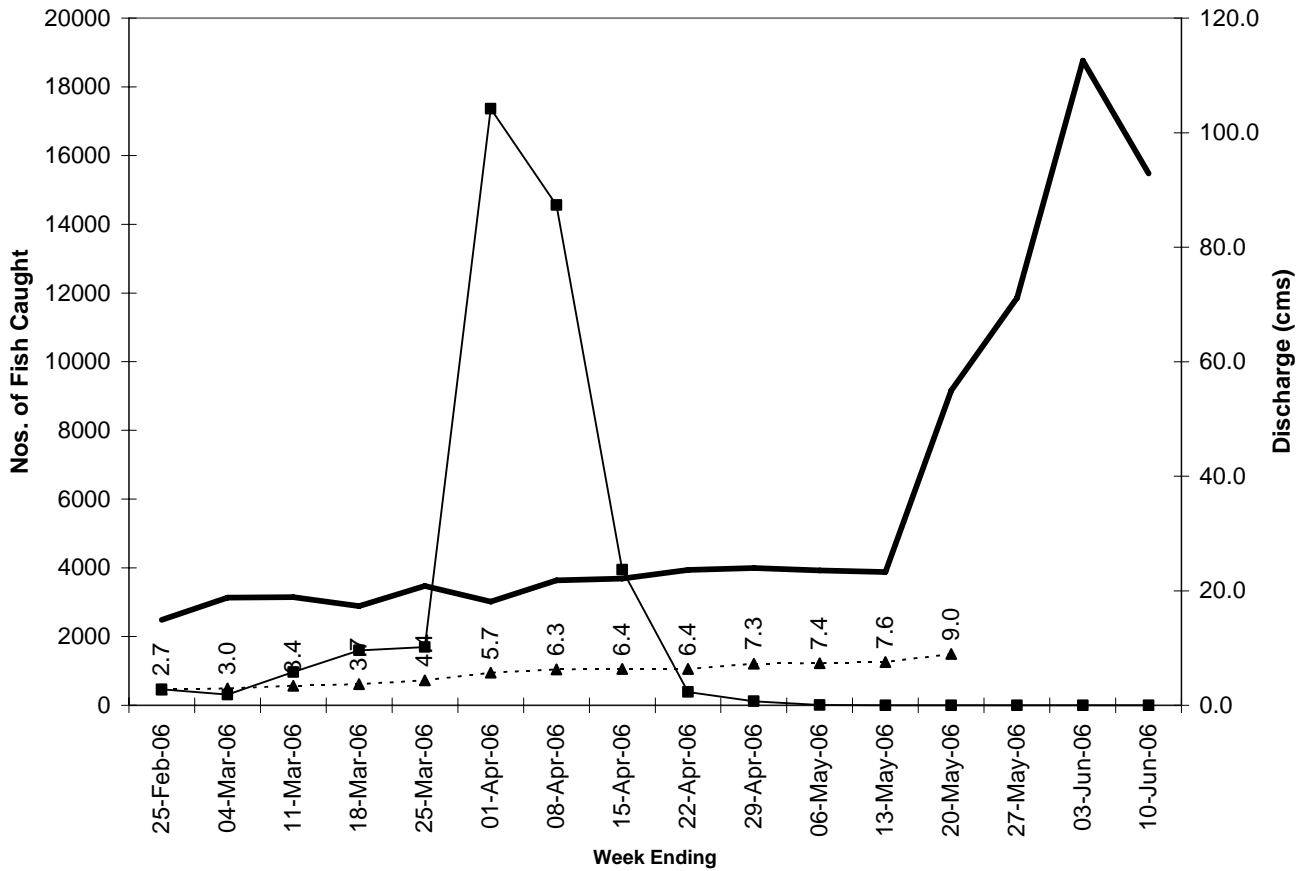
**Figure 4. Photo showing 3 hours of algae build-up on drum of RST, May 17th, 2006.**



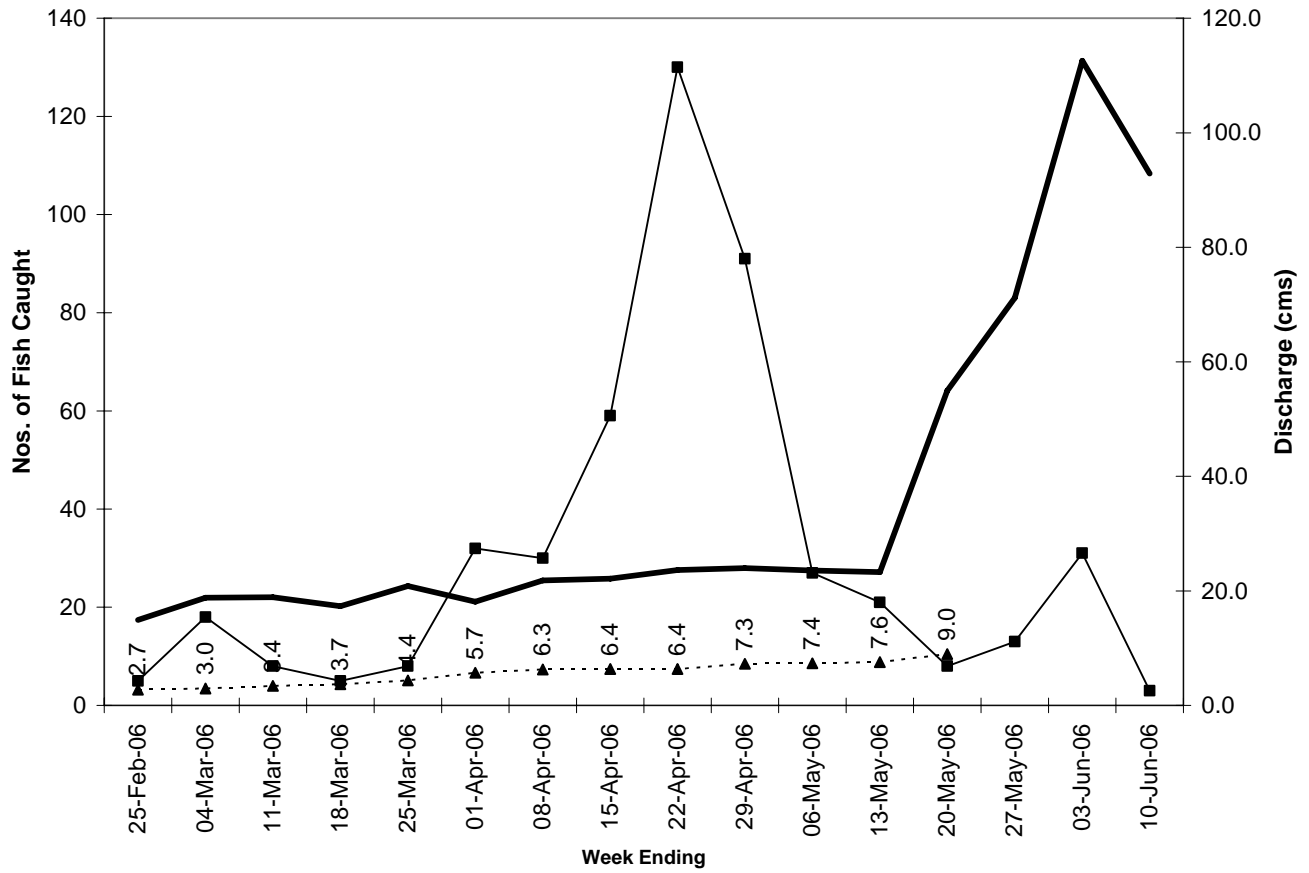
**Figure 5. Average Daily Water Temperature in °C, of the Cheakamus River, as recorded by a logger located at the trap site, Spring 2006.**



**Figure 6. Weekly catch summary of chum fry (solid line, squares) related to temperature in °C (broken line, triangles) and discharge (solid line) from the Cheakamus River, Spring 2006.**



**Figure 7. Weekly catch summary of pink fry (solid line, squares) related to temperature in °C (broken line, triangles) and flow (solid line) on the Cheakamus River, Spring 2006.**



**Figure 8. Weekly catch summary of chinook fry (solid line, squares) related to temperature in °C (broken line, triangles) and flow (solid line) on the Cheakamus River, Spring 2006.**

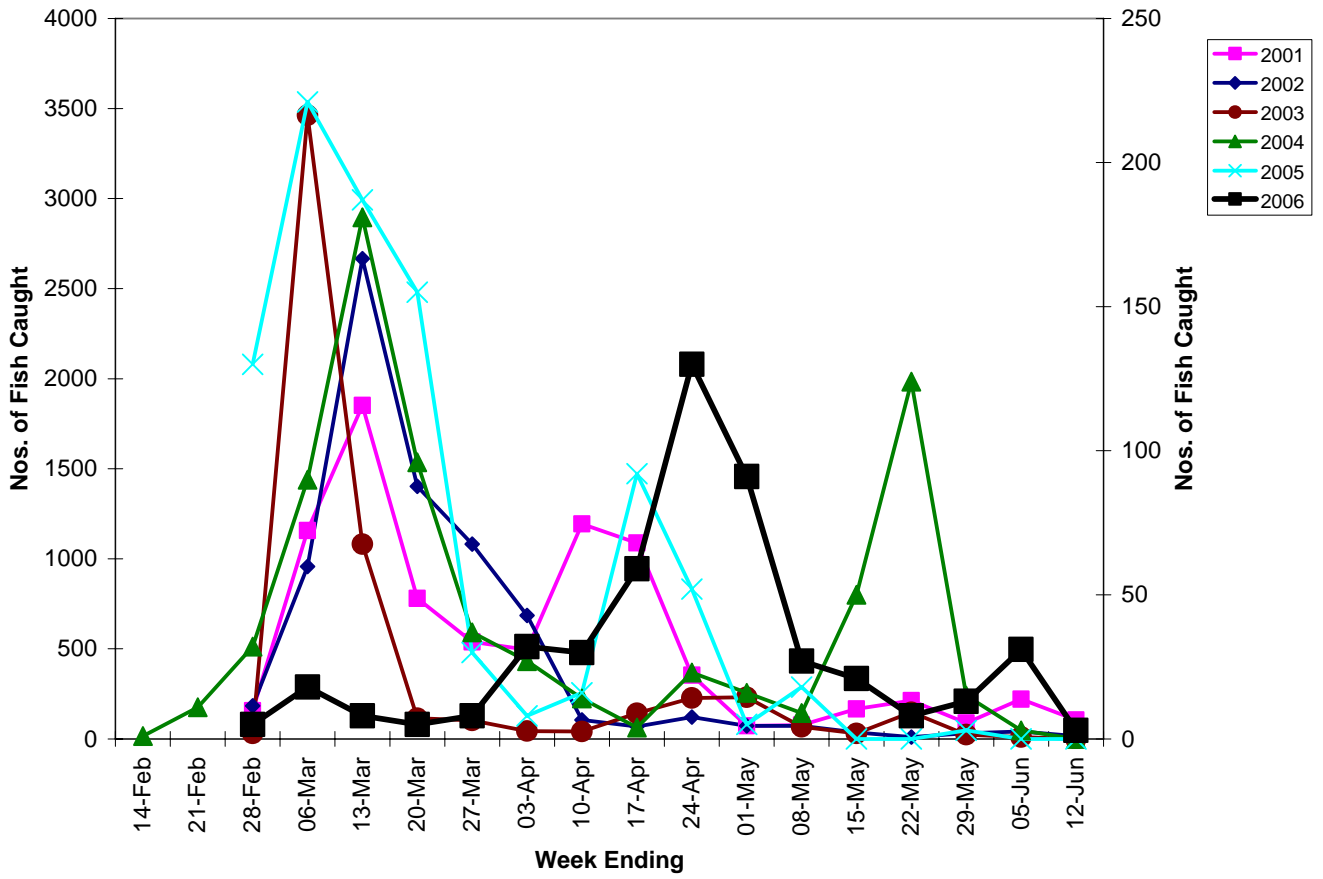
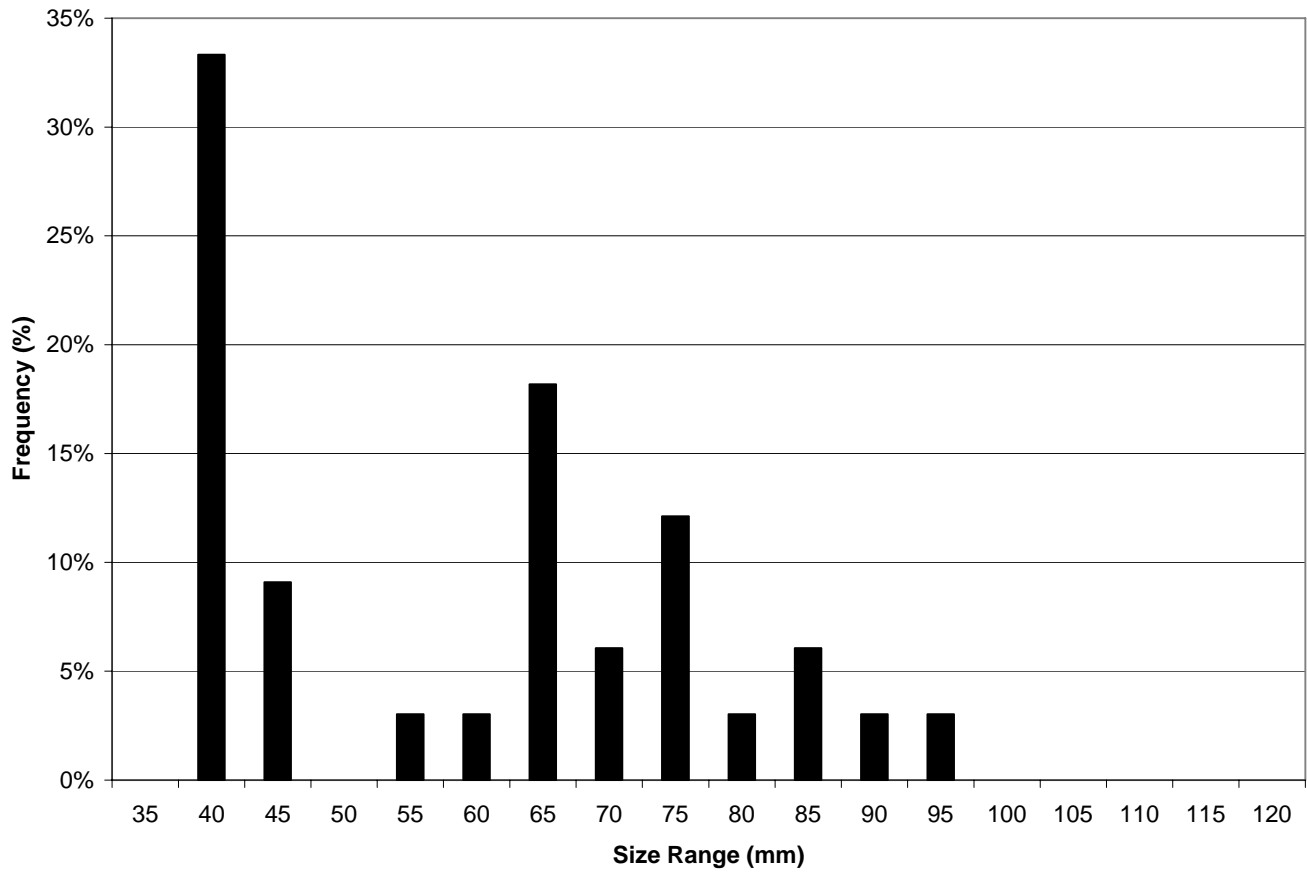
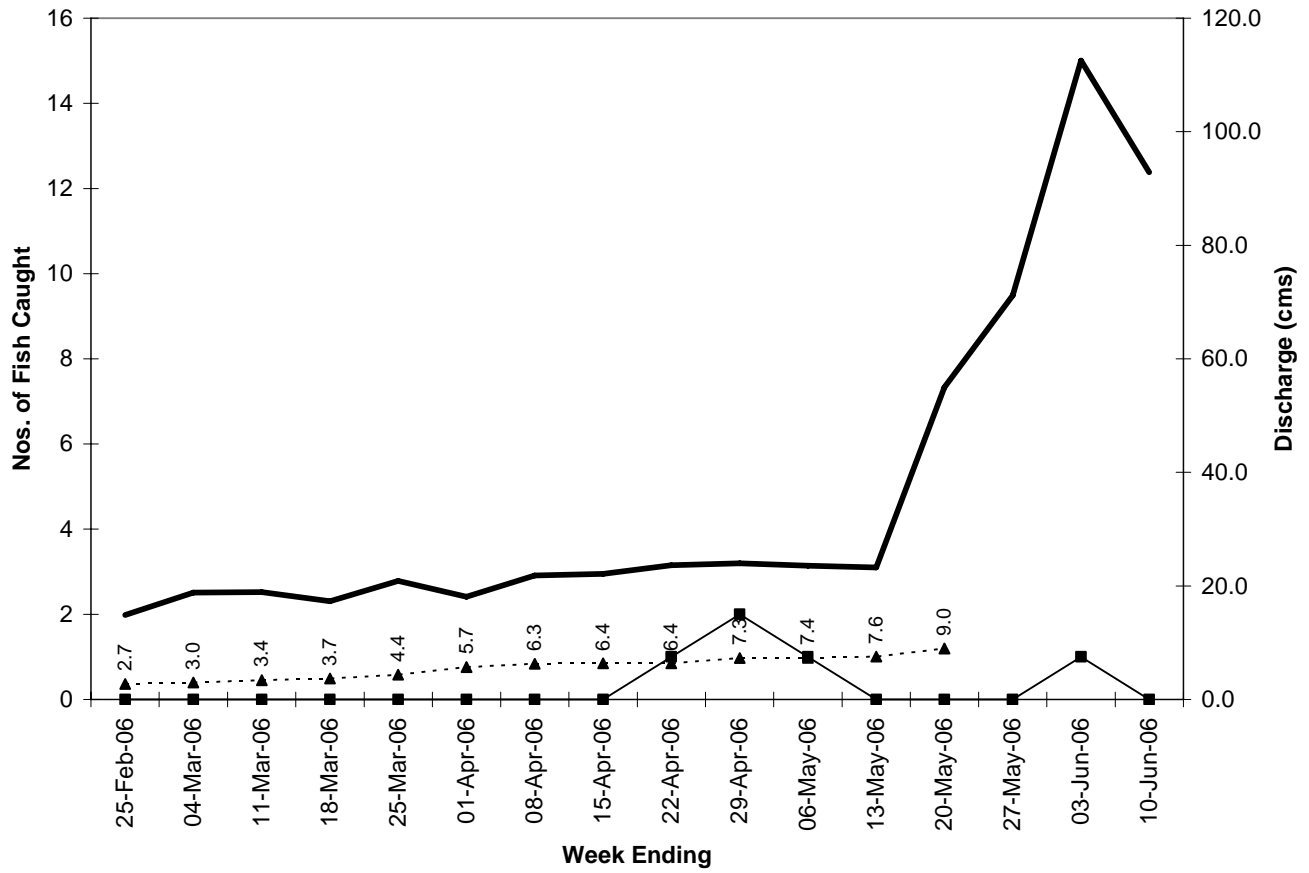


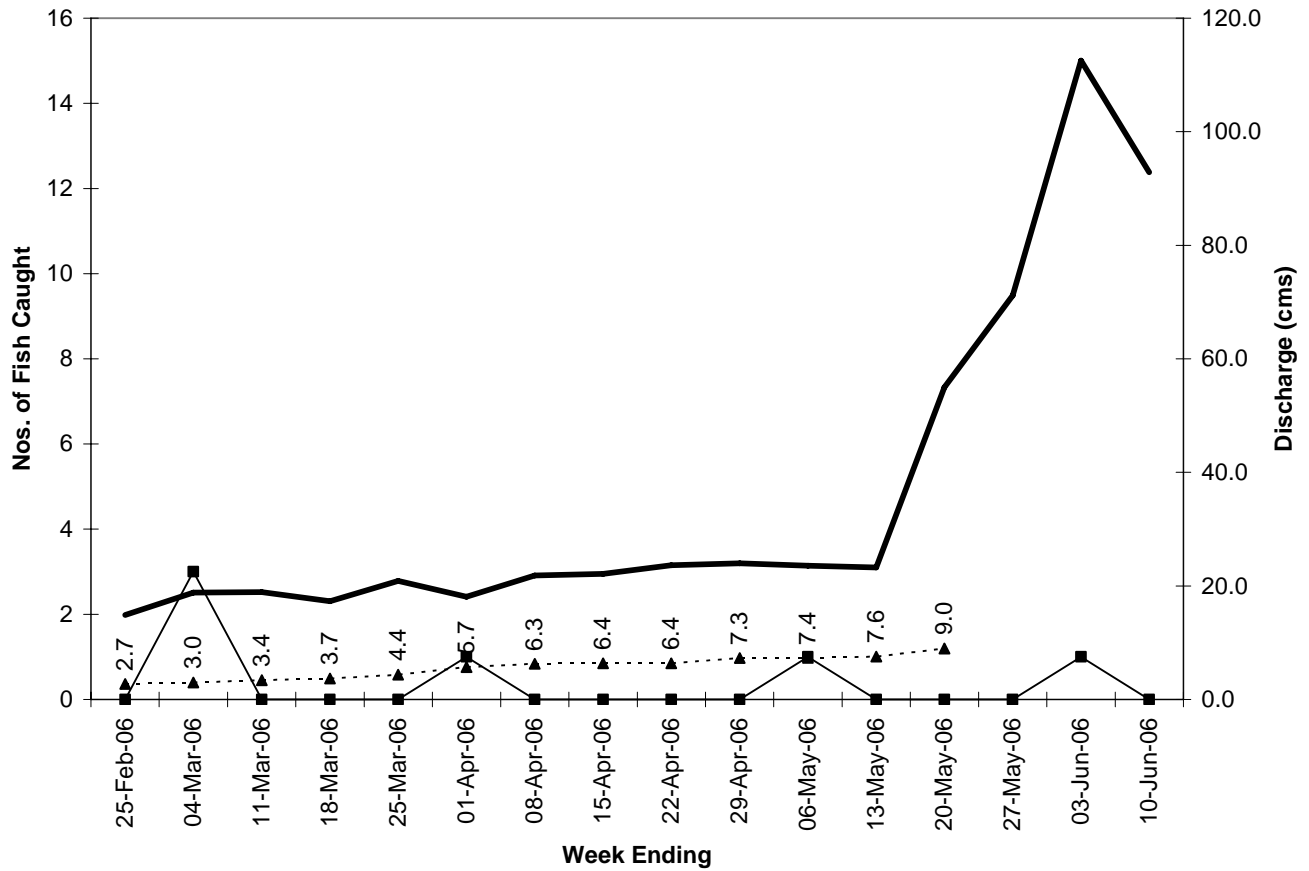
Figure 9. Weekly catch summary of chinook fry 2001 to 2006 from the Cheakamus River.



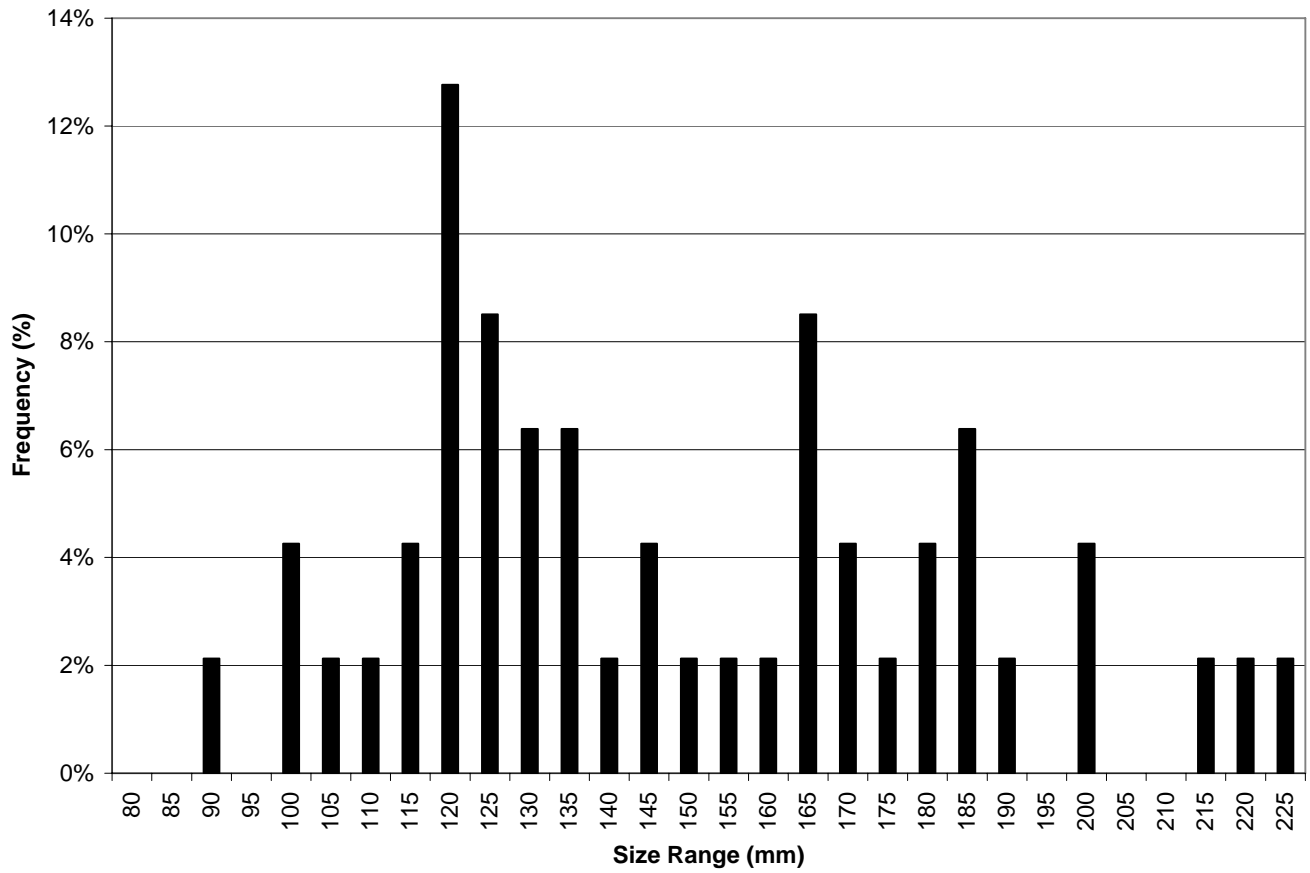
**Figure 10. Length frequency distribution of chinook juveniles from the Cheakamus River, Spring 2006.**



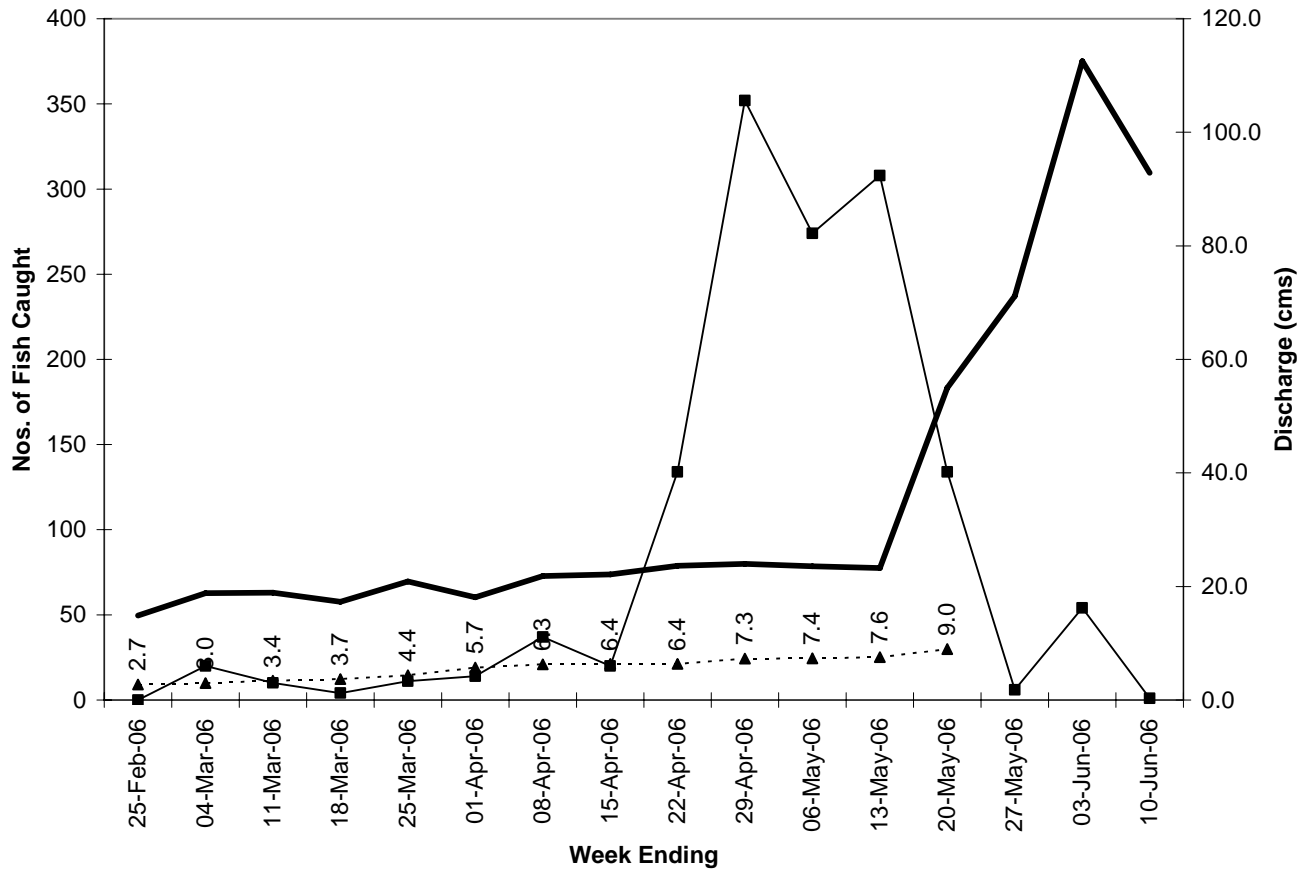
**Figure 11. Weekly catch summary of steelhead smolts (solid line, squares) related to temperature in °C (broken line, triangles) and flow (solid line) on the Cheakamus River, Spring 2006.**



**Figure 12. Weekly catch summary of steelhead parr (solid line, squares) related to temperature in °C (broken line, triangles) and flow (solid line) on the Cheakamus River, Spring 2006.**



**Figure 13. Length frequency distribution of steelhead juveniles sampled on the Cheakamus River, Spring 2006.**



**Figure 14. Weekly catch summary of coho smolts (solid line, squares) related to temperature in °C (broken line, triangles) and flow (solid line) on the Cheakamus River, Spring 2006.**

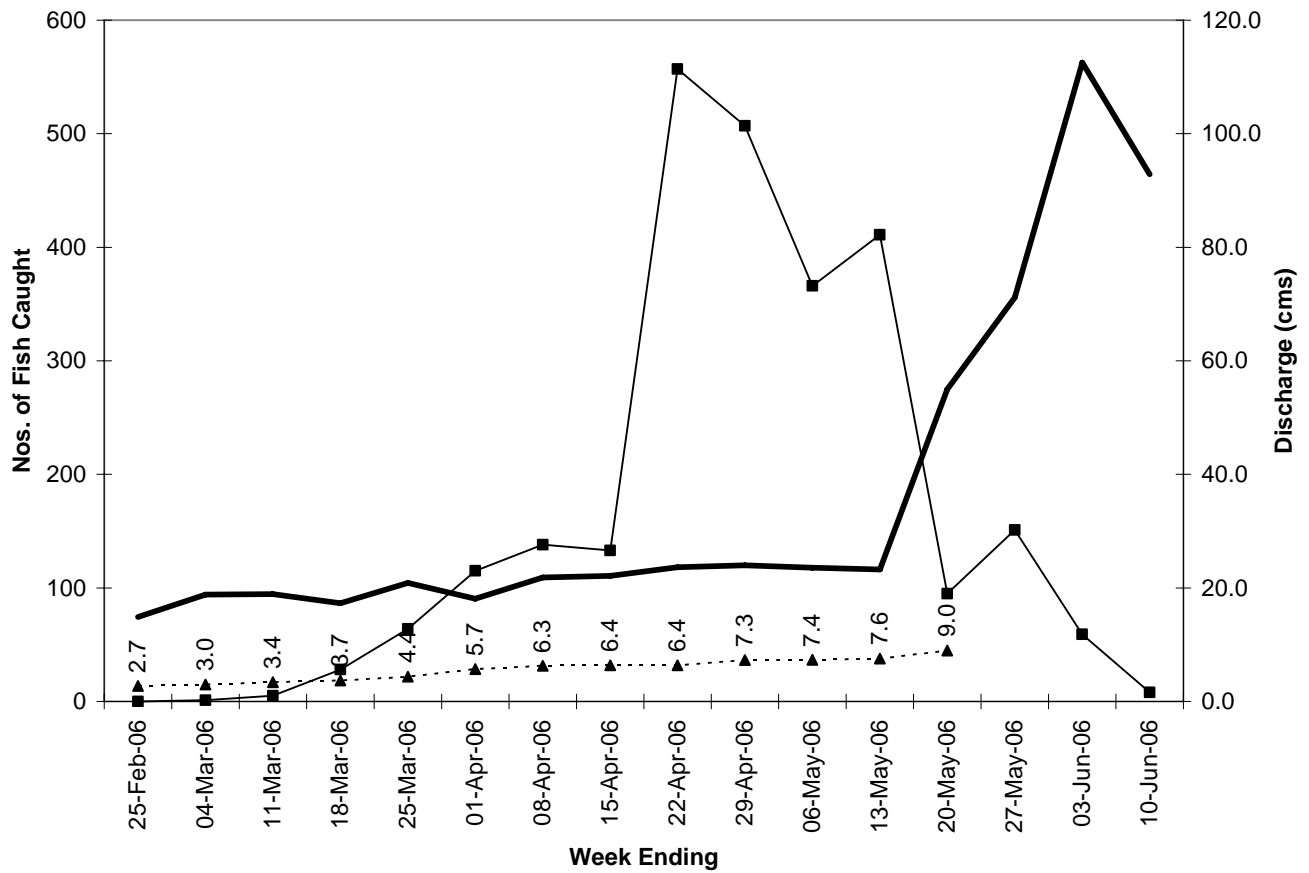
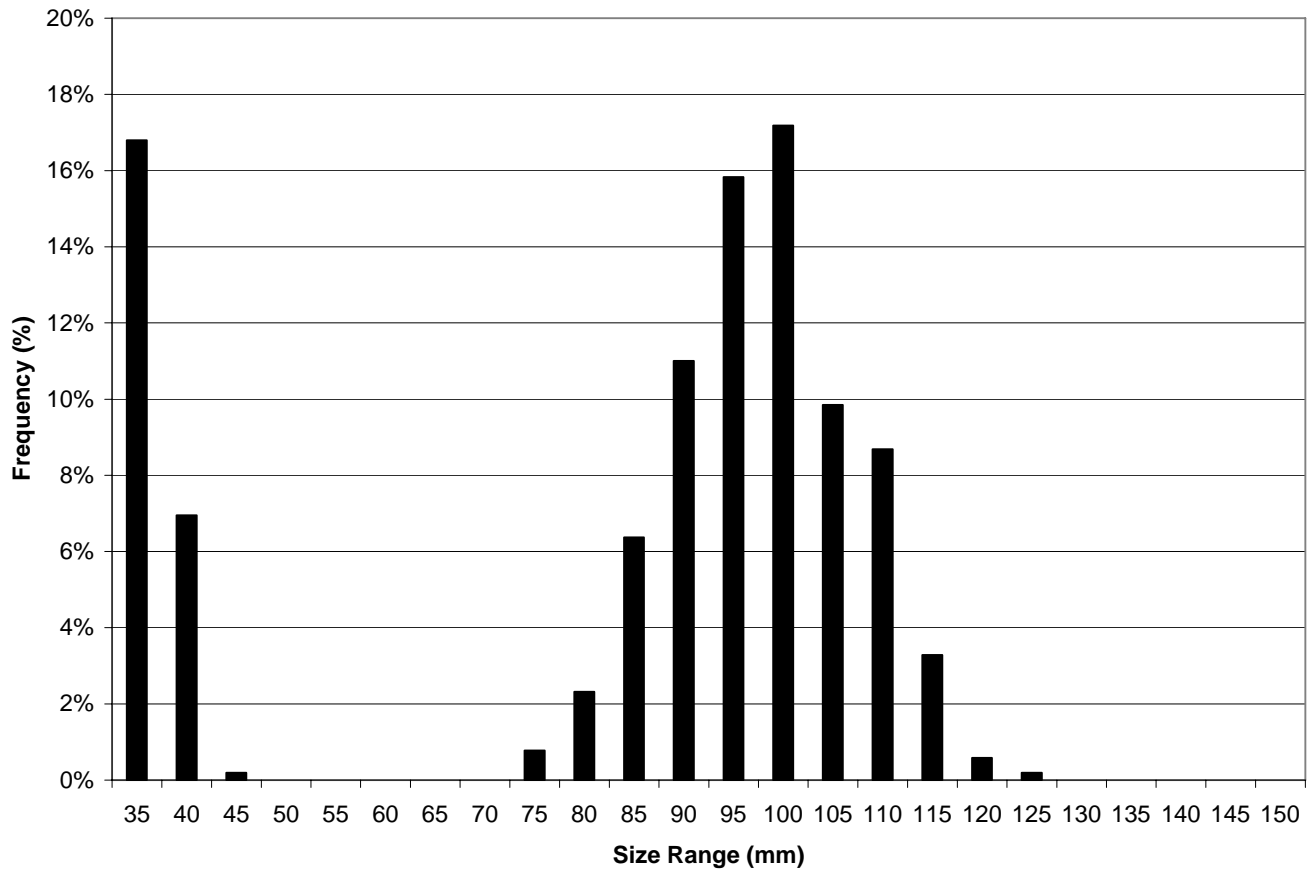
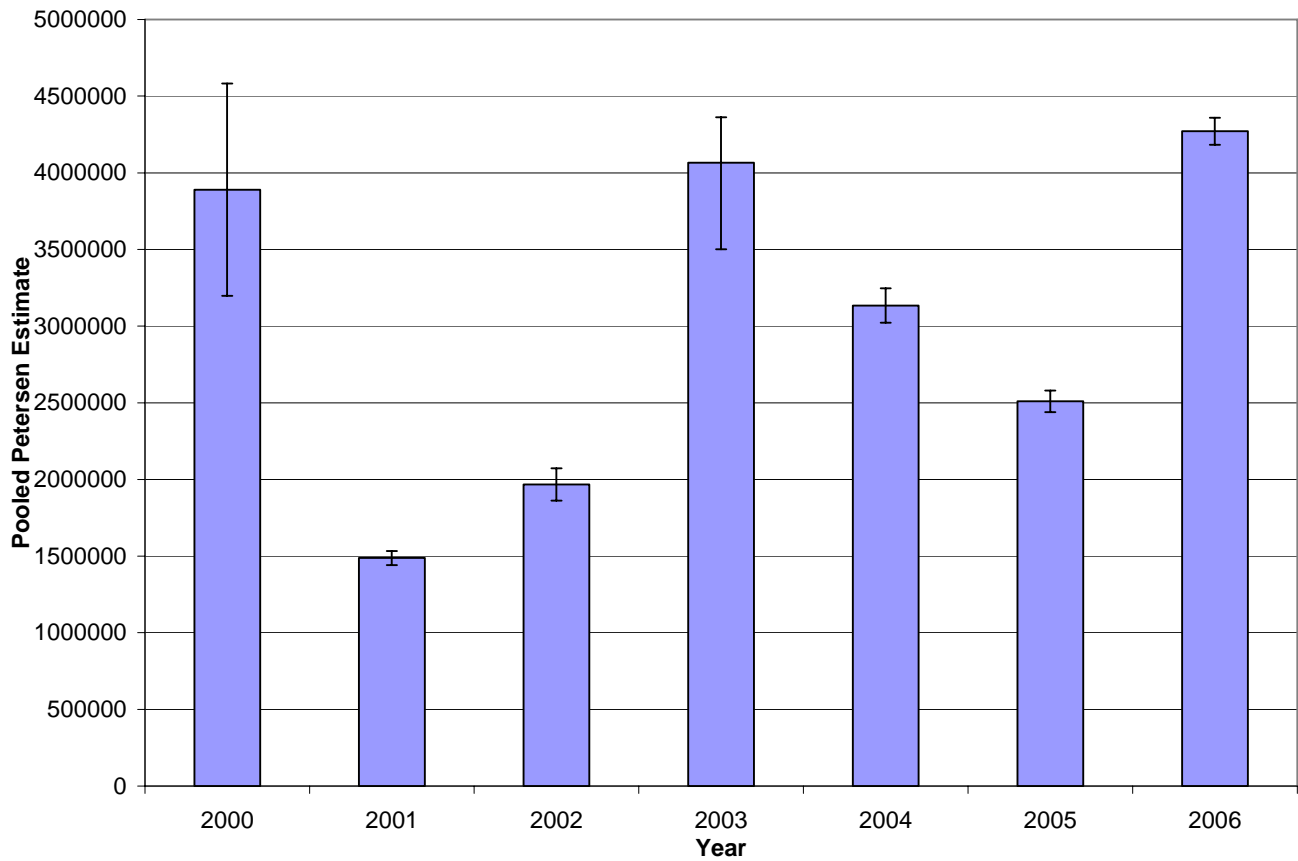


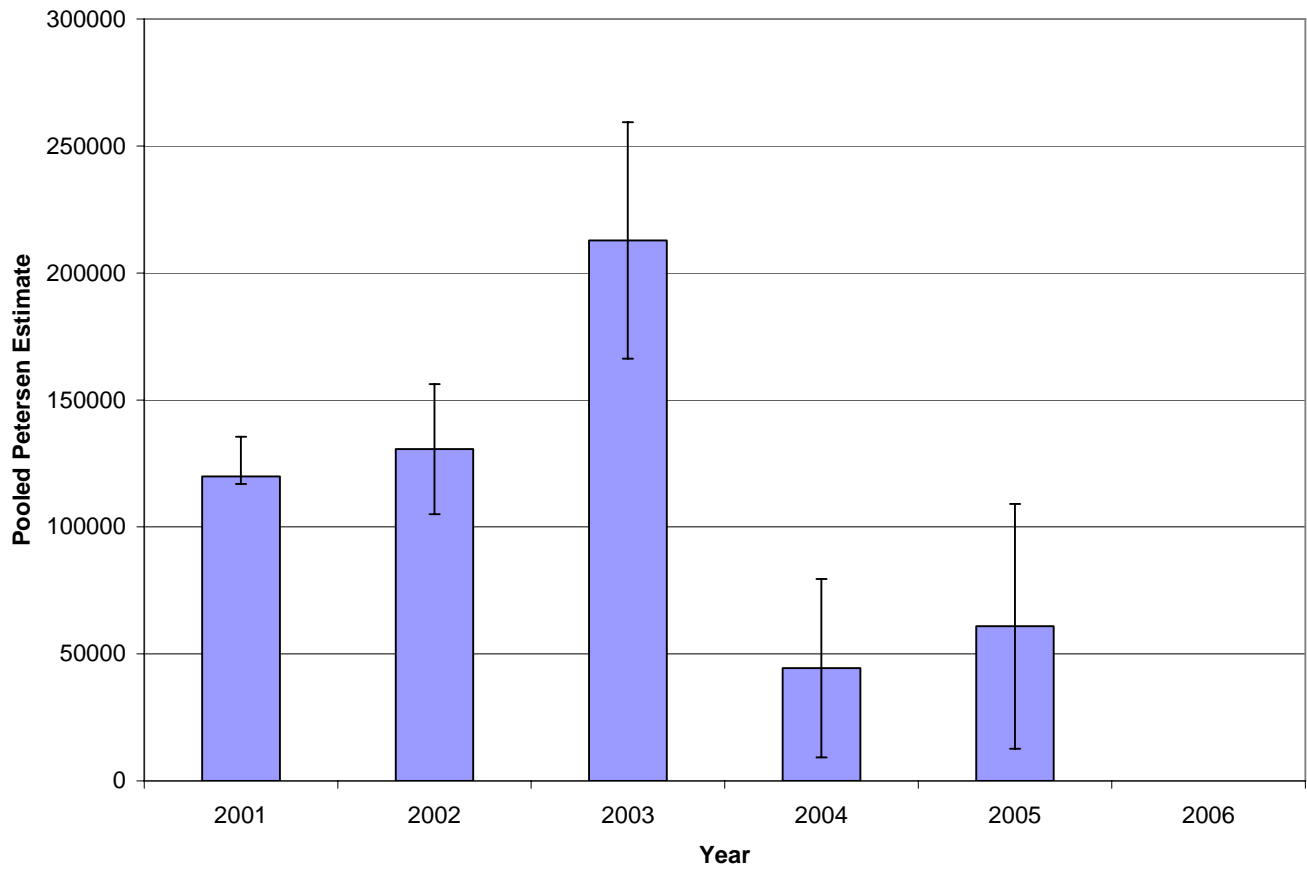
Figure 15. Weekly catch summary of coho fry (solid line, squares) related to temperature in °C (broken line, triangles) and flow (solid line) on the Cheakamus River, Spring 2006.



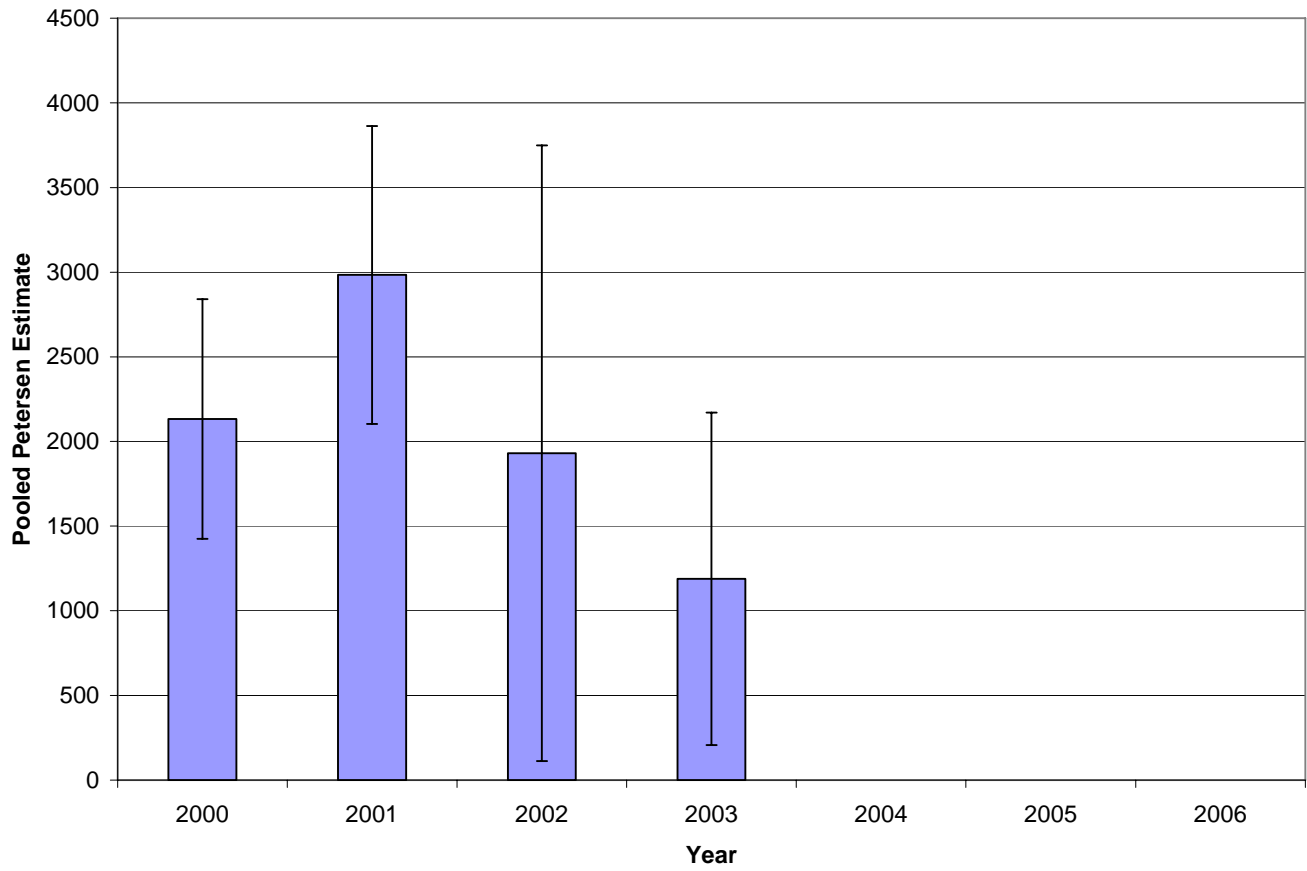
**Figure 16. Length frequency distribution of coho juveniles from the Cheakamus River, Spring 2006.**



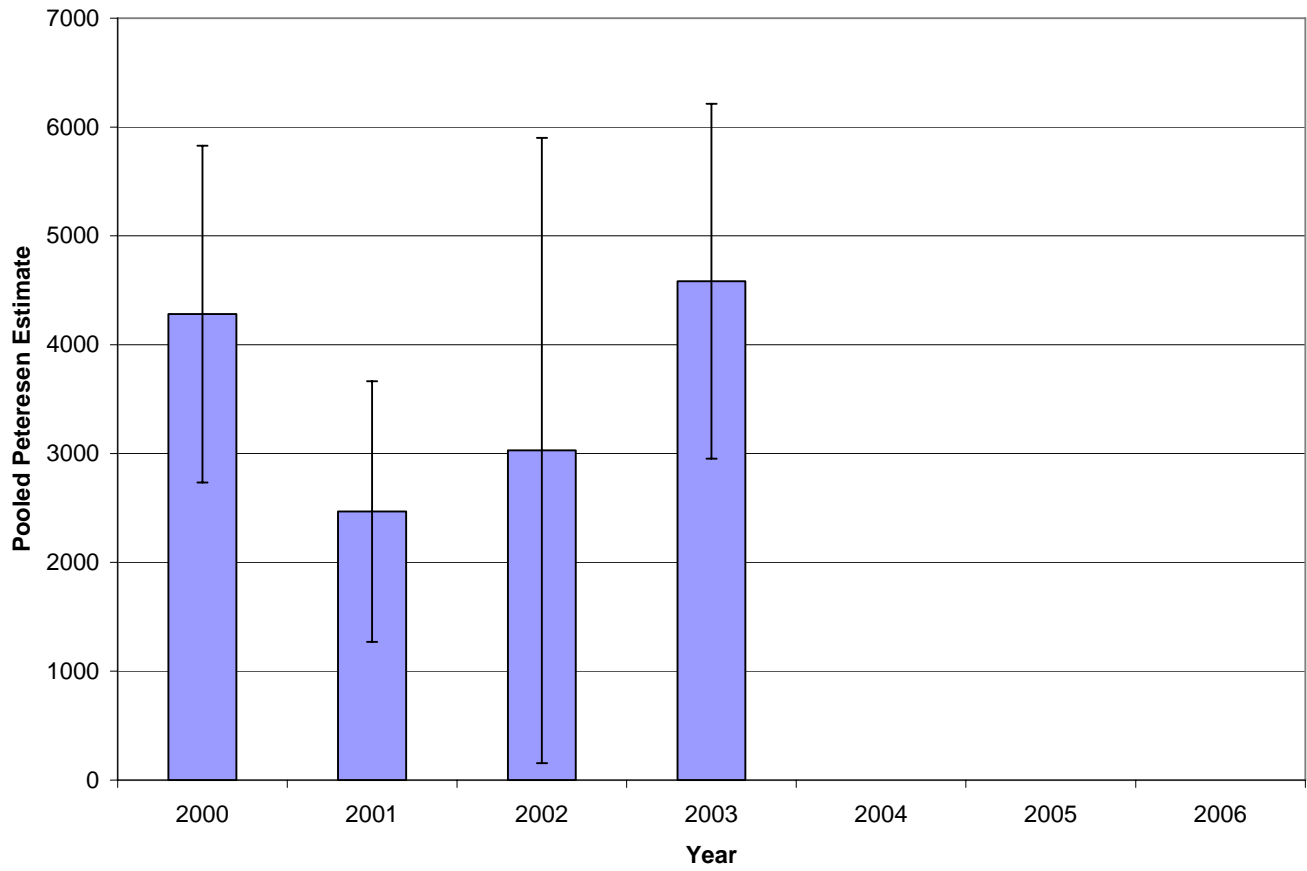
**Figure 17. Pooled Petersen Estimates of chum fry from Spring 2000 to 2006, including 95% confidence limits.**



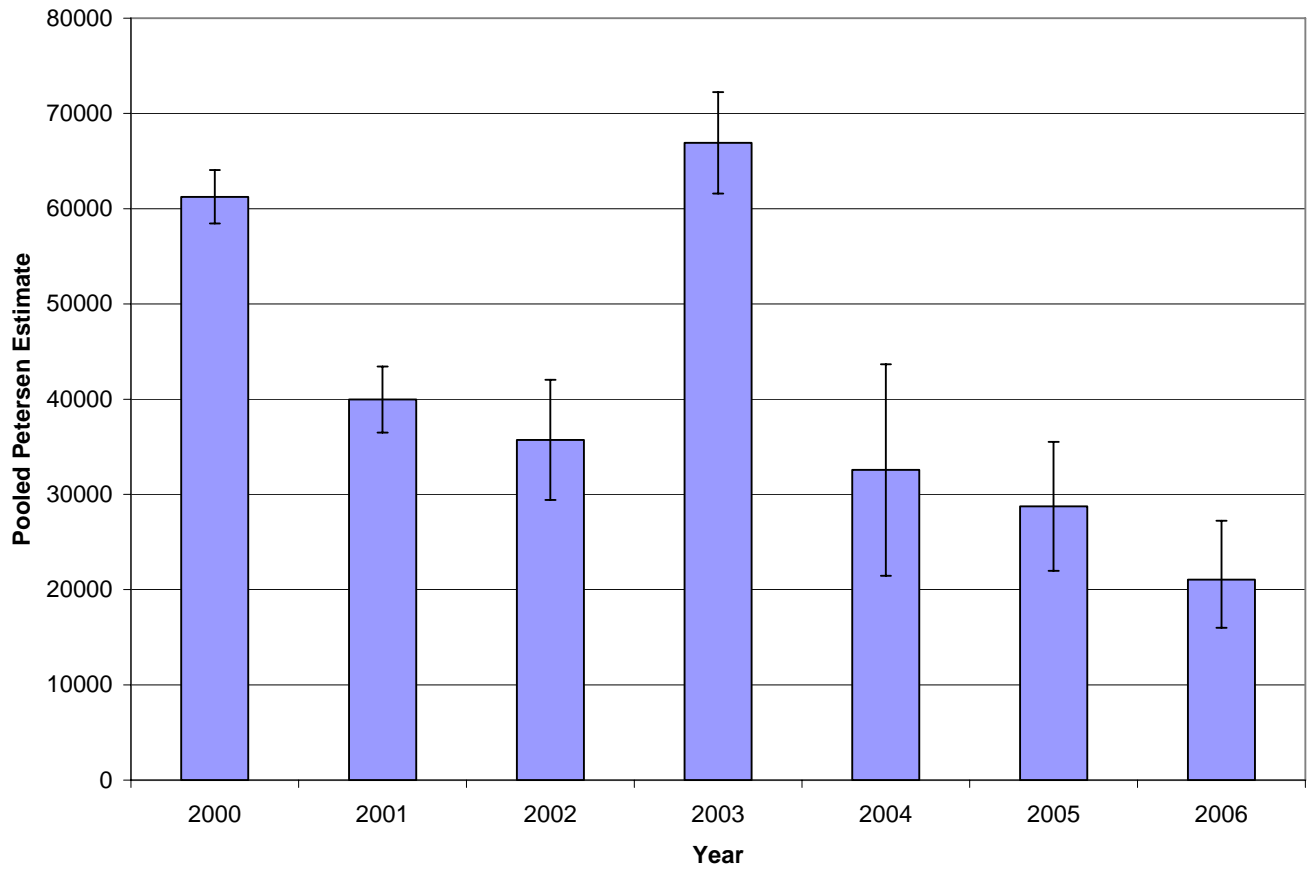
**Figure 18. Pooled Petersen Estimates of chinook fry from Spring 2001 to 2006, including 95% confidence limits.**



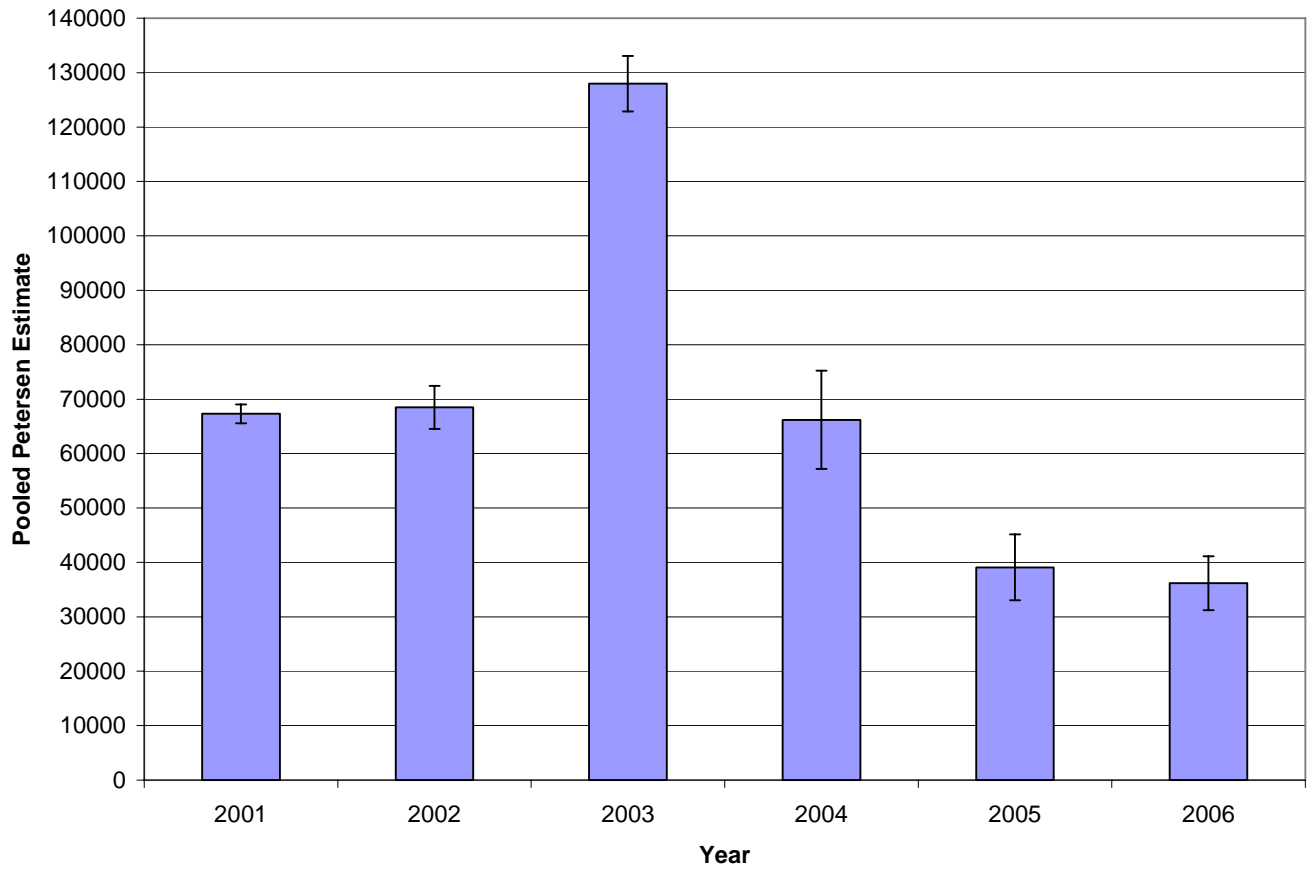
**Figure 19. Pooled Petersen Estimates of chinook smolts from Spring 2000 to 2006, including 95% confidence limits.**



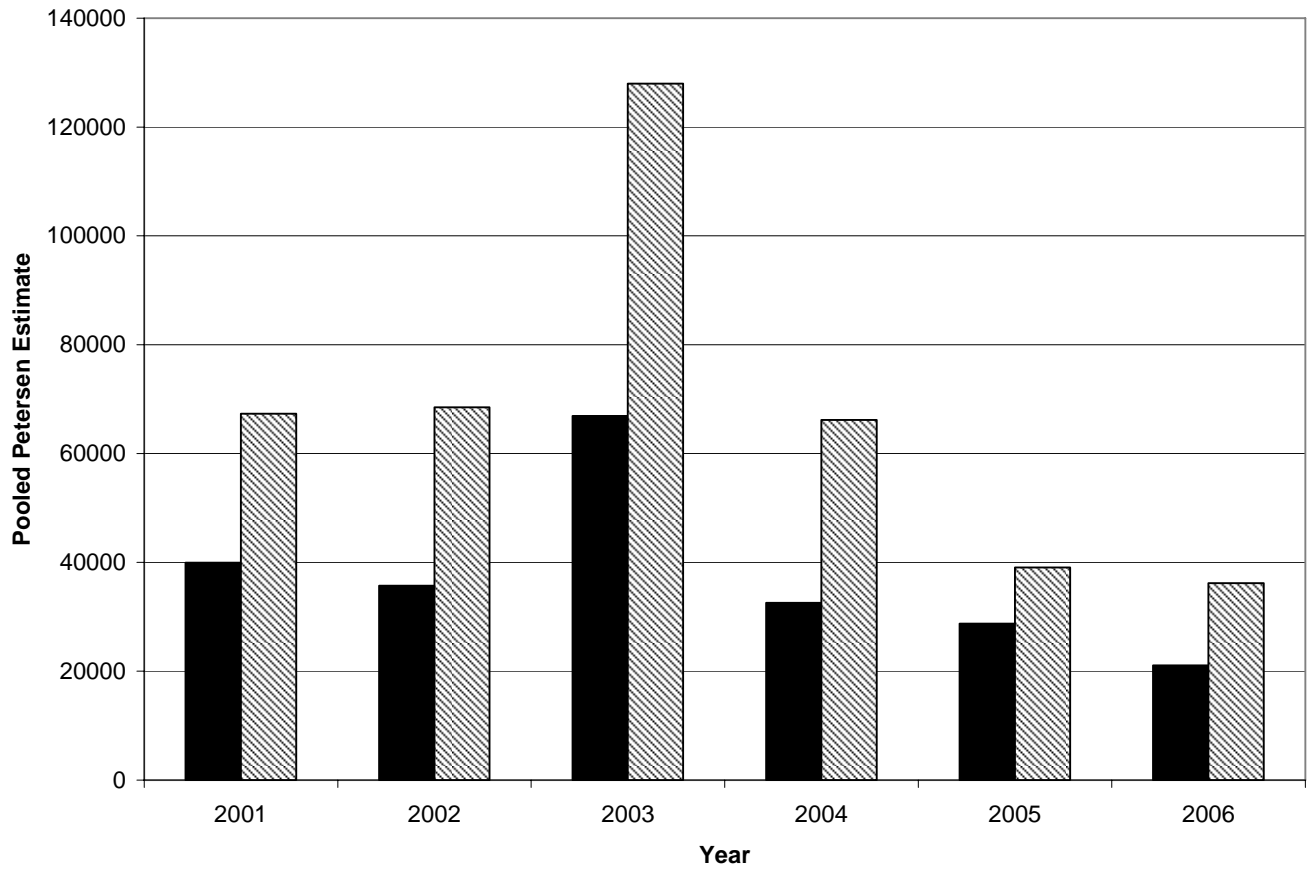
**Figure 20. Pooled Petersen Estimates of steelhead smolts from Spring 2000 to 2006, including 95% confidence limits.**



**Figure 21. Pooled Petersen Estimates of coho smolts captured and marked at the RST site from Spring 2000 to 2006, including 95% confidence limits.**



**Figure 22. Pooled Petersen Estimates of mainstem coho smolts out-migration, calculated using coho smolts captured and marked at the side-channels from Spring 2000 to 2006, including 95% confidence limits.**



**Figure 23. Comparison population estimates of coho smolts derived from RST marked fish (solid black bar) and side-channel marked fish (diagonal striped bar) from 2001 to 2006 on the Cheakamus River.**

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## APPENDICES

### Appendix 1. Catch and Population Estimate Summary: Spring 2006

Total Chum Fry (live)	Total Chum Fry (mort)	Total Chum Fry Marked	Total Chum Fry Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit	M.L. Darroch Estimate	+95% Confid. Limit	-95% Confid. Limit
352,456	1,881	94,285	7,798	8.5	4,270,934	4,359,472	4,182,395	4,379,297	4,488,259	4,270,066

Total Pink Fry (live)	Total Pink Fry (mort)	Total Pink Fry Marked	Total Pink Fry Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit	M.L. Darroch Estimate	+95% Confid. Limit	-95% Confid. Limit
41,102	316	10,811	1,567	14.5	296,405	309,716	283,093	309,758	329,716	289,808

Total Chinook Fry (live)	Total Chinook Fry (mort)	Total Chinook Fry Marked	Total Chinook Fry Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit	M.L. Darroch Estimate	+95% Confid. Limit	-95% Confid. Limit
496	3	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A

Total Chinook Smolts (live)	Total Chinook Smolts (mort)	Total Chinook Smolts Marked	Total Chinook Smolts Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit	M.L. Darroch Estimate	+95% Confid. Limit	-95% Confid. Limit
1	0	N/A	N/A	N/A	N/A	-	-	N/A	-	-

Total Steelhead Smolts (live)	Total Steelhead Smolts (mort)	Total Steelhead Smolts Marked	Total Steelhead Smolts Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit	M.L. Darroch Estimate	+95% Confid. Limit	-95% Confid. Limit
5	0	0	N/A	N/A	N/A	-	-	N/A	-	-

**Appendix 1: Catch and Population Estimate Summary: Spring 2005 (cont).**

Total Steelhead Parr (live)	Total Steelhead Parr (mort)	Total Steelhead Parr Marked	Total Steelhead Parr Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit	M.L. Darroch Estimate	+95% Confid. Limit	-95% Confid. Limit
6	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Total RST Coho Smolts (live)	Total RST Coho Smolts (mort)	Total RST Coho Smolts Marked	Total RST Coho Smolts Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit	M.L. Darroch Estimate	+95% Confid. Limit	-95% Confid. Limit
1,373	3	757	49	6.5	21,602	27,230	15,973	21,067	27,657	14,476

Total SC Coho Smolts (live)	Total SC Coho Smolts (mort)	Total SC Coho Smolts Marked	Total SC Coho Smolts Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit	M.L. Darroch Estimate	+95% Confid. Limit	-95% Confid. Limit
5,472	0	4,578	173	3.8	36,209	41,128	31,219	37,962	26,903	49,012

Total Coho Fry (live)	Total Coho Fry (mort)	Total Coho Fry Marked	Total Coho Fry Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit	M.L. Darroch Estimate	+95% Confid. Limit	-95% Confid. Limit
2,622	16	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

## Appendix 2. Mark Recovery Stratum

### A. Chum Fry (Mainstem Marked)

Release Stratum	Period ending	Fish Marked	Recovery Stratum															Percent Recoveries
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
			27-Feb	06-Mar	13-Mar	20-Mar	27-Mar	03-Apr	10-Apr	17-Apr	24-Apr	01-May	08-May	15-May	22-May	29-May	05-Jun	
<b>1</b>	06-Mar	1615	0	149	0	0	0	0	0	0	0	0	0	0	0	0	0	9.2
<b>2</b>	13-Mar	9247	0	0	816	0	0	0	0	0	0	0	0	0	0	0	0	8.8
<b>3</b>	20-Mar	9687	0	0	0	913	0	0	0	0	0	0	0	0	0	0	0	9.4
<b>4</b>	27-Mar	9831	0	0	0	0	799	0	0	0	0	0	0	0	0	0	0	8.1
<b>5</b>	03-Apr	9058	0	0	0	0	0	1528	0	0	0	0	0	0	0	0	0	16.9
<b>6</b>	10-Apr	7881	0	0	0	0	0	0	958	0	0	0	0	0	0	0	0	12.2
<b>7</b>	17-Apr	9180	0	0	0	0	0	0	0	568	0	0	0	0	0	0	0	6.2
<b>8</b>	24-Apr	10096	0	0	0	0	0	0	0	0	815	0	0	0	0	0	0	8.1
<b>9</b>	01-May	9737	0	0	0	0	0	0	0	0	0	664	0	0	0	0	0	6.8
<b>10</b>	08-May	9630	0	0	0	0	0	0	0	0	0	0	288	0	0	0	0	3.0
<b>11</b>	15-May	8323	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0	6.0
	Untagged Fish		604	9299	27836	52776	43806	59884	41176	31415	33015	22597	17801	13880	241	5	2	
	Total Recovered		604	9448	28652	53689	44605	61412	42134	31983	33830	23261	18089	14380	241	5	2	
	Marked proportion		0.00	1.58	2.85	1.70	1.79	2.49	2.27	1.78	2.41	2.85	1.59	3.48	0.00	0.00	0.00	

B. Pink Fry (Mainstem Marked)

Release Stratum	Period ending	Fish Marked	Recovery Stratum															Percent Recoveries
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
			27-Feb	06-Mar	13-Mar	20-Mar	27-Mar	03-Apr	10-Apr	17-Apr	24-Apr	01-May	08-May	15-May	22-May	29-May	05-Jun	
1	06-Mar	96	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10.4
2	13-Mar	605	0	0	51	0	0	0	0	0	0	0	0	0	0	0	0	8.4
3	20-Mar	462	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	4.8
4	27-Mar	974	0	0	0	0	75	0	0	0	0	0	0	0	0	0	0	7.7
5	03-Apr	3328	0	0	0	0	0	506	0	0	0	0	0	0	0	0	0	15.2
6	10-Apr	3912	0	0	0	0	0	0	706	0	0	0	0	0	0	0	0	18.0
7	17-Apr	1281	0	0	0	0	0	0	0	178	0	0	0	0	0	0	0	13.9
8	24-Apr	92	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	15.2
9	01-May	61	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	8.2
Untagged Fish			569	515	979	1670	1837	19767	13635	2099	238	101	7	1	0	0	0	
Total Recovered			569	525	1030	1692	1912	20273	14341	2277	252	106	7	1	0	0	0	
Marked proportion			0.00	1.90	4.95	1.30	3.92	2.50	4.92	7.82	5.56	4.72	0.00	0.00	0.00	0.00	0.00	

C. Coho Smolts (Mainstem Marked)

Release Stratum	Tagged Period	Release Period	Fish Marked	Recovery Stratum													
				1	2	3	4	5	6	7	8	9	10	11	12	13	14
				25-Feb	04-Mar	11-Mar	18-Mar	25-Mar	03-Apr	17-Apr	30-Apr	07-May	14-May	21-May	28-May	02-Jun	07-Jun
1	17 to 29 Apr	18 to 30 Apr	254	0	0	0	0	0	0	0	21	0	0	0	0	0	0
2	30 Apr to 6 May	1 to 7 May	170	0	0	0	0	0	0	0	0	7	0	0	0	0	0
3	7 to 13 May	8 to 14 May	216	0	0	0	0	0	0	0	0	0	15	0	0	0	0
4	14 to 20 May	15 to 21 May	94	0	0	0	0	0	0	0	0	0	0	4	0	0	0
5	21 to 27 May	22 to 28 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	28 May to Jun 1	29 May to Jun 2	23	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Untagged Fish				0	20	10	4	11	21	78	455	291	333	92	24	35	1
Total Recovered				0	20	10	4	11	21	78	476	298	348	96	24	37	1
Marked proportion				0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	2.3	4.3	4.2	0.0	5.4	0.0

D. Coho Smolts (Side Channel Marked)

Release Stratum	Tagged Period	Release Period	Fish Marked	Recovery Stratum													
				1	2	3	4	5	6	7	8	9	10	11	12	13	14
				25-Feb	04-Mar	11-Mar	18-Mar	25-Mar	03-Apr	17-Apr	30-Apr	07-May	14-May	21-May	28-May	02-Jun	07-Jun
1	3 Apr to 16 Apr	4 to 17 Apr	458	0	0	0	0	0	0	27	1	0	0	0	0	0	0
2	17 to 29 Apr	18 to 30 Apr	620	0	0	0	0	0	0	0	29	2	1	0	0	0	0
3	30 Apr to 6 May	1 to 7 May	574	0	0	0	0	0	0	0	0	28	1	0	0	0	0
4	7 to 13 May	8 to 14 May	779	0	0	0	0	0	0	0	0	0	42	3	0	0	0
5	14 to 20 May	15 to 21 May	1324	0	0	0	0	0	0	0	0	0	0	7	0	0	0
6	21 to 27 May	22 to 28 May	347	0	0	0	0	0	0	0	0	0	0	0	4	0	0
7	28 May to Jun 1	29 May to Jun 2	476	0	0	0	0	0	0	0	0	0	0	0	0	27	1
	Untagged Fish			0	20	10	4	11	21	51	425	261	289	82	20	8	0
	Total Recovered			0	20	10	4	11	21	78	455	291	333	92	24	35	1
	Marked proportion			0.0	0.0	0.0	0.0	0.0	0.0	34.6	6.6	10.3	13.2	10.9	16.7	77.1	100.0