Cheakamus Project Water Use Plan

Juvenile Salmonid Outmigration Enumeration

Implementation Year 5

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Cheakamus River Water Use Plan Monitoring Program: Juvenile Salmonid Outmigration Enumeration Assessment, Spring 2011

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Caroline Melville and Don McCubbing
InStream Fisheries Research Inc.

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Prepared for BC Hydro

By

Caroline Melville and Don McCubbing

InStream Fisheries Research Inc.
1698 Platt Crescent,
North Vancouver, BC.
V6J 1Y1
Tel 1-604-737-1510
E-mail don@instream.net

Executive Summary

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

In 2011, an estimated 1.4 million chum fry, 741,085 chinook fry, 60,428 coho smolts, and 3,772 steelhead smolts were produced in the area of the Cheakamus River upstream of the monitoring site at the North Vancouver Outdoor School (NVOS) property. No estimate was formed for chinook smolts as catches were too low.

Chinook fry yield was the highest observed since the study began while coho and steelhead smolts and chum fry yields were lower than in the previous two years.

The estimated chum fry yield was much reduced in 2011; likely due to a large scale change in distribution of adult spawners (see Monitor 1b, McCubbing et al. 2011) rather than purely a reduction in egg to fry survival, although this was observed at some locations.

Estimates of coho smolt yield in 2011 were lower than 2010 data, but well within the variance observed prior to the WUP. Steelhead smolt estimates have not been generated in 4 of the 12 years due to low capture numbers. This year an estimate of 3,772 was generated.

Side-channel production estimates were obtained for coho smolts and chum fry. Confidence in side-channel productivity estimates of coho smolts from Kisutch, Upper Paradise and BC Rail full span traps was high. A mark recapture pre-smolt estimate of channel yield was derived for Tenderfoot Creek and Lake as compared to partial trap operation in previous years. Estimates were within the range expected but had broad confidence limits due to low recaptures.

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1.0 INTRODUCTION

The Cheakamus River is a major tributary of the Squamish Watershed and drains upstream of Brackendale gauging station, an area totaling 1010 km^2 of the Coastal Mountain range in south-western BC. River discharge is affected by BC Hydro through operation of Daisy Reservoir and the Cheakamus generating plant, a 155 MW storage and diversion project. The generation project, completed in 1957, consists of a 28 m high, 680 m long dam that impounds Daisy Reservoir. From this reservoir, a portion of the river flow is diverted through an 11km long tunnel to a powerhouse on the Squamish River. The Cheakamus River, downstream of the reservoir, extends 26 km to its confluence with the Squamish River. Only the lower 17 km of this river are accessible to anadromous salmon as a number of natural barriers preclude further upstream migration (Figure 1). The Cheakamus River anadromous mainstem habitat is complimented by a large area of man-made restoration channels which are fed either by groundwater or river water diverted from the mainstem.

In 1999 the Cheakamus Water Use Planning (WUP) process identified the need to determine the response of juvenile salmonid populations to an Interim Flow Order (IFO) which was implemented in 1997, and the subsequent Instream Flow Agreement (IFA). A juvenile salmon outmigration study utilizing rotary screw traps commenced in the spring of 2000 (Melville and McCubbing 2001) and has continued annually through 2011.

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

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

1) Minimum required flow below Daisy Lake Dam:

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

2) Minimum required flow at the Brackendale gauge:

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

The likely effects on fish populations of the new operating regime are uncertain because the benefits presented during the WUP process were modeled using complex relationships between fish habitat and flow, and assumed relationships between fish habitat and fish production (Marmorek and Parnell, 2002). The Juvenile Outmigration Monitor in conjunction with other monitors will help to reduce this uncertainty and monitor potential effects of the new flow regime on salmon populations.

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

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

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

The outmigration data will also be used in conjunction with data collected as part of the Chum Salmon Adult Escapement Monitor (Cheakamus Water Use Plan Monitoring Program Terms of Reference, Feb 2007, Monitor #1b) to address the management question:

- How does fry yield correlate to chum adult escapement distribution and density and is this affected by variance in discharge?

In addition, outmigrant data from this program will be used as part of the Groundwater Side-channels Monitor (Cheakamus Water Use Plan Monitoring Program Terms of Reference, Feb 2007, Monitor #6) to address the management question:

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

The expanded study includes detailed assessment of juvenile salmonid outmigration using a combination of total capture, and estimated counts from mark-recapture; the choice of methodology is based on the site and the age class of the fish being assessed.

This data report concludes year-five of the expanded study. A more detailed report of the data and correlations with river discharge since 2000 will be completed in 2012. This will include an improved statistical method of assessing the utility of RST derived yield estimates to track variations in smolt and fry production (Bonner and Schwarz 2011). This new statistical method will allow for improved understanding of the linkages, if any, between estimated yields and inter-annual river discharge. This interim report summarizes the results of 2011 data collection and reports only the Pooled Petersen estimate for chum, chinook young of the year (YOY), steelhead smolts and coho smolts in comparison with past years results.

1.1 Study Area and Trapping/Enumeration Locations

The primary location of fish enumeration consists of two rotary screw traps (RSTs) operated adjacent to the North Vancouver Outdoor School (NVOS) property (10U 0489141:5518035, Figure 1 & 2) at river kilometer (RK) 5.5. Secondary enumeration sites were operated on both river augmented and ground water side-channels at locations on the NVOS property (various locations, Figure 2) as well as at the BC Rail channel (10U 0489301:5519270, Figure 2). In 2011, as in 2009 and 2010, due to the logistical issues presented by numerous hatchery releases at Tenderfoot Creek through the migration period, it was decided to abandon the trap site (10U 048392:5519514,Figure 2) on this tributary and attempt to assess the population of wild coho pre-smolts utilizing mark-recapture techniques.

Due to low precision of estimates in the previous four years, fyke trap operations at Site B in the Upper Paradise Groundwater were suspended. This data was intended to be utilized in Monitor #6, but due to the now shortened length of ground water channel and a lack of confidence in the fish estimates at this site, the data were deemed unsuitable for this purpose. As a result, trap operations at the site was terminated.

1.2 Hatchery Releases

Releases of hatchery fish are done annually into the Cheakamus River by various organizations. In 2010, hatchery 1+ coho, chinook young of the year (YOY) and chum fry were all released into the Cheakamus River at various locations by Department of Fisheries and Oceans Canada (DFO, Tenderfoot Hatchery, Figure 2). Chum fry were also released by the North Vancouver Outdoor School Hatchery (NVOS) into Upper Paradise side-channel complex (Figure 2).

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

Coho 1+ smolts are released every spring directly from the hatchery into Tenderfoot Creek. These fish are marked with an adipose clip and can be easily identified. In 2011, unlike years prior to 2007, additional unmarked coho smolts were also released at RK 12-15. As for chinook YOY, the upper river releases are being done to mitigate losses observed during the caustic soda spill in 2005 (McCubbing et al. 2006). Generally RST operations were suspended in 2011 for one to two days following their release, thus allowing the majority of the outmigrants to pass the RST site without the risk of capture.

The NVOS and Tenderfoot Creek Hatchery (Figure 2) also release chum fry each spring. Depending on release numbers, RST and/or fyke net operations are occasionally suspended for one day to allow fish passage. This operational protocol has been established because hatchery chum fry cannot be differentiated from wild fry based on size or morphology and as chum fry migrate quite quickly (usually overnight) past the traps (C. Melville, pers. obs.).

2.0 METHODS

Two methods were used for enumerating outmigrant salmonid fry and smolts from the Cheakamus River in 2010:

1) partial traps; RSTs, fyke nets and minnow traps which rely on mark recapture methodology to evaluate fry and smolt outmigration,
2) complete channel traps; which allow for manual counting of all outmigrant smolts from a designated area,

During study design, a method was chosen based on the logistics of each trapping location. Considerations evaluated when choosing trapping methodology included species life-stage (i.e. fry or smolt), number of fish that can reasonably be enumerated during a 24 hour sample period (i.e. fry), potential stress and mortality of fish (i.e. ensuring that the method reduced the risk of mortality to the population), ability to operate traps during hatchery releases, manpower requirements, and environmental factors (i.e. flow and location).

Unlike total capture methods which aim to count all fish passing the enumeration site, mark recapture methods estimate the number of outmigrants by sampling only a portion of the total fish passing the trapping/counting location. To determine the actual number of fish passing downstream in a given sample time period, a known number of marked fish are released into the population upstream of the enumerating location with the assumption that these fish will move downstream and pass the enumeration station (RST or fyke net) and that a portion of these fish will be recaptured. Assuming that fish do not lose their marks before recapture, that no marks are missed during sampling, and that the chance of capturing any marked fish is equal to unmarked fish, the efficiency of a capture trap can be calculated for a given time period (Seber 1982, AFS 2007). These data are then used to statistically model the number of outmigrants actually passing the trap location during each sample period. Factors which may confound such estimates include residualization (non migration) of marked fish, loss of mark fish to predators, or marked fish bypassing the enumeration site without the potential for capture (AFS 2007, Frith et al. 1995). Our study design utilizes best practice methods to minimize the risk of challenging these assumptions, which include but are not limited to: marking fish while minimizing handling stress, avoiding fish releases that may encourage targeted predation on marked fish (i.e. avoiding day time marking and release), and using marking traps separate from recapture traps where practicable to reduce fish transport stress.

2.1 Fish Trap Operations

2.1.1 Rotary Screw Traps

RST trapping methods for the Cheakamus follow those outlined in Melville and McCubbing 2001, 2002a. Briefly, emigrating salmonid juveniles are captured in the mainstem of the Cheakamus River at RK 5.5 using one or two six-foot diameter rotary screw traps during the sampling period from February 17th to June 15th (Table 1). The traps are oriented on a cableway system that allows them to be brought to shore for sampling, the upstream trap is designated as RST 1 and the downstream trap is RST 2 (Figure 3). Each RST is checked a minimum of twice per day (morning and evening) – once to bio-sample fish and mark smolts, and the second time to mark fry and ensure proper trap operation. Frequency of RST checks and maintenance are increased when flow and fish numbers warrant, minimizing trap-induced mortality and insuring optimal trap operation. Due to operational safety concerns, trap operation may be restricted or discontinued as river discharge approaches 75 m^3/s.

A new cableway was installed part way through the sampling period in the spring of 2008 (Melville and McCubbing 2009). This new cableway system is intended to improve safety margins and allow trap operation under higher discharges, therefore theoretically improving capture efficiency.

In 2011 as in the previous four years, a change to operational procedures was placed in effect in an effort to increase trap operating efficiency in May and early June when the bulk of coho and steelhead smolt migration occurs (data on file). With lengthening days and increased sunlight, conditions are often dominated by higher discharges due to high elevation snowmelt and increased algal growth which clogs screens during this time period. Thus the 3/16" mesh screen drums (fry) are replaced by larger 1/2" mesh (smolts) in order to reduce screen surface area and thereby reduce resistance to water flow as well as minimize clogging due to algal and debris build up. This allows for more efficient trap operation, particularly at higher discharge. In 2010 the change was undertaken on both traps on May 1st. While the 1/2" mesh drums do not capture fish <60 mm (chum, pink and YOY chinook fry) in May and June; data analysed from 2001-2006 indicates that 90% of these three species-age classes have migrated by the beginning of May (Melville and McCubbing 2010).

2.1.2 Side-Channel Fyke Net Traps

Side-channel fry production upstream of the RST site was estimated at a number of sites in the Upper Paradise/Gorbushca (NVOS) channel complex and in the BC Rail (BCR) channel, by deploying fyke net traps (Figure 2). The fyke nets (1/8" mesh) had openings of 1 m by 1 m tapering down to a 15 cm tube which was attached to a capture box (Figure 4). A total of 6 fyke net traps were utilized through the study period. In an effort to minimize handling stress, separate upstream capture nets (herein referred to as marking traps) were used to obtain fish for marking and fish were released at the site of marking. A portion of these released marked fish were subsequently captured in downstream traps (herein referred to as enumerator traps), allowing a population estimate to be derived using the mark-recapture methods as described in Section 2.5 The upstream marking fyke traps were operated for 4 days per week while the downstream enumerator traps operated 7 days per week. All fyke nets (marking and enumerator) were deployed by February 16th in 2011. Marking trap operation was suspended on April 26th and enumerator trap operation ended on April 30th (Table 1). Operation of the fyke nets was suspended when enumeration of fry at the mainstem RST location ended due to RST drum changes and as fry numbers had fallen to minimal catches, as described in Section 2.1.1.

An estimate of chum production from the entire NVOS channel complex was provided by marking at sites C & H upstream of the enumerator fyke at Site F (Figure 2 & 5). On the groundwater only channels chum fry estimates were provided by operating fyke nets on Kisutch (marking site C, enumerator site B; Figure 2 and 5) and BC Rail (marking site K, enumerator site J).

2.1.3 Complete Channel Traps

Complete channel traps are intended to capture all smolts migrating from an area upstream of the trap. In general the fish (primarily steelhead and coho smolts) are captured in holding boxes, enumerated, sampled and released downstream.

A trap has been operated in previous study years (2001-2010) on the Upper Paradise channel (Trap Site 6; Figure 2). The primary objective of this trap was to provide a large sample of coho smolts for marking to derive mark-recapture estimates at the RST site, as reported in 2001 through 2010 (Melville and McCubbing 2002a, 2002b, 2003 - 2010). It has also provided a count of all out-migrating smolts (but not fry) from the Upper Paradise channel and the portion of Farpoint channel which is diverted into Upper Paradise (Figure 2).

In 2011 as in 2010 the complete capture trap (Trap Site 1; Figure 2, 6 & 7) was operated at the downstream end of Upper Paradise channel complex. This trap is intended to capture all smolts migrating from the channel complex and provide steelhead and coho smolts for marking for the RST derived estimates.

Unlike previous years the Upper Paradise trap (Site 6) was only operated as a back-up to the newer complete capture Upper Paradise/Gorbushca trap (Trap Site 1; Figure 2 & 7). Site 6 was only operated for a few days in May to obtain fish for Site 1 efficiency tests and from June 8-15th when Site 1 no longer could operate due high water in the mainstem Cheakamus backwatering the trap.

Complete channel traps were also operated on Kisutch and BC Rail groundwater channels (Sites 3 & 4; Figure 2 & 5). Data from these traps contributed to the Ground Water Study (Monitor 6) as well as the complete estimate of sidechannel production of smolts upstream of the RST site.

In 2011 coho and steelhead smolts from Kisutch; Site 3 were moved downstream to be released with Site 1 fish. Thus the total capture of Site 3 and Site 1 fish constitutes the migration of coho and steelhead juveniles from the Upper Paradise channel complex.

2.1.4 Minnow Trap Mark Recapture

Since 2009 full creek trapping efforts to assess the coho migration were not attempted at Tenderfoot Creek (Site 5, Figure 2). This was deemed necessary as the frequency and number of hatchery releases required long periods when the trap could not be operated to allow hatchery fish to leave without creating a risk of high fish mortality and/or handling stress. During the periods when the trap is removed, an unknown number of wild migrants likely leave along with the hatchery fish. In an attempt to generate an improved estimate of the contribution that Tenderfoot Lake and Creek make to the total wild coho smolt outmigrant population of the Cheakamus a mark-recapture assessment of pre-smolts utilizing minnow trapping in early April just prior to migration was undertaken (as observed in previous years with full span channel traps, data on file). This approach has previously been employed successfully on Cheakamus side-channels (Foy et al. 2002; Triton 2007).Sampling occurred from April 5th to 7th, 2011.

The Tenderfoot study area was broken into two sections: the lake and the creek. Approximately 100 baited minnow traps were set for 24 hours in each area. Traps were retrieved and fish were marked utilizing methods described for smolts in Section 2.3.2 and released in the same area. The difference being that a Visible Elastomer Tag (VIE, Northwest Marine Technology, Figure 8) was utilized rather than the coloured dye applied with a jet inoculator. After a period of 24 hours the traps were then reset for 24 hours. Total catch and marks were recorded and a mark–recapture estimate using the simple Petersen estimate formula described in Section 2.5 was derived.

2.2 Biophysical Monitoring

Five temperature loggers were maintained and data collected in the mainstem Cheakamus River in 2010. The five locations are described as follows and are shown in Figure 1:

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

The temperature loggers were operated for the full calendar year and for the duration of the Juvenile Monitor study (5-10 years). Loggers are downloaded once every month and the data are archived for use in other Cheakamus WUP monitors. The temperature data recorded at the Rotary Screw Trap (Temperature Logger 4; Figure 1) were used for analysis in this study.

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), located 100 m upstream of the RST site (Figure 1). These readings are used for analysis in this study.

2.3 Fish Marking

As previously described, mark recapture methods were used to assess capture efficiency of the RSTs and side-channel enumerator fyke traps. Capture efficiencies were then used to calculate population estimates of outmigrants. Since trap capture efficiencies are expected to vary over the migration period based on flow conditions, fish migration patterns and abundance as well as other factors, population estimates calculated using capture efficiency estimates over shorter time periods (strata) are likely to be more accurate than population estimates calculated using average capture efficiency over the entire migration period (Seber 1982). This requires a planned marking regime where individual strata may be differentiated based on separation of mark groups.

2.3.1 Fry Marking

Chum, pink and chinook fry marking procedure at the RSTs and the side-channel fyke nets in 2011 followed the same protocol as reported by Melville and McCubbing (2005). Fry collected at the RSTs and at the marking fyke traps were not sampled in the morning of capture but held in the trap boxes until late afternoon. A maximum (due to time constraints) of 5,000 fry were marked each day by immersion in Bismark Brown Y (BB) at the RST site or Neutral Red (NR) dye at the side-channel marking sites at a concentration 1:100,000. Fish were immersed for 1 hour in 50 litres (maximum 2500 fish per 50 l) of dye solution aerated with electric air pumps. This marking technique 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 and McCubbing 2002b). Marking was restricted to the peak fry migration period (February 16th to April 30th) as recaptures of marked fry are often at or near zero when available fry for marking numbered less than 100 individuals per day. Such low recapture rates preclude the ability to calculate a robust efficiency estimate (Schwarz and Taylor 1998). After marking, fry were immediately released. RST marked fry were moved upstream to Eagle Point prior to release, while side-channel marked fish were released immediately downstream of marking fyke traps (Figure 2, 5 & 9). All marked fry subsequently recaptured in enumerator or mark fykes upstream of Site F (Figure 2) were taken downstream of Site F and released. These fish were subtracted from the marks available to be recaptured at Site F.

Marking and enumeration were timed such that each release of marked fry would coincide with dusk. This procedure was undertaken for four days each week (Monday through Thursday). A 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 or enumerator fyke traps, 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). Thus this method allows for calculations of weekly capture efficiency.

Daily fry catch data collected at the RST on fry marking days represent the sample period from late afternoon through late afternoon. This differs from daily reported smolt catch at each site and the fry catch at side-channel enumerator sites where daily sample counts are evaluated in the morning. However, as visual observations since the study commenced in 2000 indicate few fry or smolts are captured during daylight hours at any trap, the daily sample totals are likely comparable.

2.3.2 Smolt Marking

Steelhead smolt marking methods differed from previous years (2001-2006; see Melville and McCubbing 2001-2006) when only RST captured fish were marked and released at Eagle Point (Figure 2) and 2009 when RST and Site 6 and 1 fish were combined and released at Site 1 (Melville and McCubbing 2010). In 2011 steelhead were marked with a different mark each day at Site 1; combined and released at Eagle Point with RST marked fish (Figure 2 & 10). Steelhead captured at the RSTs were marked with the same mark for the duration of a week during the migration period (April 1-June 15) and released at Eagle Point (Figure 2 and 10). All of the marked steelhead were combined to calculate the pooled Petersen estimate. As in previous study years, fish which were utilized for mark recapture evaluations were not sampled for length, weight or scales to avoid additional handling related stress that could affect subsequent behavior and recapture success. All fish were held on the day of marking in a holding box and released at dusk to minimize predator related mortality on these fish.

Coho smolts were marked each day at the trap located on Upper Paradise restoration channel (Site 1; Figure 2 & 11). Coho captured and marked at Site 1 were released at Site 1 (Figure 2). These fish are available on a daily basis for the majority of the outmigration period as side-channel trap operation is not influenced to the same extent as the RSTs by high flows and thus trap operation is rarely suspended. In addition, fish have been more abundant than those available to mark at the RST site. Each day smolts captured at the Upper Paradise channel trap were marked in the morning and held until dusk in a holding box immediately downstream of the trap Site 1. This differed from 2001 to 2004 where fish were released immediately after recovery from marking. The modified procedure was implemented in 2005 in an attempt to minimize predator related mortality (Melville and McCubbing 2006).

In 2011, as in 2008 through 2010, but unlike previous years (when one mark was used for a pre-determined number of days), the mark applied to coho smolts was changed each day at the marking sites (Site 6 and Site 1; Figure 2). This change in methodology was done to evaluate the effects of daily variations in trap efficiency on yield estimates. A statistical model to evaluate the benefit of this method of marking is now available (Bonner & Schwarz 2007a) and will be reported in the 2012 review report. Therefore in this report these daily data are compiled to provide weekly strata for comparative analysis with previous sample years. In addition to the above change, in 2011 as in 2008 through 2010 (Melville and McCubbing 2008), marking of coho smolts at the RST site with upstream relocation was suspended due to a low number of fish available for marking, which previously resulted in an imprecise estimate of coho production.

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 and Pritcher 1969; Figure 11). The fin mark was varied during the migration period to determine the efficiency of the traps through time (temporal stratification).

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 ¼ 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 3-4mm 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 out of direct sunlight. The holding, anesthetic and recovery water were changed frequently during the procedure and aerated using battery-operated pumps. Generally, fish sampled for length, weight and/or scale samples are not used for marking as the added stress may affect their migration behavior and thus their chance of recapture (Frith et al. 1995). As such, when the numbers of available smolts were low (<10 per day or estimated 200 per annum), marking fish was deemed more important than bio-sampling and thus bio-sample sizes may be low or zero. Chinook smolts were not marked in 2011 due to the low numbers captured. All fish caught at the RST and not marked were enumerated and released 300 m downstream of the RST site (Figure 2). Each day's smolt migration is defined as the fish caught in a 24-hour period (approx. 8am to 8am).

For the purpose of marking and enumeration estimates, coho and steelhead age classes were defined by the following fork lengths (as per Table 2): ≥70 mm for coho smolts (age 1, 2009 brood), <70 mm for coho fry (age 0, 2010 brood), and ≥140 mm for steelhead smolts (age 3 and age 2, 2008 and 2009 brood), <140 mm but ≥70 mm for steelhead parr (age 2 and age 1, 2009 and 2010 brood), and <70 mm for steelhead fry (age 0, 2011 brood). Steelhead age was based on the length partitioning of steelhead smolts and parr from juvenile scale samples collected from 2000 to 2003 which were examined by methods described in Ward et al. (1989), and has been previously reported (Melville and McCubbing 2005; Korman and McCubbing 2007). For clarity in comparing reports, steelhead juveniles sampled by snorkeling and electrofishing during March and April under program #3 (Korman et al. 2010) report the ages as one year younger than in this study as the spawning timing in the Cheakamus is typically April/May. For example, an age 2 parr sampled by snorkeling in March 2010 under program #3, would be referred to as an age 3 smolt when it is subsequently captured in the RST during outmigration in

May/June 2010. Three components of the chinook juvenile outmigration were classified by fork lengths – these being as follows: 0+ (2010 brood) early spring (February & March) fry,<70 mm in length; 0+ (2010 brood) late spring (April & May) fry, 70-90 mm in length; and spring 1+ (2009 brood year) spring smolts, >90 mm in length (Table 2)

2.4 Fish Sampling

On the majority of days, 25 coho smolts and 20% of steelhead and chinook smolts and steelhead parr (up to 25 individuals) were measured at the RSTs and at Upper Paradise (Site 1; Figure 2).

Chum, chinook, coho and pink fry were sampled bi-weekly at the RST site for length and weight throughout the sampling period; provided sufficient fish were available.

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 a small stratified sub-sample of steelhead and coho juveniles by the methods detailed in Ward et al. (1989). Steelhead scales are currently being mounted for evaluation and the results will be reported in the five year review of post WUP data collection.

2.5 Mark Recapture Data Analysis

Pooled Peterson population estimates can be calculated from the basic mark recapture equation provided by Ricker (1975):

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

Where **N** = population estimate

C = total catch

R = number of marked fish recaptured

M = number of marks released

In this report as in previous years, analysis was carried out utilizing the SPAS computer program (Arnason et al. 1996) which reports the pooled Peterson estimate (PPE) and its standard error using the

Chapman hyper geometric model, as described in Seber (1982). The term pooled refers to pooling of all mark strata. Actual daily outmigrations 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 residualization 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. The maximum likelihood Darroch (ML Darroch) estimator developed by Plante (1990) has been calculated in previous reports although estimates could not always be produced using this methodology due to sparse data in some strata, therefore to date we have utilized the PPE when comparing annual abundance. Therefore in 2011 in anticipation of calculating all estimates since 2000 utilizing the new statistical model previously described in Section 1.0 (Bonner and Schwarz 2007a; 2007b) the PPE is the only estimate being reported for comparative purposes. Our results in this data report should be considered provisional at this time.

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 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. These small variations in trap efficiency may have a significant effect on yield estimates where catch of unmarked fish is high but when efficiency of capture of marked fish is low and varied. Current statistical methods do not adequately allow for examination of these variances. Further examination of this data in the 2012 review report may result in improved precision and accuracy of population estimates. Modeling to address these issues is ongoing (Bonner and Schwarz 2007a; 2007b) and is in part focused on addressing estimates during the latter part of RST operating periods when river discharge is high and recapture efficiencies may be low.

2.6 Migration Timing - Data and Analysis

In previous reports migration timing has been reported as actual catch per week at the RST, but this method of reporting does not take into account the varied capture efficiencies in each strata. The new statistical model which will be reported in the 2012 summary report generates migration timing curves based on the capture efficiencies in each stratum. In addition the model will assess the effects co-variates such as temperature, discharge and days that trapping was suspended have on capture efficiency and subsequent population estimates in a given strata resulting in a more accurate run-timing curve based on the estimate of number of fish that passed the RST site in a given strata (weekly or daily where the data is available). Therefore we have not included migration timing graphs in this report.

3.0 RESULTS

3.1 Trap and Fyke Net Operations

Operation of traps and fyke nets are affected by river discharge and releases of hatchery fish. High discharge may reduce effective trapping or result in trap loss if precautions are not taken (i.e. trap removal) while hatchery releases result in large numbers of co-migrating fish during short periods which may overwhelm trap box capacities. As such, proposed operational times may be reduced or enumeration days missed during these events. In the case of full span traps, this will result in an estimated minimum outmigration based on the total fish captured rather than an assessment of total numbers passing the trap location. In the case of mark recapture estimates, the theory is that reduced trap operation times will not affect the potential to derive population estimates provided marked fish are still being released. It will however likely result in broader confidence limits around the estimate as a result of lower amounts of marked fish captured than if the trap/fyke net had been fishing (Ricker 1975).

3.1.1 River discharge and trapping operations

The new cableway installed in 2008 allows for the RSTs to fish in deeper flow pockets than the previous system and enabled both RSTs to be operated commencing February 15th, 2011. Due to high flows operation of the RSTs was suspended on June 5th.

In general, two traps were operated until June 5th except when trapping was suspended (i.e. no traps operated) on February 24th and 28th , March 13th -16th , April 1st and 14th , May 7th -9th, 12th -13th, 16th, 31st and June 1st for high water/severe weather events and hatchery releases – a total of 16 days. Limited operation of 1 trap (RST 1) occurred on March 10th (Table 3).

In summary, during the juvenile migration period of February 15th to June 5th, two traps were operated 86% of available days, one trap was utilized for 1% and no traps were operated for 13% of the potential 120 trapping days in 2011.

Enumerator fyke nets were not affected by discharge and were operated until April 30th (Table 1). All fyke net operations were suspended for one day on February 28th due to heavy snowfall limiting safe access to traps. No days of fyke net operation were lost due to NVOS hatchery releases as they moved the release site to downstream of the traps for release (Table 3).

In spring 2011, Upper Paradise/Gorbuscha (UPG) side-channel smolt trap (Site 1; Figure 2) was operated from April 1st to June 5th with no days missed. Trapping was suspended on June 6th due to the trap being overtopped by backwatering from the mainstem Cheakamus (Table 1 & 3). Upper Paradise smolt trap (Site 6; Figure 2) was operated from June 7th to 15th once Site 1 was backwatered; this catch was included in the total side channel production. Kisutch and BC Rail smolt traps were operated from April 1st to June 15th with no trapping days missed (Table 1& 3).

3.1.2 Hatchery releases and trap operations

Trap operations were suspended on a number of days due to hatchery releases from the NVOS hatchery and from the Tenderfoot Creek Hatchery operated by DFO (Table 3).

Chum Fry 0+ (2010 brood)

NVOS released 23,329 chum fry, throughout the trapping period. These fish were all released downstream of the RST site so trapping was not suspended during any of the releases. DFO Tenderfoot Hatchery carried out one release totaling 67,175 chum fry to Tenderfoot Creek on April 13th. Trapping was suspended at the RSTs on April 14th. As the operation of the RSTs was suspended on all chum fry releases the total number of TH hatchery fry was not subtracted from the total estimated chum fry migration at the RSTs, as it was assumed that all these fish passed the enumeration site during trapping suspension.

Coho smolts1+ (2009 brood)

DFO Tenderfoot Hatchery undertook two releases of coho smolts to the Cheakamus in 2011. The first on May 6th comprised of 149,642 adipose clipped fish (average 20.1 g) released to Tenderfoot Creek. The second release on May 11th consisted of 82,684 non-adipose clipped coho smolts (average 19.1 g) released at RK 13-14 (FOC, data on file). To allow the first release to move out of the watershed RST operations were suspended on the evenings of May 6th -8th. Trapping was also suspended after the May

11th release for one night. Unmarked hatchery coho smolts caught after May 11th were easily identified by their appearance and size (average hatchery fish weigh 19.1 g while wild coho sampled at the RST averaged 8.2g in 2011). Hatchery fish were not sampled or included in production estimates.

Chinook 0+ (2010 brood)

As part of a mitigation response to chinook salmon losses after the 2005 NaOH spill, a single release of chinook juveniles to the Cheakamus was done by DFO in the spring of 2011. A release of 98,258 non-adipose clipped juvenile chinook occurred on May 7th into Tenderfoot Creek with RST trapping already suspended for the coho release. The trap was not fished again until the evening of May 9th. The growth of 0+ chinook is accelerated in the hatchery compared to their wild counterparts thus making them easily identifiable by size and appearance. Hatchery chinook averaged 7.23 g while wild 0+ chinook fry captured after April 15th historically have averaged 3 g and 1+ chinook smolts have historically average 10 g (data on file). Thus captured hatchery chinook juveniles were identified based on appearance (size, and colouration) and were not recorded. These fish were excluded from all production estimates.

3.2 Biophysical Monitoring

Discharge (measured at WSC 08GA043) at the Cheakamus River near Brackendale during trap operation ranged from an average daily value of 14.57 m^3/s to 122.46 m^3/s over the period of February 15th to June 15th, 2011 (Figure 12).

Average daily water temperature at the RST data logger ranged from 4.42°C to 9.34°C from February 15th to June 15th, 2011 (Figure 13).

3.3 Mainstem Chum Fry Migration and Production

Chum fry migration appeared to have started just prior to RST operations beginning on February 15th, as small numbers of fish were captured on the first day of trapping – in the first week ending Feb. 18th, 138 fish were caught. The majority of observed fish were sampled between March 7th and April 10th – a total of 70% of chum fry captures. Proportionally, 10%, 50% and 90% of chum fry captures were made by March 9th, March 27th, and April 22nd, respectively. Based on diminished captures in previous years, 90% of the chum fry were estimated to have migrated prior to the drums being changed to larger mesh on April 30th (Melville and McCubbing 2007). The total number of live chum fry caught at the RST site was 170,350 (Appendix 1-A). This is one of the lower captures of chum fry since the study began in 2000, the range of which is 54,527 to 404,883 (Table 4). In addition 17,361 chum fry mortalities were incurred between the two traps. This represented approximately 1.2% of the estimated chum fry emigration, or 9% of the chum fry caught in the traps (Appendix 1-A) and was higher than previously observed.

Eleven mark groups totaling 59,734 fish were re-released upstream. A total of 7,919 of these marked fish were recaptured at the traps. This resulted in an average ECE of 13.3%, the second highest ECE for chum fry in any sample year (Table 4), and an individual mark group recapture rate that ranged from 2.6% to 15.7% (Appendix 2-A). The observed weekly ECE was relatively constant for the weeks during the main portion of the chum fry outmigration (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 1,415,779 fish with a 95% confidence interval of 1,387,360 and 1,444,198 (Appendix 1-A).

3.3.1 Chum Fry Length and Weight

Mean length and weight for chum fry in spring 2011 was 38.5 mm and 0.42 g (Table 5). A statistically significant observed difference in mean fry length was found between the eleven sample years, 2000 to 2011 (ANOVA, $p=0.001$, $F=45.7$, $df=11$). Largest fry were captured in 2001 and 2003, with smallest fish captured in 2004 and 2010 (Table 6).

3.4 Side-Channel Chum Fry Migration and Production

A total pooled Petersen estimate of 669,561 chum fry was calculated for the restoration channels upstream of the RST (Table 7). This figure is the sum of Upper Paradise/Gorbushca complex enumerator fyke trap (Site F; Figure 2 & 5) and BC Rail complex enumerator fyke trap (Site J; Figure 2 & 5) estimates.

3.4.1 Upper Paradise/Gorbushca Complex Chum Migration and Production

Small numbers of chum fry were captured in the first few days after installation on Feb 16th of the Upper Paradise/Gorbushca complex enumerator fyke trap (Site F; Figure 2 & 5). In the first week of operation ending Feb 20th, 11 chum fry were captured. Trapping ended on April 30th when daily capture was diminishing and the drums were changed on the RSTs precluding further estimations of mainstem chum fry. Historic migration timing data also indicates that the chum migration was near completion (Melville and McCubbing 2010; data on file).

The total number of chum fry caught at Site F was 44,350 (Appendix 1-B). In addition 400 chum fry mortalities were incurred. This represented approximately 0.06% of the estimated chum fry emigration, or 0.9% of the chum fry caught in the traps (Appendix 1-B).

Eleven mark groups totaling 35,734 fish were marked and released at the marking fyke traps upstream of Site F on the Upper Paradise/Gorbushca complex (Site B, C; Figure 2 & 5).A total of 3,074 of these marked fish were recaptured at the Upper Paradise/Gorbushca complex enumerator trap (Site F), giving an average ECE of 8.6% and an individual mark group recapture rate that ranged from 3.5% to 11.6% (Appendix 2-B).

Based on the combined mark and recapture data (i.e., pooled Peterson estimator) the total chum fry emigration past the NVOS enumerator trap Site F was estimated to be 651,267 fish with a 95% confidence interval of 629,834 and 672,702 (Appendix 1-B).

3.4.2 Kisutch Groundwater Channel Chum Migration and Production

Chum fry migration did not appear to be underway on February 16th, the first day of operation of the Kisutch enumerator fyke trap (Site D; Figure 2 & 5), as no fish were captured until Feb 20th and only 129 prior to March 1st. The fyke trap was changed to the smolt trap with a holding box on April 1st. The smolt trap does not catch 100% of migrating fry but does increase capture efficiency relative to the fyke net set up. These differences are apparent and accounted for in the stratified estimate methodology. Enumeration of chum fry ended on April 30th, prior to which daily capture in the preceding week was less than 10 fry per day and migration timing data indicated that the chum migration was completed (Melville and McCubbing 2010; data on file).

The total number of live chum fry caught at Kisutch enumerator fyke/smolt trap (Site D) was 19,962 (Appendix 1-B). In addition 275 chum fry mortalities were incurred. This represented approximately 0.25% of the estimated chum fry emigration, or 1.4% of the chum fry caught in the traps (Appendix 1-B).

Seven mark groups totaling 12,581 fish were released upstream at the Kisutch marking fyke trap (Site C; Figure 2 & 5). A total of 2,306 of these marked fish were recaptured at the enumerator fyke trap, giving an average ECE of 18.3% and an individual mark group recapture rate that ranged from 0% to 90.3% (Appendix 2-C).

Based on the combined mark and recapture data (i.e., pooled Peterson estimator) the total chum fry emigration past the Kisutch enumerator fyke trap Site D was estimated to be 110,374 fish with a 95% confidence interval of 106,543 and 114,204 (Appendix 1-B).

3.4.4 BC Rail Complex Chum Migration and Production

No chum fry were captured in the first few days after installation of the BC Rail complex enumerator fyke trap (Site J; Figure 2 & 5) on February 16th. Prior to March 1st only 21 fish were captured. Trapping ended on April 30th when daily capture had diminished to <10 fry per day and migration timing data indicated that the chum migration was near completion (Melville and McCubbing 2010; data on file).

The total number of live chum fry caught at Site J was 6,717 (Appendix 1-B). In addition 110 chum fry mortalities were incurred. This represented approximately 0.6% of the estimated chum fry emigration, or 1.6% of the chum fry caught in the traps (Appendix 1-B).

Three mark groups totaling 977 fish were marked and released at the marking fyke trap (Site K) upstream of Site J on the BC Rail complex (Figure 2 & 5). A total of 364 of these marked fish were recaptured at the BC Rail complex enumerator trap (Site J), giving an average ECE of 37.3% and an individual mark group recapture rate that ranged from 22% to 50.6% (Appendix 2-D).

Based on the combined mark and recapture data (i.e., pooled Peterson estimator) the total chum fry emigration past the BC Rail enumerator trap Site J was estimated to be 18,294 fish with a 95% confidence interval of 16,851 and 19,738 (Appendix 1-B).

3.5 Mainstem Pink Fry Migration and Production

Sixty-four pink fry were captured at the RSTs and one in the side-channels in 2011. These numbers are low as 2010 was an off-year for adult migration to the Cheakamus River and few spawners were observed.

3.6 Chinook Fry and Smolts

3.6.1 Chinook Fry Migration and Production

On February 16th, the first day of trap operations, 310 chinook fry were captured. During the sampling period outmigration was characterized by two peaks in catch: between Feb 16th and March 13th when 38% of the total sample was caught and April 18th to 30th when 35% were caught. No chinook fry were captured after the drums were changed on April 30th. The two temporal modes in the migration pattern are similar to the earlier years of the study 2000-2008, when a later peak of migration was observed (Melville and McCubbing 2008). Proportionally, 10%, 50% and 90% of chinook fry captures were observed on February 22nd, March 29th and April 28th, respectively.

The total number of live chinook fry caught in both traps was 28,910 (Appendix 1-A). This catch ranks as the highest since the study began in 2000, the previous range of which was 499 to 8,742 (Table 4). In addition 2,992 chinook fry mortalities were incurred. This represented approximately 0.4 % of the estimated chinook fry emigration, or 9.4 % of the chinook fry caught in the traps (Appendix 1-A).

Ten mark groups totaling 10,127 fish were re-released upstream. A total of 435 of these marked fish were recaptured at the traps, giving an average ECE of 4.3% and an individual mark group recapture rate that ranged from 3.1% to 7.7% (Appendix 2-E). No fish were marked in the third strata due to higher than normal mortalities being incurred by chinook fry.

Based on the combined mark and recapture data (i.e., pooled Peterson estimator) the total chinook fry outmigration past the trap site was estimated to be 741,085 fish with a 95% confidence interval of 673,579 and 808,590 (Appendix 1-A).

3.6.2 Chinook Smolt Migration and Production

The first captures of chinook smolts occurred on March 20th, and were captured in small numbers until May 30th. Only 56 fish were captured with no mortalities. While the highest daily capture of chinook smolts occurred on May 6th (11 fish) the sampling period was characterized by intermittent daily catches of 1-3 fish.

Insufficient chinook smolts (1+) were captured to undertake a mark recapture experiment and thus no estimate is derived in this sample year for this age class of chinook outmigrants.

3.6.3 Chinook Length and Age Data

Mean length and weight for early chinook fry in spring 2010 was 37.8 mm and 0.45 g (Table 5). There was a statistically significant observed difference in mean length of chinook fry between the eleven sample years 2000 to 2011 (ANOVA, $p<0.001$, $F=248$ $df=10$). Fry lengths in 2011 were similar to those observed in 2009-2010 and are amongst the smallest observed across all years. Fry length has generally been smaller since 2007 (Table 6). Since 2007 the drums have been changed to the larger mesh size at the end of April precluding the capture and sampling of late (90 day) chinook fry likely resulting in the statistical difference in mean length of chinook over the eleven sample years.

Mean length and weight for chinook smolts caught at the RST in the spring of 2011 was 107 mm and 13.52 g. There was a statistically significant observed difference in mean length of chinook smolts between the sample years 2000-2003, 2007 through 2011 (ANOVA, $p<0.001$, $F=4.88$, $df=8$). Insufficient fish were sampled in 2004-2006 for comparative purposes. Sample sizes were low in all years except 2000, 2001 and 2009 (Table 6). Size of smolts was smallest in 2000 and largest in 2003 (likely due to small sample size).

Length frequency for all chinook juveniles was bi-modal with the first mode in the 31 to 45 mm range, representing 0+ fry, and a much less frequent second mode (96-120mm), representing 1+ smolts (Figure 14, Table 2). This is similar to all sample years, 2000 to 2010 (Melville and McCubbing 2000-2010).

3.7 Mainstem Steelhead Parr and Smolts

3.7.1 Mainstem Steelhead Smolt Migration and Production

In 2011, a total of 410 steelhead smolts were captured in the two RSTs with zero mortalities (Appendix 1-A). The range of steelhead smolt numbers captured since 2000 is 5 to 707 (Table 4). Four steelhead smolts were captured prior to marking which commenced on April 18th. Eighty percent of the observed captures (369) occurred between May 2nd and May 29th.

Seven mark groups of fish captured from the RST and Site 1 totaling 444 fish were released upstream at the Eagle Point RST marked fish release site (Figure 2 & 10) between April 18th and June 5th. A total of 47 of these marked fish were recaptured at the traps, giving an average ECE of 10.6% and an individual mark group recapture rate that ranged from 0.0% to 16.7% (Appendix 2-F).

Based on the combined mark and recapture data (i.e., pooled Peterson estimator) the total steelhead smolt outmigration past the trap site was estimated to be 3,772 fish with a 95% confidence interval of 2,835 and 4,709 (Appendix 1-A).3.7.2 Mainstem Steelhead Parr Migration and Production

In total 200 live steelhead parr were captured at the RSTs. Two mortalities were incurred (Appendix 1-A). This is similar to the annual average capture mean of 253 with the range being 6 to 621 fish since the study began in 2000 (Table 4). The peak of steelhead parr captures occurred between April 25th and May 29th, when 77% of steelhead parr were captured. Steelhead parr were not marked and population estimates were not attempted.

3.7.3 Steelhead Lengths and Weights

Mean steelhead smolt length and weight in spring 2011 was 172 mm and 54.16 g, while steelhead parr mean length and weight was 90 mm and 9.1 g (Table 5). There was a statistically significant observed difference in mean length of steelhead smolts between the sample years 2000-2003, 2008 through 2011 (ANOVA, $p<0.01$, $F=2.5$, $df=6$). Insufficient fish were sampled in 2004-2007 for comparative purposes. Smolt lengths were smallest in 2004 and largest in 2003 (Table 6).

Length frequency for all steelhead juveniles (parr and smolts) was bimodal in 2011; likely representing 1 and 2 year old parr (non-migratory) in the 51 to 140 mm range and 2 to 4 year old smolts in the 141 to 220 mm range (Figure 15, Table 2). Scale samples of fish >140 mm were collected, mounted and aged. Data will be summarized for all years in the 2012 summary report.

3.8 Side-channel Steelhead Smolt and Parr Migration & Production

A total count of 153 live steelhead smolts and 483 steelhead parr was obtained for the restoration channels upstream of the RST (Table 7). This figure is the sum of Upper Paradise/Gorbushca complex enumerator trap (Site 1; Figure 2 & 7), Kisutch enumerator trap (Site 3; Figure 2 & 7) and BC Rail complex trap (Site 4; Figure 2 & 7) counts.

3.8.1 Kisutch Channel Steelhead Production

Kisutch channel trap was operational from April 1st through June 15th (Site 3, Figure 2 & 7). During this time a total of 1 steelhead smolt and 27 steelhead parr were captured and all were released downstream of Site 1 (Table 7).

3.8.2 BC Rail Channel Steelhead Production

BC Rail channel counter and trap was operational from April 1st through June 15th (Site 4, Figure 2 & 7). During this time a total of 0 steelhead smolts and 41 steelhead parr were captured and all were released immediately downstream of the trap (Table 7).

3.8.3 Tenderfoot Creek Steelhead Production

A yield of steelhead smolts from Tenderfoot was not possible as the trap was not operational in 2011 and no steelhead were captured during minnow trapping.

3.8.4 Upper Paradise/Gorbushca Steelhead Production

The Upper Paradise/Gorbushca (UPG) full span trap (Site 1) was operated as in previous years from April 1st to June 5th. The UP trap (Site 6) was operated from June 7th to June 15th. The UPG (Site 1) trap captured 373 steelhead parr (plus 3 mortalities) and 151 steelhead smolts (plus 0 mortalities) and the UP (Site 6) trap captured 1 steelhead smolt and 42 steelhead parr between June 7th and 15th (Table 4 & 7).

In an effort to establish the effectiveness of the UPG (Site 1) trap three efficiency tests were conducted in late May by marking coho at the Kisutch and UP (Site 3 and 6) traps and releasing them downstream of this site (Site 6, Figure 2 & 7). The ECEs derived from the coho marked ranged from 77% to 92% and averaged 83% (Table 8). At this time no correction of data has been undertaken as a result of these efficiencies.

3.9 Mainstem Coho Smolt and Fry Migration& Production

The first coho smolt (1+) captures occurred in February but only 371 or 6% of the total was captured prior to March 28th. Coho smolt captures peaked between April 18th and May 29th when 85% of the total sample was caught. The last coho smolts (4) were captured on June 5th. Proportionally, 10%, 50% and 90% of coho smolt captures occurred on April 10th, May 6th, and May 25th, respectively.

A total of 5,665 live coho smolts were captured at the RST in the spring of 2011 (Appendix 1-A). In addition 59 coho smolt mortalities were incurred between the two traps. This represented approximately 0.1% of the estimated coho smolt emigration, or 1.0% of the coho smolts caught in the traps (Appendix 1-A). As in other years, a small component of outmigrants (360 or 6%) was classified as (1 year old) coho parr. These fish were caught primarily in February and March and had not yet achieved the size (>70 mm) and appearance of smolts. Based on previous years' length frequency data (Melville and McCubbing 2001 - 2006), coho juvenile migration on the Cheakamus River is primarily made up of 1 year old smolts (2009 brood year; Table 2).

A final component of coho juvenile monitoring in 2011 was the presence of coho fry, totaling 4,847 live fish and 505 mortalities (Appendix 1-A). These fish have been captured in varying numbers in all years of the study (Table 4). Coho fry migration commenced with newly emerged fry and increased as flows increased during the sample period and dropped to zero when the drums were changed to large mesh on April 30th.

Coho smolts were only marked at the Upper Paradise Gorbushca smolt trap in 2011 (Site 1; Figure 2 & 10). Daily marks were combined to create nine mark groups totaling 5,665 fish, all of which were released at dusk at the Upper Paradise Gorbushca trap site (Site 1, Figure 2) of the day they were marked. A total of 501 of the side-channel marked fish were recaptured at the RST location, giving an average ECE of 8.8%. Recapture rates ranged from 0% to 16.2% (Appendix 2-G).

Using side-channel marked smolts, the combined mark and recapture data (i.e., pooled Peterson estimator) of total coho smolt outmigration past the RST site was estimated to be 60,428 coho smolts with 95% confidence limits of 55,629 and 65,228 (Appendix 1-A).

3.9.1 Coho Lengths

Mean length and weight of coho smolts caught in spring 2011 at the RST site was 90 mm and 8.2 g. Mean length and weight sampled at Upper Paradise channel and Upper Paradise Gorbushca (Site 1) was 86 mm and 7.02 g (Table 5). As in 2010 there was a statistical difference between lengths of smolts captured at the RST (potentially mainstem and/or off-channel rearing, excluding Upper Paradise channel marked smolts) compared with those sampled in the trap at Upper Paradise channel (t test $p<0.001$, $t=10.26$). In general side channel fish were larger and there was a statistically significant difference in the mean length of coho smolts sampled at the RSTs between the ten sample years 2000 to 2011 (ANOVA $p<0.001$, $F=50.7$ $df=12$). Mean smolt length sampled at the RST site was lowest in 2007 and highest in 2006 (Table 6).

The length frequency of all coho juveniles captured at the RSTs and Upper Paradise side-channel in 2011 was normally distributed with smolts peaking between 76 mm and 105 mm in range, and fry between 31 mm and 40 mm (Figure 16). Scales were taken and archived in 2011 for future analysis by the DFO scale reading lab.

3.10 Side-Channel Coho Smolt Migration and Production

A total estimate (combination of trap counts and minnow trap mark recapture estimate) of 18,877 coho smolts was obtained for the restoration channels upstream of the RST (Table 7). This figure is the sum of Upper Paradise/Gorbushca complex enumerator trap count (Site 1; Figure 2 & 7), Upper Paradise smolt trap count (Site 6; Figure 2 & 7) BC Rail complex trap (Site 4; Figure 2 &7) counts and Tenderfoot Creek mark recapture estimate (Table 9). Confidence limits on this combined trap counts/TF estimate are broad due to the low precision derived at Tenderfoot. Estimates incorporating the uncertainty of the mark recapture element of side channel yield range from 13,950 to 23,804 calculated as the sum of all full span capture traps and the upper and lower confidence limits of the Tenderfoot Creek estimate.

Peak capture of coho smolts was between May 9th and June 5th when 72% of the fish were captured (data on file).

3.10.1 Kisutch Channel Coho Smolt Production

Kisutch channel trap was operational from April 1st through June 15th (Site 3, Figure 2 & 7). During this time a total of 1,146 live wild coho smolts plus 6 mortalities were enumerated (Table 7).

3.10.2 BC Rail Channel Coho Smolt Production

BC Rail channel trap was operational from April 1st through June 15th (Site 4, Figure 2 & 7). During this time a total of 806 live coho and 1coho mortality were enumerated (Table 7).

3.10.3 Tenderfoot Creek Coho Smolt Production

In order to assess the coho smolt contribution from Tenderfoot Creek a mark-recapture estimate utilizing minnow traps was undertaken. On April 5th and 6th a total of 80 traps baited with salmon roe each day and were set in Tenderfoot Lake (45) and Creek (35). A total of 629 1+ coho (315 in the lake and 314 in the creek) were marked on April 5th& 6th utilizing a Visible Implant Elastomer tag in the adipose tissue behind the eye (North West Marine Technology, Figure 8). These fish were released and 80 traps were reset on April 7th in roughly the same locations. A total of 448 unmarked coho were captured (214 in the lake and 234 in the creek) with 27 recaptures (16 in the lake and 11 in the creek). A total combined estimate of 10,163 coho smolts was generated with 95% confidence limits of 5,236 to 15,090 (Table 7 & 9). Stratified estimates were not possible as the data relate to one marking and one recapture period and low recapture numbers in both habitat types.

3.10.4 Upper Paradise Gorbushca Coho Smolt Production

The Upper Paradise/Gorbushca (UPG) full span trap (Site 1) was operated as in previous years from April 1st to June 5th. The UP trap (Site 6) was operated from June 7th to June 15th. During this time 6,516 live coho smolts and 23 mortalities were captured at Site 1 (Table 4 & 7). A further 223 coho smolts with no mortalities were captured at Site 6 from June 7th to 15th.

4.0 DISCUSSION

4.1 Fish Trap Operations

Rotary screw trap operation in 2011 was characterized by generally stable river flows between February 16th and May 10th with one moderate (30-40 m^3/s) discharge event March 13th-17th. After May 10th until June 5th, due to warmer temperatures and snow pack melt, river discharge increased to between 50 and 60 m^3/s. In the first week of June the discharge started to increase beyond the operational threshold of 75 m^3/s and it was decided to not fish the RSTs. One or more traps were not operated on a total of 14% of the 120 planned fishing days due to hatchery releases or high water events; 1% of these days only one trap was operated, which is similar to previous years operations.

After fry numbers had declined post-April 30th (Melville and McCubbing 2009) improvements were made to RST design by increasing drum mesh size which visually appeared to improve trap operations in higher flows by reducing drag on the cableways. As observed in 2009, improved capture efficiencies of smolts were recorded, by increasing the velocity of water passing through the trap and subsequently increasing drum rotation speed during average discharges.

Fish traps were operated from early April 1st through June 15th on three side-channels until fish migration declined towards zero in mid-June (Table 1). No days of operation were lost due to trap malfunction but trap operation at the new Site 1 was suspended for 10 days due to backwatering of the main river, instead site 6 was operated. This was typical of previous sample years.

Fyke traps were operated to assess fry production between February 16th and April 30th (Table 1) at a number of restoration channel locations. There were no days lost to hatchery releases or trap malfunctions in 2011 and just one day lost due to weather (snow). This was similar to previous sample years.

4.2 Juvenile Outmigration Production

4.2.1 Data Analysis

In 2011 Pooled Peterson estimates were calculated for all the major migratory species/age class cohorts. No stratified statistical analysis (i.e Darroch) was undertaken in 2011. In previous years these analyses have indicated that there may be bias in the calculated pooled estimates due to capture limitations (i.e. low and varied trap efficiency). To examine the potential bias incorporated in these estimates a new Bayesian model has been developed (Bonner and Schwarz 2011) and all mark recapture data since 2001 is being re-analysed and will be presented in a future summary report.

In addition to dealing with potential bias in the total population estimates this model will also estimate migration timing based on individual strata estimates. In previous years migration timing has been reported based on fish captured per week at the RSTs uncorrected for trap efficiency. However, inaccurate evaluation of migration timing curves is likely if catch is low due to our inability to fish (hatchery releases, discharge etc.). By estimating the population in each strata and then using those individual estimates to develop a migration curve we will more accurately estimate how many fish actually passed the trap in a given strata. These results will be presented in the 2012 summary report.

4.2.2 Chum Fry Migration

Mainstem Chum Fry Production

In 2011, average recapture rates (13.3%) for chum fry were the second highest on record (2009 was 14%) and some three-fold that of some previous years (2002 and 2004; 4.6% and 4.4%, respectively) and ten-fold the lowest recapture rates recorded in 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 2009, 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 (Table 4). In 2011 we captured very high numbers of fish for marking (approximately 60k) while actual capture of chum was low, and were able to operate two traps most of the time due to new cableway installation (completed in 2008) and generally stable flows during the fry migration.

In 2011 results indicate a below average production year with the lowest estimate to date with 1.4 million fry outmigrating from above the RST site. The pooled Petersen estimate and 95% confidence limits calculated for chum fry at the RST site has varied over the twelve study years from a high of 4.6 million in 2006 through a low of just less than 1.5 million in 2011 (Figure 17; Table 4).

Side-Channel Chum Fry Production

As part of increased monitoring efforts derived for the WUP, chum fry production from several channels has been assessed since the spring of 2007. These locations represented groundwater only channels (Upper Paradise groundwater; Site B, BC Rail; Site J; and Kisutch Site D), as well as the entire Upper Paradise/Gorbushca complex (Site F) which includes flow-through and groundwater channels.

Total chum fry production was estimated at 651,000 fish above Site F the yield for the entire Upper Paradise/Gorbushca channel complex. This compares with an estimated yield of 817,149 fry in 2009 – a similar figure to the 834,316 yield estimate for this location in 2008, but much less (~1/3) the estimates in 2010 and 2007; 1.8 and 1.6 million fry respectively. In 2007 this yield did not include an unknown number that migrated prior to the start of trapping on March 3rd (~14 days later than 2008 through 2011).

An estimated 110,374 chum fry were enumerated leaving Kisutch channel in 2011. This compares with a range of 103,404 to 501,504 in all sample years and 283,720 in 2010. Accurate adult escapement data for this channel is not available, although the entire complex was noted to have a chum spawner escapement 3 fold higher in 2009 than in 2008. Of the Upper Paradise/Gorbushca complex production in 2011, we estimate 17% of the yield originated from the groundwater fed source Kisutch channel, compared with a range of 12-35% in 2007-2010.

In 2011, 18,294 chum fry were estimated outmigrating from BC Rail channel. This compares with a range of 163,480 to 266,313 in 2008 through 2010. The large decrease in fry yield in this channel in 2011 is in part explained from the much lower spawner escapement observed in 2010 (McCubbing et al. 2011) but may also be affected by lower flows associated with a beaver dam at Dave’s Pond (Figure 2) and observed increases in sediment accumulation in the channel.

Due to the connection of a new flow-through channel (Sue's Channel, 2006) some 500 m downstream of the blind end of the Upper Paradise channel, the effective area of groundwater only influenced habitat in this location has been much reduced and as such fry abundance is low, making enumeration imprecise. Therefore no data was collected for this channel in 2011.

The total production of chum fry from the Upper Paradise/Gorbushca spawning channel complex and BC Rail channel combined in 2011 was 670,000 fry the lowest since sidechannel assessment commenced in 2007 (1-2 million fry). In 2011 this represents approximately 48% of the total chum fry production estimated by the Pooled Peterson method at the RST site (1.4 million) which is similar to the 50% contribution which was observed in 2009 (Melville and McCubbing 2009) but slightly lower than the 60% and 64% proportional yield observed in 2010 and 2008. Regardless of the shifts in annual proportional yield the data highlights the significant annual contribution of these and likely other natural (i.e. Tenderfoot) channels to chum salmon productivity in the Cheakamus River above the RST site at RK 5.5.

4.2.3 Pink Fry Migration

As it was an off year for pink salmon adult returns in 2010, very few pink spawners returned to the river and subsequent fry observations confirm the lack of recruitment that is typical in this species in the Cheakamus in off years (Figure 18; Table 4).

4.2.4 Chinook Juvenile Migration

Chinook juvenile migration on the Cheakamus River appears to be made up of four migrant components: spring 0+ chinook fry (early: February and March), spring 0+ chinook fry (late: April and May), spring 1+ chinook smolts (April-June), and fall (October/November) 0+ fry (Melville and McCubbing 2001, 2002; Table 4). 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 2010).

An estimate of 741,085 0+ outmigrant chinook fry was generated in 2011. This is the highest estimate of chinook fry since the study began in 2000. The pooled Petersen estimate and 95% confidence limits for chinook fry has varied over the eight years that estimates were obtained. Prior to 2011 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 sample years where the estimate was derived from small numbers of fish that were available to mark and recapture (300 and 329 marked in 2004 and 2005, respectively (Figure 19; Table 4). In 2011, the high yield estimate of 0+ chinook fry coincides with the highest (3-fold) capture of chinook fry which indicates a stronger population of chinook than has been observed in the previous 11 years of the study. There is some evidence this may be in part the result of good spawner escapement in 2010 (B. Klassen, pers. comm.)

In 2011, no estimate of outmigrant chinook smolts could be derived due to low captures of fish for marking (56). In comparison, the pooled Petersen estimate for chinook smolts has varied from a high of 4,534 smolts in 2009 to a low of 1,189 in 2003 in the four years for which an estimate has been calculated (2000-2003; Figure 28; Table 4). However, the relatively low number of chinook smolts captured and marked each year (55 to 254 fish) has resulted in wide confidence limits around each of these estimates. Each year since 2004 except 2009, very low captures of chinook smolts (1-81) have been recorded and no estimate of outmigration has been possible. This situation will likely have resulted from low trap efficiencies in previous years but in 2011 with capture efficiencies acceptable for other smolts it is more likely related to low numbers of outmigrants.

As previously reported, it has been difficult to obtain consistent and precise estimates of all cohorts of chinook juvenile outmigration (Melville and McCubbing 2006). Given not only the challenges in obtaining juvenile and adult population estimates but also the diversity in life history, the unquantified effects of varied hatchery releases, and, more recently, the potential effects of the 2005 chemical spill (McCubbing et al. 2006) and subsequent hatchery intervention on future cohort strengths, chinook salmon may be a poor choice for utilization in monitoring the effects of flow regulation. However, continued collection of abundance data and development of production estimates where possible are warranted if only for evaluation of trend data, given that fish are captured incidentally during trapping operations.

4.2.5 Steelhead Juvenile Migration

Spring steelhead juvenile migration on the Cheakamus River consists of two components: steelhead smolts and steelhead parr. No young of the year steelhead fry were captured in the spring as fry emergence occurs in July after the end of the trap operations (Melville pers. obs., data on file).

In 2011, we estimated a pooled Peterson estimate of 3,772 outmigrant steelhead smolts. However, as in previous years and compared to more abundant species (chum, pink, and coho) the relatively low numbers of fish captured and marked over the six years where an estimate has been derived has resulted in low precision of generated estimates (Figure 21). Previous estimates of smolt yield have ranged from a low of 2,467 in 2001 to a high of 6,617 in 2008 (Figure 21; Table 4). The estimated yield of 3,772 steelhead smolts ranks sixth of the eight sample years where an estimate has been calculated.

The inability to consistently develop robust estimates of steelhead smolts at the RST site due to low fish numbers and low recapture efficiencies at elevated flows later in the migration period precludes direct comparisons to adult estimates in some years and restricts the utility of this data in assessing the effects of varied flow regimes. To augment these data a monitor assessing YOY recruitment and abundance of 1+ and 2+ parr was initiated in 2007 (Cheakamus Water Use Plan: Monitoring Program Terms of Reference, Monitor #3, Feb. 2007, Korman et al 2009). This study, in addition to data collected in the existing juvenile and adult programs, will improve the understanding of freshwater production and the status of steelhead juveniles in the Cheakamus River in future years. It should also provide important information on the effects of events such as the new flow regime, the 2003 flood, and the 2005 fish kill on juvenile steelhead production and abundance.

Steelhead parr captures at the RST site are classified as incidental as these fish are unlikely to migrate to the ocean or survive if they do (Ward et al. 1989) and may just be relocating within the watershed. In 2011, 202 steelhead parr were captured. While these data are likely to be a trend indicator of parr abundance, there has been no definitive relationship derived between RST parr captures and smolt PPE in subsequent years (Table 4).

4.2.6 Mainstem Coho Smolt Migration

The pooled Petersen estimate for coho smolts estimated from smolts captured and marked at the side-channels has varied over the eleven 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 (Figure 22; Table 4) compared with 60,428 this year which ranks ninth in all sample years. The 95% confidence limits for each of the eleven years have been fairly consistent with the narrowest confidence limits occurring in 2001 (Figure 22). The highest number of fish caught and marked occurred in 2001 (marking occurred at more side channel traps) and is likely responsible for the low confidence limits around that years estimate, as despite lower efficiencies than recent years, more marks were recaptured. The highest ECE was recorded in 2010, and the second highest in 2009, while the 2011 ECE ranks fifth of the eleven sample years. This lower ECE may have been the result of a number of lost trapping days in the peak migration due to hatchery releases.

4.2.7 Side-Channel Coho Smolt Migration

A total yield of 7,662 coho smolts were enumerated outmigrating from Upper Paradise in 2011 (Site 1 & 3 combined). This is the lowest catch since the UPG complex has been assessed (2009-2011). At Kisutch channel 1,146 coho smolts were enumerated, the second lowest catch on record (275-9,664; avg: 3,060). BC Rail channel in comparison produced 806 smolts, similar numbers to recent years, (mean post WUP of 1,093) but much lower than the one pre WUP sample of 5,744 fish in 2001. The estimates for Tenderfoot Creek (6,168) and Lake (3,995) in 2011 were more precise than in 2010 whose estimates were compromised by an early release of hatchery fish during the normal trapping period but still exhibit broad confidence limits due to low recapture efficiency.

Historically between 7 and 27% (mean = 15%) of the total annual estimated coho yield at the RST has been derived from the Upper Paradise Site 6 trap (Site 1 trap not having been added to our monitoring plan until 2007) indicating the high variance in contribution of this restoration channel to each outmigration year class. In 2011, combining the estimates of coho smolt yield from the Upper Paradise complex (7,662), BC Rail channel (806), and the Tenderfoot Lake and Creek estimate (10,163) 31% of the RST derived coho smolt outmigration estimate originated from the restoration channels which were enumerated.

5.0 SUMMARY AND RECOMMENDATIONS

The objectives for the twelfth year of trap operation in the Cheakamus River were largely attained for all species and age classes at all locations. In summary, the data we obtained included:

- mark-recapture data for migrating juveniles with 95% confidence intervals on the estimates of chum and chinook fry, steelhead and coho smolts
- biological data on all species: lengths and weights
- a twelfth year of smolt and fry yield data with comparisons to previous sample years and to river discharge and temperature
- a fifth year of expanded side-channel production for partitioning from mainstem production

Chum fry estimates were successfully generated in three channels and at the RST site. The methodology used for fry marking at the RST site in 2011 was the same as was used since 2004 although as in 2010 improved capture efficiencies were reported compared to pre 2008 data. This is likely linked to the new trap cableway system and trap fishing flexibility.

The physical geography of Upper Paradise groundwater channel has been altered since the study was designed and, as a result, the area available for groundwater production evaluation is now much reduced in size and with minimal directional flow. Fyke nets operated in 2007 through 2010 failed to capture sufficient fish for marking purposes and thus provided unreliable yield estimates (Melville and McCubbing 2010). No effort to operate these traps was made in 2011. The fyke net and trap boxes were used instead in BC Rail channel in 2011 as in 2008 through 2010 for fry enumeration, creating an additional yield estimate for chum fry in a groundwater channel, as well as defensible estimate in an area being enumerated during the chum adult study (Troffe et al. 2008; McCubbing et al. 2011). Linkages between adult chum escapement and fry yield from the groundwater channels can now be examined with preliminary survivals within the range expected from the literature.

The smolt enumeration facility operated in 2011 on the Upper Paradise/Gorbushca channel complex (Site 1; Figure 2.) was intended to capture all smolts originating from the entire channel complex. A redesign of this facility in 2010 resulted in much improved catches of coho and steelhead smolts and an estimated catch efficiency of greater than 80% was recorded through mark recapture experiments therefore the trap at Site 6 was only operated at the end of the trapping season when the mainstem Cheakamus backwatered the Site 1 trap.

New RST drums with an increased mesh size were utilized from early May 2011 through early June as in 2007 through 2010. From visual observations, these drums appear to have increased water flow and reduced drag. Improvements in infrastructure including permanent moorings with increased cable tolerances also allowed for improvements in trap operations at elevated flows and during periodic flood events with increased river discharge and water velocities, provided that discharges remained below 75 m3/s.

Efforts to enumerate coho smolt yield from Tenderfoot Creek have been varied in the three years (since 2009) the utilization of a minnow trap mark recapture method has been used. This change to study design was undertaken as full span trapping (the preferred method) required frequent suspension due to large releases of hatchery fish over prolonged periods. During these periods when the trap was not fishing, an unknown number of wild fish would likely pass the trap without enumeration. As in 2009, estimates derived by this method exhibited relatively broad confidence limits a result of low recapture efficiencies, thought to be due to outmigration of tagged fish occurring during the study period.

An improved statistical method of assessing the utility of RST derived yield estimates to track variations in smolt and fry production is now available for evaluation. This will be used to evaluate current statistical analysis methods and linkages between estimated yields and inter-annual river discharge. Current evidence of the precision of annual yield estimates indicates the potential for the use of this data in assessing the reasons for annual yield variances, but we must be certain they are real changes in yield and not artifacts of data collection methods. The current time series of data and additional data collected from unique daily marking of coho smolts is being used to ground truth modeling exercises which seek to examine the effects of run timing and river discharge on trap efficiency and by default the confidence of smolt yield estimates (J. Korman, Ecometric Ltd, pers. comm.). This data will be analysed in the 2012 summary report.

After a sixth full year of river discharges affected by the WUP (February 2006 through June 2010), the estimated outmigration mainstem derived yields of chum, pink and chinook fry and steelhead and coho smolts remained within the variance observed of yields reported during pre WUP flow requirements years (Melville and McCubbing 2006). At this time no trend data has been observed in juvenile salmonid yields. Other factors which will have affected recent yields will likely include river discharge including natural extreme flood events (2003), adult escapements (linked to marine survival), and the 2005 chemical spill and resultant fish kill. In the planned summary report a review of juvenile yield and discharge conditions during spawning, incubation and rearing will be undertaken to evaluate if linkages between juvenile yields and discharge are observed. This report will also utilize the Bayesian model developed by Bonner and Scwharz (2007a) to improve yield estimate confidence particularly in periods of elevated discharge when trap efficiencies are compromised.

6.0 TABLES

Table 1. Start and end dates for all traps and counters operated on the Cheakamus River, Spring 2011.

Trap/Counter Name	Start Date	End Date	Comments
RST1	February 15	June 5	Larger mesh drums installed on April 30. Limited operation after May 30 due to high water
RST2	February 15	June 5	Larger mesh drums installed on April 30. Limited operation after May 30 due to high water
NVOS side channel complex Fyke: F1	February 16	April 30	Downstream side-channel fry enumerator
Upper Paradise Fyke: F2	February 16	April 30	Upstream side-channel fry marking
Kisutch Fyke 2: F3	February 16	April 1	Downstream side-channel fry enumerator Changed to smolt/fry trap (Site 3) on March 31
Kisutch Fyke 1: F6	February 16	April 21	Upstream side-channel fry marking
Sue's Channel Fyke: F4	n/a	n/a	Upstream side-channel fry marking. Not operated in 2011
BC Rail: F7	February 16	April 30	Downstream side-channel fry enumerator
BC Rail: F8	February 16	April 14	Upstream side-channel fry marking
NVOS side channel complex smolt trap (Site 1)	April 1	June 6	Total capture fish trap & Upstream of RST smolt marking
Upper Paradise smolt mark trap (Site 6)	April 1	June 15	Upstream smolt marking
Kisutch Smolt Counter (Site 3)	April 1	June 15	Counter estimate and total capture smolt and fry trap
BC Rail Counter (Site 4)	April 1	June 15	Counter estimate and total capture smolt trap
Tenderfoot Counter (Site 5)	n/a	n/a	Counting replaced with minnow trap estimate as hatchery released confound results

Table 2. Summary of size ranges for age classes of salmonid and trout species on the Cheakamus River, Spring 2011.

Species	Age(s)	Brood year(s)	Code	Size range	Reference
Coho smolt	1	2009	COS	≥70mm	Cheakamus length frequency data (2000-2006)
Coho Fry	YOY	2010	COF	< 70mm	Cheakamus length frequency data (2000-2006)
Steelhead Smolt	2 to 4 years	2007 to 2009	SHS	≥ 140mm	Melville &McCubbing, 2004, Korman&McCubbing 2007
Steelhead Parr	1+	2009 and 2010	SHP	< 140mm	Melville &McCubbing, 2004, Korman&McCubbing 2007
Early Chinook Fry (Feb. & March)	YOY	2010	CHF	< 70mm	Cheakamus length frequency data (2000-2006)
Late Chinook Fry (April & May	YOY	2010	CHF	70-90mm	Cheakamus length frequency data (2000-2006)
Chinook Smolts	1 year +	2009	CHS	>90mm	Cheakamus length frequency data (2000-2006)

Table 3.Trap dates for which trap operation was limited or suspended (1 day = 24 hrs).

River	Trap_Code	Date	Comments
Cheakamus	RST 1	24-Feb-11	Hurricane Force winds/crew safety
Cheakamus	RST 2	24-Feb-11	Hurricane Force winds/crew safety
Cheakamus	RST 1	28-Feb-11	Heavy snowfall limiting access to traps
Cheakamus	RST 2	28-Feb-11	Heavy snowfall limiting access to traps
Cheakamus	F1	28-Feb-11	Heavy snowfall limiting access to traps
Cheakamus	F2	28-Feb-11	Heavy snowfall limiting access to traps
Cheakamus	F3	28-Feb-11	Heavy snowfall limiting access to traps
Cheakamus	F6	28-Feb-11	Heavy snowfall limiting access to traps
Cheakamus	RST1	10-Mar-11	Cable malfunction
Cheakamus	RST1	13-Mar-11	Highwater and debris
Cheakamus	RST2	13-Mar-11	Highwater and debris
Cheakamus	RST1	14-Mar-11	Highwater and debris
Cheakamus	RST2	14-Mar-11	Highwater and debris
Cheakamus	RST1	15-Mar-11	Highwater and debris
Cheakamus	RST2	15-Mar-11	Highwater and debris
Cheakamus	RST1	16-Mar-11	Highwater and debris
Cheakamus	RST2	16-Mar-11	Highwater and debris
Cheakamus	RST1	1-Apr-11	Highwater and debris
Cheakamus	RST2	1-Apr-11	Highwater and debris
Cheakamus	RST1	14-Apr-11	Hatchery cmf release
Cheakamus	RST2	14-Apr-11	Hatchery cmf release
Cheakamus	RST1	7-May-11	Hatchery cos release
Cheakamus	RST2	7-May-11	Hatchery cos release
Cheakamus	RST1	8-May-11	Hatchery cos and chf release
Cheakamus	RST2	8-May-11	Hatchery cos and chf release
Cheakamus	RST1	9-May-11	Hatchery cos and chf release
Cheakamus	RST2	9-May-11	Hatchery cos and chf release
Cheakamus	RST1	12-May-11	Hatchery cos release
Cheakamus	RST2	12-May-11	Hatchery cos release
Cheakamus	RST1	13-May-11	Highwater and debris
Cheakamus	RST2	13-May-11	Highwater and debris
Cheakamus	RST1	16-May-11	Highwater and debris
Cheakamus	RST2	16-May-11	Highwater and debris
Cheakamus	RST1	31-May-11	Highwater and debris
Cheakamus	RST2	31-May-11	Highwater and debris
Cheakamus	RST1	1-Jun-11	Highwater and debris
Cheakamus	RST2	1-Jun-11	Highwater and debris

Table 4. Eleven-year summary of live fish caught and marked at the rotary screw trap and side-channels on the Cheakamus River.

Species	Year	Total Caught (live)	Total Marked	Total Recap	ECE%	PPE
Chum Fry	2000	54,527	8,415	109	1.3	3,889,974
Chum Fry	2001	120,742	43,520	3,557	8.2	1,486,982
Chum Fry	2002	103,932	23,685	1,101	4.6	1,967,233
Chum Fry	2003	65,505	12,239	193	1.6	4,066,391
Chum Fry	2004	135,372	63,005	2,775	4.4	3,134,252
Chum Fry	2005	173,924	62,283	4,425	7.1	2,509,793
Chum Fry	2006	354,337	94,285	7,798	8.5	4,270,934
Chum Fry	2007	395,378	82,827	6,975	8.4	4,635,606
Chum Fry	2008	85,923	35,533	1,962	5.5	1,544,234
Chum Fry	2009	284,958	48,382	6,759	14.0	2,036,694
Chum Fry	2010	404,883	94,647	10,801	11.4	3,544,576
Chum Fry	2011	187,711	59,734	7,919	13.3	1,415,779
Chinook Fry	2000	1,537	185	3	1.6	n/a
Chinook Fry	2001	8,558	3,111	220	7.1	119,841
Chinook Fry	2002	7,554	1,571	91	5.8	130,646
Chinook Fry	2003	5,758	2,435	75	3.1	212,796
Chinook Fry	2004	733	300	4	1.3	44,426
Chinook Fry	2005	917	329	4	1.2	60,851
Chinook Fry	2006	499	n/a	n/a	n/a	n/a
Chinook Fry	2007	8,742	2,853	146	5.1	150,374
Chinook Fry	2008	5,144	2,015	45	2.2	186,741
Chinook Fry	2009	8,024	3,172	274	8.6	84,562
Chinook Fry	2010	3,574	1,082	73	6.7	44,636
Chinook Fry	2011	31,924	10,127	435	4.3	741,085

Table 4. continued

Species	Year	Total Caught (live)	Total Marked	Total Recap	ECE%	PPE
Pink Fry	2000	1,241	156	0	0	n/a
Pink Fry	2001[1]	8	n/a	n/a	n/a	n/a
Pink Fry	2002	26,876	5,304	113	2.1	1,255,981
Pink Fry	2003[1]	0	n/a	n/a	n/a	n/a
Pink Fry	2004	2,844	1,521	53	3.5	81,679
Pink Fry	2005[1]	3	n/a	n/a	n/a	n/a
Pink Fry	2006	41,418	10,811	1,567	14.5	296,405
Pink Fry	2007[1]	19	n/a	n/a	n/a	n/a
Pink Fry	2008	41,873	19,299	846	4.4	945,448
Pink Fry	2009[1]	1	n/a	n/a	n/a	n/a
Pink Fry	2010	234,316	57,124	3,942	6.9	3,363,608
Pink Fry	2011	64	n/a	n/a	n/a	n/a
Coho Fry	2000	1,088	n/a	n/a	n/a	n/a
Coho Fry	2001	5,295	n/a	n/a	n/a	n/a
Coho Fry	2002	1,239	n/a	n/a	n/a	n/a
Coho Fry	2003	2,163	n/a	n/a	n/a	n/a
Coho Fry	2004	3,121	n/a	n/a	n/a	n/a
Coho Fry	2005	597	n/a	n/a	n/a	n/a
Coho Fry	2006	2,638	n/a	n/a	n/a	n/a
Coho Fry	2007	10,691	n/a	n/a	n/a	n/a
Coho Fry	2008	2,696	n/a	n/a	n/a	n/a
Coho Fry	2009	1,306	n/a	n/a	n/a	n/a
Coho Fry	2010	6,622	n/a	n/a	n/a	n/a
Coho Fry	2011					

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

Table 4. continued

Species	Year	Total Caught (live)	Total Marked	Total Recap	ECE%	PPE
Chinook Smolt	2000	348	158	28	17.7	2,133
Chinook Smolt	2001	313	254	33	13.0	2,984
Chinook Smolt	2002	89	62	2	3.2	1,931
Chinook Smolt	2003	81	55	3	5.5	1,189
Chinook Smolt	2004	4	n/a	n/a	n/a	n/a
Chinook Smolt	2005	2	n/a	n/a	n/a	n/a
Chinook Smolt	2006	1	n/a	n/a	n/a	n/a
Chinook Smolt	2007	47	n/a	n/a	n/a	n/a
Chinook Smolt	2008	52	n/a	n/a	n/a	n/a
Chinook Smolt	2009	412	115	9	7.8	4,534
Chinook Smolt	2010	83	n/a	n/a	n/a	n/a
Chinook Smolt	2011	56	n/a	n/a	n/a	n/a
RST Steelhead Smolt	2000	429	238	23	9.7	4,281
RST Steelhead Smolt	2001	207	154	12	7.8	2,467
RST Steelhead Smolt	2002	115	76	2	2.6	3,028
RST Steelhead Smolt	2003	373	287	23	8.0	4,583
RST Steelhead Smolt	2004	9	n/a	n/a	n/a	n/a
RST Steelhead Smolt	2005	21	n/a	n/a	n/a	n/a
RST Steelhead Smolt	2006	5	n/a	n/a	n/a	n/a
RST Steelhead Smolt	2007	20	n/a	n/a	n/a	n/a
RST Steelhead Smolt	2008	388	208	11	5.3	6,617
RST Steelhead Smolt	2009	705	491	60	12.2	5,314
RST Steelhead Smolt	2010	378	289	23	8.0	4,494
RST Steelhead Smolt	2011	410	444	47	10.6	3,772

Table 4. continued

Species	Year	Total Caught (live)	Total Marked	Total Recap	ECE%	PPE
UP[2] Steelhead Smolt	2001	138	n/a	n/a	n/a	n/a
UP[2] Steelhead Smolt	2002	125	n/a	n/a	n/a	n/a
UP[2] Steelhead Smolt	2003	78	n/a	n/a	n/a	n/a
UP[2] Steelhead Smolt	2004	54	n/a	n/a	n/a	n/a
UP[2] Steelhead Smolt	2005	38	n/a	n/a	n/a	n/a
UP[2] Steelhead Smolt	2006	13	n/a	n/a	n/a	n/a
UP[2] Steelhead Smolt	2007	30	n/a	n/a	n/a	n/a
UP[2] Steelhead Smolt	2008	193	n/a	n/a	n/a	n/a
UP[2] Steelhead Smolt	2009	186	n/a	n/a	n/a	n/a
UP[2] Steelhead Smolt	2010	155	148	11	7.4	4,593
UP[2] Steelhead Smolt	2011					
RST Steelhead Parr	2000	136	n/a	n/a	n/a	n/a
RST Steelhead Parr	2001	238	n/a	n/a	n/a	n/a
RST Steelhead Parr	2002	143	n/a	n/a	n/a	n/a
RST Steelhead Parr	2003	256	n/a	n/a	n/a	n/a
RST Steelhead Parr	2004	36	n/a	n/a	n/a	n/a
RST Steelhead Parr	2005	42	n/a	n/a	n/a	n/a
RST Steelhead Parr	2006	6	n/a	n/a	n/a	n/a
RST Steelhead Parr	2007	621	n/a	n/a	n/a	n/a
RST Steelhead Parr	2008	171	n/a	n/a	n/a	n/a
RST Steelhead Parr	2009	314	n/a	n/a	n/a	n/a
RST Steelhead Parr	2010	620	n/a	n/a	n/a	n/a
RST Steelhead Parr	2011	202	n/a	n/a	n/a	n/a

[2] Upper Paradise (Site 6) catch.

Table 4. continued

Species	Year	Total Caught (live)	Total Marked	Total Recap	ECE%	PPE
UP[2] Steelhead Parr	2001	132	n/a	n/a	n/a	n/a
UP[2] Steelhead Parr	2002	159	n/a	n/a	n/a	n/a
UP[2] Steelhead Parr	2003	387	n/a	n/a	n/a	n/a
UP[2] Steelhead Parr	2004	660	n/a	n/a	n/a	n/a
UP[2] Steelhead Parr	2005	73	n/a	n/a	n/a	n/a
UP[2] Steelhead Parr	2006	14	n/a	n/a	n/a	n/a
UP[2] Steelhead Parr	2007	371	n/a	n/a	n/a	n/a
UP[2] Steelhead Parr	2008	113	n/a	n/a	n/a	n/a
UP[2] Steelhead Parr	2009	216	n/a	n/a	n/a	n/a
UP[2] Steelhead Parr	2010	380	n/a	n/a	n/a	n/a
UP[2] Steelhead Parr	2011					
RST Coho Smolt	2000	11,177	7,222	1,478	20.5	61,244
RST Coho Smolt	2001	6,394	2,517	400	15.9	39,960
RST Coho Smolt	2002	3,120	1,382	112	8.1	35,726
RST Coho Smolt	2003	7,616	4,129	500	12.1	66,911
RST Coho Smolt	2004	1,238	755	30	4.0	32,557
RST Coho Smolt	2005	1,618	1,060	61	5.8	28,748
RST Coho Smolt	2006	1,379	757	49	6.5	21,602
RST Coho Smolt	2007	7,235	6,031	625	10.4	80,737
RST Coho Smolt	2008	3,036	n/a	n/a	n/a	n/a
RST Coho Smolt	2009	7,634	n/a	n/a	n/a	n/a
RST Coho Smolt	2010	12,651	n/a	n/a	n/a	n/a
RST Coho Smolt	2011	5,724	n/a	n/a	n/a	n/a

Table 4. continued

Species	Year	Total Caught (live)	Total Marked	Total Recap	ECE%	PPE
SC Coho Smolt	2000	n/a	n/a	n/a	n/a	n/a
SC Coho Smolt	2001	30,616	29,883	2,851	9.3	67,298
SC Coho Smolt	2002	21,221	17,861	813	4.6	68,484
SC Coho Smolt	2003	28,666	24,606	1,812	7.4	127,974
SC Coho Smolt	2004[3]	10,588	8,249	175	2.1	66,186
SC Coho Smolt	2005[3]	4,580	3,355	138	4.1	39,087
SC Coho Smolt	2006[3]	5,472	4,578	173	3.8	36,209
SC Coho Smolt	2007[3]	9,159	7,422	676	9.1	85,018
SC Coho Smolt	2008[3]	6,596	5,972	196	3.3	91,170
SC Coho Smolt	2009[4]	10,330	8,764	1,035	11.8	60,736
SC Coho Smolt	2010[4]	22,996	14,857	2,030	13.7	89,673
SC Coho Smolt	2011[4]		5,665	501	8.8	60,428
UP[2] Coho Smolt	2000	n/a	n/a	n/a	n/a	n/a
UP Coho Smolt	2001	18,386	n/a	n/a	n/a	n/a
UP Coho Smolt	2002	15,794	n/a	n/a	n/a	n/a
UP Coho Smolt	2003	20,241	n/a	n/a	n/a	n/a
UP Coho Smolt	2004	10,588	n/a	n/a	n/a	n/a
UP Coho Smolt	2005	4,580	n/a	n/a	n/a	n/a
UP Coho Smolt	2006	5,472	n/a	n/a	n/a	n/a
UP Coho Smolt	2007	9,159	n/a	n/a	n/a	n/a
UP Coho Smolt	2008	6,596	n/a	n/a	n/a	n/a
UP Coho Smolt	2009	8,091	n/a	n/a	n/a	n/a
UP Coho Smolt	2010	11,295	n/a	n/a	n/a	n/a
UP Coho Smolt[5]	2011	n/a	n/a	n/a	n/a	n/a

3. Only Upper Paradise trap operated (in previous years Tenderfoot and Kisutch were used).
4. Catch is combined live catch at UP (Site 6) and UPG (Site 1) not expanded for trap efficiency at Site 1.
5. Upper Paradise (Site 6) was only operated to obtain fish for UPG (Site 1) efficiency tests and when UPG was backwatered.

Table 5.Summary of length & weight data from fish captured at the rotary screw traps on the Cheakamus River, Spring 2011.

Species		Length (mm)	Weight (g)
Chum Fry	**N**	465	465
	Range	35-45	0.28-0.62
	Mean	39	0.42
	SD	1.44	0.06
Chinook Fry (early - prior to April 15)	**N**	350	350
	Range	33-48	0.34-0.68
	Mean	38	0.45
	SD	1.86	0.07
Chinook Fry (late - after April 15)	**N**	97	97
	Range	33-82	0.32-6.40
	Mean	44	1.03
	SD	12.55	1.29
Chinook Smolts	**N**	55	55
	Range	76-119	5.2-19.1
	Mean	107	13.52
	SD	8.95	3.28
Pink Fry	**N**	n/a	n/a
	Range		
	Mean		
	SD		
Coho Fry	**N**	217	216
	Range	30-40	0.30-0.52
	Mean	35	0.39
	SD	1.61	0.04
Steelhead Smolts	**N**	142	141
	Range	140-220	14.0-124.8
	Mean	172	54.16
	SD	17.73	18.23
Steelhead Parr	**N**	178	175
	Range	55-138	1.5-42.2
	Mean	90	9.1
	SD	17.74	6.5
Coho Smolts (RST)	**N**	1196	1196
	Range	70-120	3.1-19.3
	Mean	90	8.20
	SD	9.73	3.10
Coho Smolts (SC)	**N**	1025	1017
	Range	70-114	1.2-16.0
	Mean	86	7.02
	SD	8.49	2.17

Table 6. Summary of mean lengths 2000-2011 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
	2007	525	38
	2008	507	39
	2009	400	39
	2010	425	38
	2011	465	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
	2007	n/a	n/a
	2008	477	34
	2009	n/a	n/a
	2010	427	33
	2011	n/a	n/a

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
	2007	247	38
	2008	267	39
	2009	279	38
	2010	301	39
	2011	350	38

Table 6. continued

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
	2007	393	36
	2008	258	35
	2009	176	39
	2010	352	35
	2011	217	35

Species	Year	N	Mean Length
Chinook Smolts	2000	123	100
	2001[1]	n/a	n/a
	2002	25	108
	2003	13	111
	2004	2	90
	2005	1	103
	2006	1	95
	2007	34	103
	2008	41	104
	2009	176	103
	2010	72	107
	2011	55	107

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

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
	2007	18	166
	2008	189	170
	2009	217	171
	2010	87	176
	2011	142	172

Table 6. continued

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
	2007	573	93
	2008	238	88
	2009	172	86
	2010	306	106
	2011	178	90

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
	2007	509	88
	2008	507	89
	2009	1319	89
	2010	1433	94
	2011	1196	90

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
	2007	1227	91
	2008[2]	138	88
	2009[2]	250	90
	2010	1088	96
	2011	1025	86
[2] Few coho were sampled as majority were used for marking			

Table 7. Counts and estimates of live migration from Cheakamus side-channel traps, 2011.

Counter/Weir Site	Chum Fry (PPE)	Wild Coho smolts	Wild Steelhead smolts	Wild Steelhead parr
Upper Paradise/Gorbushca Weir (Site 1) and Fyke Site F	651,267	6,516	151	373
Kisutch (Site 3) and Fyke Site D	110,374	1,146[1]	1	27
BC Rail (Site 4) and Fyke Site J	18,294	806	0	41
Upper Paradise (Site 6)	n/a	223[2]	1	42
Tenderfoot Lake and Creek	n/a	10,163[3]	n/a	n/a
Total Side-channel Yield upstream of RST	669,561	18,794	153	483

1) Kisutch catch moved downstream of UPG (Site 1) therefore added into total.
2) Catch at UP (site 6) was used from June 8 until June 15 as UPG (Site 1) was backwatered.
3) Mark-Recapture Estimate utilizing minnow trapping.

Table 8. Capture Efficiency for coho smolts at Upper Paradise Gorbushcasmolt trap (Site 1), Spring 2011.

Date	#Marks (KS/UPS Site 3 & 6)	#Recaptures (UPGS/Site1)	Capture Efficiency (%)
April 27 and 28	63	49	77%
May 13	100	92	92%
May 17	200	161	80.5%
Total	**363**	**302**	**83%**

Table 9. Minnow trap mark-recapture estimates of coho production from Tenderfoot Lake and Creek, Spring 2011.

Date	Location	#Marked	#Unmarked	#Recaps	ECE %	Pooled Petersen
	Tenderfoot Lake	315	214	16	5.1	3,996 (2272-5718)
	Tenderfoot Creek	314	234	11	3.5	6,169 (2964-9372)
	Tenderfoot Combined	629	448	27	4.3	10,103 (5236-15090)

7.0 FIGURES

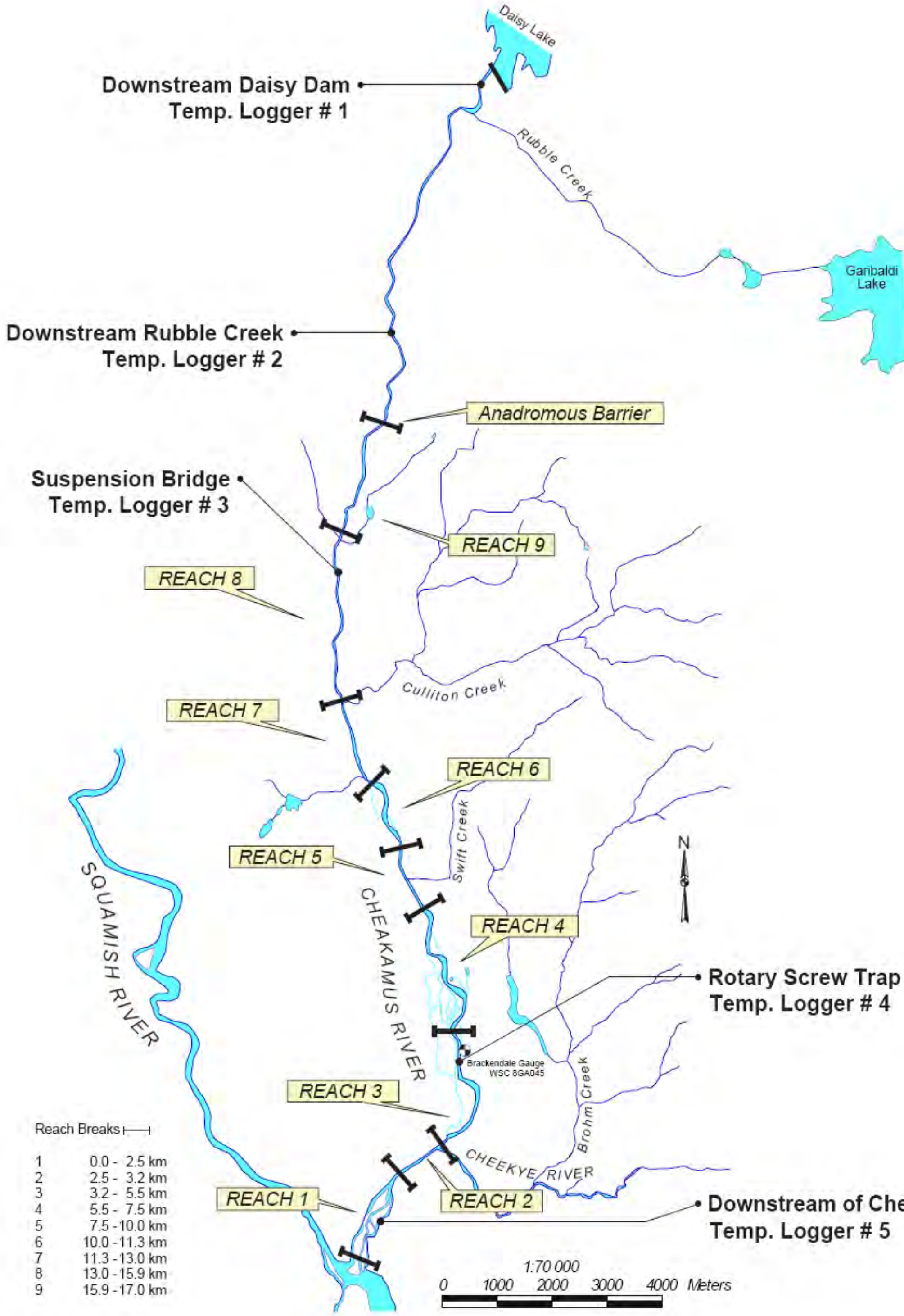

Figure 1. Cheakamus River watershed indicating Reaches 1 through 9, WSC gauging station, temperature loggers, and RST trap location.

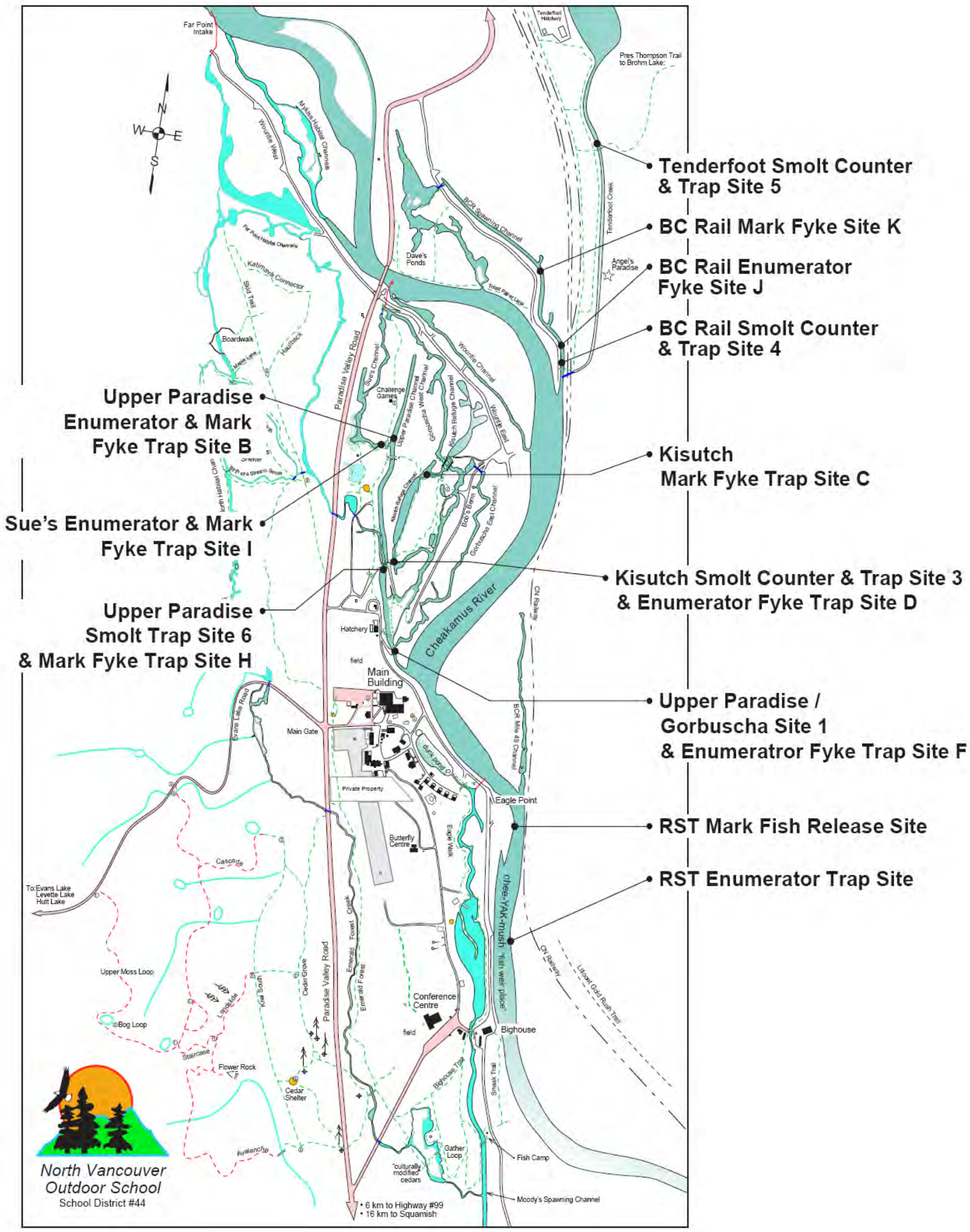

Figure 2.Site Map indicating trap sites utilized in 2011 on the Cheakamus River.

Figure 3. RST 1 (upstream) and RST 2 (downstream) on the Cheakamus River.

Figure 4. Fyke Net used to trap and produce estimates of chum and pink fry on the Cheakamus River side channels.

Schematic of Side-channel Fry Production
Marking Fyke traps and enumerator fyke traps

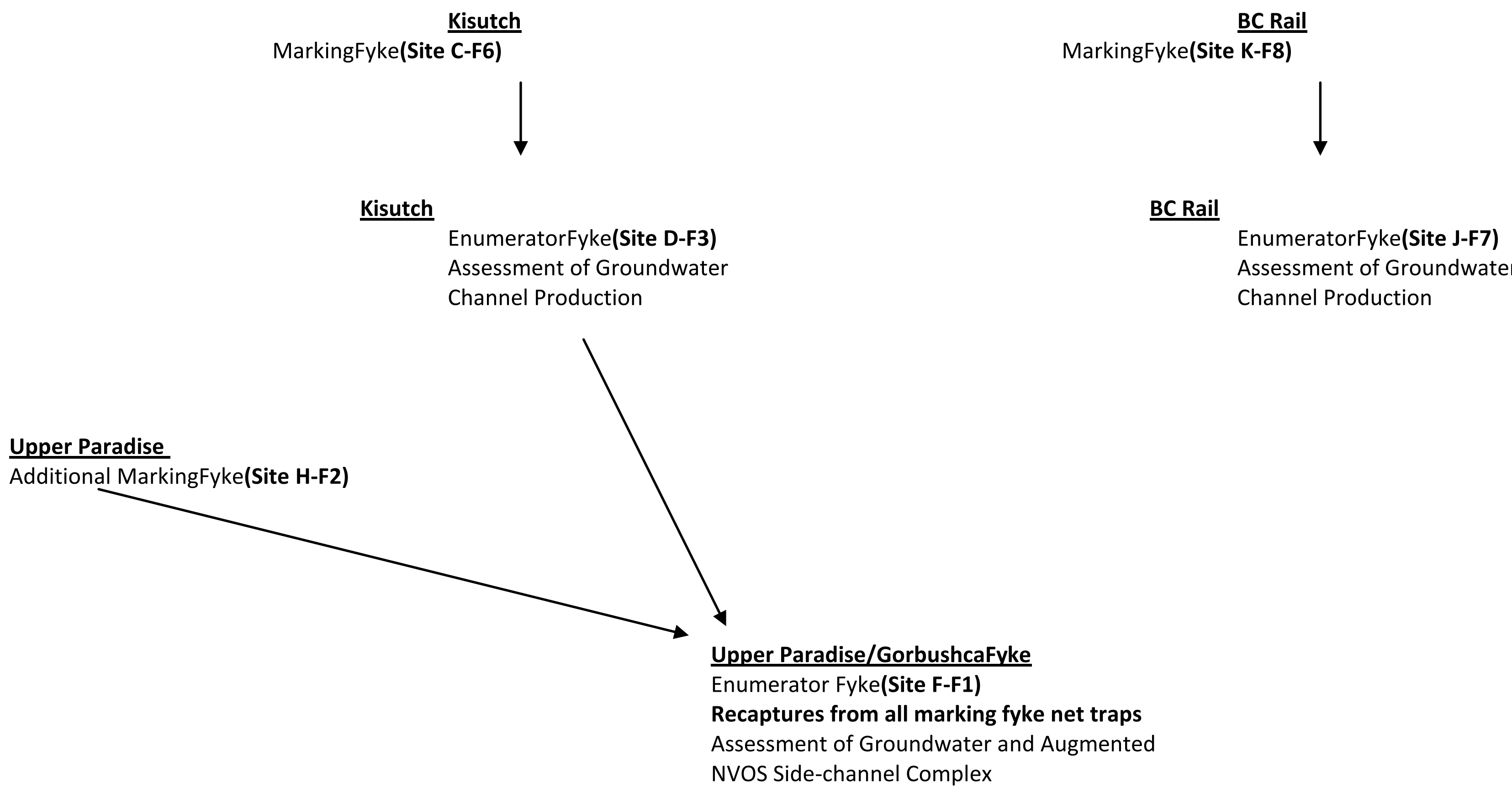

Figure 5. Diagram of side-channel fry production marking and enumerator sites in the Upper Paradise/Gorbushca side-channelcomplex, Spring 2011.

Figure 6. Upper Paradise Gorbushca (Site 1) Smolt Trap used to enumerate coho and steelhead smolts on the Cheakamus River side channel.

Schematic of Side-channel Smolt Production Traps

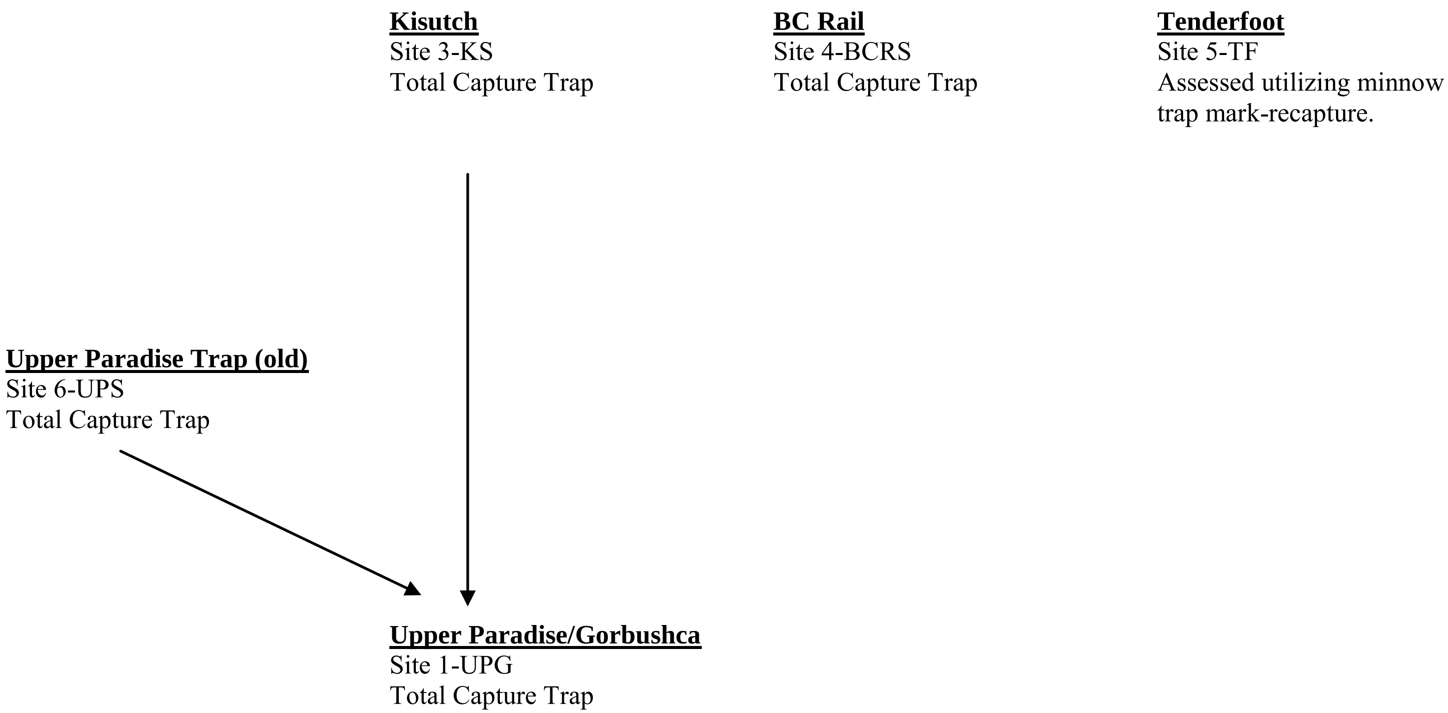

Figure 7. Diagram of side-channel smolt production trap and counter sites, Spring 2011.

Figure 8. Photo of Visible Implant Elastomer (North West Marine Technology) tag utilized during minnow trap mark-recapture on the Cheakamus River, Spring 2011.

Mainstem Chum, Chinook

and
Pink Fry Mark-Recapture
Production Schematic

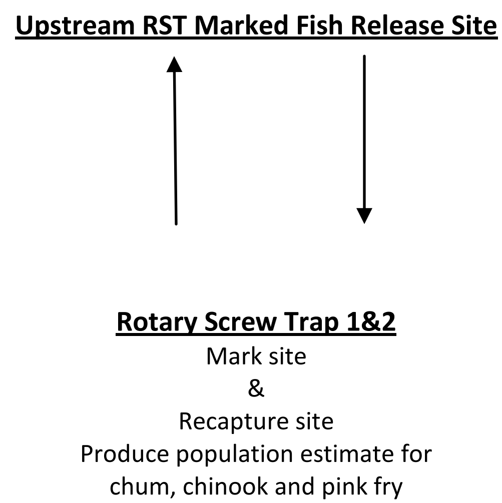

Figure 9. Diagram of Cheakamus mainstem fry production estimate marking and recapture sites, Spring 2011.

Mainstem Smolt Mark-Recapture
Production Schematic

Upper Paradise/Gorbushca (UPG)
Marking Trap Site 1 and (for steelhead only) RST fish marked and moved upstream
Total Capture traps
Mark cohoand steelhead smolts

↓

Rotary Screw Trap (RST) 1&2

Recapture site

Figure 10. Diagram of Cheakamus mainstem smolt production estimate marking and recapture sites, Spring 2011.

Figure 11. Coho smolt with caudal clip being marked with panjet.

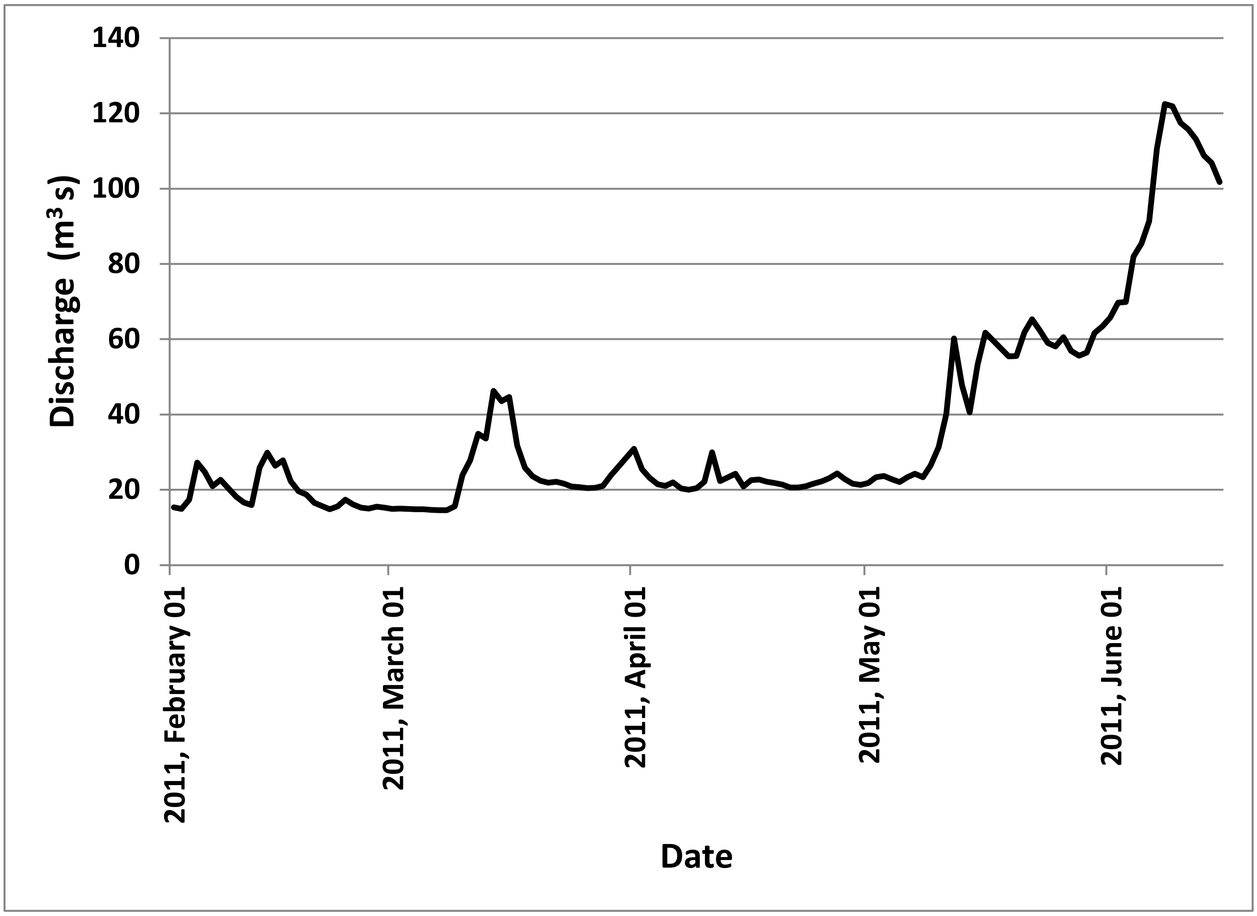

Figure 12. Mean Daily Discharge from Water Survey of Canada Station 08GA043 Cheakamus at Brackendale, Spring 2011.

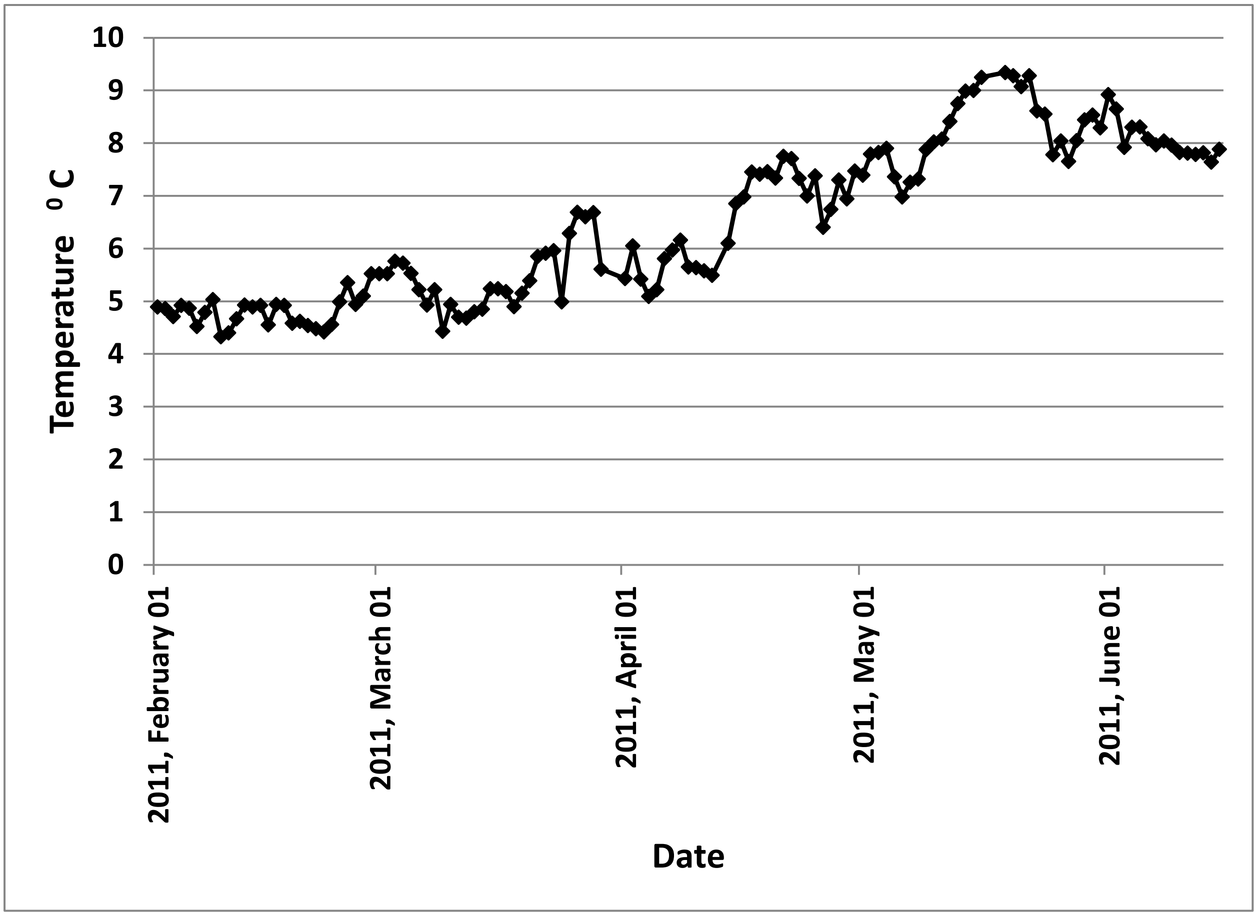

Figure 13. Average Daily Water Temperature in ^{0}C of the Cheakamus River, as recorded by a logger located at the trap site, Spring 2011.

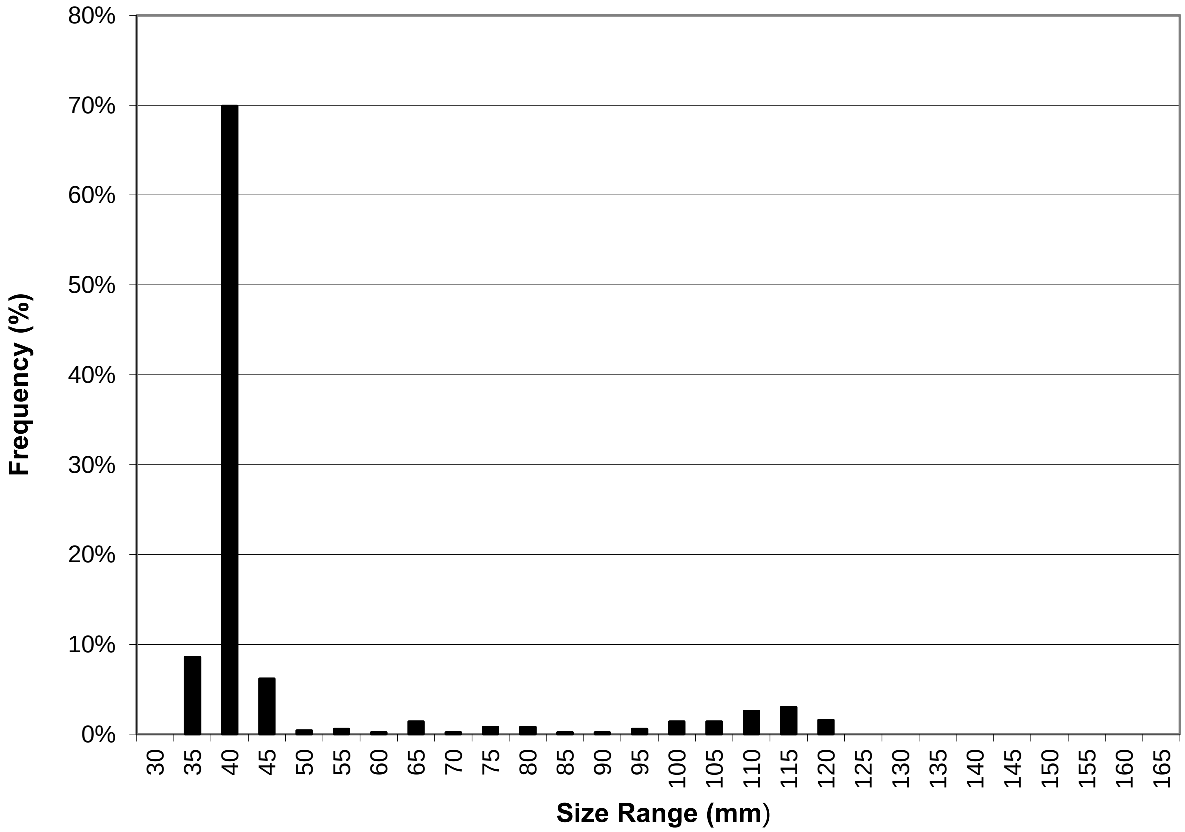

Figure 14. Length frequency distribution of chinook juveniles from the Cheakamus River, Spring 2011.

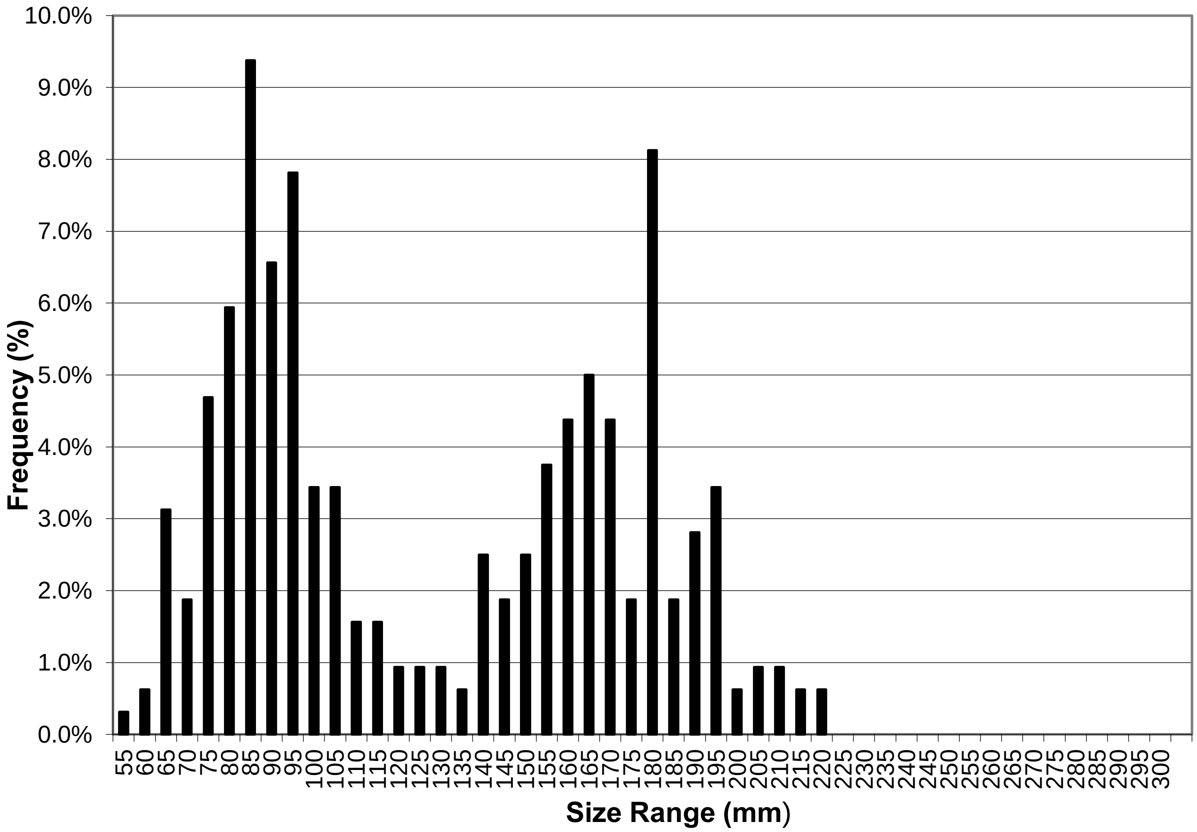

Figure 15. Length frequency distribution of steelhead juveniles sampled on the Cheakamus River, Spring 2011.

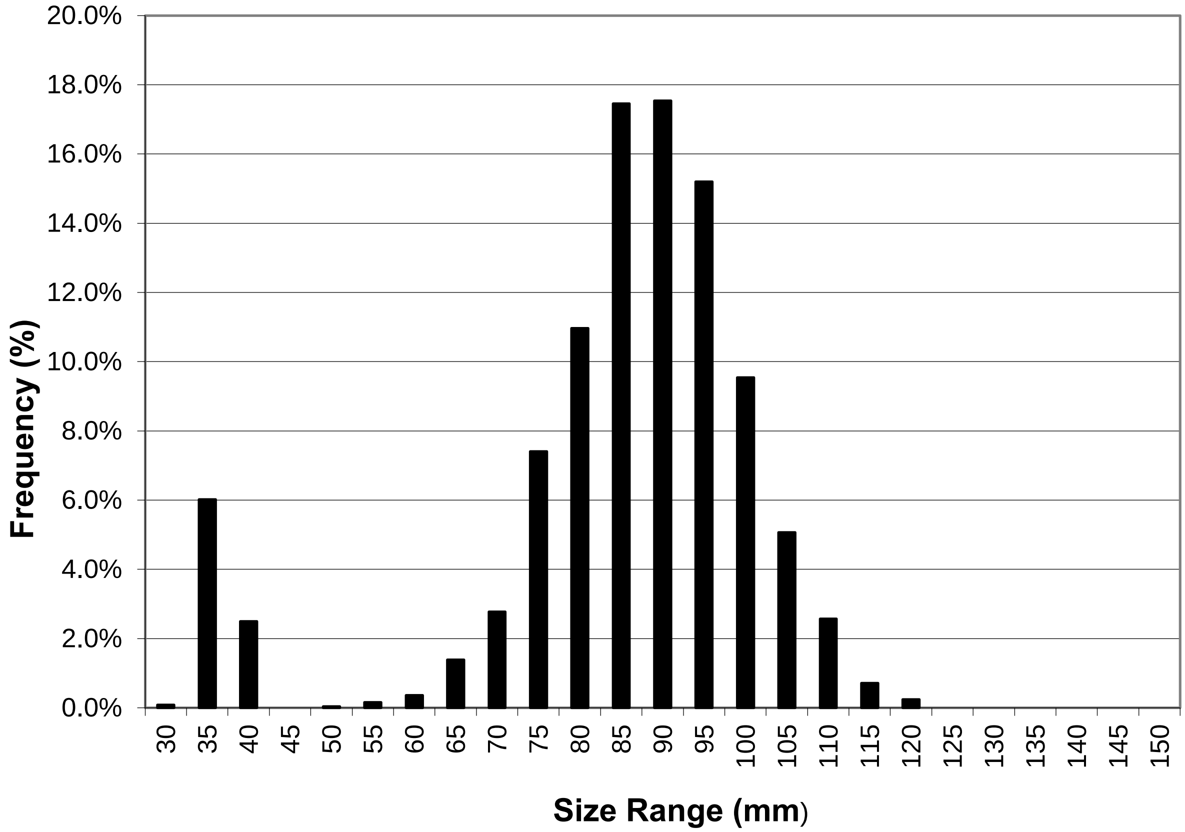

Figure 16. Length frequency distribution of coho juveniles from the Cheakamus River, Spring 2011.

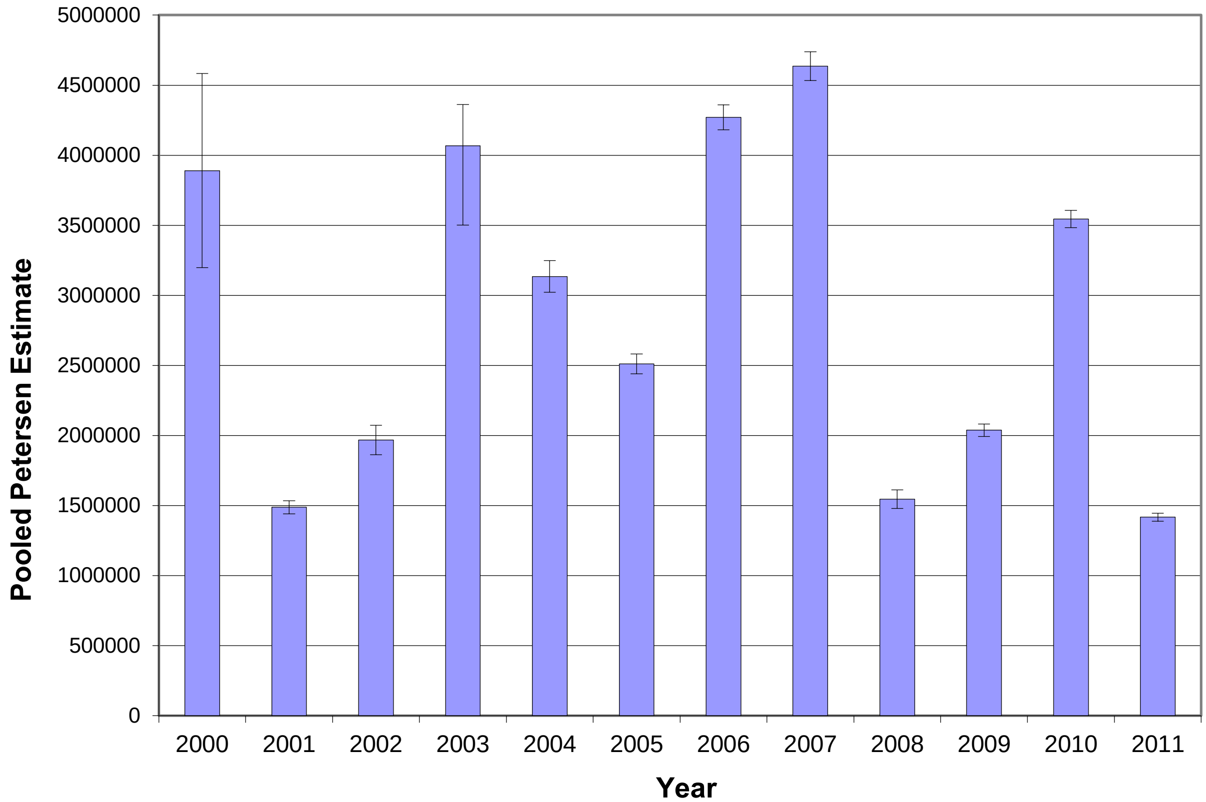

Figure 17. RST derived pooled Petersen estimates of chum fry from Spring 2000 to 2011, including 95% confidence limits.

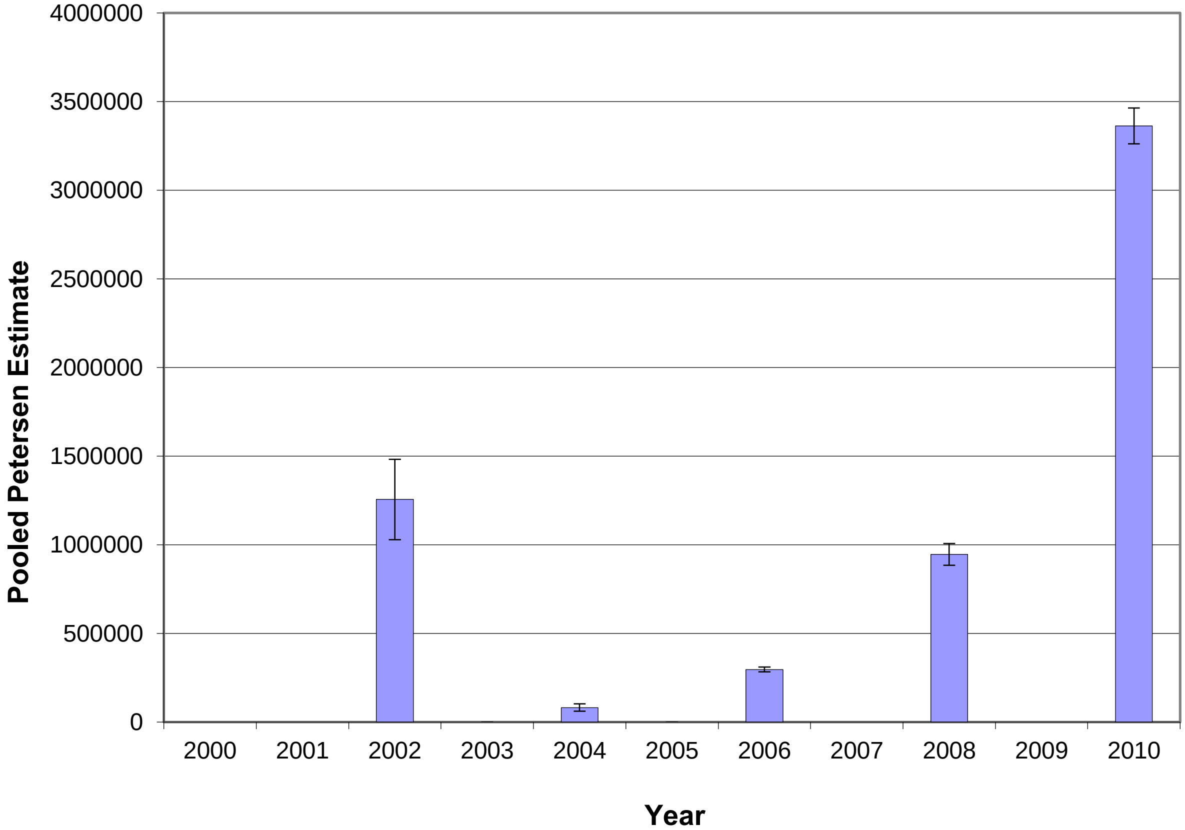

Figure 18. RST derived pooled Petersen estimates of pink fry from Spring 2000 to 2010, including 95% confidence limits.

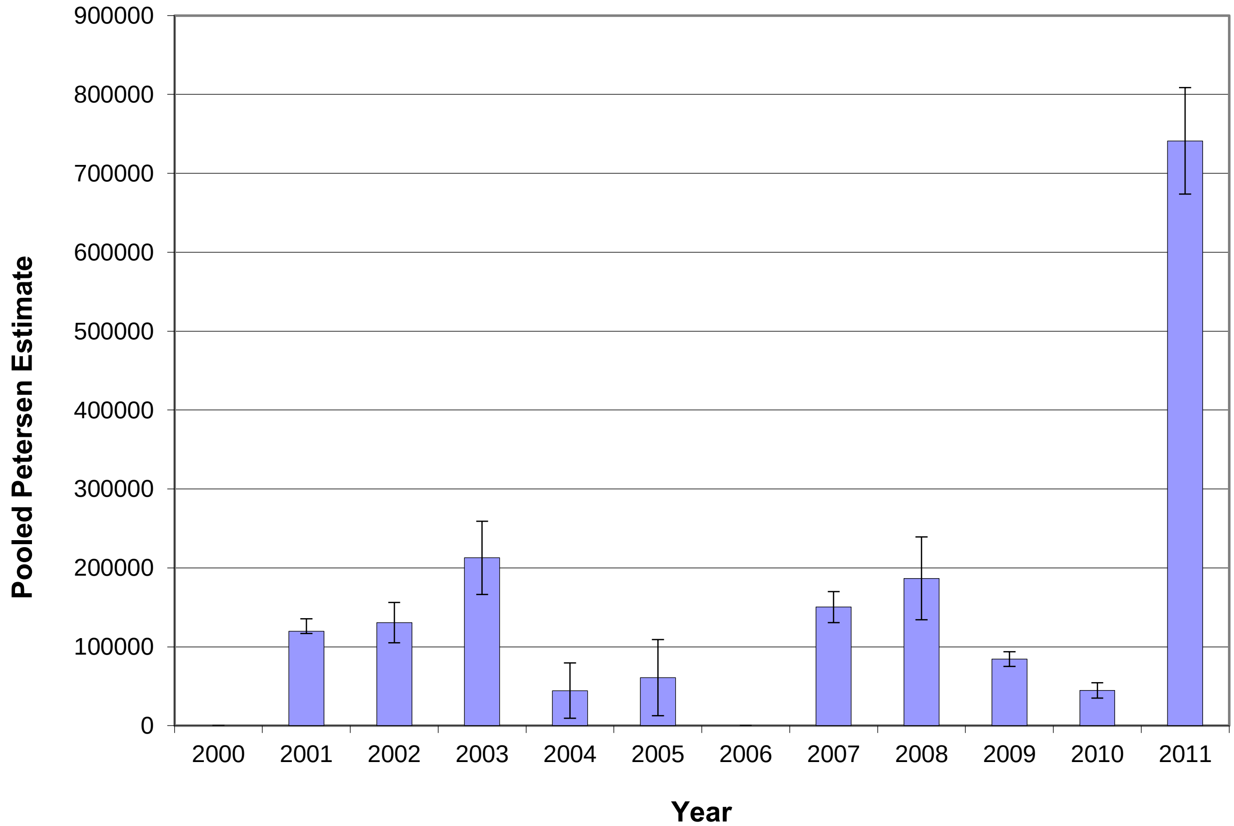

Figure 19. RST derived pooled Petersen estimates of chinook fry from Spring 2000 to 2011, including 95% confidence limits.

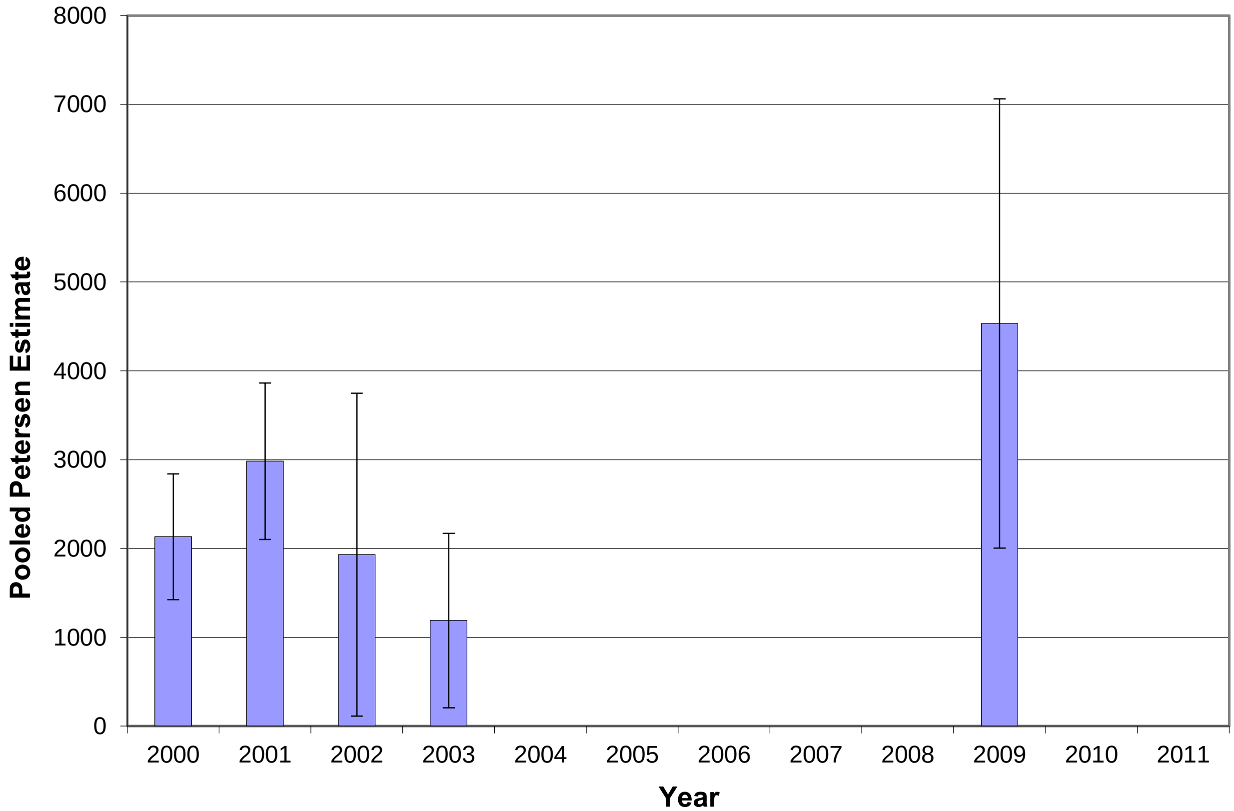

Figure 20. RST derived pooled Petersen estimates of chinook smolts from Spring 2000 to 2011, including 95% confidence limits.

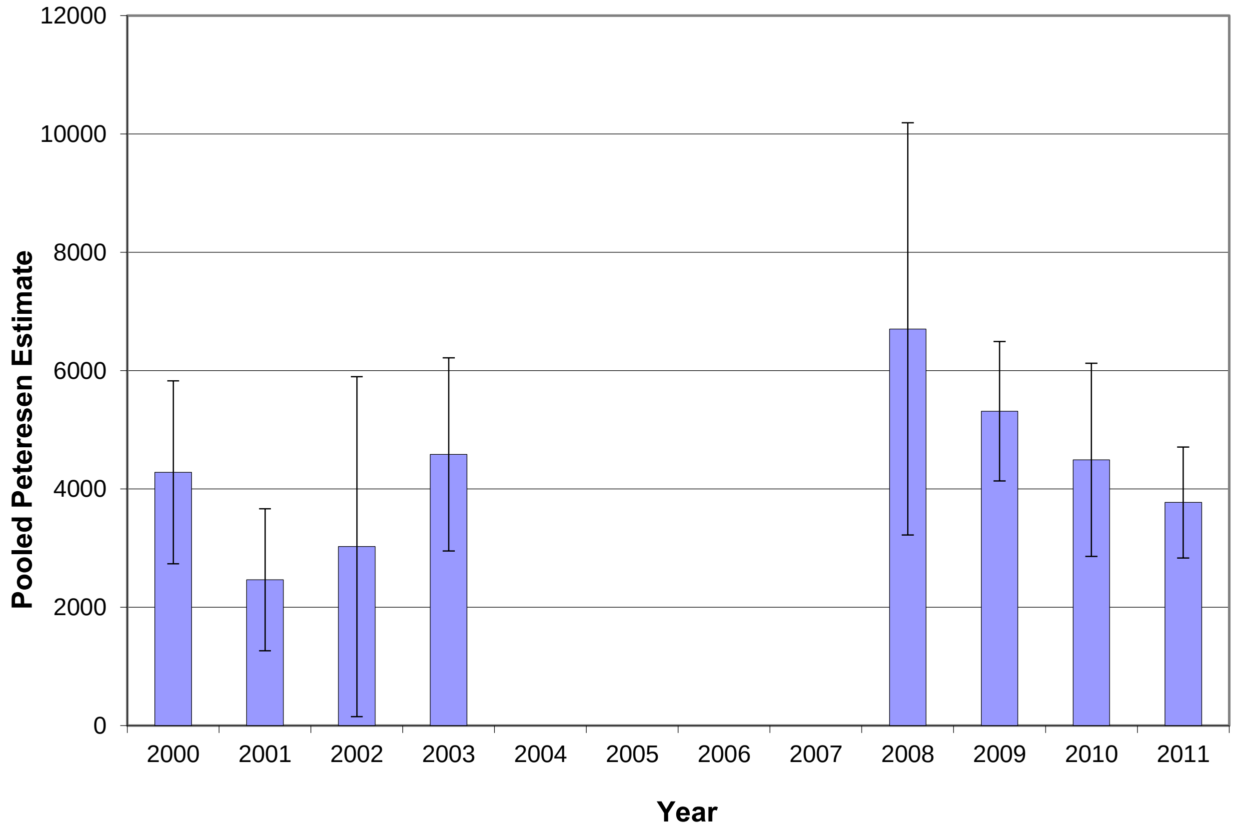

Figure 21. RST derived pooled Petersen estimates of steelhead smolts from Spring 2000 to 2011, including 95% confidence limits.

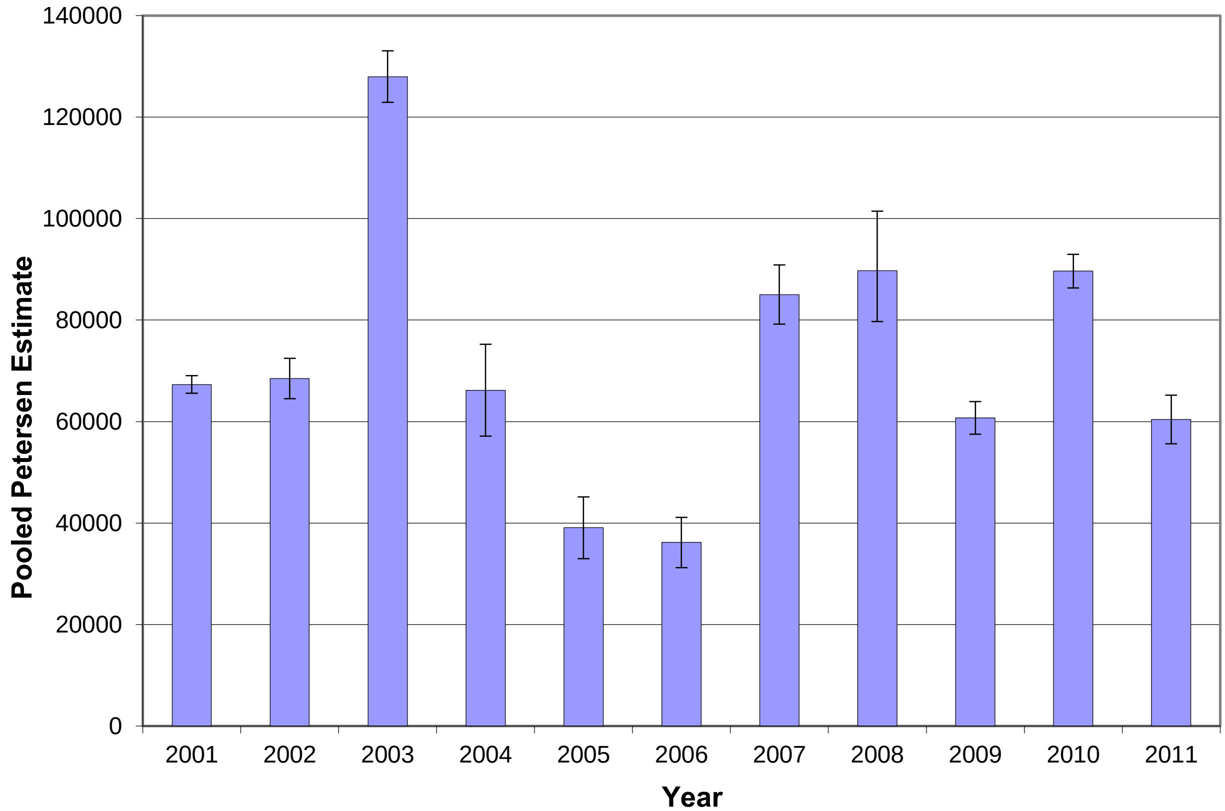

Figure 22. RST derived pooled Petersen estimates of mainstem coho smolts outmigration, calculated using cohosmolts captured and marked at the side-channels from Spring 2001 to 2011, including 95% confidence limits.

8.0 GLOSSARY OF ABBREVIATIONS

BB: Bismark Brown Dye

BCR: BC Rail

CHF: Chinook Fry (< 90mm YOY)

CHS: Chinook Smolts (≥ 90mm; 1 year old)

CMF: Chum Fry (YOY)

COS: Coho Smolts (≥ 70mm; 1 and 2 year old)

DFO: Department of Fisheries and Oceans Canada

ECE: Estimated Capture Efficiency

IFA: Interim Flow Agreement

IFO: Interim Flow Order

LC: Lower Caudal Clip

NR: Neutral Red Dye

NVOS: North Vancouver Outdoor School

PKF: Pink Fry (YOY)

PPE: Pooled Petersen Estimate

Q: Discharge

RK: River Kilometre from confluence

RST: Rotary Screw Trap

SHP: Steelhead Parr (< 140mm; 1 and 2 year old)

SHS: Steelhead Smolts (≥140 mm; 2 to 4 year old)

Site 1: Upper Paradise/GorbushcaSmolt Trap; enumerating production of coho, steelhead parr and steelhead smolts, including Farpoint channel to Birth of a Stream South.

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

Site 3: Kisutch Smolt Trap and Counter Site; enumerating production of coho and steelhead parr and steelhead smoltsto meet Groundwater Study Monitor 6 data requirements.

Site 4: BC Rail Smolt Trap and Counter Site; enumerating production of coho and steelhead parr and steelhead smolts.

Site 5: Tenderfoot Creek Smolt Trap and Counter Site; enumerating production of coho and steelhead parr and steelhead smolts. Not operated in 2009. Replacedwith minnow trapping mark recapture to assess coho production.

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

Site A: Upper Paradise Marking Fyke Net; abandoned after 2007 as not enough fry captured to mark.

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

Site C: Kisutch Marking Fyke Net; to obtain chum fry to mark for productivity estimate at Site D & F.

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

Site E: Little Gorbushca Marking Fyke; abandoned after 2007 as not enough fry captured to mark.

Site F: Upper Paradise/Gorbushca Enumerator Fyke Net; recapture trap for chum & pink fry to obtain productivity of side channels.
Site G: Big Gorbushca Marking Fyke Net; abandoned after 2007 as not enough fry captured to mark.
Site H: Upper Paradise Marking Fyke; capture chum & pink fry to mark for productivity estimate at Site F.
Site I: Sue's Marking Fyke; capture chum & pink fry to mark for productivity estimate at Site F.
Site J: BC Rail Enumerator Fyke Net; recapture trap for chum fry to obtain productivity of side channels and Groundwater Study Monitor 6 data requirements.
Site K: BC Rail Marking Fyke; capture chum fry to mark for productivity estimate at Site J.

TH: Tenderfoot Hatchery

UC: Upper Caudal Clip

UP: Upper Paradise channel

UPG: Upper Paradise/Gorbushca channel complex

VIE: Visible Elastomer Tag

WSC: Water Survey of Canada

WUP: Water Use Planning

YOY: young of the year

9.0 REFERENCES

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APPENDICES

Appendix1-A. Mainstem (RST) Catch and Population Estimate Summary: Spring 2011.

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
170,350	17,361	59,734	7,919	13.3	1,415,779	1,444,198	1,387,360

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
64	1	n/a	n/a	n/a	n/a	n/a	n/a

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
28,910	2,992	10,127	435	4.3	741,085	808,590	673,579

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
56	0	n/a	n/a	n/a	n/a	n/a	n/a

Total (RST) 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
410	0	444	47	10.6	3,772	4,709	2,835

Total (SC) 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
153	0	n/a	n/a	n/a	n/a	n/a	n/a

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
200	3	n/a	n/a	n/a	n/a	n/a	n/a

Appendix 1-A continued. Mainstem (RST) Catch and Population Estimate Summary: Spring 2011.

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
5,665	59	n/a	n/a	n/a	n/a	n/a	n/a

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
8,627	64	5,665	501	8.8	60,428	65,228	55,629

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
4,847	505	n/a	n/a	n/a	n/a	n/a	n/a

Appendix 1-B: Side-Channel Catch and Population Estimate Summary: Spring 2011.

UPG (Site F) Chum fry (live)	UPG (Site F) Chum fry (mort)	UPG Chum fry Marked	UPG (Site F) Chum fry Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit
44,350	400	35,734	3,074	8.6	651,267	672,702	629,834

KS (Site D) Chum fry (live)	KS (Site D) Chum fry (mort)	KS (Site C) Chum fry Marked	KS (Site D) Chum fry Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit
19,962	275	12,581	2,306	18.3	110,374	114,204	106,543

BCR (Site J) Chum fry (live)	BCR (Site J) Chum fry (mort)	BCR (Site K) Chum fry Marked	BCR (Site J) Chum fry Recap.	Estimated Catch Efficiency (ECE%)	Pooled Peterson Estimate	+95% Confid. Limit	-95% Confid. Limit
6,717	110	977	364	37.3	18,294	19,738	16,851

Appendix 2-A: Mainstem Chum Fry Mark and Recovery Strata: Spring 2011.

Release Strata	Period Ending	Marks	Recovery Stratum 1	2	3	4	5	6	7	8	9	10	11	Percent Recoveries
1	20-Feb-11	39	1	0	0	0	0	0	0	0	0	0	0	2.6%
2	27-Feb-11	516	0	28	0	0	0	0	0	0	0	0	0	5.4%
3	6-Mar-11	2242	0	0	352	0	0	0	0	0	0	0	0	15.7%
4	13-Mar-11	9077	0	0	0	1259	0	0	0	0	0	0	0	13.9%
5	20-Mar-11	2411	0	0	0	0	367	0	0	0	0	0	0	15.2%
6	27-Mar-11	9068	0	0	0	0	0	1327	0	0	0	0	0	14.6%
7	3-Apr-11	7619	0	0	0	0	0	0	1089	0	0	0	0	14.3%
8	10-Apr-11	10448	0	0	0	0	0	0	0	1317	0	0	0	12.6%
9	17-Apr-11	2946	0	0	0	0	0	0	0	0	298	0	0	10.1%
10	24-Apr-11	7961	0	0	0	0	0	0	0	0	0	1150	0	14.4%
11	1-May-11	7407	0	0	0	0	0	0	0	0	0	0	731	9.9%
	Total Recovered		401	1715	7427	17331	19660	49426	21201	23925	12959	21680	11986	
	Marked Proportion		0.2%	1.6%	4.7%	7.3%	1.9%	2.7%	5.1%	5.5%	2.3%	5.3%	6.1%	

Appendix 2-B: Upper Paradise/Gorbushca Side-Channel (Site F) Chum Fry Mark and Recovery Strata: Spring 2011.

Release Strata	Period Ending	Marks	Recovery Stratum 1	2	3	4	5	6	7	8	9	10	11	Percent Recoveries
1	20-Feb	0	0	0	0	0	0	0	0	0	0	0	0	
2	27-Feb-11	0	0	0	0	0	0	0	0	0	0	0	0	
3	6-Mar-11	1104	0	0	39	0	0	0	0	0	0	0	0	3.5%
4	13-Mar-11	4940	0	0	0	357	0	0	0	0	0	0	0	7.2%
5	20-Mar-11	11666	0	0	0	0	1322	0	0	0	0	0	0	11.3%
6	27-Mar-11	11644	0	0	0	0	0	751	0	0	0	0	0	6.4%
7	3-Apr-11	5006	0	0	0	0	0	0	494	0	0	0	0	9.9%
8	10-Apr-11	484	0	0	0	0	0	0	0	56	0	0	0	11.6%
9	17-Apr-11	516	0	0	0	0	0	0	0	0	29	0	0	5.6%
10	24-Apr-11	274	0	0	0	0	0	0	0	0	0	21	0	7.7%
11	1-May-11	100	0	0	0	0	0	0	0	0	0	0	5	5.0%
	Total Recovered		11	117	1056	7062	13487	11009	6519	2376	1236	1362	515	
	Marked Proportion		0.0%	0.0%	3.7%	5.1%	9.8%	6.8%	7.6%	2.4%	2.3%	1.5%	1.0%	

Appendix 2-C: Kisutch Ground Water Channel (Site D) Chum Fry Mark and Recovery Strata: Spring 2011.

Release Strata	Period Ending	Marks	Recovery Stratum 1	2	3	4	5	6	7	8	9	10	11	Percent Recoveries
1	20-Feb	0	0	0	0	0	0	0	0	0	0	0	0	
2	27-Feb-11	0	0	0	0	0	0	0	0	0	0	0	0	
3	6-Mar-11	653	0	0	121	0	0	0	0	0	0	0	0	18.5%
4	13-Mar-11	1422	0	0	0	323	0	0	0	0	0	0	0	22.7%
5	20-Mar-11	3768	0	0	0	0	838	0	0	0	0	0	0	22.2%
6	27-Mar-11	4497	0	0	0	0	0	533	0	0	0	0	0	11.9%
7	3-Apr-11	2018	0	0	0	0	0	0	332	0	0	0	0	16.5%
8	10-Apr-11	176	0	0	0	0	0	0	0	159	0	0	0	90.3%
9	17-Apr-11	47	0	0	0	0	0	0	0	0	0	0	0	0.0%
10	24-Apr-11	0	0	0	0	0	0	0	0	0	0	0	0	
11	1-May-11	0	0	0	0	0	0	0	0	0	0	0	0	
	Total Recovered		2	127	1145	5597	5380	3743	2572	1407	198	44	22	
	Marked Proportion		0.0%	0.0%	10.6%	5.8%	15.6%	14.2%	12.9%	11.3%	0.0%	0.0%	0.0%	

Appendix 2-D: BC Rail Groundwater Channel (Site J) Chum Fry Mark and Recovery Strata: Spring 2011.

Release Strata	Period Ending	Marks	Recovery Stratum 1	2	3	4	5	6	7	8	9	10	11	Percent Recoveries
1	20-Feb-11	0	0	0	0	0	0	0	0	0	0	0	0	
2	27-Feb-11	0	0	0	0	0	0	0	0	0	0	0	0	
3	6-Mar-11	0	0	0	0	0	0	0	0	0	0	0	0	
4	13-Mar-11	0	0	0	0	0	0	0	0	0	0	0	0	
5	20-Mar-11	377	0	0	0	0	83	0	0	0	0	0	0	22.0%
6	27-Mar-11	446	0	0	0	0	0	203	0	0	0	0	0	45.5%
7	3-Apr-11	154	0	0	0	0	0	0	78	0	0	0	0	50.6%
8	10-Apr-11	0	0	0	0	0	0	0	0	0	0	0	0	
9	17-Apr-11	0	0	0	0	0	0	0	0	0	0	0	0	
10	24-Apr-11	0	0	0	0	0	0	0	0	0	0	0	0	
11	1-May-11	0	0	0	0	0	0	0	0	0	0	0	0	
	Total Recovered		0	21	20	354	587	3095	2524	150	29	34	13	
	Marked Proportion		0.0%	0.0%	0.0%	0.0%	14.1%	6.6%	3.1%	0.0%	0.0%	0.0%	0.0%	

Appendix 2-E: Mainstem Chinook Fry Mark and Recovery Strata: Spring 2011.

Release Strata	Period Ending	Marks	Recovery Stratum 1	2	3	4	5	6	7	8	9	10	11	Percent Recoveries
1	20-Feb	386	20	0	0	0	0	0	0	0	0	0	0	5.2%
2	27-Feb-11	1223	0	38	0	0	0	0	0	0	0	0	0	3.1%
3	6-Mar-11	0	0	0	0	0	0	0	0	0	0	0	0	
4	13-Mar-11	1325	0	0	0	55	0	0	0	0	0	0	0	4.2%
5	20-Mar-11	70	0	0	0	0	5	0	0	0	0	0	0	7.1%
6	27-Mar-11	218	0	0	0	0	0	10	0	0	0	0	0	4.6%
7	3-Apr-11	494	0	0	0	0	0	0	38	0	0	0	0	7.7%
8	10-Apr-11	952	0	0	0	0	0	0	0	51	0	0	0	5.4%
9	17-Apr-11	566	0	0	0	0	0	0	0	0	19	0	0	3.4%
10	24-Apr-11	865	0	0	0	0	0	0	0	0	0	35	0	4.0%
11	1-May-11	4028	0	0	0	0	0	0	0	0	0	0	164	4.1%
	Total Recovered		2350	2861	3812	3152	911	2163	1980	2126	1506	3310	7731	
	Marked Proportion		0.9%	1.3%	0.0%	1.7%	0.5%	0.5%	1.9%	2.4%	1.3%	1.1%	2.1%	

Appendix 2-F: Mainstem Steelhead Smolt Mark and Recovery Strata: Spring 2011.

Release Strata	Period Ending	Marks	Recovery Stratum 1	2	3	4	5	6	7	8	9	10	Percent Recoveries
1	3-Apr-11	0	0	0	0	0	0	0	0	0	0	0	
2	10-Apr-11	0	0	0	0	0	0	0	0	0	0	0	
3	17-Apr-11	0	0	0	0	0	0	0	0	0	0	0	
4	24-Apr-11	6	0	0	0	0	1	0	0	0	0	0	16.7%
5	1-May-11	37	0	0	0	0	1	1	0	0	0	0	5.4%
6	8-May-11	85	0	0	0	0	0	6	0	0	0	0	7.1%
7	15-May-11	133	0	0	0	0	0	0	20	2	0	0	16.5%
8	22-May-11	97	0	0	0	0	0	0	0	9	3	0	12.4%
9	29-May-11	67	0	0	0	0	0	0	0	0	4	0	6.0%
10	5-Jun-11	19	0	0	0	0	0	0	0	0	0	0	0.0%
	Total Recovered		0	0	2	3	20	71	139	90	69	12	
	Marked Proportion				0.0%	0.0%	10.0%	9.9%	14.4%	12.2%	10.1%	0.0%	

Appendix 2-G: Mainstem Coho Smolt Mark and Recovery Strata (fish marked at sidechannels): Spring 2011.

Release Strata	Period Ending	Marks	Recovery Stratum 1	2	3	4	5	6	7	8	9	10	Percent Recoveries
1	3-Apr-11	0	0	0	0	0	0	0	0	0	0	0	
2	10-Apr-11	57	0	1	0	0	0	0	0	0	0	0	1.8%
3	17-Apr-11	81	0	0	5	0	0	0	0	0	0	0	6.2%
4	24-Apr-11	117	0	0	0	14	0	0	0	0	0	0	12.0%
5	1-May-11	197	0	0	0	0	31	1	0	0	0	0	16.2%
6	8-May-11	531	0	0	0	0	0	65	1	0	0	0	12.4%
7	15-May-11	1189	0	0	0	0	0	0	98	0	0	0	8.2%
8	22-May-11	1141	0	0	0	0	0	0	0	110	1	0	9.7%
9	29-May-11	1316	0	0	0	0	0	0	0	0	128	1	9.7%
10	5-Jun-11	1036	0	0	0	0	0	0	0	0	0	45	0.0%
	Total Recovered		49	130	155	440	878	984	901	981	690	145	
	Marked Proportion		0.0%	0.8%	3.2%	3.2%	3.5%	6.7%	11.0%	11.2%	18.7%	0.7%	