Cheakamus River Project Water Use Plan

Cheakamus River Chum Salmon Escapement Monitoring and Mainstem Spawning Groundwater Survey

Implementation Year 4

Reference: CMSMON-1B

Cheakamus River Water Use Plan Monitoring Program:2010 Cheakamus River Chum Salmon Escapement Monitoring and Mainstem Spawning Groundwater Survey

Study Period: October 2010 to March 2011

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Cheakamus River Monitoring Program #1b

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EXECUTIVE SUMMARY

During this fourth year of chum adult escapement monitoring, physical changes to the Cheakamus River resulting from a July 2009 storm event appear still to have had a significant influence on the 2010 chum spawner distribution although in a different way from the changes observed in 2009. At the Cheekye/Cheakamus River confluence the large accumulation of bed material from this flood event continues to constrict a portion of the Cheakamus River and backwatered the river upstream past Moody's side channel confluence as far as Moody's Beach (RKM 3.5).

In 2010, we observed that the distribution of spawners implanted with radio tags was different to that observed during 2009 and more similar to that observed in 2007 and 2008. In 2010, 43% of lower river radio tagged fish spawned upstream of Moody's. This compares with 82% in 2009, 55% in 2008 and just 16% in 2007 of spawners. The proportion of radio tagged chum spawning above the juvenile monitoring site at river kilometer 4.5 was low in 2010, at 6% the same proportion observed in 2007 and very different when compared to the 51% recorded in 2009 and 38% in 2008.

An estimated 112,003 ± 57,875spawners were calculated in the whole river escapement estimate for 2010, which was the lowest estimate of all study years 2007-2010 (2007:179k, 2008:117k, 2009:130,144) albeit with broad confidence limits. In this year's study the proportion of side channel pit tag detections of fish tagged in the lower river was 2-3 times lower than observed in 2009 indicating that spawners moving through the lower river tagging site were relatively less motivated to utilize spawning habitats higher in the watershed. This was an observation also borne out in the behavior of radio tagged individuals. This evidence of a shift in spawner distribution back to lower river dominance is striking when we consider that the upper river spawner estimate (above RST site) in 2010 is 16,786 ± 3,782 fish compared to 103,655 ± 13,952 in 2009. In 2010 the upper river spawners represented just 15% of total spawners while in 2010 approximately 80% of spawners used this upper river area. These large annual variances in spawner distribution tend to overwhelm annual differences in total escapement, in that observations of side-channel abundance are clearly not directly related to whole river chum escapement. Instead they appear related to variances in the choice of spawning locations, the reasons for which can be hypothesized but as yet not explained by empirical data measurements. Annual differences in spawner escapement into monitored side-channels and the upper river area have been large through the study period (4 to 8 fold) and should allow for the effects of variance in spawner density and the resultant fry outmigration to be evaluated against annual discharge patterns.

At two sections of the river where large spawning aggregations have been observed during previous years we explored the possibility that Cheakamus River mainstem chum spawners might select mainstem spawning habitat based on groundwater upwelling. Temperature logger capsules placed in chum redds through the egg incubation period showed that temperatures in the majority of redd sites where eggs were present, were consistently 3-5° Celsius warmer than river water throughout egg development. There were some individual differences in the temperature profiles among redds, however, most recorded temperatures ranged 5-8° Celsius, with the exception of four periods when the river experienced a rapid increase in discharge and river stage forced cooler river water into the warmer redd sites. The origins and relationship of this groundwater to the river's discharge profile are unclear and another year of observations is planned.

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1.0 INTRODUCTION

1.1 BACKGROUND

The Water Use Plan (WUP) for the Cheakamus River (BC Hydro 2005) includes a flow regime for the Cheakamus River designed to balance environmental, social and economic values. One of the fundamental objectives of the Cheakamus River WUP was to maximize wild fish populations, and the WUP recommended an operating alternative and associated river flow regime based in part on expected benefits to wild fish populations. However, the benefits to fish populations from the new river flows were uncertain because they were modeled based on uncertain relationships between fish habitat and flow, and assumed relationships between fish habitat and fish production (Parnell et al. 2003). To reduce this uncertainty, the Cheakamus WUP Consultative Committee recommended a number of environmental monitoring programs.

The Cheakamus River chum salmon population was identified during the consultative process as a key-stone indicator species, and the effect of flow on chum salmon spawning and incubation was of particular concern. To reduce this uncertainty, one recommendation was to link adult chum salmon spawner escapement with juvenile out migration data and use the resultant spawner-fry index (H') as an indicator of flow effects. The potential value of this index was highlighted during an exercise that modeled alternative monitoring designs (Parnell et al. 2003). BC Hydro has monitored Cheakamus River juvenile chum fry out-migration for the last eleven years (see Melville and McCubbing 2000-2010) and monitoring of out-migrant fry is continuing at several locations. However, until this monitor commenced no accurate adult chum salmon spawner escapement data existed for the Cheakamus watershed and the linkages between adult spawner escapement and juvenile out-migration were poorly understood.

Another important uncertainty during the consultative process was the relation between river discharge and groundwater upwelling in mainstem spawning areas. The effective spawning area “Performance Measure” for chum salmon and other salmon species was influential in the selection of flow alternatives during the consultative process. The performance measure was calculated using a model based on River 2-D simulations, depth, velocity and substrate preference curves, and redd stranding calculations. This model identifies those areas where spawning is likely or unlikely to occur based on depth, velocity and substrate criteria, and thus the approach will tend to overestimate the area of spawning habitat relative to empirical measures (Parnell et al. 2003). The model does not predict the precise location of spawning. Thus, the model is useful for comparing alternative flows, but does not provide precise measures of spawning habitat. Modeling suggested that lower and more stable flows during the fall (relative to the existing Interim Flow Order) would provide a larger area suitable for spawning that would also remain wetted during incubation, resulting in relatively greater effective spawning area. These findings and the modeling approach in general, was uncertain because chum spawning habitat selection can also be driven primarily by groundwater upwelling, and not the surface flow characteristics of water depth/velocity and spawning gravel suitability. It was suggested by some committee members that lower flows during the fall spawning period would result in reduced surface water-to-groundwater exchange, reduced upwelling, poorer spawning site selection and thus lower chum egg to fry survival, and that the River 2-D modeling had greatly overestimated suitable spawning area under low flows. The key management questions are:

1) What is the relation between discharge and chum salmon spawning and incubation?
2) Do the models used to calculate effective spawning area provide an accurate representation of chum salmon spawning site selection, and the availability of spawning habitat?

This monitor was developed to examine the effects of the WUP flow regime on chum salmon spawning in the mainstem of the Cheakamus River and major side channels and includes two components:

i) Estimating annual escapement of adult chum salmon in the Cheakamus River, and distribution within the mainstem and in key off channel habitats.

ii) Examining the relation between discharge, groundwater upwelling, and the selection of spawning habitat by chum salmon in the mainstem.

Data from this study will also be used in conjunction with data from other monitoring programs to develop stock-recruitment relationships that are critical for separating effects of spawning escapement from flow-related changes in survival during incubation.

The primary null hypotheses (and sub-hypotheses) associated with these management questions are:

H_1: Discharge during the chum salmon spawning and incubation period does not affect productivity, measured as the number of fry per spawner in the mainstem.

This first hypothesis is general, and the specific hypotheses below will assist in diagnosing the likely reason(s) for any observed patterns.

H_2: Spawning chum salmon do not select areas of upwelling groundwater for spawning in the mainstem.

The key water use decision that would potentially be affected by the results of the monitoring is the seasonal flow release from the Daisy Dam, in particular, releases during the chum spawning and incubation period. Such changes would affect power generation and other social and environmental values in the Cheakamus River.

This report summarizes results from Year 4 (2010 spawners) of the study. Reporting on results from Years 1 through 3 (2007 through 2009 escapement) can be found at:

> **www.bchydro.com/.../wup/.../cmsmon-1b_yr3_2010-11-25.Par.0001.File.CMSMON-1B-Yr3-2010-11-25.pdf**

1.2 EXPERIMENTAL DESIGN

There are many challenges to estimating chum escapement and spawning distribution in the Cheakamus watershed due to its size and environmental conditions. Observations of considerable downstream movement of spawned-out moribund fish among mainstem spawners combined with restricted water visibility and poor access to some river/channel reaches when river discharges are high (*see*: Melville and McCubbing 2000; Korman et al. 2002) create challenges for traditional visual tag mark recapture approaches that are commonly employed in smaller coastal systems.

Traditional visual mark recapture escapement surveys involve tagging salmon with external tags followed by detailed foot carcass surveys of all possible spawning grounds. Instead, this monitor uses a passive mark recapture technique in place of a traditional mark recapture carcass recovery or visual estimation study methods. This passive tag recovery approach involves the use of fixed location resistivity fish counters to enumerate all fish entering selected side channels, coupled with PIT (Passive Integrated Transponder) scanning tag readers to scan for tags on all fish at these locations. PIT tags are small sealed electronic modules with unique identification codes that can be implanted in, or externally attached to juvenile and adult fish. Fixed station river pass-through antennas monitor movements of fish with tags and record data with logging equipment.

PIT technology has many advantages over externally mounted visual tag techniques and has been extensively used as an adult and juvenile salmonid monitoring tool since the mid-1980s in the Columbia River basin (e.g. Zydlewski et al. 2006; Prentice et al. 1986; Prentice et al. 1990; McCutcheon et al. 1994; Downing et al. 2001; Matter and Stanford 2003) and is currently used in a wide variety of aquatic and terrestrial monitoring programs worldwide (see: biomark.com for a bibliography and Thorsteinsson (2002) for additional references).

In this study year, as in 2008 and 2009, we use two different marking locations and three side channel detection locations in a design after Schwarz and Taylor

(1998). The marking site for the 'whole river' estimate, is located in the lower river (River KM 1.5), while the 'upper river' tagging site at river kilometer 5.5 provides a more robust estimate of the number of fish that spawn upstream of the mainstem juvenile (RST) monitoring site. At both sites PIT and Peterson disk tags were applied to adult chum salmon with subsequent detections of tagged and untagged fish at three upper river side channel complexes with sizable chum spawning habitat (Upper Paradise, BC Rail and Tenderfoot Creek). In addition radio tags were gastrically implanted in a subsample of fish to: determine spawner distribution upstream and downstream of the current juvenile out-migration monitoring site, assess post tagging behavior that may affect estimates, provide information on spawner distribution to assist with mainstem ground water/spawner evaluations, as well as assisting in evaluating spawner residence time during the initial four years of the monitor.

The addition of the second marking site in 2008 immediately above the mainstem juvenile monitoring site adds significantly more marks to those fish most likely to spawn and produce progeny above the juvenile assessment location increasing the precision of the estimates and analytical power of the study. In an effort to assess the likelihood of marked fish dropping out of the assessment zone and skewing our upper river estimate high, a portion of the radio tags applied were used at the upper river tagging site in 2010, a departure in method from previous study years.

2.0 METHODS

2.1 CAPTURE - Upper and Lower Sites

Fish capture methods, effort and timing in 2010 generally followed those from 2007-09, except for the re-distribution of capture effort to the upper-site in 2008 - 09, as described in section 1.2. Fishing effort directed at the capture of chum salmon for tag application was conducted during daylight hours from mid-October through late November, 2010. As in 2007-09, the lower river tagging site was located upstream of the Cheakamus/Squamish River confluence at River KM 1.5, and is commonly known as the 'stables pool' (49° 48 053 N - 123° 09 004 W, Figure 1). Fish capture was also undertaken in two pools one approximately 200m upstream and one a similar distance downstream of this location in 2010 as pool topography at the stables site had changed and less fish were being captured per unit effort. Suitable spawning/incubation habitat downstream of this area has previously been visually assessed as limited and of poor quality, (Troffe et al 2009) suffering from high bed-load movement and siltation from the Cheekye River.

The upper river tagging location was located at River KM 5.5, approximately 250 m upstream of the RST juvenile out-migrant monitoring location at a pool commonly known as the 'gauge pool' (49 º 47 978 N - 123 º 09 348 W; Figure 1). To ensure that all fish had an equal probability of being tagged, we endeavored to allocate tagging effort at the upper and lower tag application sites in proportion to fish abundance throughout the migration period. Chum salmon were captured using 18 x 4.5 m or 13.5 x 3.6 m tangle type floating gill net hung with 15 cm stretched length ‘Alaska twist’ tangle mesh. As often as river conditions were appropriate (discharges < 45 $m^{3/}s$ at Brackendale WSC gauge), a two person crew deployed and drifted a tethered net from a small pontoon raft at the upstream section of the fishing area, while a separate shore based two person crew walked the tethered line through the 50-120 m of pool to a bank side landing location. All captured chum salmon were quickly placed into floating fish tubes for holding prior to processing (Figure 2), while other fish species, as well as any re-captured chum that had been previously tagged, were recorded and placed in holding for later release. Fishing effort was recorded as the number of fish captured during each standardized net set.

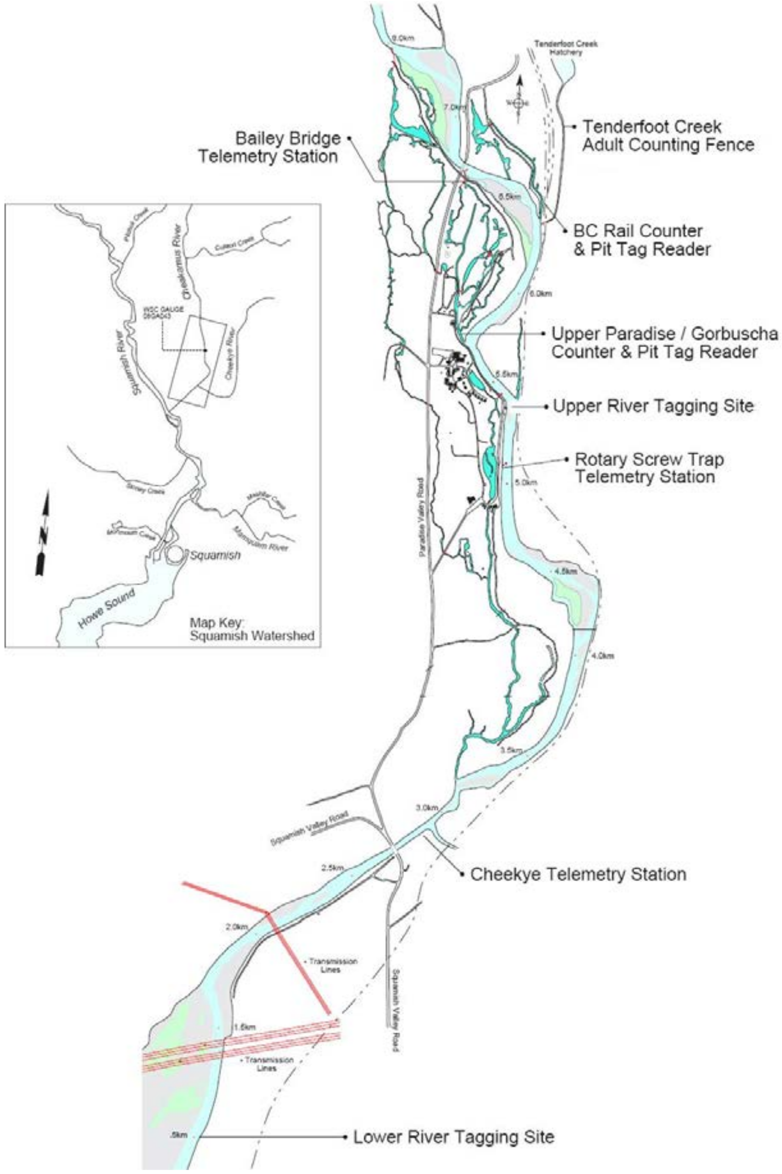

Figure 1: *Study area for Cheakamus River chum salmon escapement monitoring (River KM 0.5- 8.0) with tagging sites, side channel resistivity counter / PIT detection sites, and fixed radio telemetry receiver locations.*

Figure 2: *The Cheakamus River at river KM 1.5 at the lower river 'stables' pool. In the foreground are fish holding tubes, the tagging cradle table, one of two holding pens. In the back ground the crew of four deploys the tangle net from a small raft.*

Prior to tag application fish were removed from holding tubes and sex and fork length were recorded. To increase likelihood of tagging pre-spawners destined for upstream migration, body condition was assessed according to a five point scale (descriptions below) and tags were applied only to 0 through 2 condition pre-spawners.

Condition 0 and 1 - fish were 'silver' uncoloured pre-spawners, which appeared to have entered the river recently and Condition 0 fish displayed sea lice on their body.

Condition 2 – fish exhibited some spawning colouration, but were in fresh condition and free body decay.

Condition 3 – fish clearly display spawning colouration and are showing early signs of body decay.

Condition 4 – fish are heavily coloured, have some body deterioration, and may show signs of previous spawning activity.

2.2 TAGGING and RELEASE

All high condition chum salmon were placed in a portable tagging cradle with the dorsal surface exposed and tagged through the leading edge of the dorsal fin with a uniquely numbered one inch Petersen Disk tag (Floy Ltd., Seattle WA), with site and sex specific tag colours. In addition to the visual Petersen Disk tag, each fish was implanted with a 20 mm 1420 SST Destron-Fearing 134.2 kHZ full-duplex glass encapsulated PIT tag which was placed into muscle tissue on the lateral surface just below the dorsal fin (Figure 3). For pre-spawners both sites approximately every fifth tagged fish was also gastrically implanted with a 90 day life span Lotek radio tag (model MCFT-3A) in a methodology similar to Brown and Eiler (2005). Tagging time, from holding tube removal through tag application to placement in the recovery pen was usually less than one minute. Tagged fish were held in two 2.5 x 2.5 m recovery pens and released once the day's fishing and tagging sessions were complete. Tagged pre-spawners remained vigorous after tagging and no recovery/mortality problems were observed during the tagging portion of this survey.

2.3 SPAWNER ENUMERATION, TAG DETECTION and TAG RECOVERY

Briefly, the enumeration technique involved the use of full spanning fish fences at the lower reaches of two side channel sites each fitted with fish counters and PIT antenna arrays at the upstream and downstream openings in the fences (Figures 4 and 5). The fish counters continuously monitor and log the number of tagged and untagged pre-spawners entering or leaving each side channel while the PIT receivers continuously monitor for PIT tagged individuals. At Tenderfoot Creek DFO annually operates a fence and at this site pre-spawners were enumerated manually in place of a fish counter (Figure 6).

2.3.1 Radio Telemetry - Mobile and Fixed Sites

A total of five directional fixed station Lotek W31 radio receivers and one mobile Lotek radio tracking unit were used to survey the side channels and mainstem habitats to determine spawner distribution and to assist in evaluating spawner residence time data. As in previous years four fixed station receivers were utilized, located near the Cheakamus/Squamish River confluence, at the confluence of the Cheakamus and Cheekye rivers near the Sunwolf Recreation Centre (49 º 47 978 N, 123 º 09 348 W), at the juvenile monitoring (RST) site, and 50 m downstream of the Bailey bridge (49 º 49 572 N, 123 º 09 161 W), (Figure 1). During 2010, one additional fixed location receiver was installed at the 'wood 'pool' on the Cheakamus River approximately 200 m downstream of the RST site.

Mobile tracking was performed by foot and raft one to two times per week from 200 m upstream of the Bailey bridge (River KM 7.0) downstream to the Cheakamus River confluence (River KM 0.0) to assess spawner movements between fixed telemetry stations. In addition two mobile tracks were undertaken from 'road end' (RKM 13) to the confluence. Evaluation of spawner location was undertaken combining mobile tracking and fixed station records. The upper location of a fishes likely spawning migration was estimated from mobile tracking to be the area in which a fish was found resident for at least two consecutive surveys (>48hours). Due to the frequency of the mobile tracks, this assessment method may underestimate the total number of spawners above a particular location. For example, if a fish makes an upstream movement after a survey, is resident in the new location for >48hours but moves downstream post spawning to a location at or below that previously observed prior to the next survey then its spawning location may be misclassified. Fixed station records will detect such movement but are generally unable to accurately detect spatial locations of fish to a range of better than 400m. To evaluate fine scale behavior of radio tagged fish around the RST site, we installed the additional receiver at the 'wood pool' and mobile tracked fish in the area from the 'gauge pool to the 'wood pool' every other day at minimum. .

Figure 3:TOP **-** *Once the pre-spawner is placed in the tagging cradle a brightly coloured one inch Petersen Disk tag and a 20 mm PIT tag is applied by a four person crew.*

BOTTOM – *Dissected post spawned carcass recovered in BC Rail channel 10 days after tag application highlighting Petersen disk and PIT tag placement.*

2.3.2 Channel Walks - Enumeration and Tag Recovery

To verify enumeration timing, spawning distribution, and tag retention channel walks were conducted by a three to four person field crew twice a week during the October 15 through December 15, 2010 survey period. The intent of the channel walks was to visually estimate and tally the total number of live, dead, and tagged chum spawners in all assessable portions of spawning habitat upstream of the fish counter and PIT tag detection sites. The areas surveyed include:

- Upper Paradise – channel upstream from fish counter site to Sue's Channel, Kisutch Channel, and the Gorbuscha Channels.

- BC Rail – channel upstream from Tenderfoot Creek outlet culvert through to Dave's Pond.

2.3.3 Pit Tag Detection

To detect PIT tags applied to upstream migrant pre-spawners, full-duplex PIT tag detection and logging equipment comprised of Destron-Fearing FS2001 134.2 kHZ readers/loggers and 0.5 X 0.5 m (Biomark Inc.) pass-through river antennas. In a gated type design, two pass through antennae were deployed concurrently with each fish counter channel such that upstream and downstream migrant spawners would be monitored by both PIT antennas and the fish counter (Figures 4 and 5). As for the Logie fish counters the PIT array and loggers were operated continuously through the monitoring period. Each PIT antenna and receiver was individually tuned to reduce any background signals and periodically tested by floating a drone tag taped to a 3m piece of twine up and down through the detection field to confirm a 0.3-0.5 m tag detection range.

2.3.4 Spawning Channel– Fish Enumeration

Tag detections through PIT tag logging as well as spawner detection through resistivity counter monitoring/ trap operations were conducted from October 15 through to December 15, 2010 in the lower reaches of side channels including: Upper Paradise spawning channels, BC Rail channel, and Tenderfoot Creek (DFO trap).

- Upper Paradise counter (~100m from mainstem) – 49 º 49 219 N - 123 º 04 227 W
- BC Rail counter (~200m from mainstem) – 49 º 49 525 N - 123 º 08 935 W
- Tenderfoot Creek trap (~350m from mainstem) – 49 º 49 675 N - 123 º 08 823 W

Downloads of electronic equipment were conducted up to twice a week and each site was visited daily by maintenance crews to monitor any debris build-up along fish fencing.

Figure 4: LEFT **-** *Upper Paradise side channel enumeration site demonstrating detection chutes with resistivity counter pads and PIT antennae. Two detection chutes are operating, and each operating chute contains one resistivity counter and two PIT antennae, one at the upstream and downstream ends of each chute.* RIGHT *– view looking upstream at the entrance to a detection chute containing a resistivity counter pad (white) and full-duplex PIT detection antenna (black square) at the downstream end. The upstream PIT antenna is not visible in the background.*

Figure 5: *BC Rail side channel enumeration site. Upstream migrant spawners pass through a counter flume with a resistivity counter pad (white) and two 0.5 x0.5 m square full-duplex PIT detection antennae (black).*

Figure 6: *Tenderfoot Creek enumeration site. Pre-spawners pass into a vee-type trap box before becoming manually counted by DFO staff.*

2.4 FISH COUNTERS, TRAPS and VIDEO VALIDATION

The primary method for evaluating the numbers of pre-spawning salmon entering the BC Rail and Upper Paradise side channels was by means of a resistivity fish counter. A resistivity fish counter operates by detecting the change in resistance caused by a fish as it passes a fixed point and close to sensors submerged in water. The change in resistance observed occurs because the fish is more conductive than the water it is displacing and therefore allows a slight increase in conductance while present between a pair of electrodes. The electrode sensors in any resistivity counter are designed to encourage migrating fish to pass close enough to the sensors to be detected and in a uniform manner, such that each fish passage can be recorded consistently.

The Logie 2100C fish counter uses these changes of electrical resistance between electrodes pairs caused by fish passage to provide counts. The date, time, conductivity, channel, direction of movement (up or down) and peak signal size (PSS) are recorded by the counter when a change in electrical resistance above threshold setting is encountered. If a change of resistance occurs which is not interpreted as a fish count by the counter's fish algorithm, the direction of count is substituted with the character 'E' which denotes an unclassified event. Such events may be fish which have been miss-classified, or failed to pass completely over the counter as well as debris flow, and air entrainment noise (Aprahamian et al. 1996). To each change of resistance the counter assigns a peak signal size which relates to the maximum deviation from baseline resistance observed during the event. PSS is a function of the fish size, counter gain setting (electrode sensitivity), river conductivity conditions and of the sensors bulk resistance (a measure of the instantaneous background resistance created by water flowing over the electrodes). To avoid collecting a multitude of events with low PSS due to background 'noise' a threshold PSS is selected for each sensor and each type of counter record. The counter is then able to evaluate records which are at least 0.5 seconds apart and can enumerate fish passing over all enabled sensors simultaneously. The Logie counter is designed to re-calibrate every 30 minutes for changes in bulk resistance and conductivity. These calibrations alter the gain (sensitivity) setting so that a fish of a standard size will be attributed a similar PSS, under a wide range of environmental conditions. Data are stored on the fish counter memory and downloaded periodically by laptop computer.

2.4.1 Site Specific Design and Settings

Briefly, the Upper Paradise spawning channel counter consisted of two counter chutes affixed to a sill constructed across the channel bed approximately 100m upstream of the mainstem/channel confluence (Figure 4). Into these chutes and in a high density polyethylene (HDPE) sheet were set three stainless steel electrodes (12 by 4mm) at 30 cm spacing (Figure 4). These electrodes were connected to the Logie 2100C counter unit by copper wire.

At the BC Rail channel resistivity counter electrodes were placed on the base of a 60 cm wide, 2.0 m long flume fixed to two fence wings approximately 200m upstream of the mainstem/channel confluence (Figure 5). The sensor unit was placed flush with the base of the flume and consisted of electrodes set in HDPE as in Upper Paradise channel.

Pre-spawners were visually enumerated at Tenderfoot Creek through capture with an aluminum vee-type slot trap near Tenderfoot Hatchery (Figure 6). Each day the number, sex and presence of any Petersen disk tagged chum spawners were visually assessed by hatchery staff and recorded before the fish were released through an upstream trap gate to spawning habitat located in the groundwater fed Tenderfoot Lake. During 2010 a PIT antenna and logger unit monitored the entrance to the Tenderfoot Creek fish trap and this data was used to confirm the visual assessment of tagged spawners.

As in previous years' assessments, fish counter conductivity calibration was not required at any site as conductivity was expected to vary little and was low (circa 50 µs), resulting in the counter generating large peak signal sizes for chum salmon passage while utilizing a predetermined fixed 'gain' setting of 100. In this study and although each sites electrode arrays were of different designs a minimum threshold PSS of 30 (on a scale of 1-127) was selected for both upstream and downstream counts and events. This threshold was visually observed to minimize background noise triggers while evaluating all fish passage. Lower threshold levels while allowing for the potential enumeration of smaller fish (*i.e.*< 0.5 kg), tend to pick up resistance noise created by water turbulence and entrained air bubbles so are best avoided. As our target species were adult chum salmon with weights in excess of 3.5 kg all fish created PSS well in excess of this threshold as observed visually and by remote video.

2.4.2 Video Validation

Counter data obtained at Upper Paradise and BC Rail enumeration sites were analysed in relation to video footage recorded using digital video recorders (Capture DVMS 400 and HD Mini DVR MDVR25) linked with infra-red micro-cameras, as described in Aprahamian et al. (1995). Similar studies in the United Kingdom and British Columbia (Fewings 1987; Welton et al. 1987; Dunkley 1991) have demonstrated the utility of this video validation methodology. Counter efficiencies were based on the number of fish viewed passing completely over the counter in relationship to the number correctly assigned as upstream or downstream counts by the electronic counter. Time-lapse video records were used to provide observations of fish that might have passed by the counter without creating counter events. These video records were then compared with counter records to establish counter efficiencies unique to each enumeration location.

2.4.3 Discharge and counter efficiency

In an extension of the video validation river discharge at the Brackendale gauge which is representative of stream discharge in the sidechannels due to backwatering was used to help identify temporary periods when the fish counters were subjected might have been subjected to high water events which can result in temporary changes to counter detection efficiency. Corroborating the video validation and counter data to relative stream stage allowed us to parse correction efficiencies to ‘high’ and ‘normal’ flow periods if required.

2.4.4 Counter Efficiency and Daily Counts

By design, the resistivity counter allows fish to move freely upstream and downstream over the directional counter electrodes. Based on the literature for chum salmon spawning behaviour, originally, we expected fish to undertake one directional upstream migration ‘through’ a counter channel and one set of directional PIT tag readers. Once in the channel the fish was expected to spawn and die, with the carcasses remaining in the channel, as observed with a large accumulation of mortalities in the various preferred spawning locations. In this simple case for fish moving in a single direction upriver to spawn, the spawning escapement is the sum of all the UP counts at one counter site. However, during the inaugural enumeration season in 2007, we observed that a proportion of fish, termed as kelts, move downstream past the counter/PIT tag station after spawning. It was also suspected that a small proportion of fish may move up and down past the fish counters on several occasions (i.e. recycling) prior to spawning. This was observed as multiple through passage events on the PIT tag arrays in both directions separated by a limited time period, minutes through several hours. As the fish counters cannot identify specific individuals to determine whether a fish is a kelt or an unspawned adult an additional calculation is required to generate spawner numbers. The time marked directional PIT antennae arrays can be used to identify tagged spawner movement patterns and these data after evaluation were extrapolated and used as a surrogate to correct for side channel specific 'kelting and recycling behaviour' for those fish that exhibited downstream movements. To assist with interpretation of these behaviours we offer the following definitions:

Spawning escapement – total number of male and female chum spawners estimated to have spawned upstream of the monitoring site during the monitoring period.

Simple spawner behaviour – a fish which moves upstream past the detection sites and is not detected again during the monitoring period (one net up count and zero down counts are recorded).

Recycling behaviour – spawners which move upstream and downstream over the counter array in a period of less than 48 hours. These fish may make multiple passage events in each direction and may or may not make a final directed movement upstream.

Kelted spawner behaviour – spawners that move upstream into the side channels, but at a later date (>48hrs), after spawning make a directed downstream movement past the counter array. A spawner was considered a kelt if it was resident above the detection array for at least 48 hours, which is considered the minimum time required for female spawning (Salo 1991, Troffe 2008).

Allowing for recycling of pre-spawners but assuming no downstream movement of kelts, the total net upstream spawner escapement for each side channel monitored by a fish counter can be derived from the sum of the daily number of up counts minus down counts or equation 1. This calculation does not take into account the efficiency of the fish counter in detecting fish passage.

$$E_{sp} = \Sigma_{daily}\ [U - D]$$

Where,

E_{sp}= total side channel spawning escapement

U = the number of daily up counts

D = the number of daily down counts

As we observed through video validation that the counters are not 100% efficient (i.e. not every fish that fully passes over the sensor units in the counter channel is correctly enumerated as an up or down count), these data require correction for daily counter efficiency.

$$E_{sp} = \Sigma_{daily}\ [U(1/Q_U) – (D(1/Q_D)]$$

Where,

Q_U = efficiency of up counts at site determined through video validation

Q_D = efficiency of down counts at site determined through video validation

However as we evaluated that a proportion of down counts are created by outmigrant kelts and not just recycling fish, we must take this into account or our estimate will be bias low. To this affect the total daily escapement can be calculated as the total number of up counts minus the total number of down counts corrected for the total number of kelted fish, using the following equation:

$$E_{sp} = \Sigma_{daily}\ [U(1/Q_U) – \{(D(1/Q_D) - D(1/Q_D)K\}]$$

Where,

K= side channel specific proportion of down counts estimated to be post spawned fish exhibiting ‘kelting behaviour’. Here, calculation from PIT detections over the entire season, side-channel specific.

e.g. - During a single 24 hr period the counter records 100 up counts and 25 down counts. Video validation shows upstream and downstream efficiency of the fish counter is 90% and 95% respectively, and 10% of down counts are estimated to be post spawned kelts. Using the equation above we can derive the daily spawner escapement:

($100_{\text{up count}}(1/0.90_{\text{up effc.}})$

= 110 corrected up counts

$(25_{\text{down count}}\ (1/0.95_{\text{down effic.}}) - \{25_{\text{down count}}\ (1/0.95_{\text{down effic.}})0.1_{\text{kelt ratio}}\}$

= 24 corrected down counts

110 up counts – 24 down counts

Total spawners = 86

For the purposes of the mark recapture analysis, the total number of fish captured at a counter site is equal to the total escapement estimate. The number of marked recaptures is the number of unique PIT tag coded fish which were evaluated to have spawned in the channel. PIT tagged fish which entered the channel but left within 48 hours were excluded from the recapture total being assumed to be recycling fish which spawned in an alternative location.

$$R = \Sigma \text{ unique PIT Up} - \text{PITrec}$$

Where,

R= total number of recaptured tags

PIT Up = the number of unique tag codes detected on the upper PIT antenna

PITrec = the number of PITUp tags identified as recycling fish, i.e. leave channel without a period of at least 48 hour residence.

2.5 ESCAPEMENT ANALYSIS

Escapement estimates of chum salmon spawners into the Cheakamus River are required for hypothesis testing at a variety of levels. Our study aims to provide three key estimates of spawner abundance which are outlined below and conceptualized in Figure 7.

1) A whole river chum salmon spawner estimate – this estimate accounts for all spawners upstream of river KM 1.5 the ‘stables’ tag application location, including all side channel complexes (e.g. Upper Paradise, BC Rail, Tenderfoot Creek).

2) An estimate of the number of chum salmon spawning upstream of RST juvenile monitoring site – using detection data from spawners tagged at the upper river 'gauge' pool site and/or proportional distribution of telemetry tagged lower river spawners observed above the RST site.

3) Estimates of individual spawning channel chum escapement in BC Rail, Upper Paradise and trap counts from Tenderfoot Creek.

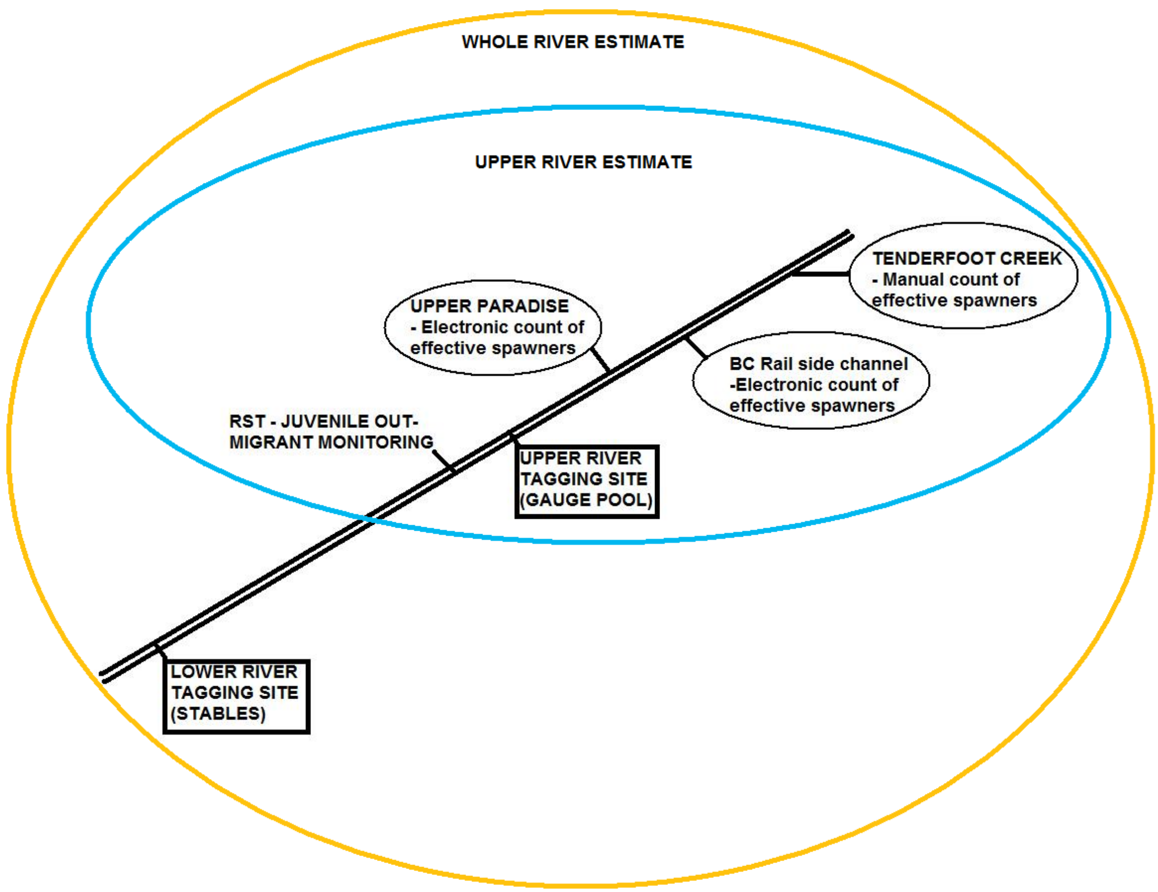

Figure 7: *Conceptual diagram of the Cheakamus River chum salmon spawner enumeration monitor illustrating the spatial relationship of tagging and monitoring locations. Whole river (yellow ellipse), Upper river (blue ellipse), and individual side channel (black ellipses) spawner estimates are highlighted.*

To determine the actual number of chum salmon arriving back to the watershed to spawn, in a given sample time period, a known number of marked fish are released into the population downstream of the side channel enumerating locations. We assume that a portion of these fish will move upstream past the enumeration station (resistivity counter with PIT tag receiver or manual trap) effectively being recaptured (i.e. re-observed). Assuming that fish do not lose their marks before recapture, that no marks are missed during sampling, and that the chance of detecting any marked fish is equal to unmarked fish and the efficiency of a capture trap on sampling marked fish can be calculated for a given time period (Seber 1982; AFS 2007). Combined with these data, when the total number of unmarked fish are also evaluated at the same recapture locations, it is then possible to statistically model the numbers of total fish in the study population from which the sub-sample was derived (*see:* equations below for Pooled Petersen estimator herein).

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 = escapement estimate

C = total catch

R = number of marked fish detected

M = number of marks released

If random mixing of marked and unmarked individuals is assumed, then the variance of recovered marks has a binomial distribution. In these cases it is best to obtain approximate confidence intervals from a table or equations that approximate the binomial distribution using recovered marks as the key parameter. Ricker (1975) derives the confidence intervals for N in large sampling regimes (>25) as in equation 1 as approximately equal to:

$$R(V) = R + 1.92 \pm 1.96 \sqrt{(R+1)}$$

Where V = the variance of R

R = number of detections

By substituting the upper and lower calculated values of R (equation 2) the confidence limits for Peterson population estimates can be derived.

2.5.1 Mark Recapture Assumptions

Mark-recapture designs can estimate the population (*N*) at either the time of tagging (N_1), or the time of recapture (N_2), and the assumptions required for each estimate differs. For this program, N_1refers to 'returns' and N_2 is 'effective spawners'. Given the intent of this program to ultimately calculate the number of fry produced per spawner, *N* at time of recapture (approximated as the spawning escapement) would be most relevant. However, several additional assumptions are required to estimate N_2 (many of which cannot be rigorously evaluated with this design). We chose, therefore, to estimate N_1 (approximated as the number of the fish that pass the tagging site) since fewer assumptions are required, if we further assume that these processes affect tagged and untagged fish equally. For example; we do not need to assume many components of the closure assumption, such as no removal of fish from harvest, predation, downstream migration, or death prior to arriving at the recapture location, if we assume that these processes affect tagged and untagged fish equally. Thus the whole river estimate whilst estimating the number of returns to the marking site, may tend to overestimate the number of effective spawners. In comparison numbers derived from the fish trap on Tenderfoot Creek close to the spawning areas are both a total count and more likely a better representation of effective spawners, while the estimates derived at the counter sites on Upper Paradise and BC Rail are likely good indicators of effective spawners but may contain some error related to varied counter efficiency and the assumptions of kelting and recycling behavior that are used in their derivation.

During our analysis we assume that:

1. ***The population is closed during the survey period, mortality and emigration affect tagged and untagged fish equally, and all components of the population are vulnerable to either capture or recapture.*** For this assumption to be valid, it is critical that marks be applied to chum salmon throughout the entire migration period, and that tagged individuals are well mixed within the population at time of recapture.

    - Spawners were tagged sufficiently downstream of recapture locations to promote equal mixing and tag application was conducted throughout migratory period except during relatively short periods when river discharges were too high for fish capture.

2. ***Tagged and untagged fish are correctly identified***. If tagged and/or untagged fish are not detected, the proportion of tagged fish may be over or underestimated in recapture samples, and population abundance may be biased high or low.

    - The detection efficiency of resistivity counters has been demonstrated to be >90 per cent and of low variance in several other river systems in British Columbia (McCubbing et al. 1999; McCubbing and Ignace 1999). Here, we use video validation to check counter efficiency.

- Most literature studies observed PIT tag detection efficiencies of >95 per cent (Prentice et al. 1990; McCutcheon et al. 1994; Castro-Santos et al. 1996). Here, we estimate PIT detection efficiency at > 98% by comparing PIT detections to those tagged carcasses reported during stream walks (2008/09).

3. ***No tags are lost***. If tags are lost (due to poor application technique or aggressive behaviour during spawning), the proportion of tagged fish will be underestimated in the recapture samples, and as a result population abundance will be overestimated.

    - Most salmonid studies using PIT technology to investigate long term survival through multiple life-stages indicate that PIT tag loss is low at< 2 % over the entire life-history cycle (Prentice et al. 1990; McCutcheon et al. 1994; Buzby and Deegan 1999; Dare 2003) In this, short duration, six week monitor we applied pit tags to returning adult fish through intra-muscular injection and have not observed any PIT tag loss (100% retention) during stream walks focused on tag retention (All recovered Petersen disk tagged carcasses are scanned for PIT tags).
    - For visual tags, Schubert et al. (1996) found loss rates from 0 to 2.7 % from adult pink salmon. During streamwalk surveys for carcass counts (2007/08/09) we have observed some damaged Petersen disk tags on spawned-out carcasses, however, it is unclear when tag damage was incurred (*e.g.* predator or spawning activity induced).

4. ***Tagging does not change the availability of fish for detection.*** The stress of capturing, holding and marking fish could lead to behavioural changes which might affect a fishes post tagging behavior and thus result in no further upstream movement or in some cases even cause mortality. Such effects would result in an overestimate in the number of tagged fish available for recapture and would bias the population abundance estimate high.

    - Visual surveys provide some inference on behaviour of both untagged and tagged spawners. Fish condition at release and radio telemetry also provides information on post-tagging behaviour.

5. ***Tagged and untagged fish have an equal probability of initial capture and subsequent detection.*** This assumption is generally violated to some extent in all mark-recapture studies (Otis et al. 1978), but can be minimized by making tag application and recovery as representative as possible, through standardized effort and the use of gear with minimal selectivity.

    - PIT detection arrays and resistivity counters are passive type technologies which are, in this study, located in very close proximity to each other by design to maximize the likelihood that tagged and untagged fish are detected equally.

2.6 MAINSTEM GROUNDWATER MONITORING

To explore any potential relationships between river discharge, groundwater upwelling, and the selection of spawning habitat by chum salmon in the mainstem Cheakamus River we followed a methodology similar to that used to by Geist et al. (2002) in the Lower Columbia River. Geist et al. (2002) identified that chum salmon spawners focused spawning activity at sites with upwelling groundwater which was identified as being significantly warmer than the surrounding river water.

To test the general hypothesis that river water temperatures do not differ from water temperatures observed in chum redds in the hyporheic zone we installed two river stage and temperature logging devices in stilling wells (located on left and right banks) proximate to eight simulated egg capsules containing temperature loggers (Onset Tidbit UTBI-001) buried at redd sites (Figure 8). Observations were limited to two small sections of the river where large spawning aggregations had been observed in 2009 and 2010 - near the Moody's Beach at RKM 3.5 and around the gauge pool tagging site at RK 5.5. The monitoring equipment was installed once the majority of spawning activity had subsided on December 3, 2010 by a three person crew. Using a method similar to that used by Troffe et al. (2008) river velocity and water depth measurements were collected at all capsule sites on January 4th 2011. The stage recorders and temperature loggers were set to log hourly and recovered approximately 90 days (March 18) later during the onset of chum juvenile emergence (Detailed information in Appendix III).

Figure 8:*<u>TOP</u> – water temperature logger becomes incorporated into a capped 30cm section of perforated PVC pipe to form a simulated egg capsule. <u>BOTTOM</u> – one of nine capsules is anchored and then 6 reburied into randomly selected chum redds near Moody's Beach and 3 at the Gauge Pool.*

3.0 RESULTS

3.1 CAPTURE AND TAGGING

Tagging effort was directed at the upper and lower tag application sites from October 2 through November 22, 2010. The best opportunities for fishing appeared related to river discharge changes. In general, more fish and higher catch per unit efforts (CPUE) were encountered when river discharges were falling after a period of recent increased discharge, especially during late October through mid-November (Figure 9, Tables 1 and 2). At the lower river 'stables' location PIT and Petersen disk tags were applied to a total of 537 chum salmon (333 Male, 204 Female) over 23 fishing dates and of these tagged fish 77 (14%) (37 Male, 40 Female) were gastrically implanted with radio telemetry tags (Table 1). At the upper river 'gauge pool' fishing location a total of 377 spawners (292 Male, 85 Female) were tagged over 16 fishing dates and of these tagged fish 52 (13%) (23 Male, 29 Female) were gastrically implanted with radio telemetry tags (Table 2). Details for each spawner tagged during 2010 are presented in Appendix I.

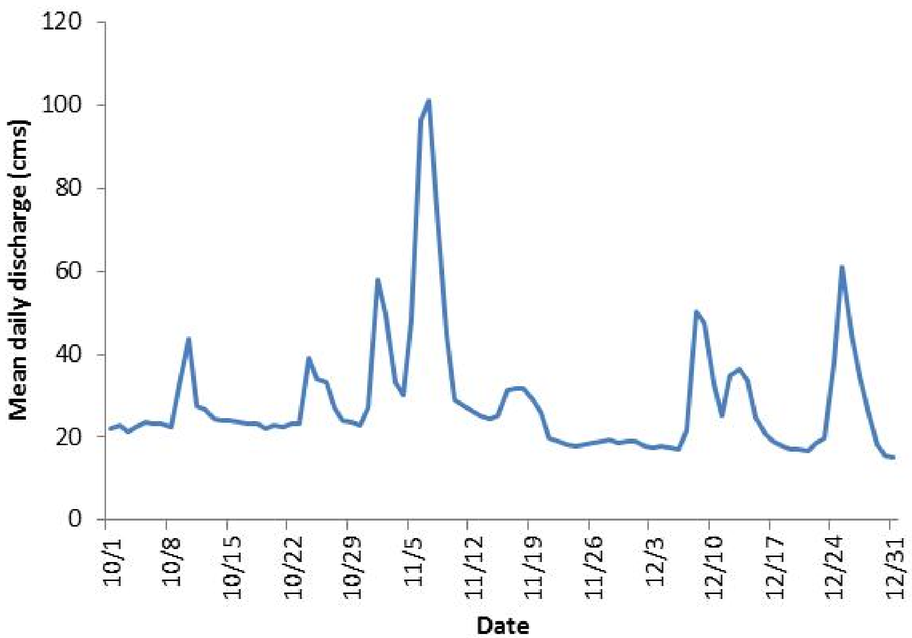

Figure 9:*Cheakamus River relative discharge from October 1- December 31, 2010. Brackendale WSC gauge 08GA043 (49° 49' 00" N - 123° 08' 54" W).*

3.1.1 Sex Ratio, Length and Condition

The sex ratio of chum salmon captured for tag application during 2010 was skewed towards male fish at the lower river 'stables' site throughout the survey period although the difference in sex ratio slowly shifted towards being less skewed to males near the end of the tagging period as more females moved into the fishing location (3.0 –1.4, average = 1.9 M:F), (Tables 1 and 2). The sex ratio of spawners tagged at the upper river 'gauge pool' site was skewed to favour males (average = 3.5 M:F) during the entire marking period (Tables 1 and 2). Combining all the data, a total of 2.2 males were tagged for every female.

The average fork length of female spawners tagged at the stables location was 29mm smaller than male fish tagged at this site (730±41vs. 759±46 S.D.). There was less of a difference in sizes at the gauge pool tagging site but females were still smaller on average (732±41 vs. 768±58 S.D., Figure 10, Tables 1 and 2). The length of tagged female and male spawners ranged 630-880mm, and 620-885mm, respectively, suggesting multiple cohorts may be present (Figure 10, Tables 1 and 2). In general the size of females tagged declined during the migration period whereas males varied throughout.

The condition of pre-spawners tagged at the lower river 'stables' locations was generally higher than those tagged at the upper river 'gauge pool' due largely to the fact that the fish were earlier in their in-river spawning migration. Some fish captured at the lower river site were observed displaying sea lice on their opercular flap or body. As in 2009 and unlike previous years, many fish captured across the entire migration period were in less than optimal condition for tagging and were thus not tagged. During tagging efforts the majority of the lower river fish were in acceptable condition for tagging (536 of 564 fish) although one of these fish was assessed a condition 3. Generally, condition 1 fish were dominant in the tag sample at >50% in most tagging stanza although condition declined during the sampling period (Figure 11). At the upper tagging site only 335 of 543 fish encountered were tagged as condition factors were generally lower. This tag group included 7 condition 3 fish. About equal numbers of condition 1 and condition 2 fish were tagged.

Table 1: *Sex ratio, catch per unit effort (CPUE), average standard length and number of PIT and radio telemetry (RT) tags applied per week at the lower river 'stables' location during October 2 – November 22, 2010.*

Tagging Date (weeks start)	FEMALE TOTAL # TAGGED/RT	MALE TOTAL # TAGGED/RT	SEX RATIO M:F	CPUE # TAGGED/ #WEEKLY SETS	FEMALE MEAN FORK LENGTH ± S.D. (mm)	MALE MEAN FORK LENGTH ± S.D. (mm)
26-Sep-10	0/0	3/0	3.0	0.8	0 ± 0	788 ± 55
3-Oct-10	0/0	0/0	NA	0.0	0 ± 0	0 ± 0
10-Oct-10	2/0	6/0	3.0	2.0	790 ± 14	785 ± 30
17-Oct-10	16/2	35/5	2.2	2.0	742 ± 39	789 ± 39
24-Oct-10	21/4	41/7	2.0	5.6	749 ± 44	764 ± 43
31-Oct-10	29/8	40/4	1.4	2.8	722 ± 69	771 ± 69
7-Nov-10	70/16	107/17	1.5	8.9	725 ± 52	757 ± 52
14-Nov-10	62/8	93/4	1.5	7.0	727 ± 54	760 ± 47
21-Nov-10	4/1	8/0	2.0	6.0	706 ± 52	740 ± 56
TOTALS	204/39	333/37	1.9	AVERAGE:	737 ± 46	769 ± 49

Table 2: *Sex ratio, catch per unit effort (CPUE), average standard length and number of PIT tags applied per week at the upper river 'Gauge pool' location during October 14 – November 17, 2010.*

Tagging Date (weeks start)	FEMALE TOTAL # TAGGED/RT	MALE TOTAL # TAGGED/RT	SEX RATIO M:F	CPUE # TAGGED/ #WEEKLY SETS	FEMALE MEAN FORK LENGTH ± S.D. (mm)	MALE MEAN FORK LENGTH ± S.D. (mm)
10-Oct-10	0/0	4/1	4.0	1.3	817 ± 30	0 ± 0
17-Oct-10	6/0	5/1	0.8	2.8	756 ± 39	763 ± 40
24-Oct-10	28/3	88/5	3.1	11.6	740 ± 50	805 ± 49
31-Oct-10	25/4	79/15	3.2	5.5	728 ± 69	775 ± 70
7-Nov-10	25/16	94/7	3.8	5.7	718 ± 52	747 ± 51
14-Nov-10	1/0	22/0	6.5	4.3	724 ± 72	731 ± 52
TOTALS	85/23	292/29	3.5	AVERAGE:	748 ± 52	764 ± 52

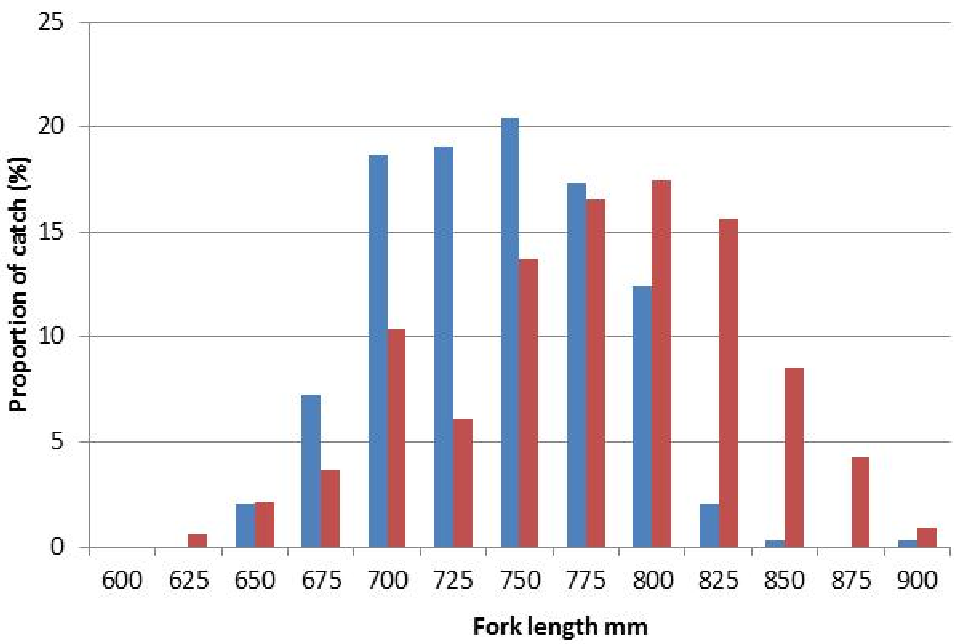

Figure 10: *Fork length (mm) of all male (red bar) and female (blue bar) adult chum salmon tagged in the Cheakamus River during 2010 spawner survey.*

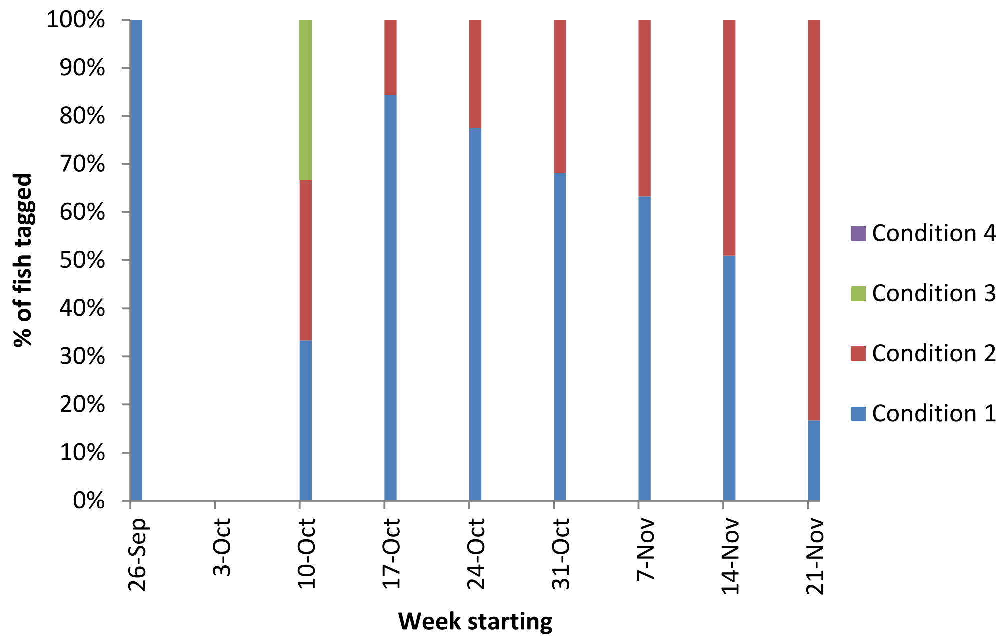

Figure 11: *Proportional condition of chum salmon spawners tagged weekly at the lower river 'stables' tagging location during October 2 – November 22, 2010.*

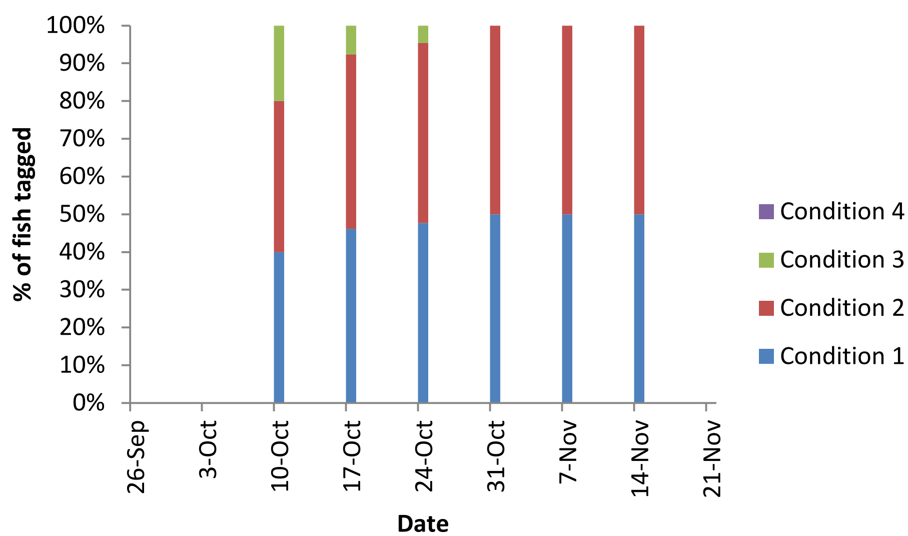

Figure 12: *Proportional condition of chum salmon spawners tagged weekly at the upper river 'gauge pool' tagging location during October 14 – November 17, 2010.*

3.2 RADIO TELEMETRY and SPAWNER DISTRIBUTION

Approximately 14% of pre-spawners with PIT tags applied at the lower and upper river tagging locations were also implanted with radio telemetry tags (Table 1). Using a combination of fixed station and mobile radio tracking the location of spawning was inferred by determining the furthest distance upstream an individual tagged spawner held in one location (usually 2-3 days) before becoming moribund, whereupon post-spawned fish either move back down river or expire close to their spawning location. During 2010 we were able to ascertain a distribution history for 95% (72/76) of spawners tagged with radio telemetry tags at the lower river stables site and 98% (51 of 52) fish tagged with radio tags at the upper 'gauge pool' site. It is unclear whether the missing tags (n=5) failed or whether they were removed from the system by anglers, First Nation harvesting or predators.

In 2010 based on lower river tags only and from combined mobile/fixed station tracking, an increased proportion (29 %, N=22) of radio tagged fish were identified as spawning in the section of river stretching from below the Cheekye river confluence at river KM 3.0 to the Squamish River confluence at RKM zero (Table 3). These fish were represented by equal numbers of males and females. A further 21% (N=16) of spawners utilized the now slow water habitats between Cheekye River and Moody's side channel confluences (River KM 3.0-4.0). It should be noted that this section of river has changed significantly (backwatered and slowed) since the 2008 monitoring season by way of a short intense flood event in the summer of 2009 which resulted in a portion of the Cheakamus River becoming partially blocked by a boulder fan originating from the Cheekye River near River KM 3.0.

The remaining 45% (N=34) of radio tagged spawners were identified as spawning upstream of Moody's confluence. A total of 34% of tagged fish were assessed by mobile tracking as having spawned between Moody's and the RST site (River KM 4.0-5.0), with just 9% spawning upstream of the RST location receiver (River KM 5.0-6.0), 1% of the total being detected above the Bailey Bridge receiver (River KM 7.0+).

In 2010 we also tagged 52 chum adults with radio tags at the upper tagging reach. The intention of this change in methods was to ascertain what if any proportion of fish tagged at the upper site may be dropping out of the area above the RST prior to spawning. This would tend to bias our spawner estimate and egg deposition calculations high if untagged unhandled fish were more likely to remain above the RST site having migrated this far upstream. Of the 52 tagged fish 36 or 70% were assessed to remain above the RST prior to spawning (Table 3b). Of these 21/23 (or 91%) of females exhibited this behavior, males apparently being affected more negatively post tagging or more likely to exhibit a straying pattern. There was no link between fish condition (1 or 2) and subsequent behavior at this site, and while fish radio tagged later in the run (post November 1st) at the upper site were more likely to enter the sidechannels, this was linked to an increasing proportion of females being tagged in the later part of the season, rather than any temporal variation in behavior of all fish. A total of 17 of the 52 (33%) radio tagged fish marked at the 'gauge pool' site were detected on the PIT tag antennas in one of the spawning channels.

Table 3: *2010 spawning distribution of chum salmon with radio telemetry tags at the lower river 'Stables' tag application site. Spawner distribution was assessed through a combination of fixed station and weekly mobile radio tracking by raft. Percentages in parentheses are percent of all tagged fish (both sexes).*

Sex (N=76)	No distribution data obtained	Downstream of Cheekeye confluence (R Km 1.5-3)	Between Cheekeye confluence and Moody's confluence (R Km 3-4)	Between Moody's Confluence and RST site (R Km 4-5)	Upstream of RST monitoring site (R Km 5-6)	Bailey bridge and above (R Km 6+)
Females	1 (4%)	11 (14%)	7 (13%)	10 (13%)	2 (4%)	1 (1%)
Males	4 (1%)	11 (14%)	5 (11%)	13 (21%)	4 (6%)	0 (0%)
Total	4 (5%)	22 (29%)	12 (24%)	37 (34%)	6 (8 %)	1 (1%)

Table 3b: *2010 spawning distribution of chum salmon tagged with radio telemetry tags at the upper river 'Gauge' tag application site. Spawner distribution was assessed through a combination of fixed station and weekly mobile radio tracking by raft. Percentages in parentheses are percent of all tagged fish (both sexes).*

Sex (N=52)	No distribution data obtained	Downstream RST Monitoring site (R Km <5)	Upstream of RST monitoring site (R Km 5-6)
Females	0 (0%)	2 (4%)	21 (40%)
Males	1 (3%)	12 (23%)	16 (30%)
Total	1 (3%)	14 (27%)	37 (70%)

3.3 CHANNEL WALKS

All reaches of BC Rail, and the Upper Paradise channel complex were surveyed by three to four person crews approximately twice a week through the October 13 to December 13, 2010 survey period. The total number of live and dead chum salmon spawners in each channel was recorded during each foot survey and any tags recovered or observed were noted. Counts of live chum spawners increased through early November with numbers peaking for Upper Paradise and BC Rail channels during the week ending November 6 (Figure 13). Carcass counts slowly increased through early November, and numbers for all channels peaked in the weeks through mid/late November, approximately two to three weeks after peak live spawner counts were observed (Figure 13).

3.3.1 Visual Tag Recoveries

During stream walks visual tag recoveries of Peterson discs on fish carcasses and of those found on the stream bed, having become detached from fish were infrequent with only 31 of 914 (3.4 %) tags applied, recovered in total (Table 4).Of these 3, or<1% of the total lower river tags applied were recovered compared to 18or 4.7% of the total upper river applied tags.

Of the tags recovered, four were observed in BC Rail channel, all upper river applied, while in Upper Paradise 14 of 16 recovered tags were from the upper river tagging site (Table 4). The remaining tags were recovered in Tenderfoot trap (7), Moody's channel (1) and at the gauge pool tagging site (1).

Two discs were recovered in the Upper Paradise complex which had become separated from the fish in which they had been placed.

Table 4: *Number and proportion of Peterson disc tags recovered during channel walks in the Upper Paradise, Moody's and BC Rail channel complexes during October 13, through December 12, 2010.*

Recovery location	Applied at Lower River 'Stables'	Applied at Upper River 'Gauge pool'
Upper Paradise	2	14
BC Rail	0	4
Moodys	1	0
Total tags applied	3 of 537	18 of 337
% recovery	0.56%	4.8 %

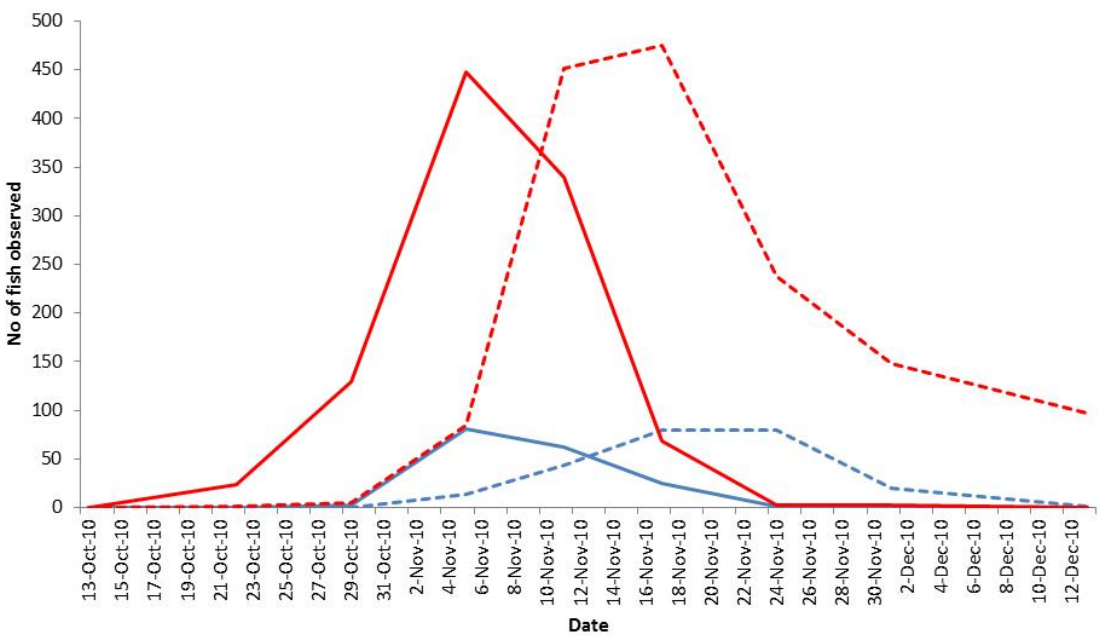

Figure 13: *Stream walk counts of live (solid line) and dead (dashed line) chum salmon spawners observed during channel walks at Upper Paradise (red line) and BC rail (Blue line) channels during weeks starting October 13, through December 13, 2010.*

3.4 PIT TAG DETECTION

Pre-spawners tagged with PIT tags were classified as detected when the unique PIT tag code was first logged on the most upstream receiver unit(s). Only spawners that transited through the downstream and upstream antennae were considered as being detected. In the majority of cases, multiple PIT detections were logged for each tagged spawner that moved through the PIT directional arrays (Table 5). An example of observed fish behaviour is illustrated in Table 5 with an example from some Upper Paradise detections; the earlier October 30, 2009 detection date illustrates the fresh migrant spawner approaching the near bank downstream antenna and then moving upstream through the upstream antenna on the array, then on a later date, November 3, 2009, the kelted fish drops back downstream through the far bank antenna array.

3.4.1 Sex Ratios

We examined the male-to-female sex ratio of remote side channel remote PIT detected marked spawners compared to the proportion marked at the tagging sites. For fish which originated at the lower river tagging site the ratio was similar to the proportional distribution of tags applied at that site although the sample size of recoveries is small (2.0:1, N=16 vs. 1.9:1, N=537). For upper river tagged fish, the ratio was skewed slightly to an increase in male spawners (4.0:1, N=46 vs. 3.5:1, N=377). Average sex ratio for all side channel verified PIT marked spawners was 3 males to every female compared to a tagging ratio of 2.2:1 for all fish marked.

In comparison the sex ratio of carcasses recovered in stream walks was 1.85 males for every female at BC rail channel and 1.8 males for every female at all NVOS channels combined. Kisutch channel was different in that the sex ratio of carcasses was 3.1 males to every female. At Tenderfoot trap 3.4 males were captured for every female. In general males were more likely to enter the sidechannels but also more likely to fail to pass through the readers: 28 males compared with just eight females (7:1 ratio). They were also more likely to enter the channel and leave within a short period (less than 48 hours), 23 males compared with 3 females (7.5:1 ratio). These fish were unlikely to have completed spawning activity. Males also exhibited more kelting behavior with 7 outmigrant fish detected post spawning compared to 2 females, but only in a similar ratio as those that entered the channels (3.5:1) given the paucity of data.

3.4.2 Pit Tag Detection Efficiency and Retention

During 2008 through 2010 we were able to estimate the detection efficiency of the PIT arrays by comparing the logged records at each detection site to those tagged fish recovered during subsequent stream walk surveys. The combined detection efficiency of PIT tagged spawners was estimated at 98.9% (88 of 89 carcass recoveries). Based on the tag application and stream walk recovery timing of the one undetected PIT tagged spawner it is hypothesised that this unrecorded fish in 2009 transited through the detection array during a period where there was a temporary power interruption to the detection field at the Upper Paradise site. PIT tag loss is not a cause for concern during this monitor as observed PIT tag retention has been 100% (2008/09) for all carcasses exhibiting a Peterson disc tag recovered in all side channels.

Table 5:*Example of PIT detection log data from a unique chum spawner detected on the Upper Paradise channel array illustrating directional detections on two separate dates. N.B. – Logging devise is set to log one event per minute if tagged fish is continuously within detection range.*

Detection Date	Time	PIT code (decimal format)	Antenna location	Fish Behaviour
Fresh Spawner 30/10/2009	20:41:31	985.121004398380	Near bank down stream	First approaches downstream antenna
30/10/2009	20:47:09	985.121004398380	Near bank up stream	Passes through counter chute and through upstream antenna
30/10/2009	20:49:09	985.121004398380	Near bank up stream	Holds within range of upstream antenna before moving further upstream into Upper Paradise spawning channels.
Kelted Spawner 03/11/2009	9:59:24	985.121004398380	Far bank up stream	Four days later detected on upstream antenna
03/11/2009	10:00:43	985.121004398380	Far bank down stream	Seconds later detected moving downstream and out of Upper Paradise spawning channels

3.4.3 Total PIT Tag Detections

Side channel detection at detection/counter arrays of pre-spawners marked at all the locations occurred throughout the sampling period (October 1 – November 22, 2010). A total of 144 of all 914 (12.5%) PIT tagged spawners were detected at NVOS, BC Rail and Tenderfoot channels during operations (Table 6). Most of the detections occurred in the Upper Paradise channels (108), followed by BC Rail (23), and Tenderfoot Creek (13) (Table 6). Of these detections 72 of 914 (7.9%) were assessed as spawning in the channels. These included 7 fish in Tenderfoot (above the trap), 52 in Upper Paradise and 14 in BC Rail channels.

3.4.4 Upper and Lower River Deployed PIT Tag Detections

Owing largely to the proximate location of the upper river 'gauge pool' tag application site to the side channel detection/counter arrays the detection rates were higher and transit times shorter than those spawners tagged lower in the river at the 'stables pool' location. A total of 111 of 377 (29%) of upper river tagged spawners were detected during the survey period (Table 6). In comparison a total of 31 of 537 (5.7%) of lower river tagged spawners were detected during the survey period (Table 6). The average transit time for spawners tagged at the upper river location ranged from a low of 2.3 ± 2.5 days for the Upper Paradise site to a high of 3.9 ± 2.9 days at the BC Rail detection array (Table 6). The average transit time for spawners tagged at the lower river location also varied among side channels and ranged from a low of 4.6 ± 1.6 (S.D.) days for the Upper Paradise channel to a high of 6.3 ± 1.5 (S.D.) days at the BC Rail detection location although sample sizes were low (Table 6).

Not all of the fish that entered the BC Rail and NVOS channel complexes as far as the PIT tag antenna and counter arrays were ultimately designated as side-channel spawners. Based on the 48 hour residency rule, total side channel spawners were just 12 of 537 or 2.2% of lower river tagged fish (Table 7) and 60 of 377 or 15.9% of the upper river tagged fish.

Table 6: *Number and total proportion of all adult chum salmon PIT tag detections observed as recorded at BC Rail and Upper Paradise side channel antennas with in 2010 the average (± S.D.) number of days from tag application to first detection.*

Detection site	Tagging location		Recovery location Average (± S.D.) days from tag application to first detection	
	Lower 'Stables pool'	Upper 'Gauge pool'	'Stables pool' site	Upper 'Gauge pool' site
Upper Paradise	25	81	4.6 ± 1.6 (n=11)	2.3 ± 2.5 (n=81)
BC Rail	5	18	6.3 ± 1.5 (n=3)	3.9 ± 2.9 (n=20)
Tenderfoot	1	12	4.0(n=1)	3.1 ± 2.2 (n=12)
Total detection / tags applied	31 of 537	111 of 377		
% recovery	5.7%	29%		

Table 7: *Number and total proportion of all adult chum salmon PIT tag detections observed as through fish as recorded at BC Rail and Upper Paradise side channel antennas and Tenderfoot trap in 2010.*

Detection site	Tagging location	
	Lower 'Stables pool'	Upper 'Gauge pool'
Upper Paradise	9	42
BC Rail	2	12
Tenderfoot	1	6
Total detection / tags applied	12 of 537	60 of 377
% recovery	2.2%	15.9%

3.5 Total Counts, Run Time and Video Validation

The distribution of peak signal size (PSS) for up and down counts recorded by resistivity counters were similar for the Upper Paradise and BC Rail channel counters and in each case peak signal size distribution was positively skewed with over 70% of counts with signal sizes of 90 units or greater (Figure 14). By design, larger fish create larger signal sizes when counted by resistivity counters, and the PSS distribution observed during the 2010 operations, coupled with observations made through video validation indicated that the up and down counts recorded at the side channels with a PSS > 50 were generated by adult chum salmon, and not by debris, entrained air, or other fish species (a very few adult Coho were observed). The differences in the distribution of peak signal size between counter locations are largely attributable to discharge differences among sites and the relationship of PSS and fish passage height over the electrode array.

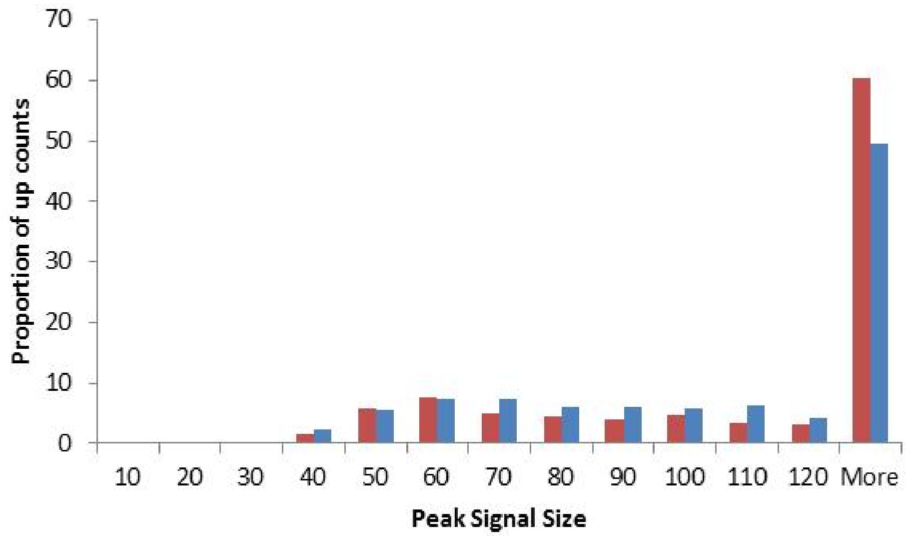

Figure 14: *The proportional distribution of peak signal size for up counts recorded at BC Rail (blue bar) and Upper Paradise (red bar) spawning channels during the 2010 monitoring season.*

3.5.1 Kelt Behaviour

Previously, during the first year of escapement estimation (2007) and in an absence of data to the contrary, we assumed that all upstream enumerated migrants die post spawning and remain in the side channels above the counter site. In 2008 and 2009 the PIT arrays were successfully upgraded to provide directionality and were able to gain inference about this key escapement assumption. The same set-up was used during 2010 and based on analysis of all PIT tagged spawner detection movements through the gated PIT arrays, 14% of BC Rail, and 11% of Upper Paradise down counts could be attributed to the downstream movement of post-spawned kelts. Kelts were assigned as fish that spent greater than 48 hours resident in the channel above the fish counter prior to a directional outmigration. These fish were mainly males at Upper Paradise channel (5 of 6) and equally male and female at BC Rail channel (1 of 2).

3.5.2 Video Validation of Counters and Discharge Correction

During 2010 there was less variation in river discharge at the Upper Paradise and BC Rail side channels sites than in 2009. The Upper Paradise site experienced one period of elevated discharge and backwatered on November 6th and 7th due to Cheakamus River flows. No fish were observed migrating at this time.

At the BC Rail side channel flow was restricted at the culvert exiting Dave’s Pond by beaver activity as in 2009. Crew members did not remove materials from the intake of the culvert this year and flows remained stable although access for spawners was thus restricted.

Video validation evaluation was conducted at the Upper Paradise enumeration site. A total of 174 up counts and 48 down counts were evaluated stratified over 19 days. Observed counter efficiency was 71% for upstream counts and 68% for downstream spawner movement(Table 8). Validation at BC Rail fish counter site indicated a somewhat higher counter efficiency from data stratifies over 17 days. Efficiencies were calculated as 76 % (n=94) for upstream migrants, and 78% (n= 87) for downstream spawner movements and were unaffected by river discharge (Table 8). Net upstream spawner count at Tenderfoot Creek was not corrected as this escapement estimate was derived from trap counts, not resistivity counters.

Run timing data from side channel resistivity counters and the Tenderfoot Creek trap indicate that chum spawners first arrived in numbers during late October at Upper Paradise channels and approximately two weeks later at BC Rail channel and Tenderfoot Creek (Figure 15). The largest number of corrected cumulative net upstream counts was observed in the Upper Paradise channels (1733spawners) where counts peaked in the third week of November. Counts of spawners in the groundwater fed Tenderfoot Creek and BC Rail channel were estimated at of 293 and 347spawners respectively (Table 8&Figure 15).

Table 8: *Total number of net cumulative upstream chum spawners enumerated at the side channel resistivity counters with video validation correction for counter efficiency. * N.B. Data from Tenderfoot Creek trap are unadjusted manual counts.*

Side Channel Enumeration site	Raw resistivity counts UP / DOWN	Video validation (% correct classification)	Correction for coho Post November 15	Kelt correction (% of down counts actually kelts)	Corrected cumulative net upstream spawner count
BC Rail	963 / 1125	78% down, 76% up,	75 % Classified as Chum for Up counts from video records	14%	367
Upper Paradise	3086/1777	68% down, 71% up	None observed	11%	2048
Tenderfoot *	293*	N.A.*	N.A.*	N.A. *	293*

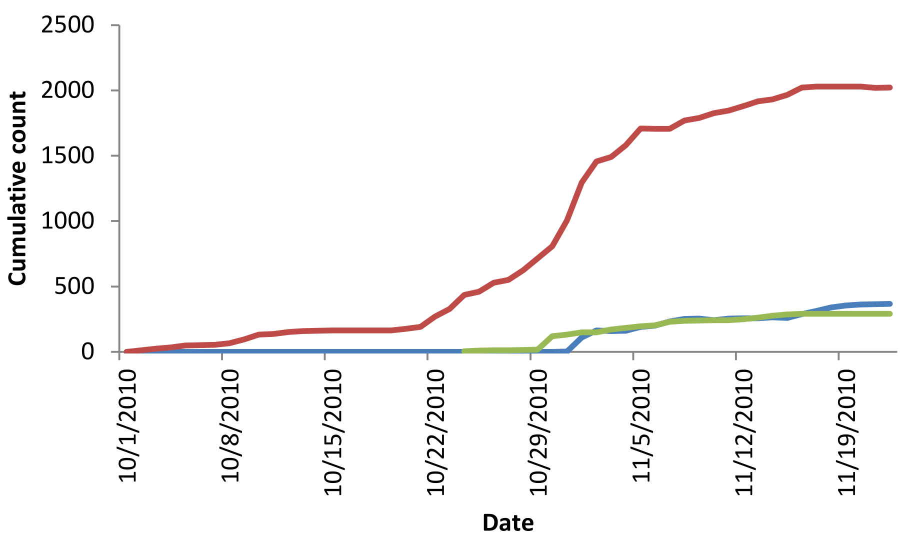

Figure 15: *Total cumulative net daily up counts observed at the Upper Paradise (red line) and BC Rail (blue line) fish counters in 2010. Tenderfoot Creek counts (green line) are total cumulative counts of chum spawners captured in a trap just downstream of Tenderfoot Lake.*

3.6 ESCAPEMENT ESTIMATES

Estimates of the number of spawners in the whole river upstream of River KM 1.5, and above the RST juvenile monitoring location were calculated by a simple Pooled Petersen (in time and detection location) model using the number of known tags applied and the number of unique tag detections/observations from spawners in the side channels to the corrected number of net upstream spawners counted at each resistivity counter site or fish trap (Table 9). We supply the weekly stratified mark-recapture matrices for the lower (whole river) and upper (above RST site) tag application sites in Appendix II & III.

3.6.1 Whole River Estimate – Spawners above lower river 'stables pool' tag site.

Using the Pooled Petersen population estimator outlined previously, a whole river escapement estimate of 112,110 (95% C.I., 54,235 to 169,983) spawners was derived for habitats upstream of the lower river tagging location at River KM 1.5. The estimate of the number of spawners in the whole river upstream of the 'stables' tagging site was based on a combined total of 12 PIT detections per 2,708 spawners counted in the Upper Paradise, BC Rail and Tenderfoot Creek side channels, for a total detection ratio of 0.44% (Table 9). As observed in previous years, there was some variance among the ratio of tagged to untagged fish at different sidechannels. Values ranged from 0.34 at Tenderfoot Creek to 0.54% at BC Rail channel (Table 9).

3.6.2 Upper River Estimate – Spawners above juvenile monitoring location.

We derived; using the Pooled Petersen estimator, a total spawner escapement of 16,787 (95% C.I., 13,002 to 20,569) chum spawners above the RST juvenile monitoring location. The estimate of the number of spawners was based on a total of 60 PIT detections per 2,708 spawners counted in the Upper Paradise, BC Rail and Tenderfoot Creek side channels, for a total detection ratio of 2.2% (Table 9). As observed for the whole river tags, some variance was observed among the ratio of tagged to untagged fish at different side channels for upper river tagged spawners. Values ranged from a high at BC Rail channel where 3.3% of counted spawners were detected with pits tags compared with 2.05 % of counted spawners with tags at Tenderfoot Creek trap and Upper Paradise Channel (Table 9).

Table 9: *Total number and proportion of unique PIT tag detections per corrected net cumulative upstream chum spawner enumerated at the side channel resistivity counters and Tenderfoot Creek trap in 2010.*

Side Channel Enumeration site	Corrected upstream spawner count	Lower River (Stables Pool) Detections	Upper River (Gauge Pool) Detections	% of upstream spawners with PIT tags (Stables, Gauge)
Upper Paradise	2,048	9	42	0.44% , 2.05 %
BC Rail	367	2	12	0.54 % , 3.27%
Tenderfoot	293	1	6	0.34 % , 2.05%
Totals all side channels	2,708	12	60	0.44%, 2.2%

3.7 MAINSTEM GROUNDWATER SURVEY

The simulated egg capsules containing temperature loggers and stilling well stage recorders logged data hourly from December 3, 2010, though the winter incubation period until March 18, 2011 when the first emergent fry were observed (Appendix IV). A total of nine egg capsules temperature loggers, 3 at the gauge pool and 6 at Moody's were installed into existing redds at an average depth of 0.28m ± 0.04 S.D. below typical river substrate grade. Water depth over logger, measured at the highest point of the redd burial mound (Troffe et al. 2008) and water velocity at these locations averaged 0.24m ± 0.11 S.D. and 0.31 m/sec ± 0.21 S.D., respectively. In comparison water depth over 25 randomly selected redds in the same locality measured in the same way resulted in mean water depths and water velocity recordings of 0.16m ± 0.08 S.D. and 0.45 m/sec ± 0.27 S.D., respectively (Figure 16), when river discharge was 16 m^3/sec at the Brackendale gauge, on Jan 4th 2011. The average substrate composition for six of the eight redds where eggs were found was visually estimated to be about 20% cobble (5-10 cm), 50 % gravel (1>4 cm), 30% sand. At 4 of the 8 sites eggs were observed in the redd mound on excavation (Appendix IV).

All nine hyporheic temperature capsules and both stage recorders were successfully recovered and data downloaded on March 18, 2011. The substrate in the spawning area had not suffered from significant scour during the winter flows, however, there was considerably more fine sand and gravel material covering the egg capsules and redds than visually observed during installation when the substrate was freshly disturbed by active spawning behaviour.

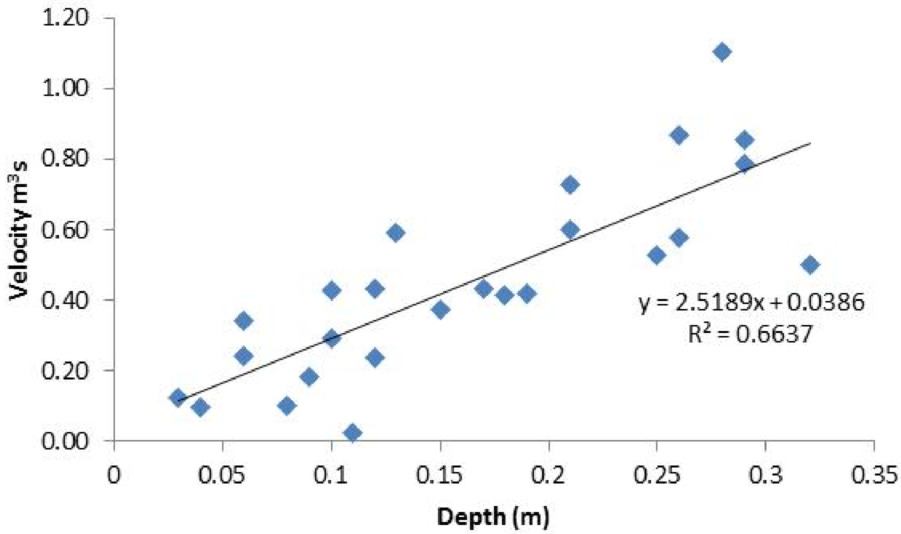

Figure 16: *Water depth (m) and velocity (m/sec) for 25 chum salmon redd sites observed near the mainstem ground water monitoring location near Moody's Beach and at the 'gauge pool'.*

River discharges were fairly stable near winter base flows (~16.5 m^3/s) during the majority of the egg incubation period with the exception of four separate occasions when river discharges increased significantly for several days before returning to base flow conditions (Figure 17).

River water temperatures from two independent logging devices (RW #1-2) located in stilling wells showed high daily and weekly variation over the egg incubation period from lows near 0.5° Celsius during early January and late February to highs of over 5° Celsius in December and mid-February, 2011 (Figure 18). Temperature profiles for the majority of loggers buried into the hyporheic zone within redds were strikingly different than those measuring river water temperature (Figure 19) in particular for sites at the Moody's area. Typically the loggers buried in the redds where eggs were observed recorded significantly less daily variation and water temperature 3-5° Celsius warmer than those recording river water. There were individual differences in the temperature profiles of the hyporheic loggers, however, most recorded temperatures ranging 5-8° Celsius after late December, with the notable exception of the four periods when the river experienced a rapid increase in discharge (Figure 19).

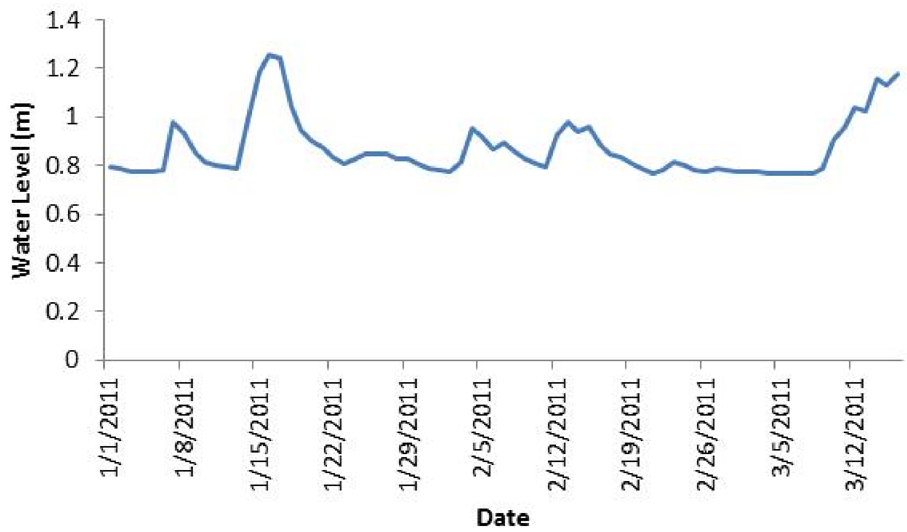

Figure 17:*Cheakamus River relative discharge from December 1, 2010 to March 15, 2011. Brackendale WSC gauge 08GA043 (49° 49' 00" N : 123° 08' 54" W).Placeholder as only level data available at this time for this period*

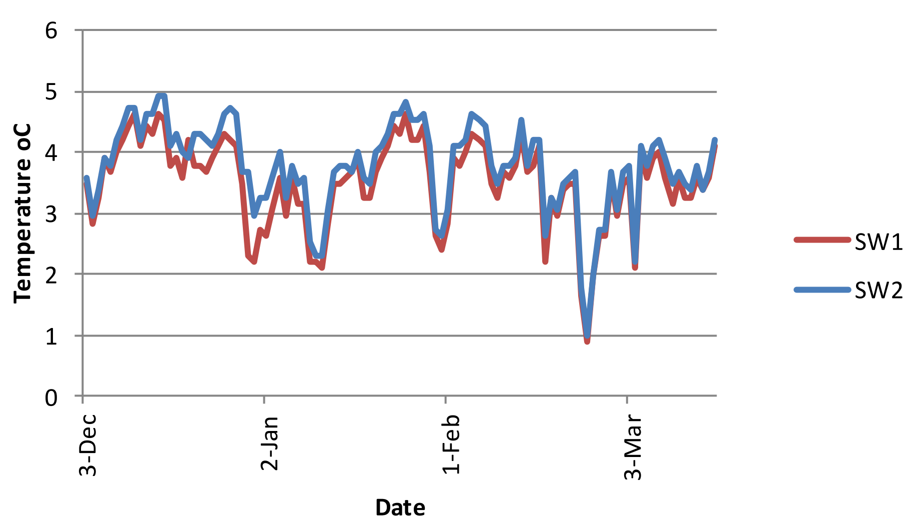

Figure 18:*Cheakamus River water temperature in degrees Celsius recorded by two separate loggers (SRW #1,2) from December 3, 2010 to March 17, 2011. Water temperature was recorded 0.30 (m) above the river substrate in two stilling wells proximate to the spawning area near Moody's Beach (RKM 3.5).*

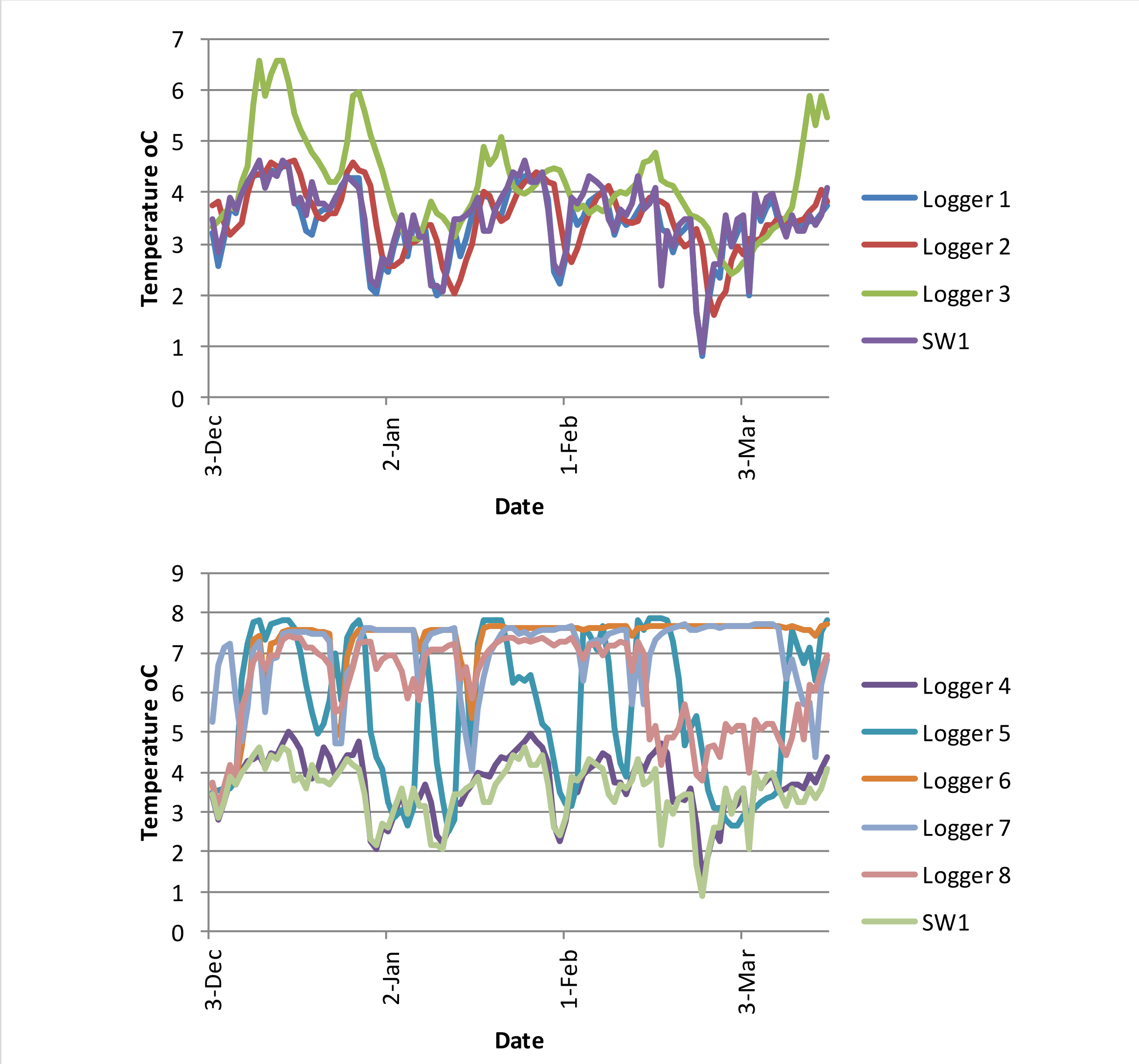

Figure 19: *Cheakamus River hyporheic zone water temperatures recorded in degrees Celsius, from December 3, 2010 to March 17, 2011 by nine logging devices buried approximately 0.3 m below grade in chum salmon redds at the Gauge Pool (#1-3 Upper) and near Moody's Beach (#4-9 Lower) mainstem groundwater loggers compared with stilling well (SW)*

4.0 DISCUSSION

The primary goal of this monitor is to evaluate the total spawner escapement and potential egg deposition of chum salmon to the Cheakamus River, in particular the numbers utilizing the area above the juvenile monitoring site located at river kilometer 4.5 and the BC Rail and NVOS spawning channels. These data are required to establish if WUP related changes in river discharge may be affecting egg to fry survival and or spawner distribution. To achieve these deliverables we require that enumeration data (by trap and counter), and tag marking and recovery data are accurate and free from sampling bias. To evaluate our methods we have included a number of validation checks to confirm data assumptions. These include validation of counter data by video records of fish movement, comparison of visual tag recovery to remote logged data for tag reader efficiency, evaluation of tag loss through carcass examination and visual stream walks to compare migration timing and for sex ratio assessments. In 2010, we also examined the potential effect of tagging on subsequent fish behavior at the upper river tagging site to establish if fish drop out prior to spawning due to handling stress might affect spawner estimates above the RST site.

This survey is the fourth of five interim monitoring seasons and one additional year of data collection is planned for 2011. Future analysis will continue to examine linkages between adult spawner escapement and fry yield through Monitor 1a & 1b - adult escapement linked with juvenile out-migration and Monitor 6, sidechannel groundwater evaluations. These relationships will be utilized to evaluate the primary discharge/yield hypothesis as described in this monitor.

Validation of the fish counter data was evaluated through comparison of video records to fish movement and while lower than in some years (68-78% versus over 80%), remained stable throughout the migration period allowing for easy correction of counter data to escapement estimates.

In efforts to validate the PIT detection methodology we continue to estimate the PIT tag retention and detection efficiency of the local arrays by comparing the logged records at each detection site to those tagged fish recovered during subsequent stream walk surveys. Observed PIT tag retention has been 100% for all carcasses recovered and a PIT detection efficiency of 99% was estimated (one tag missed over 2008 through 2010 seasons). Based on the tag application and visual recovery timing of the one undetected tagged spawner it is hypothesised that this fish transited through the Upper Paradise detection array during a period where there was a temporary power interruption to the detection field (Troffe et al 2010).

During 2010 the proportion of PIT tag detections/recoveries from fish tagged in the lower river was similar to that observed in 2007 and 2008 but 2-3 times lower than observed in 2009 suggesting that pre-spawners moving through the lower river tagging site in 2010 were much less motivated to utilize spawning habitats higher in the watershed than in 2009.

In 2010 the observed spawning distribution of radio tagged fish released at the lower river stables site was also different than that observed in 2009 and more similar to 2007 and 2008. In 2009, an estimated 82% of radio tagged spawners were identified as spawning upstream of Moody's side channel confluence, with 70% of these being detected on the fixed station receiver at the RST site. In 2010, only 43% of tagged fish were assessed spawning above the Moody's side channel confluence. We evaluated in 2009 from mobile tracking that 47% of tagged fish spawned upstream of the RST location receiver (River KM >5.0km). While in 2010 this fell to just 9%. Part of the change in distribution between the two years appears related to a large number of tagged fish in 2010 failing to pass the Cheekye fan where the remnants of a large debris torrent which entered the Cheakamus in the summer of 2009 results in a steep narrow high velocity cascade. In 2010, 29% of tagged fish failed to ascend the river past the narrows and considerable spawning was observed in the lower reaches of the river below the 'stables' tagging site during weekly telemetry raft trips. Spawning to this extent in this area has not been previously documented during annual raft trips.

From a sidechannel perspective in 2010, only 3 of 76 (4%) radio tags applied to fish at the 'stables' site were detected above the RST utilizing the side channel complexes of Upper Paradise, BC Rail and Tenderfoot Creek, one of which failed to spawn in the channels. In comparison 15 of 52 (29%) tags applied at the 'gauge pool' were detected at the channels of which 12 (23%) were actual spawners.

A study to evaluate the possible effects that tagging fish close to the spawning areas may have on post handling data was undertaken in 2010. The results indicated that male fish migration behavior may be negatively affected or is perhaps just more varied than female behavior. In females 91% of tagged fish remained above the tagging site during the spawning period, while for males this was just 57%. Based on these results and the uneven ratio of male to female spawners; detected as PIT tagged spawners, counted as mortalities in stream walks and observed during tagging efforts, evaluation of egg deposition is likely better when based on female spawner data only, rather than total escapement assuming a 50:50 sex ratio as described by Bradford 1995.

Our estimate of 16,786 chum spawners above the RST site in 2010 was similar to that observed in 2007 (16,365), slightly lower than calculated for 2008 (24,054) and just 1/6th of that recorded in 2009 (103,655). At an estimated 112,003 spawners the whole river chum spawner estimate for 2010 was similar to that estimated in 2008:117k, slightly lower than calculated for 2009:130k and 38% lower than recorded for 2007:179k. Current data for the lower river are the lowest recorded in the four survey years to date, but estimates from 2010, 2008 and

2007 have low tag recovery rates and thus broad confidence limits indicating that whole river spawner numbers may have been similar or have varied annually by as much as 50%.

Of the estimated16,786 spawners that utilized the upper river above the RST juvenile monitoring site in 2010, only 2,708 utilized the NVOS, BC Rail and Tenderfoot side channels combined; the lowest number so far recorded (since 2007). In comparison 15,603 spawners utilized side channel habitat during 2009, over twice that observed previously (2007: 7,511; 2008: 7,851) and 5 times that observed in 2010. During 2010, approximately 16% of upper river PIT tagged fish used the monitored side channels for spawning compared to 14.8% in 2009. Thus while the numbers of fish and tags recorded in the channels in 2010 was dramatically different than in previous years and in particular with 2009 data, the proportion of fish tagged in the upper river which entered remained similar. These data may indicate that the density of fish in the upper river may not be having a great influence on spawning location choice, mainstem versus side channel but that the three sidechannels combined are important spawning areas given their relatively small wetted area compared the main river.

The average sizes, sex ratio and run timing of Cheakamus River chum spawners was similar to those observed during previous years and follows patterns observed for other south coastal British Colombia populations (Salo 1991). In the lower river, the sex ratio is skewed such that males predominate early in the migration but less so later. In all years males tend to dominate visual stream counts in channels upstream of the RST monitoring location and also remote tag detections. This is important as if bio-standards are used to evaluate egg deposition they will tend to be biased high.

At two sections of the river where large spawning aggregations have been observed during 2009 (near the Moody’s Beach; RKM 3.5 and at the RST site; RKM 5.5) we collected water depth and velocity data and explored the possibility that Cheakamus River mainstem chum spawners might select spawning habitat based on groundwater upwelling. We followed a methodology similar to that used by Geist et al. (2002) in the Lower Columbia River to test the general hypothesis that river water temperatures were no different than those observed in chum redds located in the hyporheic zone. Water depths and velocities at redd sites in 2010 averaged 0.16 ± 0.08 S.D. (m) and 0.45 ± 0.27 S.D. (m/sec) respectively, similar in depth but in water of greater velocity than those observed by Quinn (2005) in Kennady Creek, Washington, by Troffe et al. (2008) at the Lower Stave River, BC and in 2009 on the Cheakamus River (Troffe et al 2010).The temperature data indicated that as in 2009 chum spawners in the Moody’s area were keying in on groundwater as water temperatures in the majority of redd sites were consistently 3-5° Celsius warmer than river water throughout egg development. Exceptions were sites where a redd appeared to have been constructed but visual evidence of egg deposition was not recorded. At the upper river site, two redds were constructed in areas where water temperatures indicated there was no groundwater influence although no eggs were observed on excavation. The other site indicated eggs present and some influence of groundwater, although not as clearly as the sites at Moody's. Although there were some individual differences in the temperature profiles among redds, most recorded temperatures ranged 5-8° Celsius, with the exception of four periods when the river experienced a rapid increase in discharge and river stage appeared to force cooler river water into the warmer redd sites. The origins and relationship of this groundwater to the river's discharge profile are unclear and under investigation as part on this monitor.

The physical changes to the Cheakamus River as a result of the July 25, 2009 Cheekye River flood event is having an ongoing significant influence on chum spawner distributions on an annual basis. Upstream of the Cheekye River confluence the new fan of bedload material from the flood event continues to partially dam a portion of the Cheakamus River with a backwatered area of the river upstream past Moody's side channel up to near Moody's Beach (River KM 3.5). In addition to the backwatering, Cheakamus River habitat downstream of the Cheekye River confluence has been subjected to significant sediments loads, especially when river discharges are high resulting in changes to many mainstem and off-channel habitats. It is unclear how these very large changes in spawner distribution will affect future fry and resultant spawner recruit relationships. As yet we have insufficient data to establish seeding capacity of different habitat units or the annual variance in egg to fry survival between areas dominated by ground water upwelling versus areas dominated by river water. The data collected in this ongoing study will assist in evaluating these variances and if or how the new WUP may impact Chum spawning and egg to fry survival.

5.0 RECOMMENDATIONS

Two primary technological and operational suggestions are proposed for Year 5 of the study. These advances will aim to continue to increase confidence and provide inference about the assumptions underlining the escapement estimates.

1) Continue to divide stratified tagging effort between upper and lower river tag application locations to evaluate gross changes in spawner habitat preference in particular in lieu of improved tag recapture rates from lower-river tagged fish observed in 2009.

   - up to 500 tags applied at upper river site (River KM 4.0-4.5)

   - up to 700 tags applied at lower river site (River KM 1.0-1.5)

2) We suggest continued use of dorsally mounted individually numbered Petersen disk tags as an external visual tag.

3) Utilization of the NVOS hatchery fish trap to evaluate sex ratio and tag retention in spawners and installation of a trap on Kisutch channel to evaluate spawner density for comparison with fry production.

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APPENDICES

Appendix I: Chum tagging data

See Electronic file attached – file: Appendix 1 chum tagging data 2010.xls

Appendix II: 2010 Lower River 'stables pool' mark-recapture table.

Release	Fish Marked	Recovery Stratum																																	
Day	Stables	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct	21-Oct	22-Oct	23-Oct	24-Oct	25-Oct	26-Oct	27-Oct	28-Oct	29-Oct	30-Oct	31-Oct	1-Nov	2-Nov	3-Nov	4-Nov	5-Nov	6-Nov	7-Nov	8-Nov	9-Nov	10-Nov	11-Nov	12-Nov	13-Nov	14-Nov	15-Nov	16-Nov	17-Nov
2-Oct-10	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-Oct-10	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Oct-10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-Oct-10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-Oct-10	8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-Oct-10	29	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-Oct-10	9	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-Oct-10	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-Oct-10	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	1	2	0	1	0	0	0	0	0	0	0	0	0	0
29-Oct-10	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-Nov-10	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
4-Nov-10	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-Nov-10	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
6-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-Nov-10	123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
11-Nov-10	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-Nov-10	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-Nov-10	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-Nov-10	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-Nov-10	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-Nov-10	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-Nov-10	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
unmarked fish counter		2	0	0	0	0	12	15	77	61	111	30	72	20	75	95	196	213	412	218	49	105	169	14	59	91	23	27	33	44	50	36	41	88	31
unmarked plus pit recaps		2	0	0	0	0	12	15	77	61	113	31	75	21	76	95	196	214	416	221	51	107	172	14	60	92	23	27	34	44	51	37	41	88	32
proportion marked		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	3.2	4.0	4.8	1.3	0.0	0.0	0.5	1.0	1.4	3.9	1.9	1.7	0.0	1.7	1.1	0.0	0.0	2.9	0.0	2.0	2.7	0.0	0.0	3.1

Appendix III: 2010 Upper River 'gauge pool' mark-recapture table.

Release	Fish Marked	Recovery Stratum																																
Day	Gauge Site	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct	21-Oct	22-Oct	23-Oct	24-Oct	25-Oct	26-Oct	27-Oct	28-Oct	29-Oct	30-Oct	31-Oct	1-Nov	2-Nov	3-Nov	4-Nov	5-Nov	6-Nov	7-Nov	8-Nov	9-Nov	10-Nov	11-Nov	12-Nov	13-Nov	14-Nov	15-Nov	16-Nov	17-Nov
2-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-Oct-10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-Oct-10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-Oct-10	9	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Oct-10	58	0	0	0	0	0	0	0	0	0	0	1	5	1	0	1	1	1	4	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
26-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Oct-10	58	0	0	0	0	0	0	0	0	0	0	0	0	6	3	2	0	4	5	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
28-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31-Oct-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-Nov-10	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0
4-Nov-10	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	1	2	1	0	1	1	0	0	0	0	0	0
5-Nov-10	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	2	0	1	1	0	0	1	0	0	0	0
6-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9-Nov-10	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	5	0	1	2	0	0	0
10-Nov-10	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	0	0	0	1	0
11-Nov-10	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	1	1
12-Nov-10	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	1	1	0	1
13-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-Nov-10	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
17-Nov-10	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Nov-10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
unmarked fish counter		2	0	0	0	0	12	15	77	61	111	30	72	20	75	95	196	213	412	218	49	105	169	14	59	91	23	27	33	44	50	36	41	88	31
unmarked plus pit recaps		2	0	0	0	0	12	15	79	61	112	31	77	27	78	98	197	218	421	220	51	110	177	17	64	92	27	33	40	48	60	39	42	93	34
proportion marked		0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.9	3.2	6.5	25.9	3.8	3.1	0.5	2.3	2.1	0.9	3.9	4.5	4.5	17.6	7.8	1.1	14.8	18.2	17.5	8.3	16.7	7.7	2.4	5.4	8.8

Appendix IV: Location and physical measurements of mainstem groundwater monitoring equipment installed during 2010.

Installed –Dec 3rd 2010,
Removed –March 18th 2011

Capsules installed into pre- existing redds when river discharge at 16.0 CMS (Brackendale WSC gauge)

Site description	Location (UTM	Logger Serial #	Logger ID #	eggs present during excavation	capsule depth below grade (cm	water depth (cm	Velocity 1 (m/s	Velocity 2 (m/s	Velocity 3 (m/s	water depth (cm) during remova
Gauge Pool temp. logger	0489179:5518319	2450182	1	no	25	20	0.47	0.46	0.53	34
Gauge Pool temp. logger	0489186:5518309	2450177	2	no	36	24	0.23	0.24	0.26	43
Gauge Pool temp. logger	0489194:5518301	2450180	3	yes	30	40	0.00	0.00	0.00	62
Upper Moody's temp. logger	0489469:5517184	2450179	4	no	25	20	0.29	0.29	0.28	25
Upper Moody's temp. logger	0489453:5517184	2450178	5	no	30	15	0.30	0.32	0.28	22
Upper Moody's temp. logger	0489418:5517175	2450185	6	no	28	12	0.08	0.07	0.05	46
Lower Moody's temp. logger	0489400:5516972	2450187	7	yes	26	20	0.70	0.68	0.77	38
Lower Moody's temp. logger	0489421:5516971	2450186	8	yes	29	45	0.25	0.30	0.30	59
Lower Moody's temp. logger	0489419:5516944	2450184	9	yes	23	18	0.39	0.41	0.44	44
Stilling Well 1, Upper Moody's	0489500:5517231	n/a	1	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Stilling Well 2, Lower Moody's	0499419:5517015	n/a	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a