CERTC
Cheakamus Ecosystem Restoration Technical Committee

Resident Fish Abundance Monitoring Program

2008

FINAL REPORT
January 2010

Fisheries and Oceans Canada   Pêches et Océans Canada

RESIDENT FISH ABUNDANCE MONITORING PROGRAM 2008

FINAL REPORT

Prepared for:

Canadian National Railway Company
CN Environment
13477 – 116 Avenue
Surrey, BC V3R 6W4

Prepared by:

TRITON ENVIRONMENTAL CONSULTANTS LTD.
8971 Beckwith Road, Richmond, BC V6X 1V4

January 2010

Fisheries and Oceans Canada · Pêches et Océans Canada

SUMMARY

The Resident Fish Abundance Monitoring Program (RAMP) was implemented in an effort to assess the recovery of fish populations affected by an accidental discharge of sodium hydroxide (NaOH). The study area includes the anadromous portion of the Cheakamus River downstream of a barrier approximately 17.5 km upstream of the Squamish River confluence. Species of principal concern for the RAMP included coastrange sculpin (*Cottus aleuticus*), prickly sculpin (*C. asper*), western brook lamprey (*Lampetra richardsoni*), river lamprey (*L. ayresii*), Pacific lamprey (*L. tridentata*), threespine stickleback (*Gasterosteus aculeatus*), bull trout (*Salvelinus confluentus*) and cutthroat trout (*Oncorhynchus clarkii*). These species were targeted in part because there was limited background information available to form the basis of recovery targets. Replication of past electrofishing survey methodologies provided a basis for comparison to historical abundance. Sampling was conducted during the periods of April 7 to 24 and September 3 to 27, 2008, along the Cheakamus River mainstem (reaches 1 to 8) and side channels, as well as in two tributaries and in Brohm River. Fish were captured by electrofishing (73 sites), minnow trapping (500 sites), and seining (15 sites). Sites were selected based on habitat preferences of target species and suitability for each sampling method.

Sculpins (coastrange and prickly) accounted for approximately 4.6% of the total catch and were represented by multiple age classes. Although river-wide sculpin densities remained below historical values, measured densities in the lower 4 km of the river (where 87% of the fish were captured) were approaching pre-spill densities. Coastrange sculpins (representing 98.8% of sculpin catch) were observed up to 12.6 km (Reach 7) from the confluence with the Squamish River, representing an increase in their upstream distribution of approximately 1.3 km from the previous year. Lamprey (western brook/river and Pacific) represented 15% of the total catch and were found in natural and man-made side channels, as well as in seven mainstem sites. Densities measured in 2008 were greater than any previously reported for this area. Threespine stickleback and bull trout catch in 2008 were similar to 2007 values, and both species were represented by multiple age classes.

Rainbow trout (*O. Mykiss*), also identified as species of interest, accounted for 32% of the total catch, with a distribution extending throughout their historical range. The species was represented by multiple age classes, with average condition reflective of fish in good health. The mean measured and adjusted densities for rainbow fry (captured in mainstem, closed electrofishing sites during September 2008) were greater than the 2006 and 2007 values, and within the range of values reported in past studies. Mean measured density for rainbow parr in September 2008 exceeded past RAMP values, as well as pre-spill densities. Furthermore, examination of biomass (identified as secondary measure of recovery) indicated the abundance of rainbow trout fry in 2008 (109.51 g/100 m^2) was within the range observed in previous surveys (50.0 to 133.6 g/100 m^2).

This report summarizes the results of the 2008 RAMP surveys, which represent the third sampling year of a multi-year program. To assess recovery, the information collected was compared to baseline data (where available), as well as to results from the two previous RAMP survey years and other studies conducted in the area. Initial results from the first three years of the program are encouraging as they suggest recovery is occurring in affected areas.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 Introduction

1.1 Background

On August 5, 2005, a derailment occurred at Mile 56.6 of the Squamish Subdivision of the Canadian National Railway Company (CN) mainline, resulting in the discharge of approximately 45,000 litres of sodium hydroxide (NaOH) into the Cheakamus River (Teal Solutions, 2005). As the product was carried down the river it caused mortalities of invertebrates, and anadromous and resident fish in the river at the time of the spill (McCubbing *et al.*, 2006). The spill also resulted in a 24-hour closure of the Cheakamus River for recreational purposes and a 48-hour closure of drinking water in wells. The product did not persist in the environment, as evidenced by the return to normal pH levels within several hours of the derailment (Triton, 2007a).

The Cheakamus Ecosystem Restoration Technical Committee (CERTC) - comprised of regulatory agencies, local government, the Squamish Nation and CN - was formed to evaluate the impacts of the spill, as well as to promote and co-ordinate the subsequent recovery of fish populations in the Cheakamus River. CN is funding several monitoring studies including the Resident Fish Abundance Monitoring Program (RAMP) and the Non-Anadromous Reach Fish Abundance Monitoring Program (CERTC, 2009). Other studies were also completed as part of the Cheakamus Ecosystem Recovery Plan (CERP), such as the *Water Quality Assessment following an Accidental Release of Sodium Hydroxide* (Triton 2007a), the *Screening Level Assessment of Ecological Effects* (Triton, 2007b) and the *Cheakamus River Benthic Invertebrate Recovery Monitoring Program* (Triton, 2008a).

This report summarizes the results of the 2008 RAMP surveys, which represent the third sampling year of a multi-year program. To assess recovery, the information collected was compared to baseline data (where available), as well as to results from the two previous RAMP survey years (Triton, 2008b and 2009a) and other studies conducted in the area.

1.2 Study Area

The Cheakamus River is one of the largest tributaries to the Squamish River watershed, draining a 1,070 km^2 area of the Coastal Mountain range in south-western BC (Northwest Hydraulic Consultants, 2000). The river flows 47 km from its headwaters in Garibaldi Provincial Park, through the Daisy Lake Reservoir, to its confluence with the Squamish River, approximately 27 km south of the Daisy Lake Dam, near the community of Brackendale (Figure 1-1). The Cheakamus River supports a variety of anadromous and resident fish. A series of impassable falls approximately 17.5 km upstream from the confluence with the Squamish River prevents anadromous fish access to upstream reaches (Appendix 1, Photo 1; Figure 1-2).

The spill occurred at river km 19.25, approximately two kilometres upstream of the first impassable falls (Figure 1-2). All anadromous and non-anadromous (resident) fish present in the river and downstream of this area at the time of the spill were affected to some degree, while fish upstream of the spill were not affected. Effects on fish populations downstream of the barrier were documented in McCubbing *et al.* (2006).

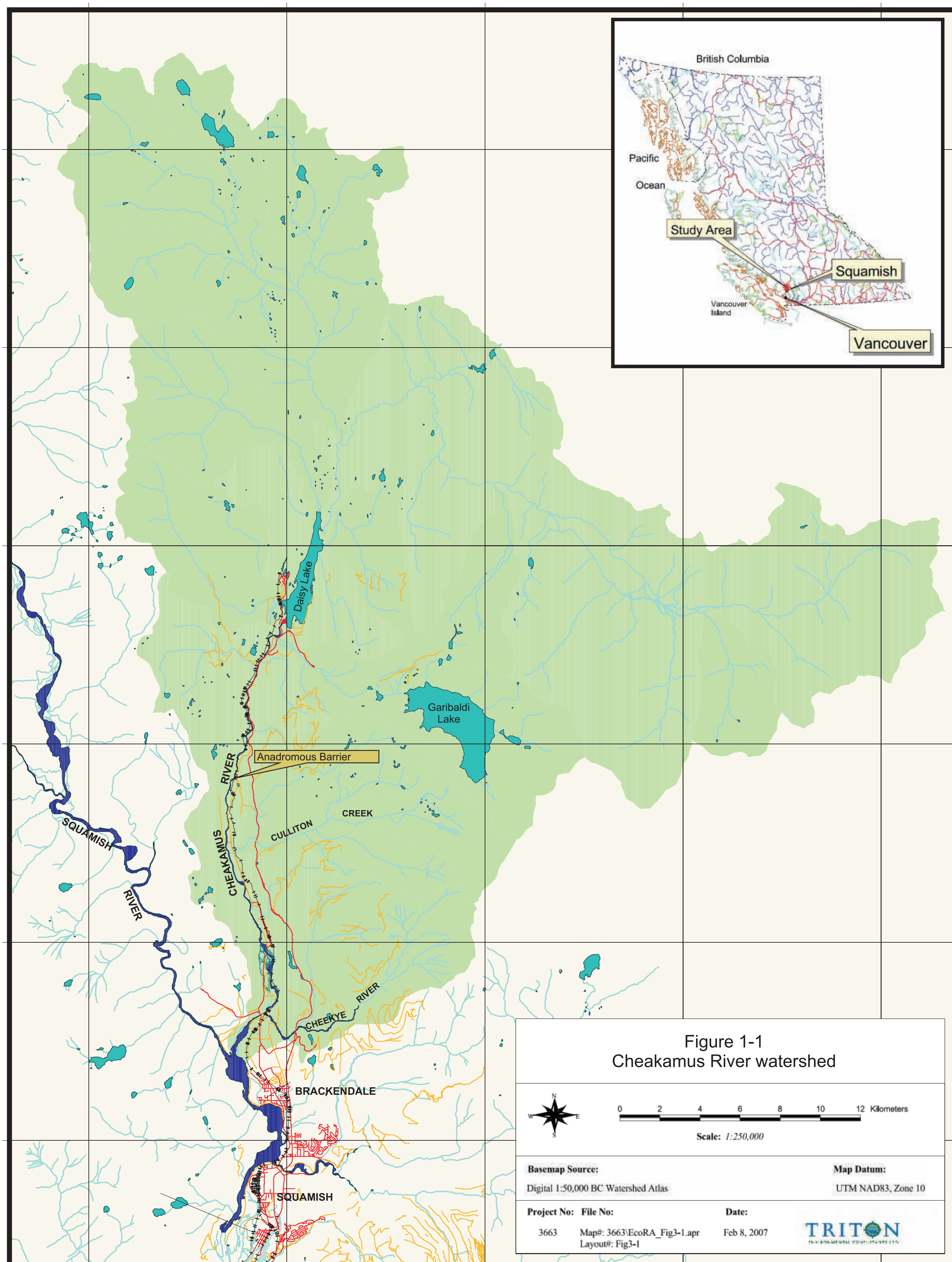
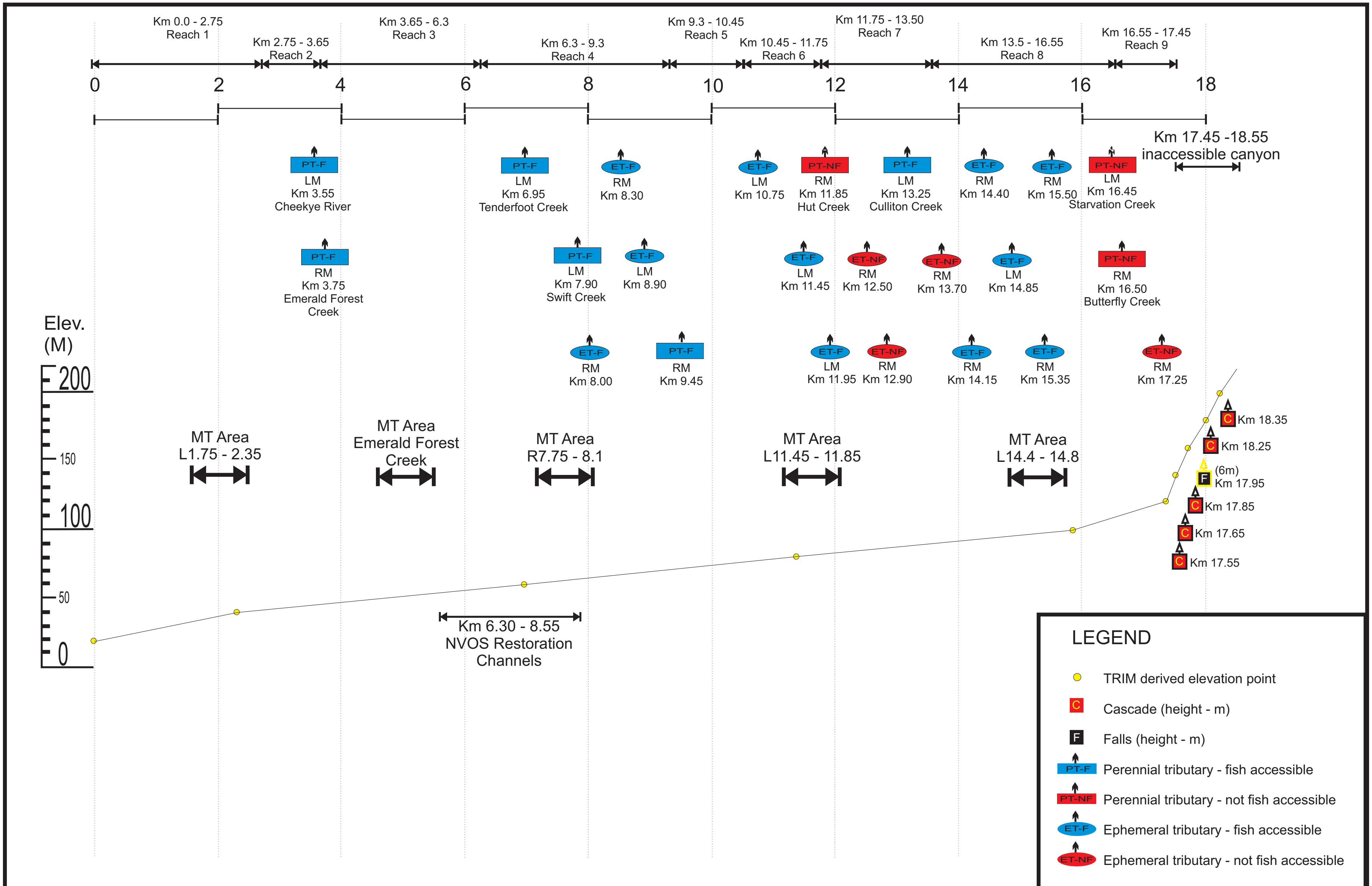


Figure 1-1
Cheakamus River watershed



Resident Fish Abundance Monitoring Program, 2008

Map # RAMP 2008 Fig 1-2

Scale: AS SHOWN

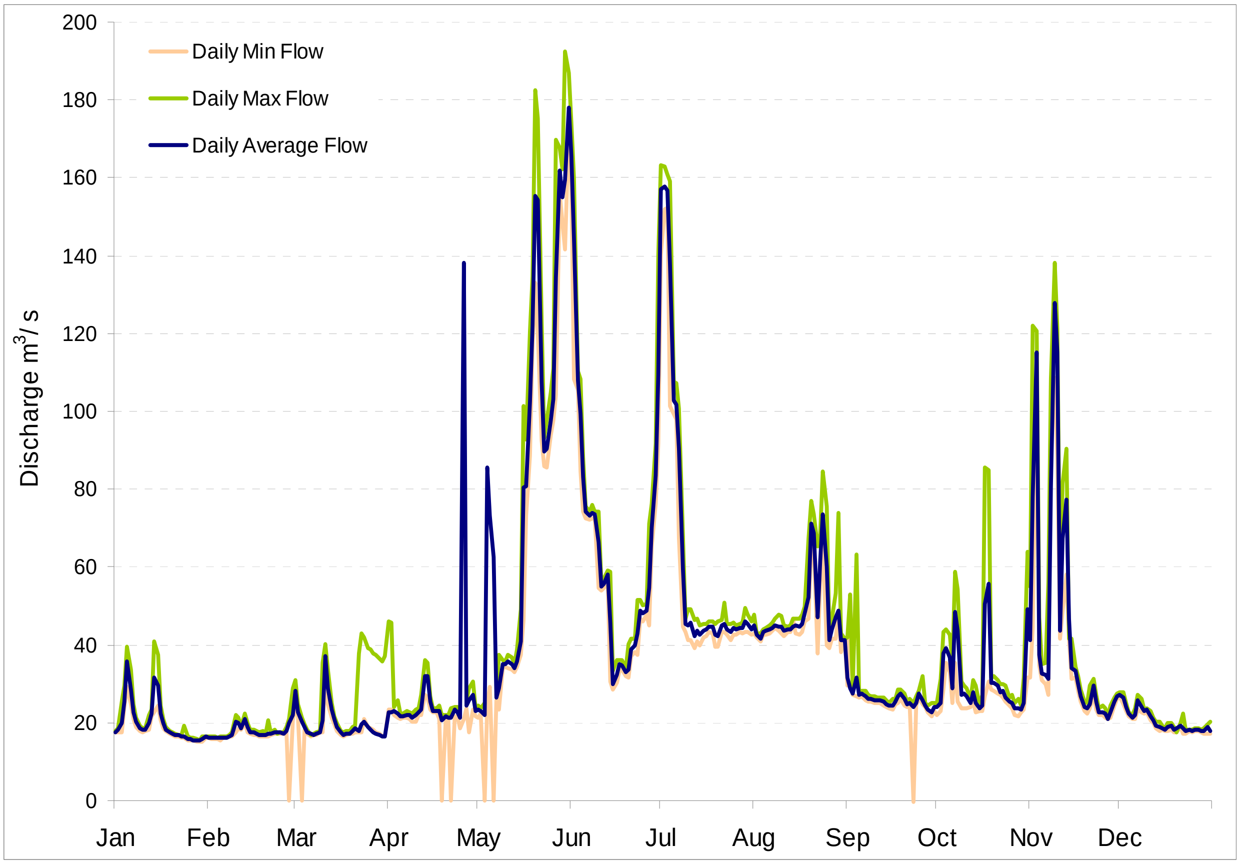
Created by: J.Thorlacius 19 June 2007
Revised by: P. Frederiksen 28 Aug 2009
Source: Triton Environmental

FIGURE 1-2. PROFILE VIEW OF THE CHEAKAMUS RIVER ANADROMOUS REACH

TRITON ENVIRONMENTAL CONSULTANTS LTD.

The flow regime of the lower Cheakamus River is regulated by the Daisy Lake Dam and reservoir, which divert a portion of the annual discharge to the Cheakamus powerhouse in the Squamish River valley. Diversion volumes and power production vary with both climate and regulation (Marmorek and Parnell, 2002). Daily discharge in the Cheakamus River in 2008 is shown in Figure 1-3. Changes in discharge reflect the influence of weather related effects such as snow or rain run-off.

Figure 1-3. Cheakamus River discharge (CMS) near Brackendale, 2008



Source: Water Survey of Canada (preliminary data; D. Albrecht (BC Hydro) written comm., 2008).

The study area encompasses the mainstem of the Cheakamus River (along with a number of natural and man-made side channels), from the confluence with the Squamish River (km 0) to the anadromous barrier (km 17.45; reaches 1 to 8, referred to as the "anadromous reach"), as well as tributary sites in Culliton Creek, Cheekye River and Brohm River (Figure 1-1).

1.3 Program Rationale

The main purpose of the Resident Fish Abundance Monitoring Program is to monitor the natural recovery of fish populations in the anadromous reach of the Cheakamus River. These include sculpin (*Cottus spp.*), lamprey (*Lampetra spp.*), threespine stickleback (*Gasterosteus aculeatus*), bull trout (*Salvelinus confluentus*), cutthroat trout (*Oncorhynchus clarkii*) and rainbow trout (*O. mykiss*). With the exception of rainbow trout, limited data exist on abundance of these species in the Cheakamus River, hence recovery is difficult to assess based on pre-existing information and recovery targets were not established.

The program's rationale and methods were developed to monitor the recovery of fish communities in the affected area while considering the limited information available. The methodology has two main assumptions:

1. There was no residual effect to the physical habitat (*i.e.* the system's integrity) and therefore no associated limitation to fish recovery in the affected area; and,
2. Fish populations will naturally return to a state of equilibrium or "normal variation".

Program Objective

The primary objective of this program is to monitor recovery of affected fish communities. Recovery will be assessed (recovered, recovering or unchanged) on a yearly basis by comparing measured parameters to those of previous program years and past studies. Parameters being evaluated to measure recovery are:

- Fish abundance (density, biomass, and spatial distribution);
- Length-frequency (to assess distribution of cohorts, or age groups); and,
- General condition of fish (based on length and weight, and condition indices).

Temporal variability is being monitored through a *repeated measures design*, where a series of parameters are measured at each sampling site, twice a year, following the same methods each time. Recovery is being assessed using a multivariate analysis of the time-series data (*e.g.*, 2006 data with subsequent years). Survey results are also compared to available data from previous studies (*e.g.*, rainbow/ steelhead pre-spill abundance, sculpin distribution, etc). Other parameters used to complement the work include visual observation of gravid adults and the presence of fish larvae (such as rainbow trout underyearlings or lamprey ammocoetes), considered indicative of successful adult spawning.

2.0 Methods

2.1 Target Species

The RAMP targets fish populations for which information gaps were identified during the literature review conducted in preparation of the 2006 CERP (Triton, 2006). Species identified as targets for abundance monitoring are listed in Table 2-1. Information regarding the life histories of target species is provided in the CERP 2008 (Triton, 2008c).

Captured fish were identified to species, where possible. Identification of lamprey ammocoetes (eyeless larvae) in the field can be challenging, as all three species known to inhabit the system have similar morphology at this stage of development. Identification of ammocoetes was based on the examination of pigmentation on the caudal ridge: clear ridge for Pacific lamprey; dark for western brook or river lamprey (Beamish, 2008 verbal comm.; Richards *et al*., 1982). Photographs of a number of specimens were also taken to confirm and supplement identification. Adults were identified in the field based on oral disc morphology (McPhail, 2007).

Table 2-1. List of target species

Common name	Scientific name	Code*
Coastrange sculpin	*Cottus aleuticus*	CAL (CC for unidentified sculpins)
Prickly sculpin	*C. asper*	CAS
Pacific lamprey	*Lampetra tridentate/ Entosphenus tridentatus*	PL (L for unidentified lamprey)
Western brook lamprey	*L. richardsoni*	BL
River lamprey	*L. ayresii*	RL
Threespine stickleback	*Gasterosteus aculeatus*	TSB
Bull trout (char)	*Salvelinus confluentus*	BT
Coastal cutthroat trout	*Oncorhynchus clarkii clarkii*	CT

* Ministry of Environment, 2008.

Rainbow trout and steelhead trout juveniles (*O. mykiss*) cannot be visually differentiated, as they are the same species but exhibit different life history strategies (therefore, all *O. mykiss* are referred to as "rainbow trout" in this report). Rainbow trout was also deemed a species of interest due to its abundance and long residency period in the Cheakamus River, as well as its sensitivity to the impacts of the spill. Furthermore, rainbow trout are relatively easy to capture and changes in their population abundance could be compared to historic information.

The following species were part of the incidental (non-target) catch: coho salmon (*O. kisutch* - CO), chinook salmon (*O. tshawytscha* - CH), chum salmon (*O. keta* - CM) and pink salmon (*O. gorbuscha* - PK). Although data were collected and are presented in this report, they are not discussed in detail as the recovery of these species is being measured by other programs (Triton, 2006).

2.2 Site Selection

The locations of 2008 survey sites were similar to those established in the previous years of the program (Triton, 2008b and 2009a; Figures 2-1, 2-2 and 2-3). Based on the principles of *adaptive management* adopted by CERTC, some site adjustments were made to optimize sampling of target species and/or adapt to physical changes in the river. Sites encompassing a variety of fish habitat types were selected - along the river's mainstem, or in natural and man-made side channels, as well as tributaries - based on accessibility and suitability for each sampling method, and habitat preferences of target species (examples of target species habitat preferences can be found in Triton, 2009a). All sites were identified by river margin and river km (*e.g.*, L2.15 = left margin, at 2.15 km from the confluence with the Squamish River: km 0). Distances along the river were based on orthophotos taken in 2008.

Mainstem electrofishing sites (reaches 1 to 8; Table 2-2) were selected based on the presence of suitable cover and velocity for target species (*e.g.*, cobble and boulder substrate, which provide a variety of velocity gradients). Other factors such as accessibility, and safe wading for survey crew (*e.g.*, depth no greater than 1.2 m) also affected site selection. In addition, a number of sites were chosen to replicate sampling conducted in past studies and allow comparison of results to pre-spill data. Some sites in natural and man-made side channels were chosen for their suitability for other target species (*e.g.*, muddy/ sandy side channels, commonly used by lamprey ammocoetes, or deep pools with instream and overstream vegetation, often preferred by threespine stickleback).

It was not possible to enclose all electrofishing sites with stop nets, because of steep banks, proximity of streamside vegetation, high velocities and/ or large uneven substrate. Closed electrofishing sites were established in areas no greater than approximately 0.6 meter in depth and mean velocities not exceeding 0.5 m/s. Two closed electrofishing survey sites were established in Brohm River (Figure 2-1) to assess rainbow trout density and distribution in a tributary not directly impacted by the NaOH disturbance, and for which background data is available (van Dishoeck, 2002; van Dishoeck and Horne, 2002; Hanson and Hryhorczuk, 2005). Sites Culliton Creek (2) and Cheekye River (1) were also sampled, in an effort to assess the potential contribution to recovery from recruitment and rearing in these two tributaries.

Minnow trapping and seining were used as complementary sampling methods, as well as valuable, effective alternatives to sample habitat where electrofishing was not practical. Sampling sites were chosen based on accessibility and habitat suitability for target species. Various habitat types were sampled in the mainstem and side channels in an effort to capture the widest possible range of species and their life stages. Criteria for trap site selection included, but were not limited to: the presence of cover [*e.g.*, large woody debris (LWD), pool, undercut bank or boulder]; depth (minimum of 20 cm to ensure traps were submerged); velocity (suitable to avoid fish impingement in trap), and; safe access for survey crew.

The monitoring program is based on a comparison of measured fish densities in preferred habitats and not on population estimates, derived from proportional sampling of all habitat types (*i.e.*, site stratification).

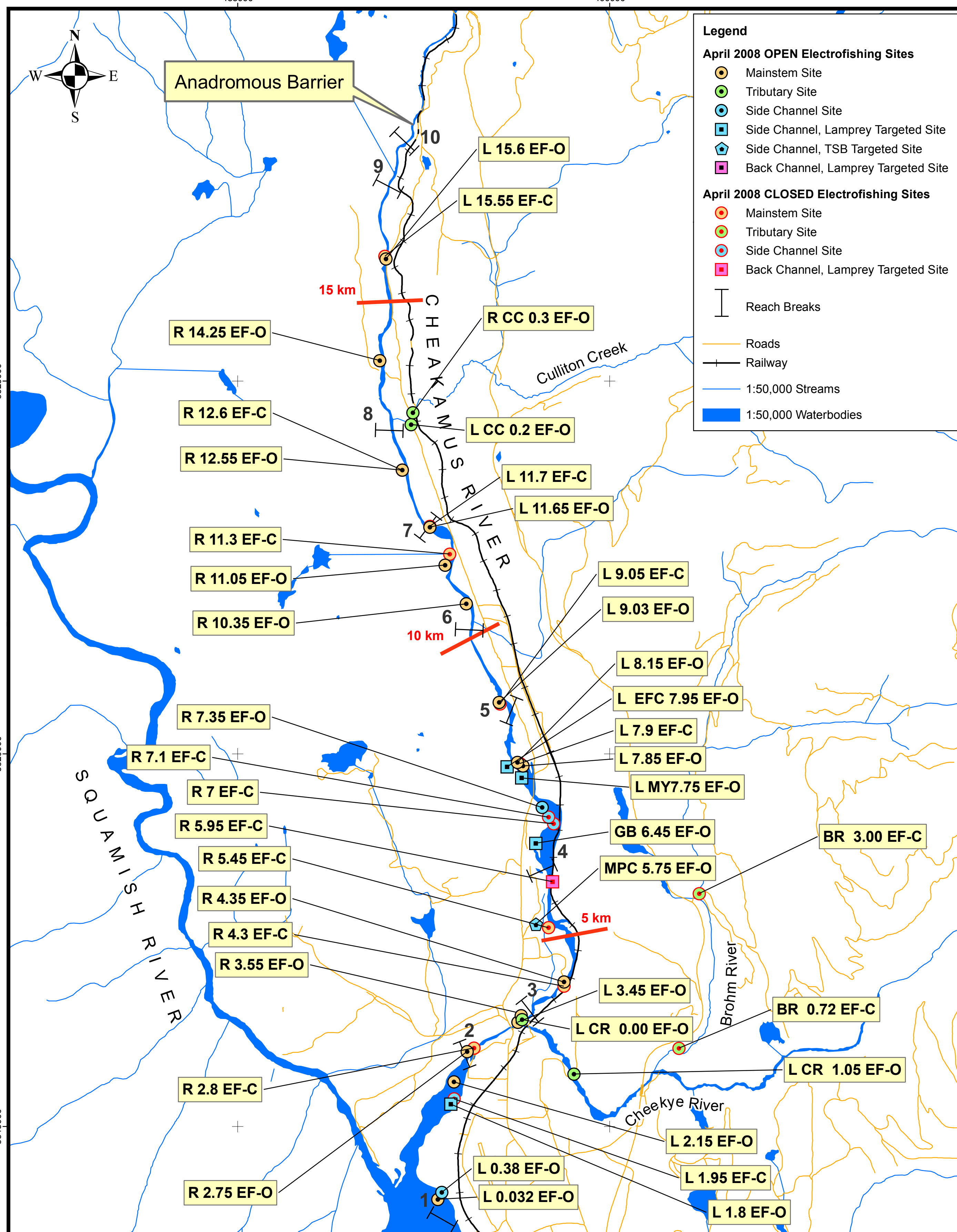


Figure 2-1. Location of Cheakamus River RAMP April 2008 electrofishing sampling sites.

Basemap Source: WSA 1:50K, TRIM 1:20K

0 250 500 1,000 1,500 2,000 2,500 Meters

Scale: 1:70,000

Map Datum: UTM NAD 83 Zone 10

Project No: 3772

File No: N:\ACTIVE\CN_Cheakamus\3772_MISC_MXD\RAMP\RAMP_EF_April_2008.mxd

Date: Oct 30, 2009

TRITON ENVIRONMENTAL CONSULTANTS LTD.

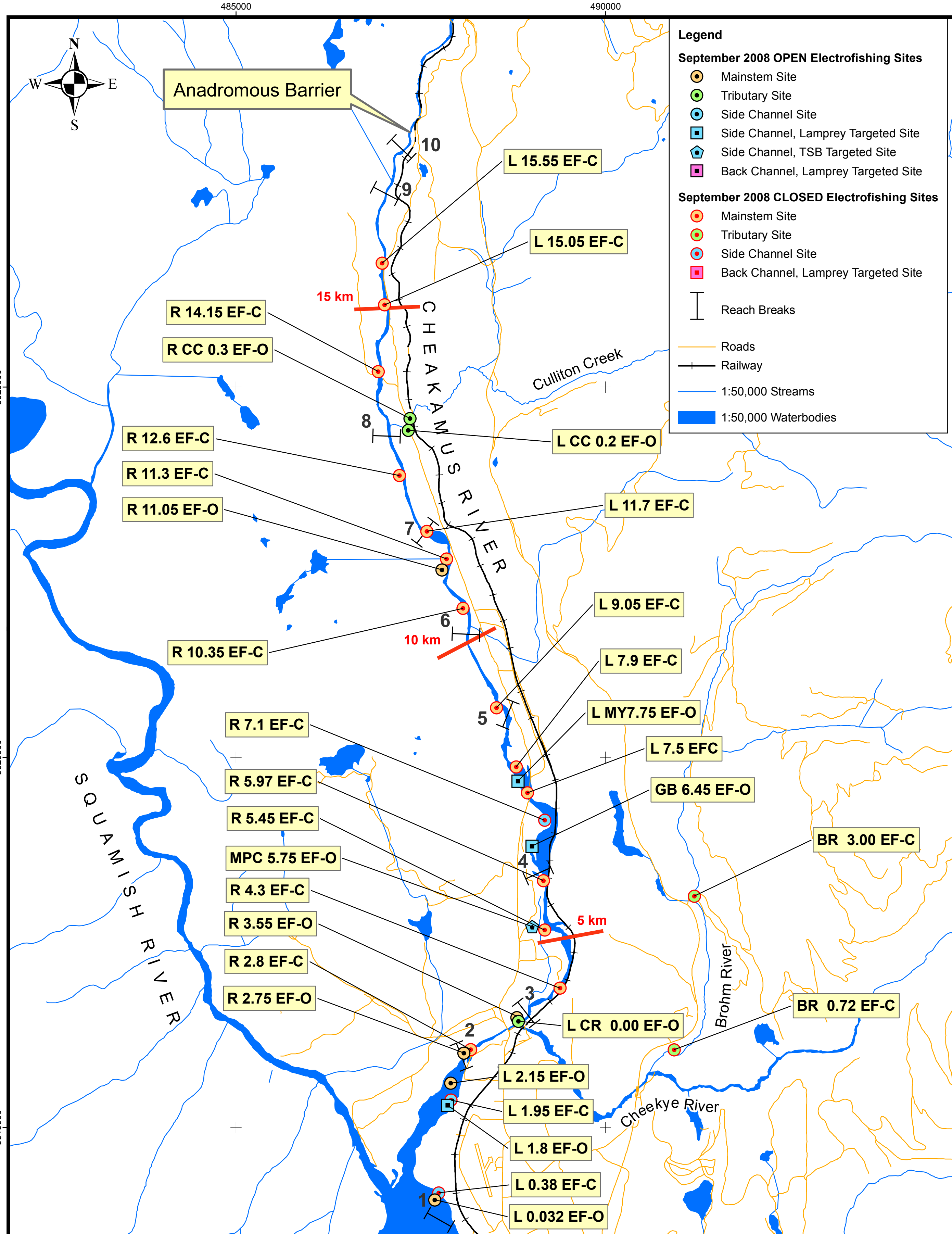


Figure 2-2. Location of Cheakamus River RAMP September 2008 electrofishing sampling sites.

Basemap Source:	Scale: 1:70,000 (0 250 500 1,000 1,500 2,000 2,500 Meters)	Map Datum:
WSA 1:50K, TRIM 1:20K		UTM NAD 83 Zone 10

Project No:	File No:	Date:
3772	N:\ACTIVE\CN_Cheakamus\3772_MISC_MXD\RAMP\RAMP_EF_Sept_2008.mxd	Oct 30, 2009

TRITON ENVIRONMENTAL CONSULTANTS LTD.

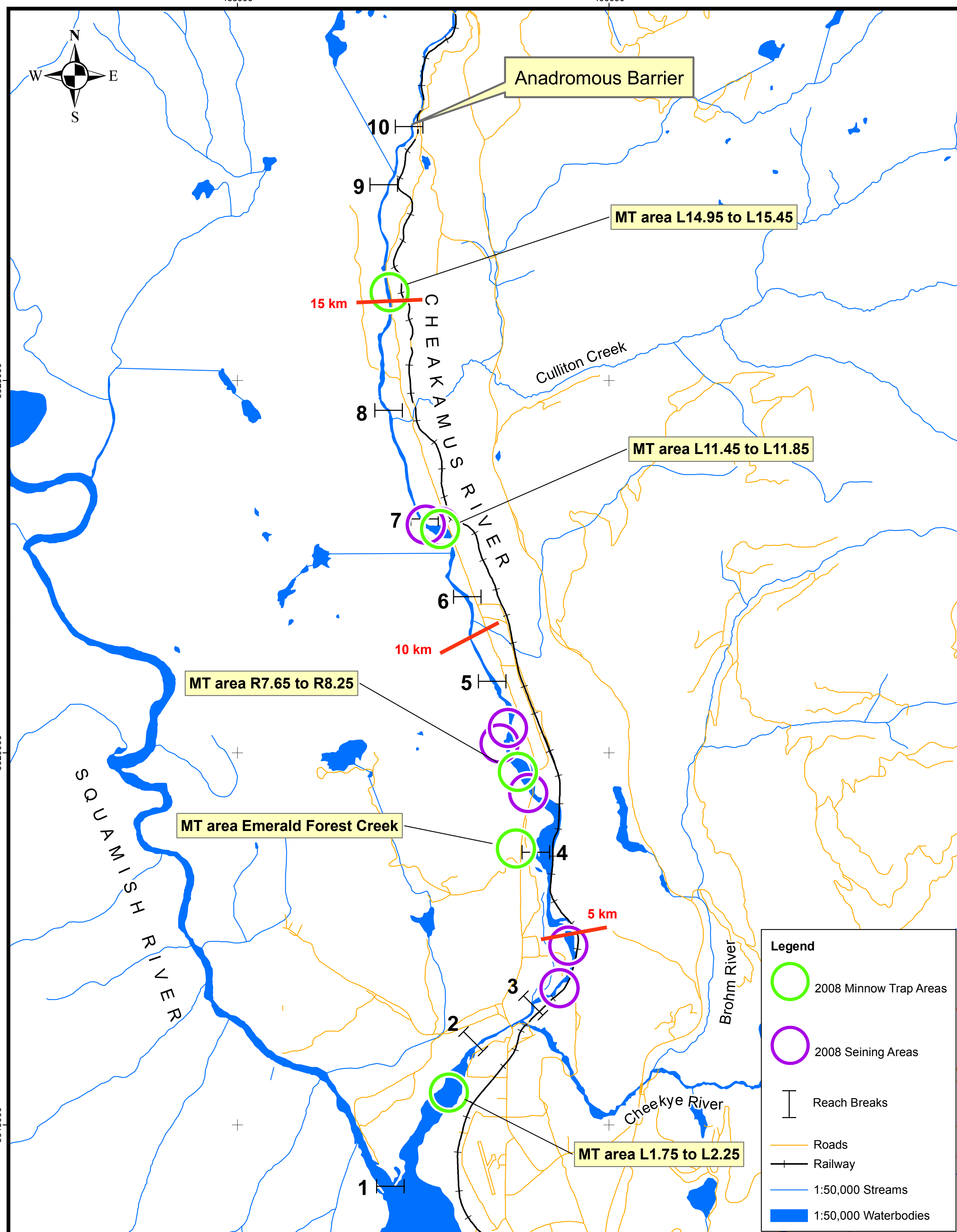


Figure 2-3. Location of Cheakamus River RAMP minnow trap and seining sampling areas

Basemap Source:	Scale: 1:70,390	Map Datum:
WSA 1:50K, TRIM 1:20K	0 250 500 1,000 1,500 2,000 2,500 Meters	UTM NAD 83 Zone 10

Project No:	File No:	Date:
3772	N:\ACTIVE\CN_Cheakamus\3772_MISC_MXD \RAMP\RAMP_MT_SN_2008.mxd	Oct 22, 2009

TRITON ENVIRONMENTAL CONSULTANTS LTD.

Table 2-2. Electrofishing sites, RAMP 2008

Stream	Reach	Date	Site[1]	Type[2]	Reach	Date	Site	Type
Cheakamus River Mainstem	1	Apr/ Sep	L 0.03	O	5	Apr	L 9.03	O
		Apr/ Sep	L 2.15	O		Apr/ Sep	L 9.05	C
		Apr/ Sep	R 2.75	O				
	2	Apr/ Sep	R 2.8	C	6	Apr/ Sep	R 10.35	O/C
		Apr	L 3.45	O		Apr/ Sep	R 11.05	O
		Apr/ Sep	R 3.55	O		Sep	R 11.3	C
	3	Apr/ Sep	R 4.3	C	7	Apr	L 11.65	O
		Apr	R 4.35	O		Apr/ Sep	L 11.7	C
		Apr/ Sep	R 5.45	C		Apr	R 12.55	O
		Sep	R 5.97	C		Apr/ Sep	R 12.6	C
	4	Sep	L 7.5	C	8	Sep	R 14.15	C
		Apr	L 7.85	O		Apr	R 14.25	O
		Apr/Sep	L 7.9	C		Sep	L 15.05	C
		Apr	L 8.15	O		Apr/ Sep	L 15.55	C
						Apr	L 15.6	O
Natural Side Channels	1	Apr/ Sep	L 0.38	O/C	4	Apr	R 7.0[3]	C
		Apr/ Sep	L 1.8	O		Apr/Sep	R 7.1[3]	C
		Apr/ Sep	L 1.95	C		Apr	R 7.35	O
						Sep	L 8.65[3]	C
	3	Apr	R 5.95	C	6	Apr	R 11.3	C
Man-made Side Channels		Apr/ Sep	Moody's Pond Complex				MP 5.75	O
		Apr/ Sep	Gorbuscha Ch.				Gb 6.45	O
		Apr/ Sep	Mykiss Ch. (back channel)				My 7.75	O
		Apr	Emerald Forest Creek (Farpoint intake)				EF 7.95	O
Cheekye River		Apr/ Sep					L CR 0.00[4]	O
		Apr					L CR 1.05[4]	O
Culliton Creek		Apr/ Sep					L CC 0.20[4]	O
		Apr/ Sep					R CC 0.30[4]	O
Brohm River		Apr/ Sep					R BR 0.72[5]	C
		Apr/ Sep					L BR 3.00[5]	C

[1] L = left bank; R = right bank, distance (km) from the confluence with Squamish R. (km 0),
[2] O = open electrofishing site; C = closed
[3] Natural side channel, re-watered and enhanced with pools, boulders and large woody debris structures
[4] Distance (km) from the confluence with the Cheakamus River
[5] Distance (km) from the confluence with the Cheekye River

2.3 Physical Habitat

Site characteristics, as well as hydrological and water quality data were collected at each electrofishing site (Table 2-3); a subset of similar data were collected for minnow trapping and seining sites. Site characteristics were measured *in situ* with electronic instruments (calibrated to manufacturer's standards) or were determined by "ground estimates" (GE) among the field crew following criteria outlined in the Reconnaissance (1:20,000) Fish and Fish Habitat Inventory-Site Card Field Guide (Resource Inventory Committee; RIC, 1999). These procedures require some site characteristics to be determined through a subjective assessment, based on crew experience and field observations, which has an inherent variability among observers. Where site parameters could not be quantitatively measured, they were discussed among the survey crew in an effort to minimize subjectivity and reach consensus on site conditions.

Table 2-3. Electrofishing site characteristics measured, Cheakamus River, 2008

Characteristic	Method	Characteristic	Method
UTM coordinates	Garmin GPS 12XL	Site length (m)	tape measure (T)/ hip chain (HC)
Hydraulic unit type (HUT) (riffle, pool, etc.)	Ground estimate (GE)	Site width (m)	T
River stage	GE	Maximum Depth (m)	meter stick (MS)
Channel & wetted width (m)	Yardage Pro Sport 450	Substrate (%)	GE
Gradient (degrees)	Clinometer (C)/GE	% Sand	GE
Temperature (°C)	Mercury thermometer (T4)/ Hanna Combo (S4)	Avg. bed material size D_{90} (cm) and D_{max} (cm)	GE/MS
pH	S4	Substrate compaction (low, moderate, high)	GE
Conductivity (µS)	S4	Cover (%)	GE
Total Dissolved Solids (ppm)	S4	Velocity (m/ s)	Swoffer 2100/ Gurley Pygmy
Turbidity (cm)	GE		

Codes from Reconnaissance (1:20,000) Fish and Fish Habitat Inventory- Site Card Field Guide (RIC, 1999).

Photographs were taken in each sampling area, to show habitat features and site conditions for future referencing in assessing habitat conditions. Additional photos showing methodologies and individual fish captured were also collected when deemed beneficial to document species composition and sampling methods. Photographs are maintained on file for future reference and where relevant for descriptive purposes are included in Appendix 1 and 2.

Depth and Velocity Profiles

Depth and velocity profiles were measured in all electrofishing sites. One transect was surveyed at a location within each site representative of flow and depth characteristics. The number of velocity and depth measurements required to characterize each transect varied, and was determined in the field based on visual examination of the depth/velocity profile, from the bank, across the width of each site.

2.4 Fish Sampling

Sampling was conducted during the periods of April 7 to 24 and September 3 to 27, 2008, by a four-person crew. Electrofishing, minnow trapping and seining were the three methods employed. Sampling methods and timing were chosen to emulate those of previous studies on the Cheakamus River (Sneep, 2001; van Dishoeck, 2000, 2002; van Dishoeck and Horne, 2002), as well as for comparison with surveys conducted for the RAMP in 2006 and 2007 (Triton, 2008b and 2009a).

Captured fish were lightly anaesthetized with clove oil diluted in water, and identified to species and measured to the nearest millimetre (mm) for fork length (salmonids) or total length (other species). A sub-sample of captured fish (minimum of 10% of total capture/species) was also weighed to the nearest 0.01 g. Fish were allowed to recover in aerated buckets, after which time they were released, near the vicinity of capture. Inadvertent mortalities (less than 1% of the total catch) were recorded.

2.4.1 Electrofishing

A total of 41 electrofishing sites were sampled along the Cheakamus River mainstem, side channels and tributaries in April and 32 sites in September (Figures 2-1, 2-2). Each site was measured to the nearest metre (length: downstream boundary to upstream boundary; width: average of at least 3 measurements along the site), geo-referenced, and marked at the upstream and downstream boundaries for replication in future surveys. Sampling methods used in April 2008 were consistent with those used during the 2007 RAMP surveys (Triton, 2009a).

In September 2008, the sampling method used for closed electrofishing sites was modified in an effort to emulate methods recommended by the Ministry of Environment (Ptolemy, verbal comm., 2008). Closed electrofishing was used at 20 sites in September, following similar methodologies as described in Ptolemy *et al*. (2006). Sites were isolated with seine nets at the upstream and downstream boundaries and then a third net was installed parallel to shore. Nets were kept in place (with the upper edge above water) by a series of poles and anchor bags, and sealed at the bottom with rocks placed along the nets' lead lines (Photo 2). In closed electrofishing sites each pass (triple-pass depletion) consisted of an "ambush", upstream sweep and a methodical downstream sweep (Ptolemy, verbal comm., 2008). Fish were also herded from the deep (outside) end towards the shore. The electrofishing protocols used for closed sites in September 2008 (*i.e*., each pass consisting of two sweeps) did vary from those used in 2006 and 2007 (*i.e*., a pass consisted of a single upstream sweep). However, *measured* densities from each year were calculated using the Maximum Likelihood Estimates (MLE; section 2.5.3) model which considers variation in efficiency by incorporating depletion rates from multiple sweeps. Therefore the measured density from all surveys was standardized and results were still comparable. Sampling methods used in open sites were consistent with those employed in April 2008 and in the previous two years of the program. Crews strived to maintain a consistent sampling effort among passes and sites of similar nature (*e.g*., by monitoring the electrofisher counter).

2.4.2 Minnow Trapping

Minnow trapping was used to complement and corroborate species and age class information obtained by electrofishing. Overnight sampling with minnow traps was also conducted to capture fish exhibiting nocturnal or crepuscular feeding habits, such as sculpins (McPhail, 2007).

Minnow traps were set overnight (for up to 23 hours), along five (5) 500 m long sections of the Cheakamus River mainstem and side channels (Figure 2-3). Traps were baited with salmon roe (~5 g/ trap) and set a frequency of approximately 1 trap every 10 m of stream length, totalling 50 traps per sampling area. Trap frequency was increased in certain areas where habitat conditions were considered suitable for greater fish abundance or capture of specific species, such as stickleback in backwater areas and areas of abundant cover for sculpins, cutthroat and char.

2.4.3 Seining

Fifteen seining sites were sampled in 2008, along the Cheakamus River (Figure 2-3). Seining (using a pole seine) was conducted in an effort to target newly emerged fish (such as sculpin and stickleback) in backwater areas. Five passes were conducted over areas averaging 50 m^2 and results from all passes were pooled. Seining was selected as a complementary sampling method to electrofishing.

2.5 Data Compilation and Analyses

Project-specific data forms were developed to ensure consistent data collection at each sampling site (Appendix 3). The data collected were then analysed to provide information on:

- Habitat quality in sampled areas
- Length/ age class distributions, growth patterns and condition
- Measured and adjusted densities , and biomass (electrofishing data)
- Catch per unit effort (minnow trap data)

2.5.1 Length-Frequency Distributions & Age Classes

Length-frequency distributions (histograms) were generated for sculpins, lamprey and rainbow trout. Age classes were assigned, when possible, based on the observed modes in length-frequency, and correlated by comparing to available historical data. This method for age determination was preferred over others, such as the examination of otoliths (or statoliths, in the case of lamprey), scales or fin rays, because these methods involve either terminal or invasive sampling. The program MIX (R Development Core Team, 2008) was also used to test length-frequency distributions against "goodness of fit models" (Chi-square) and compare to age group delineations established from histograms.

2.5.2 Condition Factors

Fish condition may reflect habitat quality and food availability, especially in the case of juveniles, where somatic condition is linked to food availability. Monitoring fish condition over time was considered a reasonable indicator of changes in habitat quality, food availability.

Condition was calculated for rainbow trout using Fulton's condition factor (K), which assumes a greater weight at a given length indicates a fish in "better condition" (Ricker, 1975). Fulton's condition factor was calculated as:

$$K = (W*FL^{-3}) *10^5 \quad \text{where} \quad W = \text{weight (g)}, \; FL = \text{fork length (mm)}$$

Although commonly used, Fulton's index has been criticized for assuming isometric growth and being size-dependent. Furthermore, while some researchers have suggested higher condition indices indicate healthier fish, in practice, fish with a condition close to 1 are generally considered in good health. In using condition indices to evaluate the growth of juvenile fish in hatchery conditions, a target condition of 1.0 is typically used. Fish with higher condition tend to have increased fatty deposits particularly among pyloric caeca, raising concerns about overall fish health (Campbell, 2007: verbal comm.). As a result, caution should be applied when utilising condition indices to make assumptions concerning fish "health". These indices however provide a reasonable method to evaluate and monitor changes in fish condition over time.

2.5.3 Abundance Estimates

Electrofishing

Electrofishing data were used to calculate density estimates for sculpin, lamprey and rainbow trout, as well as other species. Site density was calculated using Maximum Likelihood Estimates (MLE; Zippin, 1956, Seber, 1982) generated by MicroFish 3.0 (Van Deventer, 1989). Maximum Likelihood is a regression model used in conjunction with the removal method to generate population estimates (*i.e.,* the number of fish captured if sampling continued until no fish were remaining in the site). This *measured* density (population estimate divided by sampled area) was converted to fish per unit (fpu) area, where the area was equal to 100 m^2.

Measured densities were also *adjusted* for rainbow trout underyearlings (*i.e.*, 1+ fish in April and 0+ fry in September), using Bovee (1978; 1982) *probability of use* methodology, where the "usable" percentage of each sampling site was quantified. Usable area is defined as measured area x $P_{\text{habitat use}}$, where $P_{\text{habitat use}}$ is habitat use probability. The latter is based on depth and velocity profiles and habitat suitability indices (HSI; Ptolemy, 2001). Hence $P_{\text{habitat use}} = P_{\text{use| depth}}$ x $P_{\text{use| velocity}}$. Different habitat suitability indices are ascribed to various salmonid species and age classes. According to habitat suitability curves, the greatest probability of use (P = 1) for rainbow trout underyearlings occurs at depths between 0.05 and 0.25 m and velocities between 0.07 and 0.12 m/s.

Only densities for rainbow trout underyearlings were adjusted for comparison between sites. Habitat use by juvenile rainbow trout is a function of a habitat quality, and habitat quality is affected by depth and velocity characteristics, as well as the presence of cover features and suitable substrate size. Even though a site has suitable depth and velocity characteristics, a lack of suitable cover features will affect density. For example, habitat use is more strongly influenced by the presence of suitable cover features and substrate size as juveniles become larger, therefore the adjustment of parr densities based on depth and velocity characteristics is less reliable and not recommended (Ptolemy, 2007: verbal comm.), and therefore, it was not calculated for this study.

Minnow Trapping

Studies conducted by Swales (1987) indicated a decrease in minnow trap efficiency over time, and a non-linear relationship between catch and soak-time. Sneep (2001) suggested catch rates were affected by a reduction in bait efficiency over time, while Swales proposed it is a function of population density and an increase in the likelihood of fish escaping over time. Both authors suggested standardizing calculations to correct this limitation, either by calculating catch per unit effort CPUE as the number of fish per trap (Sneep, 2001), or by standardizing soak-time (Swales, 1987). As the variation in trap efficiency over time could not be quantified, the catch per unit effort was standardized as overnight sets, and catch rates for minnow traps were calculated as the number of fish per trap (*i.e*., catch per trap; CPT).

2.5.4 Biomass

Historical sampling data used to compare rainbow trout densities has been collected by several investigators, typically between August and October (*i.e.*, 1 to 3 months after emergence). The length and weight of rainbow trout fry will vary over this time period as fish begin to feed and grow. In addition, fish size can be affected by various factors (*e.g.*, temperature, time of adult spawning/fry emergence and timing of sampling). Due to the territorial behavior of salmonids, it has also been suggested rearing densities of rainbow trout are affected by fish size (*i.e.*, larger fish require and will defend a larger territory; Allen, 1969; Ptolemy, 1993; Ptolemy *et al*., 2006). Comparing site-specific biomass of rainbow trout fry [*i.e*., total weight (g)/site area (100 m^2)] provides a method of adjusting for these variables (Triton 2009a). Comparisons of rainbow trout biomass has also been used by the Ministry of Environment in other systems where long-term monitoring of rainbow trout fry abundance has been undertaken (Ptolemy *et al*., 2006).

In 2007, information from more than 70 sampling sites collected during eight (8) surveys over a twenty-year period was reviewed to develop a secondary recovery target for rainbow trout based on site biomass. The data set encompassed sites from different sections of the Cheakamus River, collected by at least five (5) different investigators applying similar methodologies. The measurement of site-specific biomass is intended to complement information collected during adult snorkel surveys and be used as part of a "weight of evidence" approach to monitoring recovery (CERP; Triton, 2009b). More information about the calculation of the biomass recovery target is available in Triton (2009a).

3.0 Results

3.1 Site Characteristics

3.1.1 Water Quality

Daily *in situ* water quality measurements were collected at electrofishing and minnow trap sites. Temperature, pH and conductivity were similar among mainstem and side channel electrofishing sites. In general, temperature in tributary sites was lower and conductivity higher than in the Cheakamus River (Appendix 4), which may reflect groundwater intrusions. All pH values (6.64 to 7.97) fell within the range of recommended values for the protection of freshwater life (CCME, 2007; MoE, 1998). Similar conditions were recorded in minnow trap sampling areas (Appendix 5). Water quality values were also similar to those reported in previous years (Triton, 2008b and 2009a).

3.1.2 Electrofishing Sites

Site characteristics (Section 2.3) were assessed for all electrofishing sites (41 in April and 32 in September) on the Cheakamus River and tributaries. Site measurements, depth-velocity profiles and photographs are provided in Appendix 2. Detailed habitat data are provided in Appendix 4 and summarized below.

Hydraulic Unit Type, Substrate and Cover

Mainstem and tributary sites consisted of over 65% riffles (turbulent, fast-flowing water) and most of the remaining sites were classified as “glides” (non-turbulent, fast flowing water – includes “runs”; Johnston and Slaney, 1996). The majority of the sites were dominated by cobble substrate, with a few sites where either boulder or gravel was dominant. Substrate composition and distribution were similar in April and September. Estimates of total available cover in mainstem electrofishing sites varied between sites (high total cover percentage often associated with pools or areas of abundant boulders). Boulders represented 100% of total available cover in most sites. Other cover types, such as pools, large and small woody debris, instream vegetation and undercut bank, accounted for a small percentage of total available cover in mainstem sites, with a greater occurrence in tributary sites.

Side channel sites varied more in their habitat characteristics than mainstem sites, and more often contained features such as LWD, SWD and undercut banks. Natural side channel sites consisted mainly of riffle and man-made side channel sites, of pool habitat. Both types of sites were dominated by smaller substrate (*i.e.*, fines and gravels) than observed in mainstem sites. Whether accumulated through natural deposition or “artificially” added to the channels, available cover in side channel sites was considered to be greater than in mainstem sites. Cover was provided mainly by pools and woody debris (large and small).

Depth and Velocity Profiles

Depth and velocity transects were measured at most electrofishing sites, with the exception of a few sites where no velocity was observed, thus only depth was recorded (Appendix 2 and 4).

Mean depth and velocity values were similar between April and September, although overall greater in April (Appendix 4). Mean depth in mainstem and tributary sites ranged from 0.09 to 0.56 m in April, and from 0.09 to 0.46 m in September. In side channels, mean depth varied between 0.15 and 0.42 m in April, and between 0.08 and 0.38 m in September. Mean velocity in mainstem and tributary sites ranged from 0.08 to 0.68 m/s in April, and from 0.04 to 0.45 m/s in September. In side channels, mean velocity varied from 0.00 to 0.37 m/s and from 0.00 to 0.24 m/s, in April and September respectively (Appendix 4).

3.1.3 Minnow Trapping Sites

Minnow trap site characteristics in four trapping areas along the Cheakamus River and one in Emerald Forest Creek are presented in Appendix 5. Mean soak time ranged from approximately 18 to 22 hours. Mean trap depth varied from 0.49 to 0.62 m and 0.37 to 0.63 m, in April and September respectively. In April, 46% of minnow traps were set in sites associated with run, 27% with riffle, 22% with pool and the remaining 6% with glide habitat. In September, 37% of traps were associated with run, 32% with pool, 26% with riffle and 5% with glide. Cover in April and September was mainly provided by boulders (38% and 42% respectively) and large woody debris (LWD: 36% and 23% respectively). All traps were set in low-to-no velocity sites to avoid fish impingement. Detailed site characteristics for individual minnow trap sites are provided in Appendix 6.

3.2 Catch Distribution

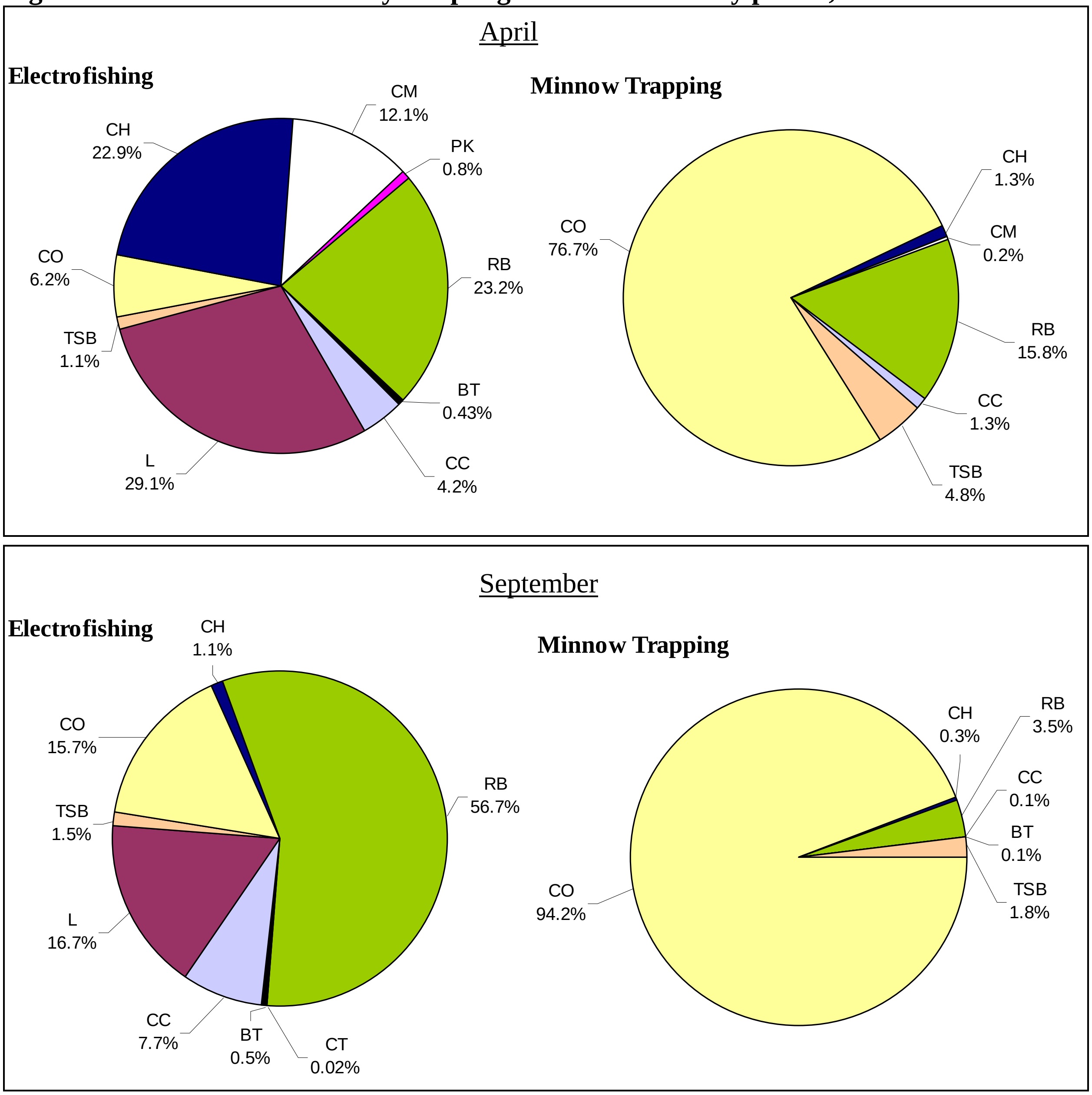
The total catch in the Cheakamus River mainstem, side channel and tributary sites in 2008 was 9,481 fish. Electrofishing accounted for 6,624 fish (Appendix 7), minnow trapping for 2,787 (Appendix 6) and seining for 75 (Appendix 8). Target species members (Section 2.1) represented 54% of total catch, including: 3,060 rainbow trout, 1,421 lamprey, 432 sculpins (427 coastrange sculpin and 5 prickly sculpin), 156 threespine stickleback, 34 bull trout and 1 cutthroat trout. The remaining catch was composed of 3,382 coho, 667 chinook, 307 chum and 21 pink salmon.

Cutthroat trout, lamprey and pink salmon were only captured by electrofishing, otherwise, electrofishing and minnow trapping yielded the same species, although in different numbers (Figure 3-1). Catch composition and distribution also varied between the two survey periods. Lamprey accounted for the majority of fish captured by electrofishing in April, followed by rainbow trout and chinook salmon. In September, rainbow trout (primarily fry) dominated the electrofishing catch. Coho salmon dominated the minnow trap catch during both sampling periods.

3.3 Population Parameters

Length-frequency distributions (used in an effort to assign age groups based on length classes) and length-weight relationships were generated for sculpins, lamprey and rainbow trout. Condition (Section 2.5.2) was also assessed for rainbow trout. The individual lengths and weights of fish measured in 2008 are presented in Appendix 9.

Figure 3-1. Catch distribution by sampling method and survey period, 2008



RB: rainbow trout, CT: cutthroat trout, BT: bull trout, CC: sculpin, L: lamprey, TSB: threespine stickleback, CO: coho, CH: chinook, CM: chum, PK: pink salmon

3.3.1 Sculpins

During the RAMP 2008 surveys, all sculpins captured (n = 432) were visually identified to species in the field (based on a field key consisting of 8 morphometric characters; Appendix 3). All but 5 fish were identified as coastrange sculpins: the others, as prickly sculpins. Results from DNA analyses (conducted in 2007, in the context of a parallel study on population distinctiveness in the Squamish drainage and for which the full results are expected to be available in 2009) suggested a good correlation between visual and microsatellite DNA identification (approximately 98% agreement), with a few genetic mismatches between mitochondrial DNA and microsatellite suggesting historical gene flow between the two species (Taylor and Gow, 2008).

Length-Frequency

Prickly sculpin length (measured as total length; TL) ranged from 112 to 134 mm (mean = 123 mm ± 10 standard deviation; SD, n = 5). Ringstad and Narver (1973) reported mean lengths of 87.5 and 98.5 mm for age four (4) prickly sculpins in June and August, respectively (based on otolith aging, Carnation Creek, Vancouver Island). This suggests prickly sculpins captured in the Cheakamus River in 2008 were most likely 4 years and older (assuming similar growth patterns between the two systems). Total lengths of coastrange sculpins ranged from 55 to 113 mm (81 mm ± 16, n = 111) in April, and from 47 to 120 mm (84 mm ± 16, n = 314) in September. Ringstad and Narver (1973) reported mean lengths for age two (2) coastrange sculpin of 47 mm and 57 mm, in June and August, respectively. This may indicate most sculpins captured in the Cheakamus River in 2008 were third year fish and older, with a small number of age two fish in September.

Age class delineation was undertaken for coastrange sculpin only. Age classes are estimates based on modes in the length-frequency histograms, as well as on previously reported data for the species (Ringstad and Narver, 1973; Wydoski and Whitney, 2003; Table 3-1). Length-frequency distributions for each sampling period (Figure 3-2 and 3-3) indicate there may have been at least five age classes (up to six, in September) present in the river at the time of the surveys.

Figure 3-2. Length-frequency and age class distribution of coastrange sculpin, April 2008

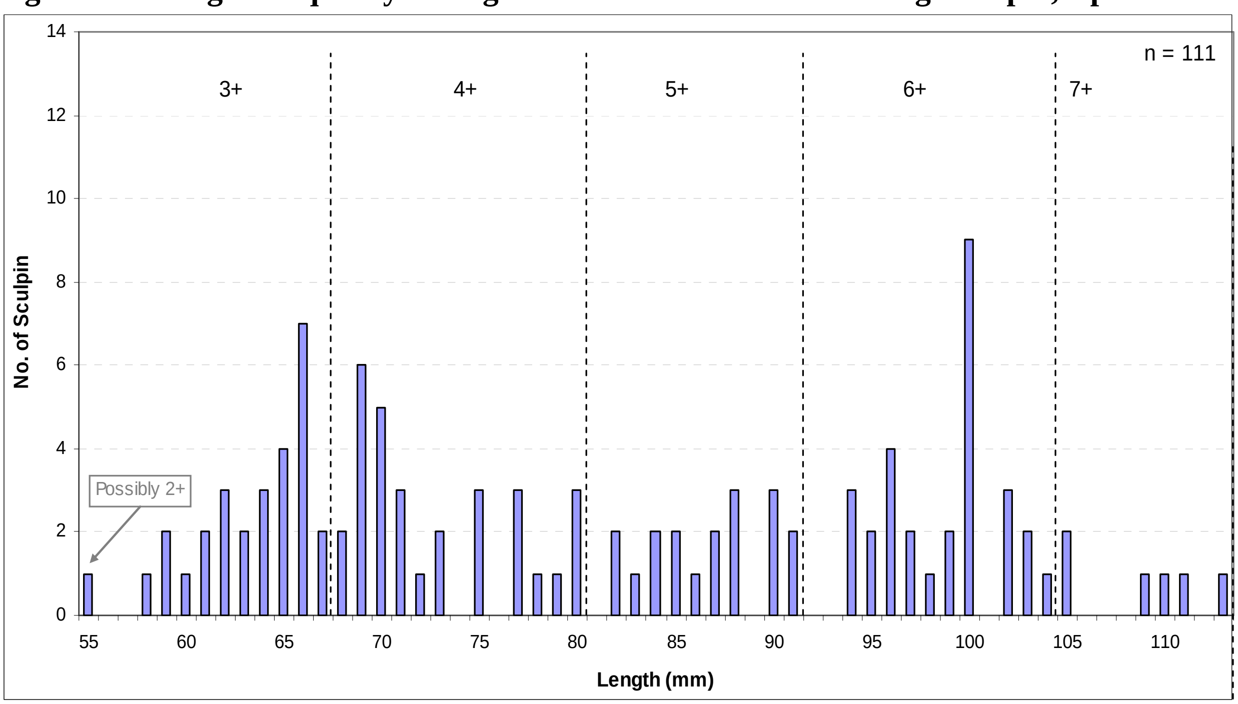


Figure 3-3. Length-frequency and age class distribution of coastrange sculpin, September 2008

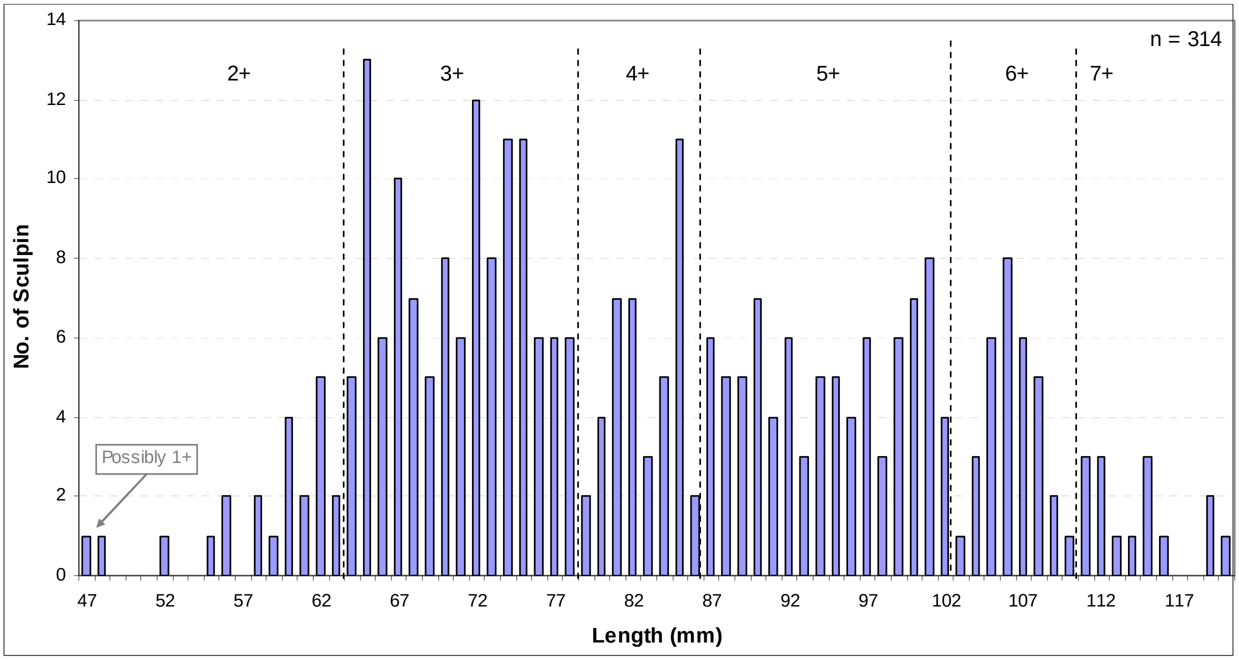


Table 3-1 presents the mean length of coastrange sculpins for each estimated age class, in comparison to values reported by Ringstad and Narver (1973), Wydoski and Whitney (2003) and McLarney (1967, in Ringstad and Narver, 1973) for similar periods. Mean lengths were comparable among studies, when considered in relation to timing of the sampling period, although larger in general for the RAMP. The established length classes for coastrange in the Cheakamus River also correlate with the growth rate reported by Ringstad and Narver (1973) of approximately 10 mm increments per year (also reflected in values by Wydoski and Whitney, 2003). Overlap between age groups is likely (as reported by Ringstad and Narver, 1973), but was not evaluated.

Table 3-1. Mean total lengths (mm) of coastrange sculpins for estimated age classes

Age class	**2+**	**3+**	**4+**	**5+**	**6+**	**7+**
RAMP April	**-**	**63** (±3)	**73** (±4)	**87** (±3)	**99** (±3)	**109** (±3)
Ringstad and Narver (1973) Vancouver I., **June**	47.0	59.5	71.5	-	-	-
Wydoski and Whitney (2003) Alaska, **July**	51	66	76	86	96	99
Ringstad and Narver (1973) Vancouver I., **August**	57	70	79.5	-	-	-
McLarney (1967, in Ringstad and Narver, 1973) Alaska	60	65	83	92	108	-
RAMP September	**59** (±5)	**71** (±4)	**83** (±2)	**95** (±5)	**106** (±2)	**114** (±3)

Note: Values in parentheses are standard deviations.

A Mixture Distribution Model (R Development Core Team, 2008) program was also used to test length-frequency distributions against "goodness of fit models" (Chi-square) and compare to age group delineations established from histograms. The April model provided a good fit for similar length classes, but with large overlap, while the September model did not converge (Appendix 10).

Length/Weight Relationship

The weight of coastrange sculpin ranged from 2.11 to 26.25 g (mean = 7.49 g ± 4.69 SD, n = 111) in April, and from 1.41 to 30.27g (8.11 g ± 5.64, n = 237) in September. Weights of prickly sculpin varied between 17.68 and 32.42 g (25.09 g ± 6.15). Figures 3-4 and 3-5 show the length/weight relationships of coastrange sculpins captured on the Cheakamus River in April and September, respectively.

Figure 3-4. Length/weight relationship of coastrange sculpins, April 2008

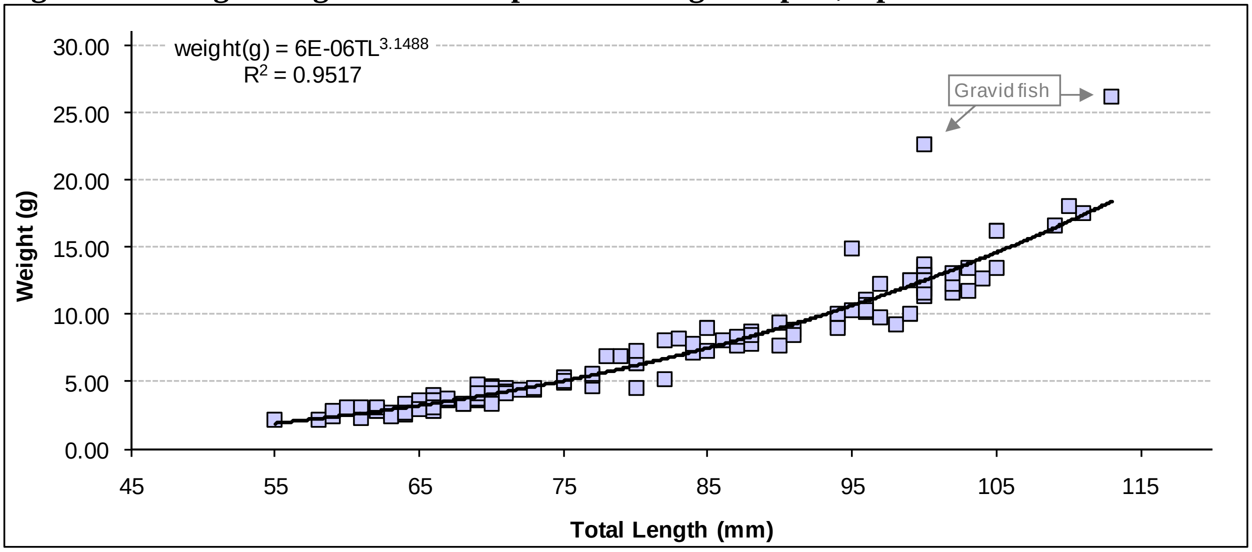
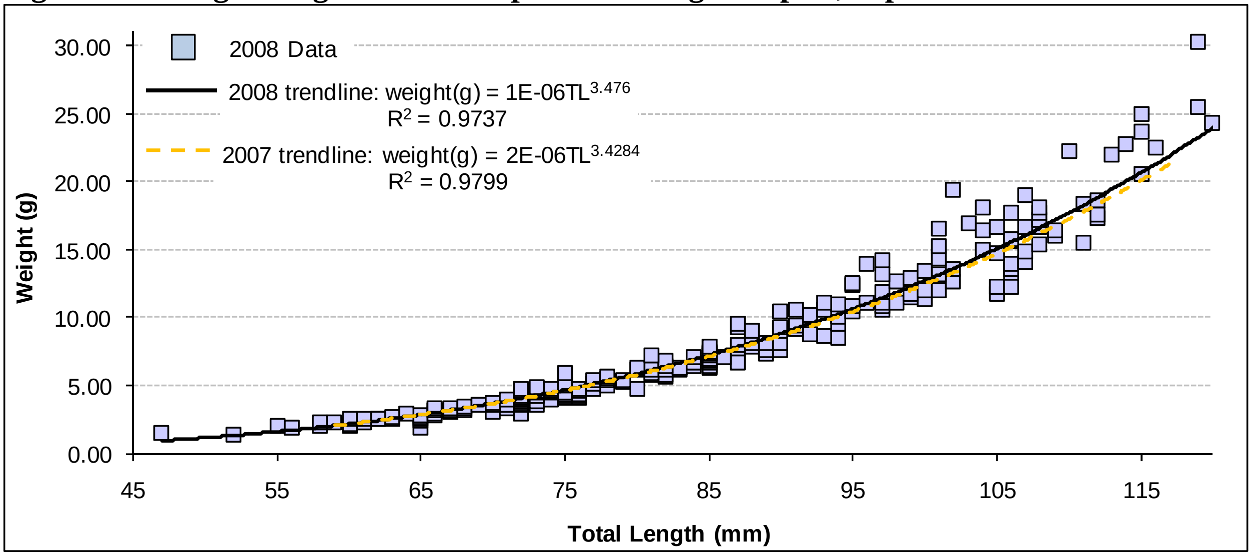


Figure 3-5. Length/weight relationship of coastrange sculpins, September 2008



Two outliers in April (Figure 3-4) were identified in the field as gravid females (Photo 3). Other specimens with enlarged abdomen were observed, along with male sculpins in breeding colours (dark body and orange trim on first dorsal fin (Photo 4; McPhail, 2007). The degree of similarity between trendlines derived from the length/weight relationships of coastrange sculpins captured in September 2007 and 2008 (Figure 3-5) suggests comparable growth between years.

3.3.2 Lamprey

A total of 1,273 lamprey were measured for total length (TL). All but three fish (juveniles, captured in September) were ammocoetes (eyeless lamprey). In April, a small subsample of the catch was photographed and subsequently used for species identification, and all lamprey were pooled for analyses. Species identification (based on morphology) was attempted for all lamprey captured in September: western brook or river lamprey were characterised by a dark caudal ridge (Photo 5), and Pacific lamprey, by a clear ridge (Photo 6; Beamish, 2008 verbal comm.; Richards *et al*., 1982). Photo documentation for 188 specimens was used to corroborate field identification in cases where distinction in the pigmentation was less obvious (*e.g*., fish less than 75 mm). Additional useful characters (Appendix 1; Photo 5 and 6) were identified through photo documentation and may be used in future sampling to support identification. Data for western brook and river lamprey ammocoetes was combined for analyses.

Length-Frequency

The total lengths of ammocoetes captured in April ranged from 16 to183 mm (mean = 94 mm ± 28 SD, n = 591; Figure 3-6). In September, the total lengths of western brook/ river lamprey ranged from 26 to169 mm (77 mm ± 26, n = 519), while that of Pacific Lamprey ranged from 35 to 138 mm (97 mm ± 21, n = 113).

Figure 3-6. Length-frequency distribution of lamprey ammocoetes, April 2008

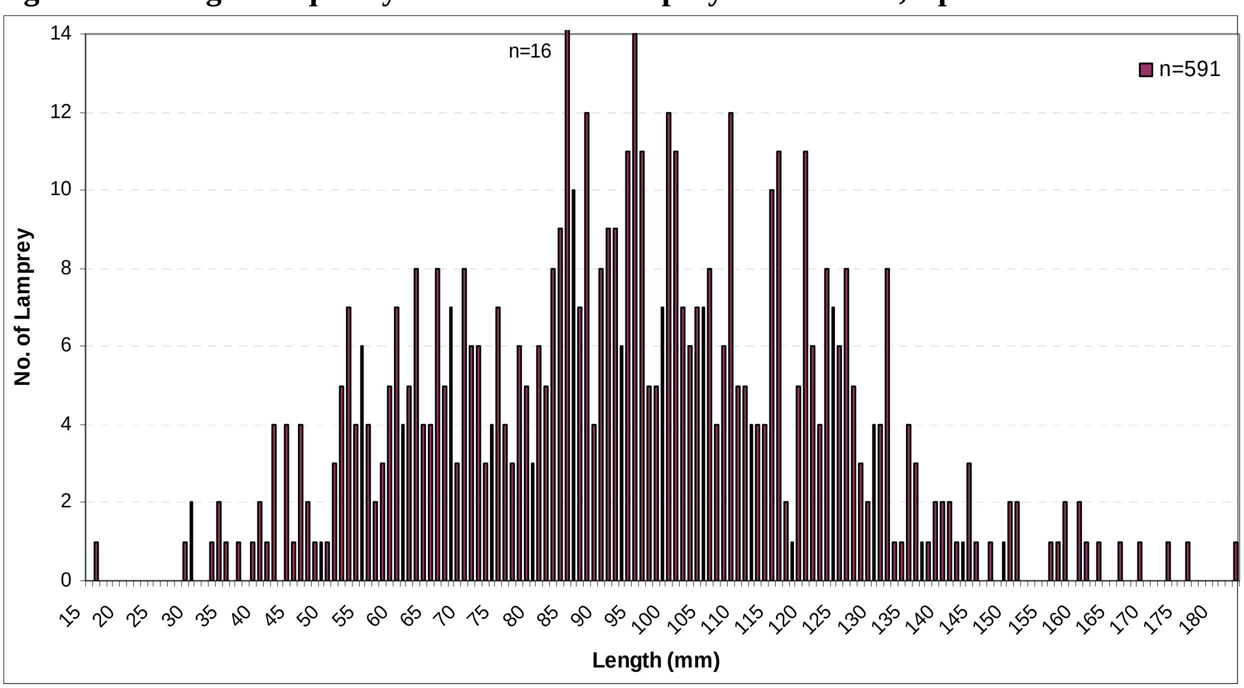
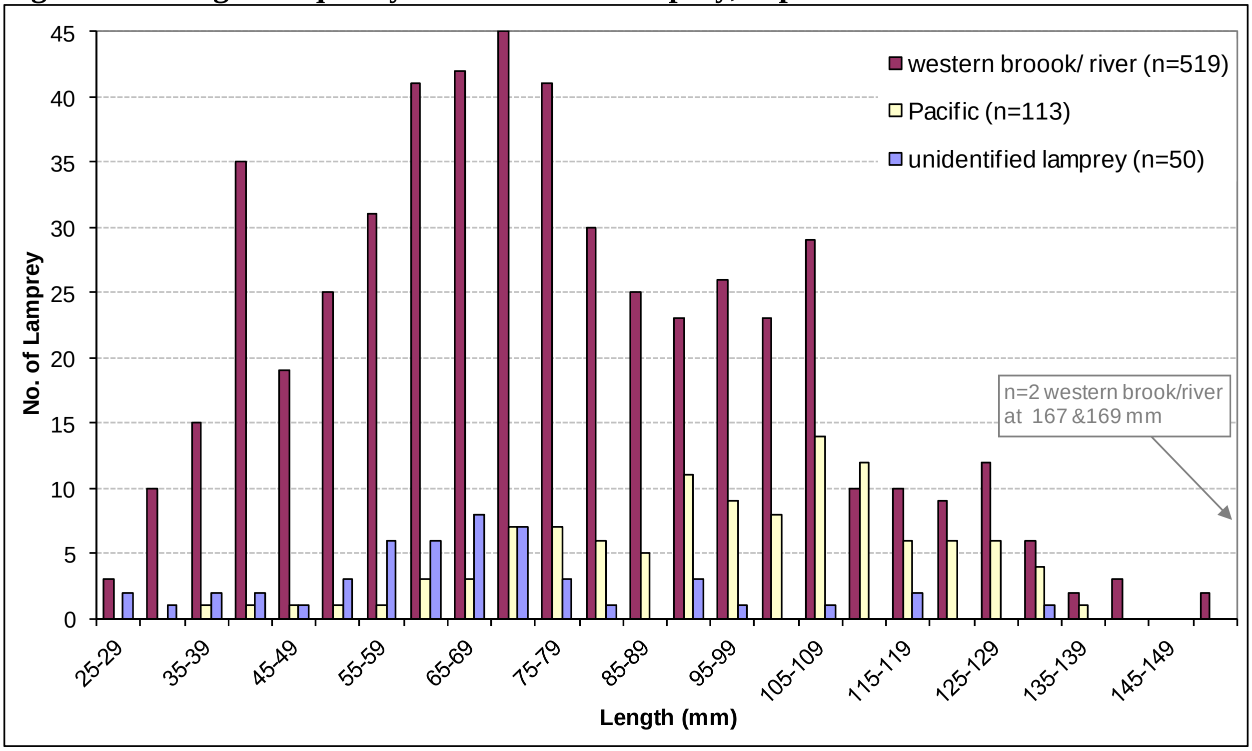


Figure 3-7. Length-frequency distribution of lamprey, September 2008



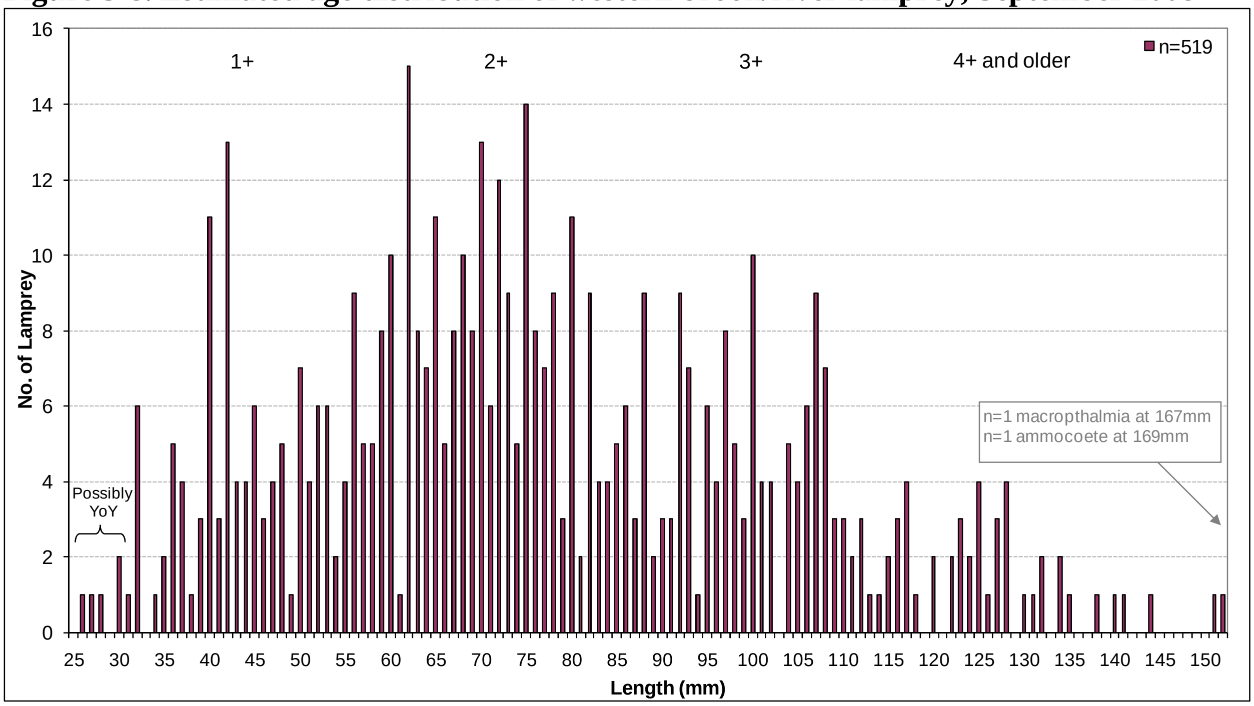
Western brook ammocoetes have been shown to have a greater length-at-age than Pacific ammocoetes: the most rapid growth for western brook lamprey occurs during the first 4 years, while for Pacific lamprey it occurs during the parasitic (adult, marine) phase (Kostow, 2002). A total of 50 lamprey (68 mm ± 22 SD) could not be identified with certainty. Pigmentation of small ammocoetes is not always well developed (Beamish, 2008 verbal comm.). Furthermore, pigmentation on the caudal fin of river lamprey has been defined as an "intermediate condition" between that of western brook and Pacific lamprey (Richard *et al*., 1982; Beamish, 2008 verbal comm.), making identification difficult. Therefore, it is considered more likely these fish were either river or western brook lamprey than Pacific lamprey.

Western Brook/River Lamprey

Western brook lamprey young-of-year were reported to reach an average length of 18 mm (ranging 14-21 mm) by September (Meeuwig and Bayer, 2005), while laboratory-reared river lamprey were reported to reach lengths of 27 to 46 mm in their first year (Beamish and Youson, 1987). Although there may be variations in length-at-age between western brook and river lamprey, these species are considered to have similar growth rates (Meeuwig and Bayer, 2005). Based on this information, western brook/river ammocoetes with a total length of 30 mm and less (n = 6) captured in the Cheakamus River (in April and September) may have been young-of-year. Kostow (2002) reported mean length-at-age of approximately 50, 80, 110 and 130 mm, for age 1 to 4 western brook ammocoetes (generalized growth pattern, Oregon). Pre-metamorphosis western brook lamprey are reported to rarely exceed 150 mm (Pletcher, 1963 in McPhail, 2007), while the maximum reported length for river lamprey ammocoetes is 122 mm (Richards *et al.*, 1982). Both McPhail (2007) and Kostow (2002) suggested the western brook lamprey may spend approximately four years as ammocoete, and both authors reported potential "shrinkage" in total length during metamorphosis (due to feeding cessation).

The length-frequency histogram for western brook/river lamprey captured in the Cheakamus River in September (Figure 3-8) showed no clear modes which could be used to differentiate age classes. The range of lengths observed indicates multiple age classes were sampled. Furthermore, based on mean length-at-age values reported in past studies (Beamish and Levings, 1991; Kostow, 2002; Meeuwig and Bayer, 2005), at least five age groups (from young-of-year to newly transformed juveniles) were present in the river at the time of the surveys.

Figure 3-8. Estimated age distribution of western brook/river lamprey, September 2008



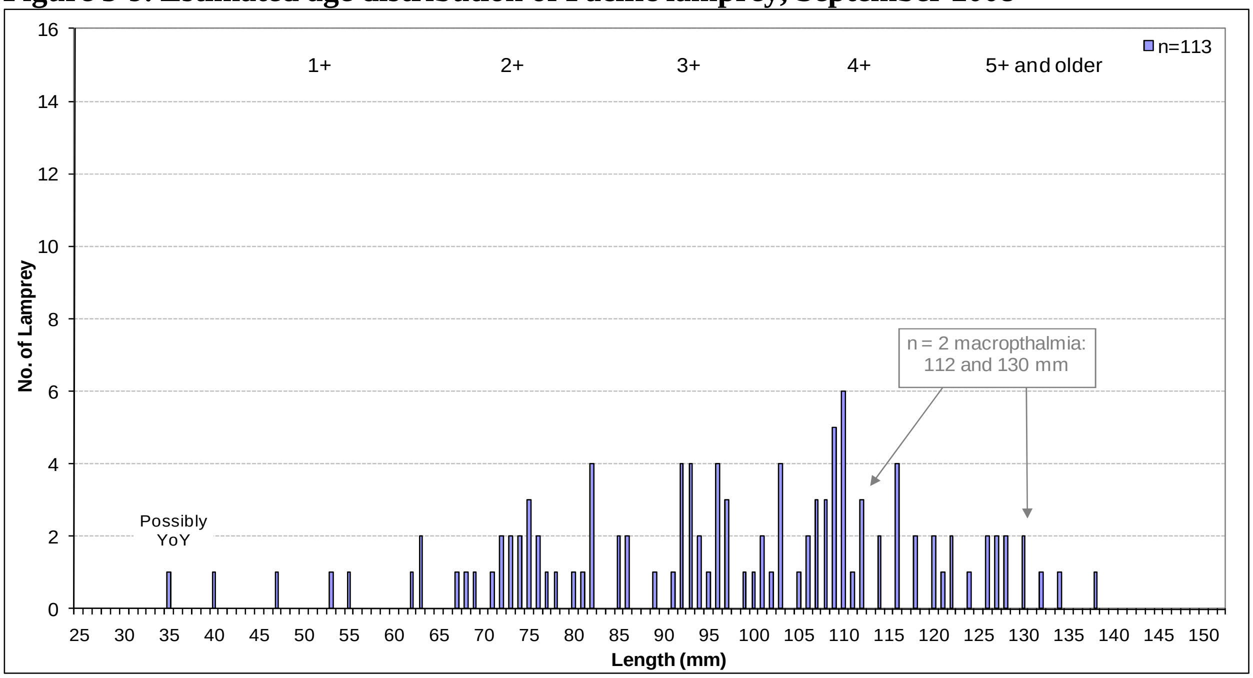
Only one macropthalmia (newly metamorphosed lamprey) was identified as either a western brook or river lamprey (167 mm TL): identification between the two species could not be determined based on the oral disc, as newly transformed western brook lamprey share similar characteristics (*i.e.*, sharp teeth) with river lamprey, for a period of two to three weeks (Beamish, 2008 verbal comm.).

Pacific Lamprey

Pletcher (1963) in McPhail (2007) reported young-of-year lengths of 10 to 25 mm (mid-August, Nicola River). Based on this information, no young-of-year were captured in the Cheakamus River in September 2008. Kostow (2002) reported mean size-at-age of 35, 65, 80 and 100 mm, for Pacific lamprey age 1 to 4 (generalized growth pattern, Oregon). Beamish and Levings (1991) reported similar values: 30, 60, 80 and 115 mm for age 1 to 4 (estimated using statoliths of fish captured in the spring and summer, in the Nicola River). The authors also reported a pause in growth (and even shrinkage, associated with metamorphosis) at age 5 and 6, with mean size at age of 115 and 120 mm respectively. The long river residency period (up to seven years) of Pacific lamprey ammocoetes and age differences in adults suggest variation in growth rates of ammocoetes (Beamish and Levings, 1991). Meeuwig and Bayer (2005) also reported increasing overlap among older ammocoete age classes. Furthermore, the average length-at-age of both ammocoetes and adults is known to vary among populations (McPhail, 2007).

The range in total lengths of Pacific lamprey captured in the Cheakamus River in September 2008 (Figure 3-9) indicates multiple age classes were sampled. Based on mean length-at-age values reported above, at least five age groups (from 1+ to newly transformed juveniles) were present in the river at the time of the surveys. One ammocoete with a total length of 35 mm may have been a young-of-year. Two macropthalmia were also captured in September: identification was based on the examination of pigmentation on the caudal ridge, since the oral disc for both specimens was not fully developed.

Figure 3-9. Estimated age distribution of Pacific lamprey, September 2008



Length/Weight Relationship

Weights of lamprey captured in April ranged between 0.07 and 8.44 g (mean = 1.84 g ± 1.43 SD, n = 339; Figure 3-10). Trendlines derived from the length/weight relationships of lamprey captured in April 2007 and 2008 were similar, suggesting comparable growth between years.

In September, western brook/river weighed between 0.11 and 5.99 g (1.14 g ± 1.00, n = 215), while Pacific lamprey weighed between 0.12 and 4.96 g (1.88 g ± 1.01, n = 99). Figure 3-11 shows different trends in growth between the two species: Pacific ammocoetes tend to be heavier than western brook/river lamprey at similar lengths. This trend was also observed in the field: the Pacific lamprey's body appeared thick throughout their length, whereas the western brook/river lamprey's posterior end of the body seemed to taper in a more pronounced way (observation subsequently confirmed by R. Beamish and J. Wade, verbal comm., 2009).

Figure 3-10. Length/weight relationship of lamprey, all species, April 2008

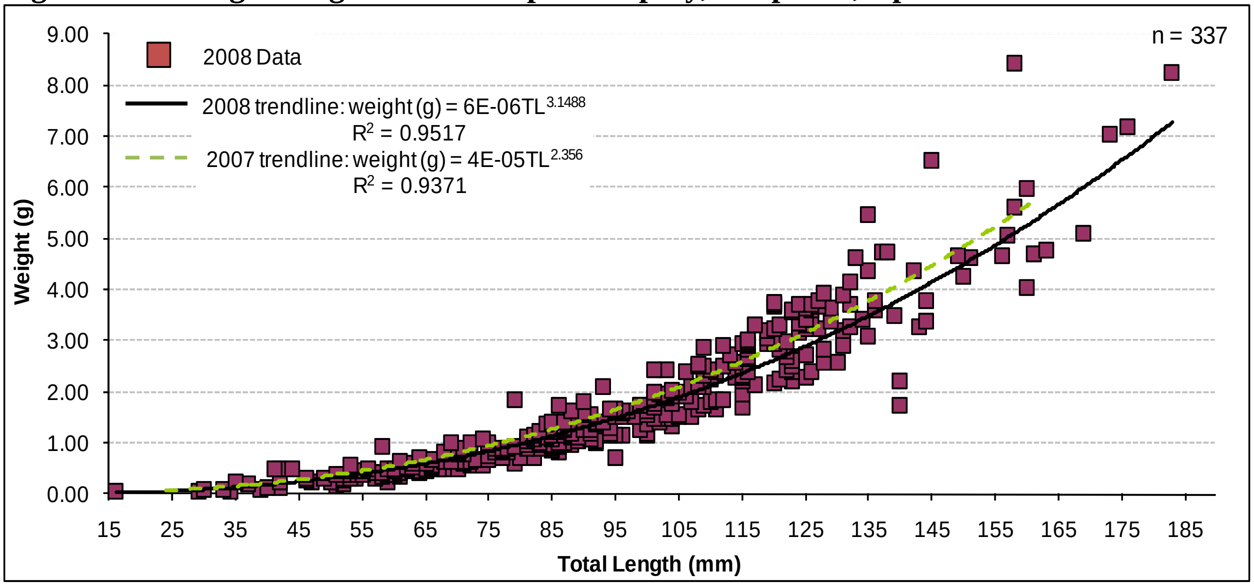
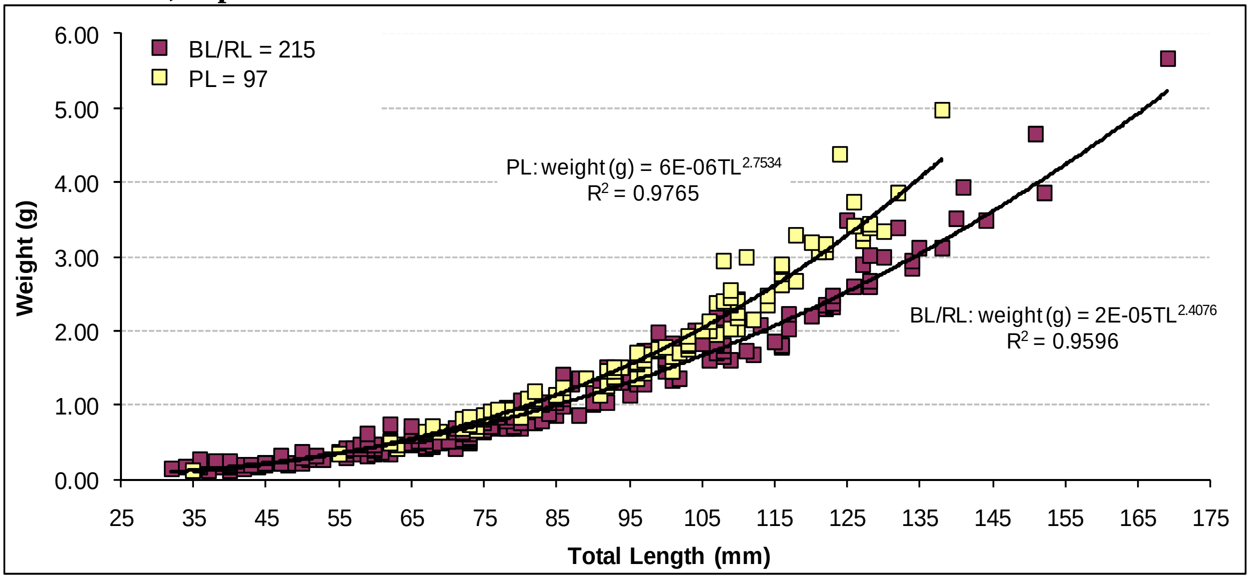


Figure 3-11. Length/weight relationships of western brook/river and Pacific lamprey ammocoetes, September 2008



3.3.3 Rainbow Trout

All rainbow trout captured in the Cheakamus River and tributaries were measured for fork length (n = 2,805 excluding Brohm River). Since there was a statistical difference in the mean length of rainbow trout captured by minnow traps compared to those caught by electrofishing (*t*-tests, Appendix 11), data for each method were analysed separately. A summary of lengths and weights for fish captured by minnow trap is provided in Appendix 9.

Length-Frequency

Length-frequency distributions of rainbow trout captured by electrofishing in April and September are shown in Figure 3-12 and 3-13. Rainbow trout classified as underyearlings ranged from 44 to 103 mm (mean = 69 mm ± 12 SD, n = 463) in April and from 25 to 74 mm (42 mm ± 7, n = 2,036) in September. Rainbow parr ranged from 105 to 236 mm (151 mm ± 28, n = 50) and from 85 to 194 mm (120 mm ± 21, n = 90), in April and September respectively. The Mixture Distribution models (R Development Core Team, 2008) provided a good fit for the younger age class of each sampling period (Appendix 10).

The distribution of parr-sized fish did not provide a clear distinction between age classes. The resulting chi-square for the April MIX model indicated a good fit with three age classes, however the plot suggested a lower than expected mean length for age 2+ rainbow trout, resulting in a large overlap between age 1+ and 2+ fish. The September model could not converge, due to the low sample size for parr. McCubbing *et al.* (2006) also reported considerable overlap in the lengths of rainbow trout parr collected in August 2005: 83 to 175 mm for age 1+, 142 to 249 mm for 2+ and 214 to 255 mm for 3+ fish. These results supported pooling older age classes under a single group (*i.e.*, "parr") for subsequent analyses (*i.e.*, abundance).

Figure 3-12. Length-frequency distribution of rainbow trout captured by electrofishing, April 2008

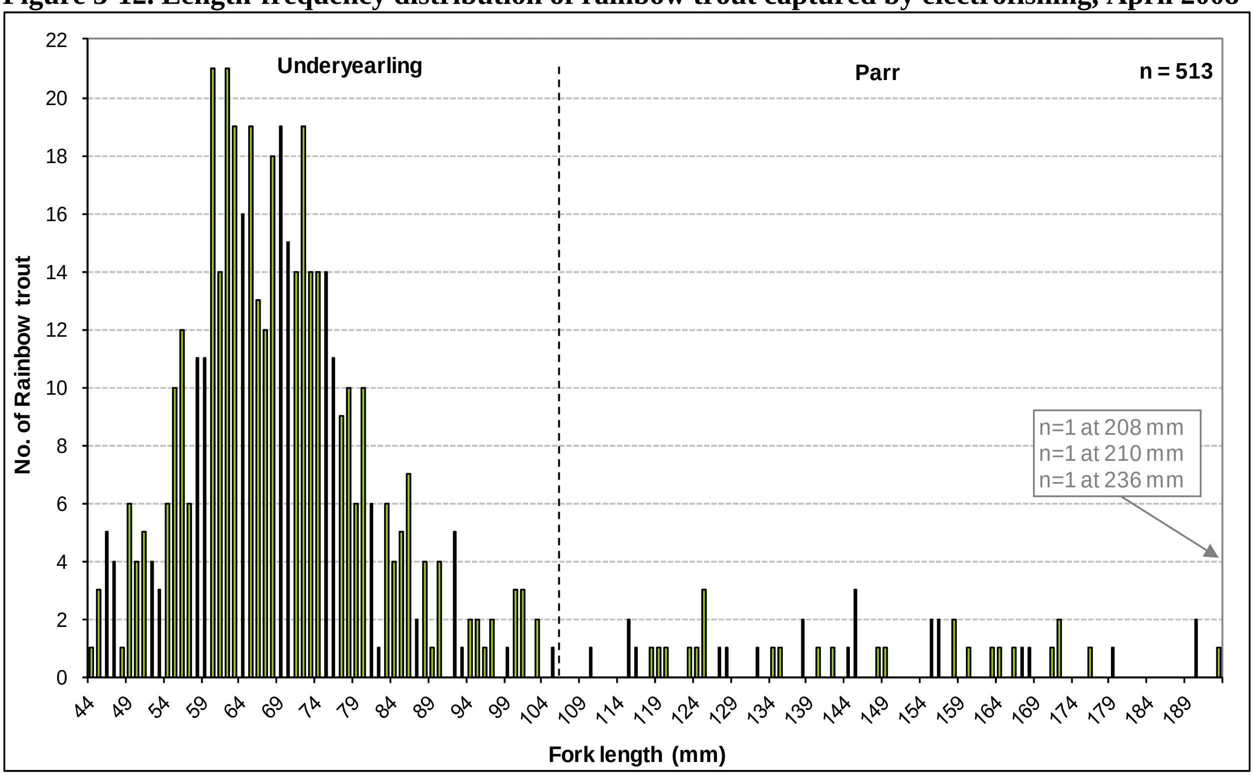
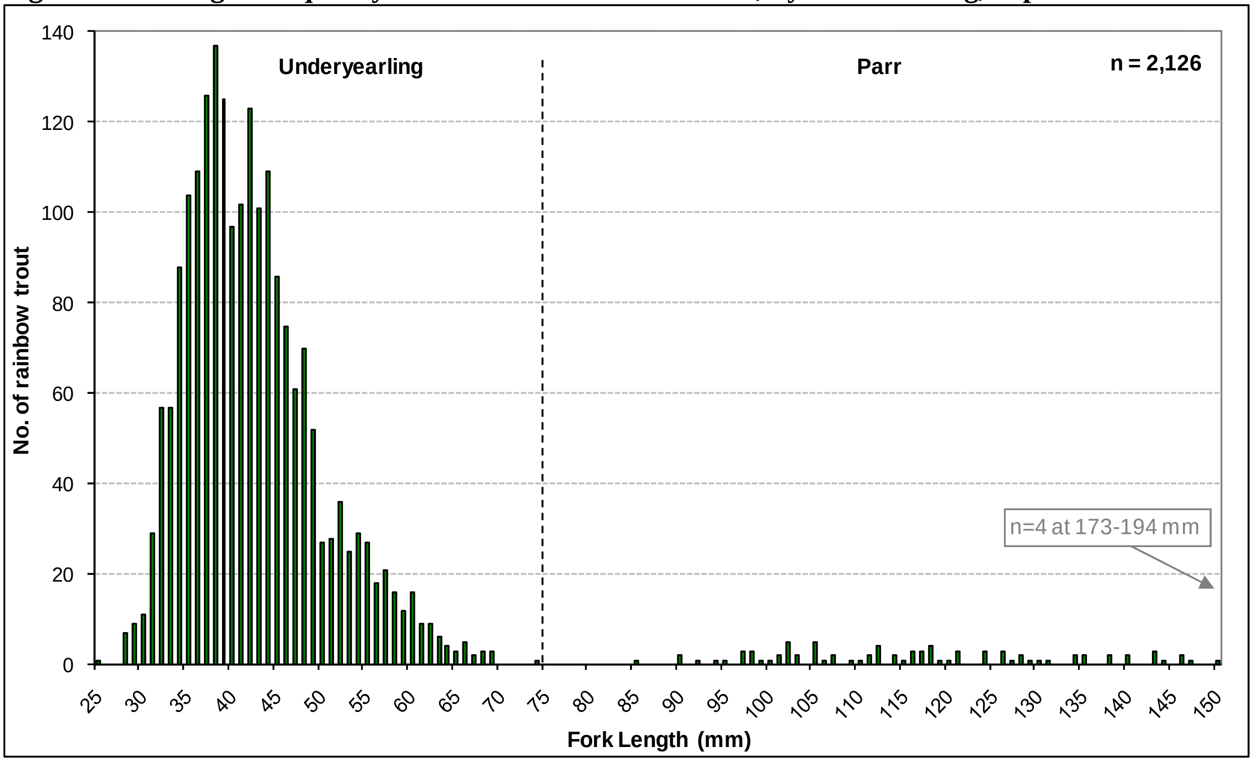


Figure 3-13. Length-frequency distribution of rainbow trout, by electrofishing, September 2008



Length/Weight Relationship

Over 90% of rainbow trout captured in April and 60% of those captured in September were measured for weight. Weights of rainbow trout captured in April ranged from 0.72 to 160.33 g (mean = 8.70 g ± 14.68 g SD; n=543) and in September, from 0.16 to 84.18 g (2.75 g ± 6.67 g; n=1,317). Trendlines derived from the length/weight relationships of rainbow trout captured in April 2007 and 2008 (Figure 3-14) were similar, as were trendlines for September 2007 and 2008 (Figure 3-15), suggesting comparable growth between years.

Figure 3-14. Length/weight relationship of rainbow trout, April 2008

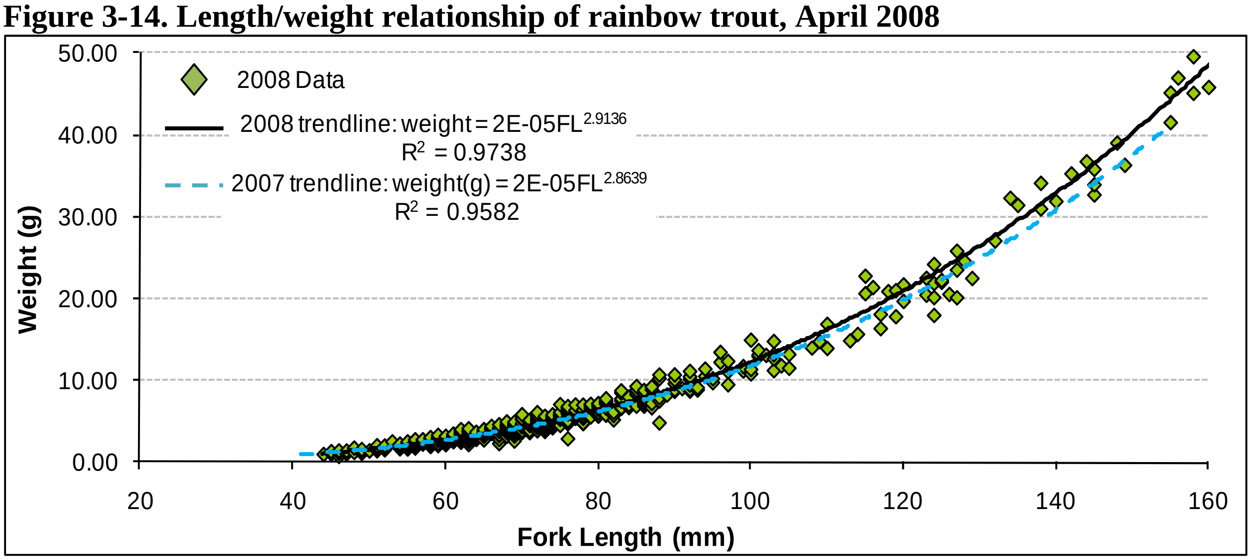
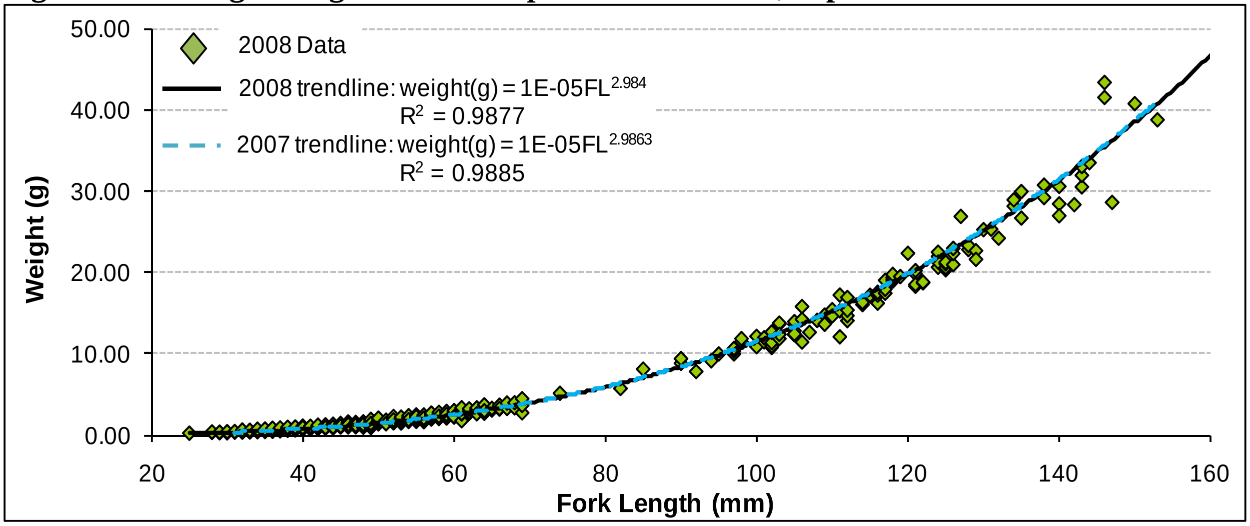


Figure 3-15. Length/weight relationship of rainbow trout, September 2008



Condition Factor

The condition factor (K) of individual rainbow trout captured in the Cheakamus River and tributaries varied from 0.7 to 1.70 (mean = 1.26 ± 0.16 SD) in April, and from 0.72 to 1.68 (1.17 ± 0.13) in September. Values below 0.7 and above 1.7 were excluded (n = 29) as they were considered "unlikely" and assumed to be the result of errors introduced while measuring weights (*e.g.*, windy conditions causing erroneous scale readings). Individual condition index for rainbow trout are presented in Appendix 9.

3.4 Estimated Densities

Densities [fish per unit of $100m^2$ (fpu); Section 2.5.3] were calculated for sculpin, lamprey and rainbow trout, as well as for coho salmon, for closed and open electrofishing sites. As only four prickly sculpins were captured by electrofishing in 2008, and since background studies did not distinguish between species, abundance analyses for sculpins included both species. For the reasons mentioned in Section 3.3.2, densities were calculated by species for lamprey captured during the September sampling only.

3.4.1 Sculpins – Closed Sites

Sculpins were captured at four closed electrofishing sites in April and at fourteen sites in September (Table 3-2). The highest measured densities were found at sites L1.95, R2.80 and R5.45: all three sites were characterized by riffle/run over large substrate, with mean water depths less than 0.20 m and mean velocities ranging from 0.18 to 0.36 m/s (Appendix 4). The highest densities were recorded within the first six river kilometres from the confluence with the Squamish River.

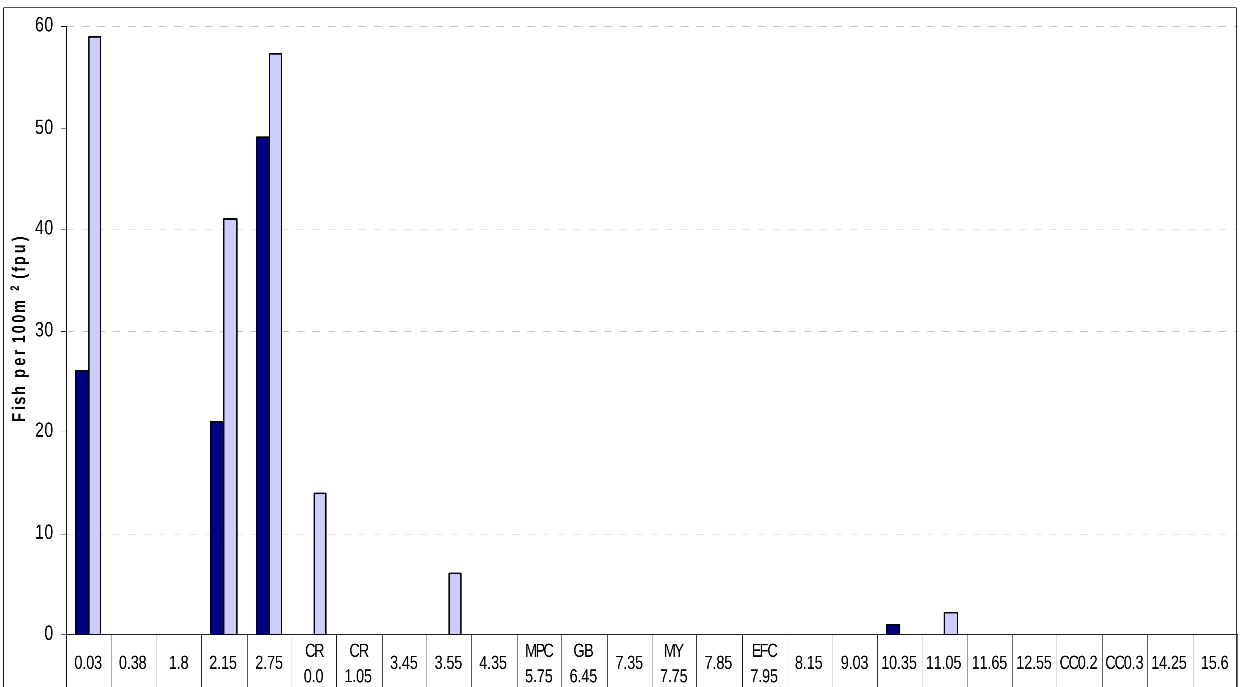
Table 3-2. Measured sculpin densities (fpu) in closed electrofishing sites, 2008

Site/ Period	L0.38	L1.95	R2.80	R4.30	R5.45	R5.97	R7.00	R7.10	L7.50	L7.90	L8.65	L9.05	R10.35	R11.30	L11.70	R12.60	R14.25	L15.05	L15.55
April		13	1	1	14		0	0		0		0		0	0	0			0
September	5	43	51	15	16	1		3	1	1	1	2	4	1	0	1	0	0	0

3.4.2 Sculpins – Open Sites

Sculpins were captured at three open electrofishing sites in April and six in September. Fish were captured along the river up to km 10.35 in April and km 11.05 in September, however all the other open sites where sculpin were captured were located within the first four kilometres of river measured from its confluence with the Squamish River (Figure 3-16). The highest densities were observed at site L0.03, characterised by riffle and cobble/ gravel substrate, with a mean depth of 0.13 m and a mean velocity of 0.23 m/s (Appendix 4) and site R2.75, characterized by a riffle and cobble/ boulder substrate, with mean water depth of 0.22 m and velocity of 0.34 m/s.

Figure 3-16. Measured sculpin densities (fpu) in open electrofishing sites, 2008



	0.03	0.38	1.8	2.15	2.75	CR 0.0	CR 1.05	3.45	3.55	4.35	MPC 5.75	GB 6.45	7.35	MY 7.75	7.85	EFC 7.95	8.15	9.03	10.35	11.05	11.65	12.55	CC0.2	CC0.3	14.25	15.6
Apr	26	0	0	21	49	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Sep	59		0	41	57	14			6		0	0		0						2			0	0		

Note: See Table 2-2 for sites' river margins.

3.4.3 Lamprey – Closed Sites

Lamprey were found at two sites in April and four in September (Table 3-3). However, among closed sites, only sites L0.38 and R5.97 were characterized as preferred habitat for lamprey ammocoetes (*i.e.*, fine substrate and low-to-no velocity). Both western brook/river and Pacific lamprey ammocoetes were found at the above-mentioned sites. A number of mainstem sites may have been suitable for overwintering and/or spawning adults (associated with gravel riffles, during the spring; McPhail, 2007), although none were captured.

Table 3-3. Measured lamprey densities (fpu) in closed electrofishing sites, 2008

Site/ Period	L0.38	L1.95	R2.80	R4.30	R5.45	R5.97	R7.00	R7.10	L7.50	L7.90	L8.65	L9.05	R10.35	R11.30	L11.70	R12.60	R14.25	L15.05	L15.55
April **L**		0	0	0	0	1	0	0		1		0		0	0	0			0
September **BL/RL**	0.4	0	0	0	0	10		0	0	0	0	0	2	0	0	0	0	0	0
September **PL**	3	0	0	0	0	13		0.9	0	0	0	0	0	0	0	0	0	0	0

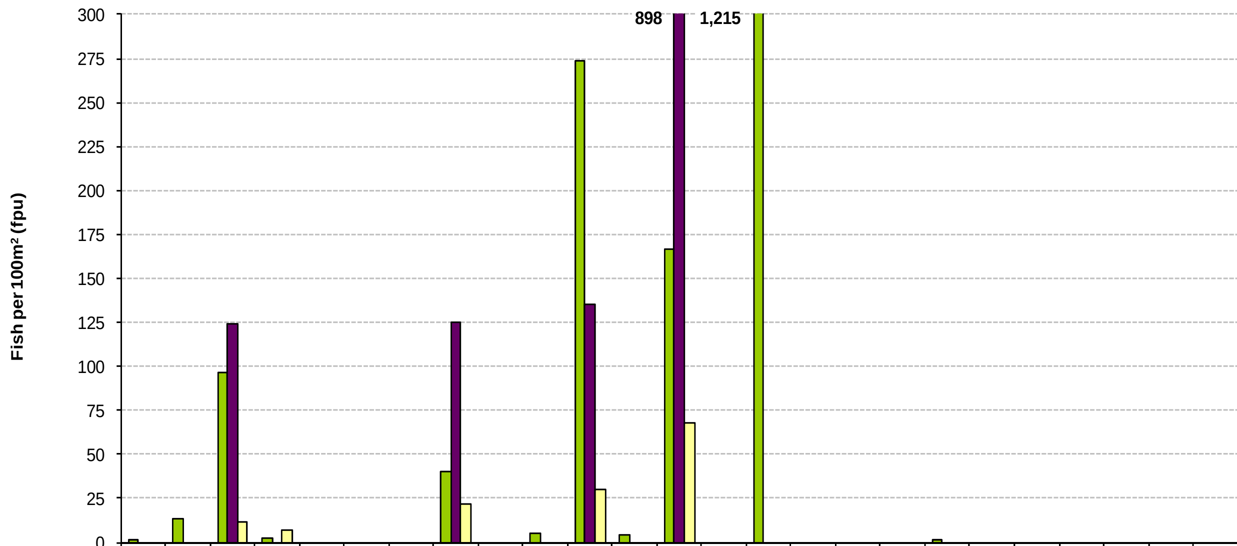
Note: Empty cells represent sites not sampled for each period. L: unidentified lamprey, BL/RL: western brook/river lamprey, PL: Pacific lamprey.

3.4.4 Lamprey – Open Sites

Lamprey were captured at 11 open sites in April, and measured densities were highest in the Emerald Forest Creek 7.95 site (also known as Farpoint intake) and in the Gorbuscha 6.45 side channel site (Figure 3-17). In September, the highest densities of western brook/river lamprey and Pacific lamprey were recorded in the Mykiss 7.75 back channel site. As reported by Stone *et al.* (2002), there is a positive correlation between larval lamprey abundance and percent fines, as well as a negative correlation with increasing velocities: sites where lamprey were captured in abundance were specifically chosen for their suitability for ammocoetes (Appendix 2).

The results from triple-pass electrofishing sampling for lamprey ammocoetes often differed from that for other fish: observed depletion patterns were not as regular as for other species. This is likely due to the burrowing nature of lamprey ammocoetes: it is suspected the sediment (in which ammocoetes live) may act as a "buffer", delaying the effect of electrofishing on the first pass. Additionally, in reaction to electrofishing, many ammocoetes display a brief flight response (*i.e.*, surface swim) and then burrow back into the substrate. Disturbance on from the first pass (suspected to bring the fish closer to the surface of the substrate) appears to make the ammocoetes more susceptible to capture on subsequent passes. Thus, catch numbers on the second pass are often similar to those on the first pass. The application of Maximum Likelihood Estimator models (relying on a declining catch over multiple passes) to derive abundance estimates was, therefore, conducted with caution. Where non-descending removal patterns resulted in large population estimates, the validity of these estimates was assessed based on the sites' known habitat characteristics and suitability for ammocoetes. In some cases (*e.g.*, site R3.55 in April and L1.8 in September) population estimates based on the MLE were rejected and densities were calculated based on catch numbers (resulting in conservative density estimates).

Figure 3-17. Measured lamprey densities in open electrofishing sites, 2008



	0.03	0.38	1.8	2.15	2.75	CR 0.0	3.45	3.55	4.35	MPC 5.75	GB 6.45	7.35	MY 7.75	7.85	EFC 7.95	8.15	9.03	10.35	11.05	11.65	CC 0.2	CC 0.3	12.55	14.25	15.6
Apr L	1	14	97	2	0	0	0	40	0	5	274	4	167	0	1215	0	0	0	1	0	0	0	0	0	0
Sep BL/RL	0		124	0	0	0		125		0	135		898						0		0	0			
Sep PL	0		12	7	0	0		22		0	30		68						0		0	0			

Note: Cells without a value correspond to sites not sampled during the associated period. Densities for sites R3.55 (April) and L1.8 (BL/RL, September) were calculated based on catch values (instead of population estimates generated by MLE), due to high standard errors caused by non-descending removal patterns. Unidentified lamprey captured in both closed and open site in September (n = 50) were excluded from density analyses.

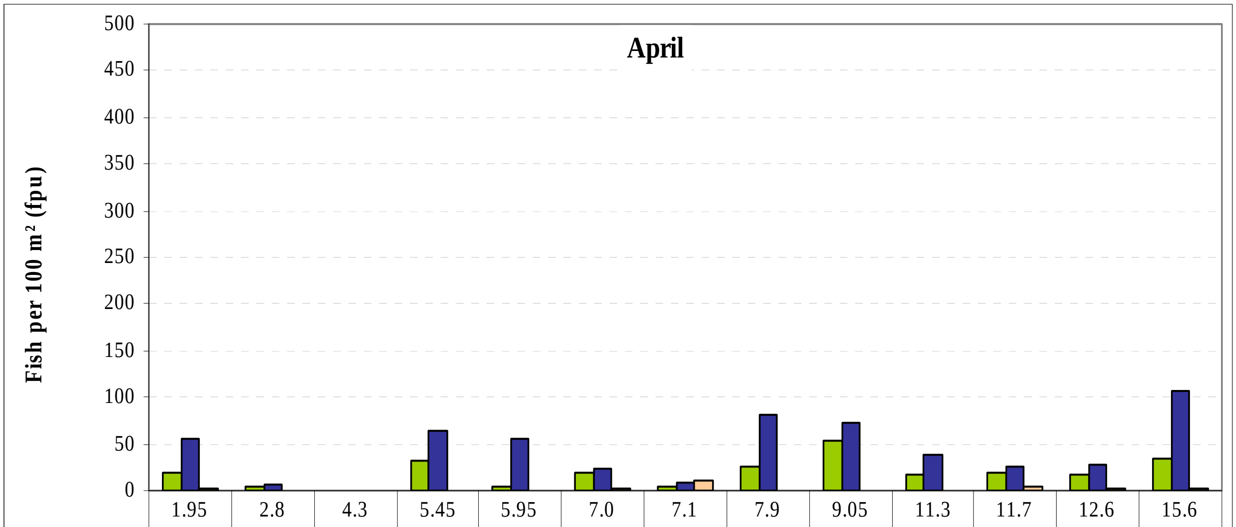
3.4.5 Rainbow Trout – Closed Sites

Variation in measured densities of rainbow underyearlings was observed among closed electrofishing sites, during both sampling periods (Figure 3-18). Mean measured densities of underyearlings were 19 fpu (± 15 SD, n = 13) in April and 122 fpu (± 72, n = 18) in September. The highest measured densities in April were recorded at sites L9.05, L15.6 and R5.45. In September, the highest measured densities of underyearlings were observed at sites L6.85, R10.35 and R5.45, and 12 of 18 sites yielded densities between 100 and 200 fpu.

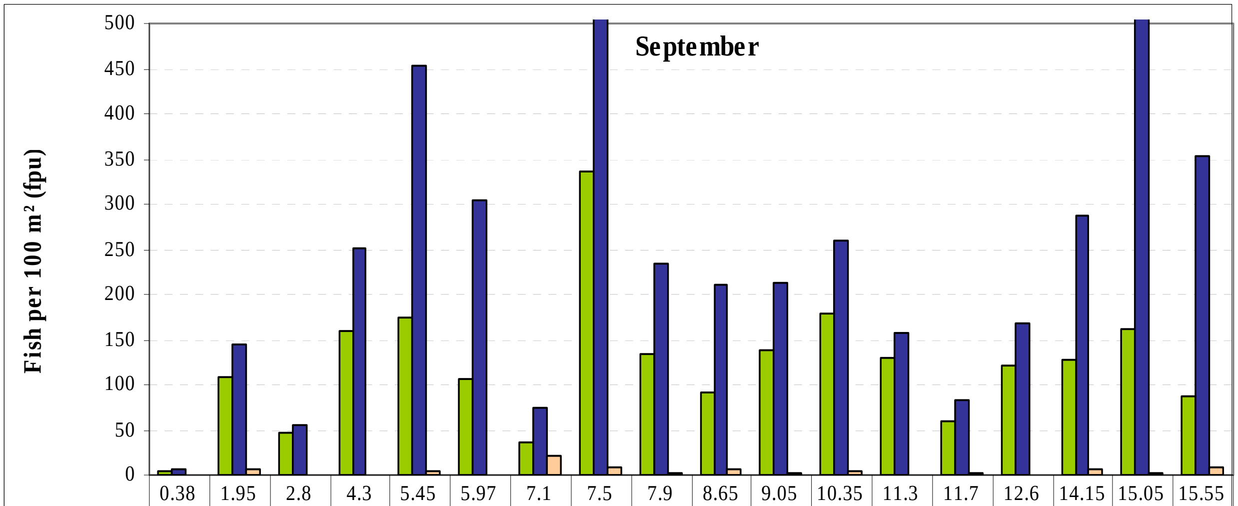
Measured densities of rainbow trout underyearlings were also adjusted for "probability of use" (Section 2.5.3). The percentage of "usable area" in closed electrofishing sites averaged 54% in April (ranging from 8% to 92%) and 57% in September (ranging from 25% to 86%; Appendix 2). Mean adjusted densities for rainbow underyearlings were 43 fpu (± 32) in April and 251 fpu (± 179) in September.

Rainbow trout parr were captured in six closed sites in April and in all but four sites in September (Figure 3-18). Parr measured densities were also variable, ranging from 0 to 11 fpu in April and from 0 to 21 fpu in September. The highest parr density was recorded in the R7.1 site, during both sampling periods. This site was located in a natural relic side channel which was excavated in 2007 and enhanced with woody debris and boulder structures, as well as large pool areas.

Figure 3-18. Rainbow trout measured and adjusted densities (fpu), closed electrofishing sites, 2008



	1.95	2.8	4.3	5.45	5.95	7.0	7.1	7.9	9.05	11.3	11.7	12.6	15.6
Measured UY	19	5	0	32	4	20	4	26	53	17	19	18	34
Adjusted UY	55	5	0	65	55	23	8	81	72	38	26	27	106
Measured parr	2	0	0	0	0	2	11	0	0	0	3	1	2



	0.38	1.95	2.8	4.3	5.45	5.97	7.1	7.5	7.9	8.65	9.05	10.35	11.3	11.7	12.6	14.15	15.05	15.55
Measured UY	5	108	47	160	175	106	36	336	133	91	139	178	129	60	121	128	162	88
Adjusted UY	7	145	55	252	453	303	75	716	234	212	214	260	158	83	169	287	544	352
Measured parr	1	7	0	0	4	0	21	9	2	7	2	4	0	2	1	7	2	9

Note: UY= underyearlings.

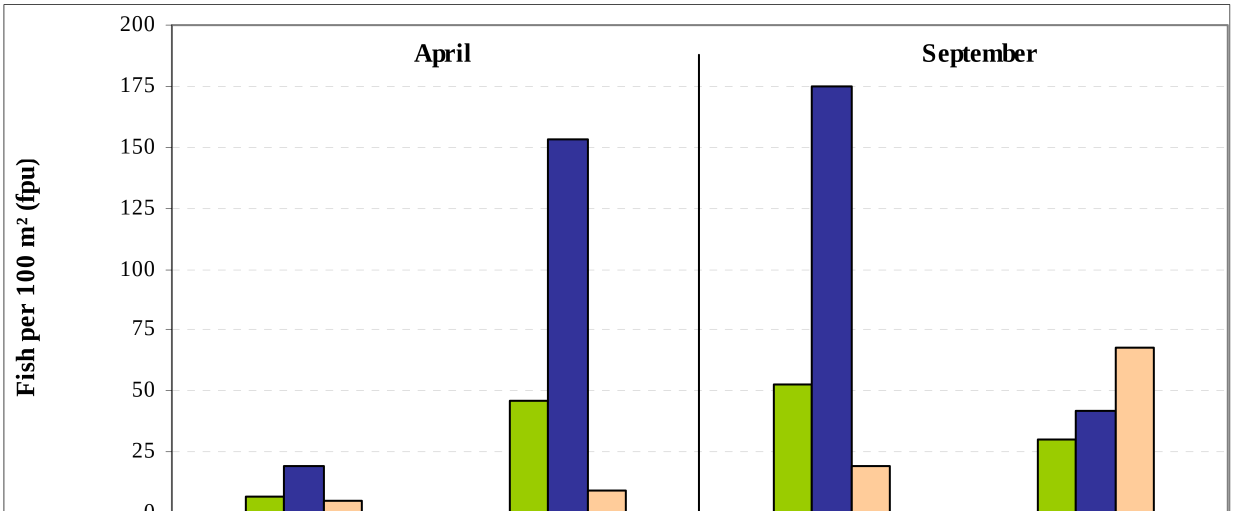
Brohm River

A total of 238 rainbow trout were captured by electrofishing (n = 2 closed sites), in Brohm River, in 2008. The fork length of rainbow trout captured in April varied between 43 and 200 mm (86 mm ± 38, n = 50), and between 32 and 102 mm (44 mm ± 11, n = 72) in September.

Measured densities of rainbow trout underyearlings captured in Brohm River in April were within the range of values recorded for closed sites in the Cheakamus River (Figure 3-19). In

September, measured fry densities in Brohm River were below the mean measured density for the Cheakamus River. Measured parr densities for both sampling periods were higher than those recorded for the Cheakamus River, with the exception of site R7.1, an enhanced side channel with large pools and abundant cover.

Figure 3-19. Rainbow trout measured and adjusted densities (fpu), Brohm River, 2008



	BR0.72	BR3.00	BR0.72	BR3.00
Measured UY	7	46	53	30
Adjusted UY	19	153	175	41
Measured parr	5	10	19	68

Note: UY= underyearlings.

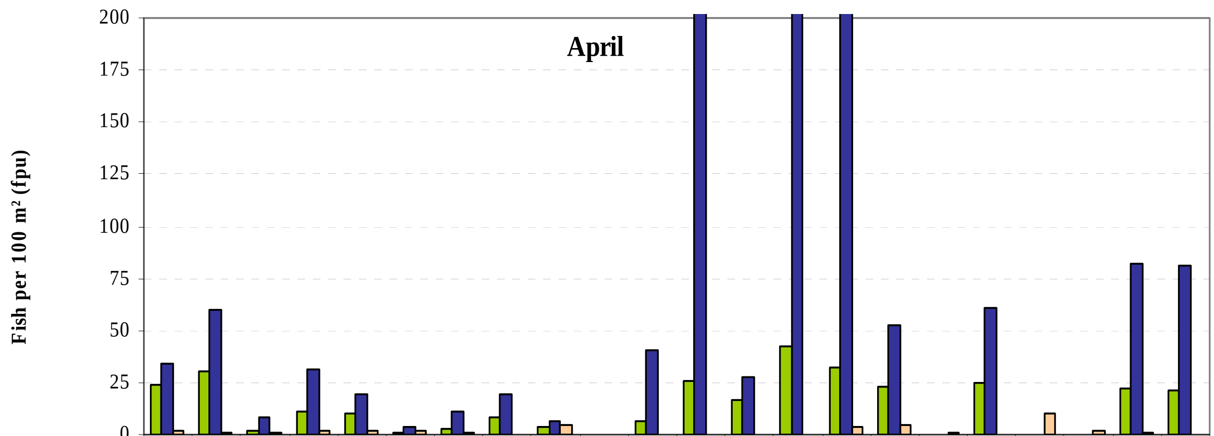
3.4.6 Rainbow Trout – Open Sites

As for closed sites, there was variation in rainbow trout densities among open electrofishing sites (Figure 3-20). However, underyearling abundance in April was on average greater in the upper reaches of the Cheakamus River (mean = 23 fpu ± 11 SD for sites within km 7.5 to 16, n = 9) compared to lower reaches (mean = 11 fpu ± 10 SD for sites within km 0 to 7.5, n = 9). Measured densities of rainbow trout underyearlings in open sites ranged from 0 to 42 fpu (mean = 14 fpu ± 13 SD, n = 22) in April and from 0 to 38 fpu (mean = 15 fpu ± 14, n = 9) in September. The highest measured density (42 fpu) was recorded in April at site L9.03.

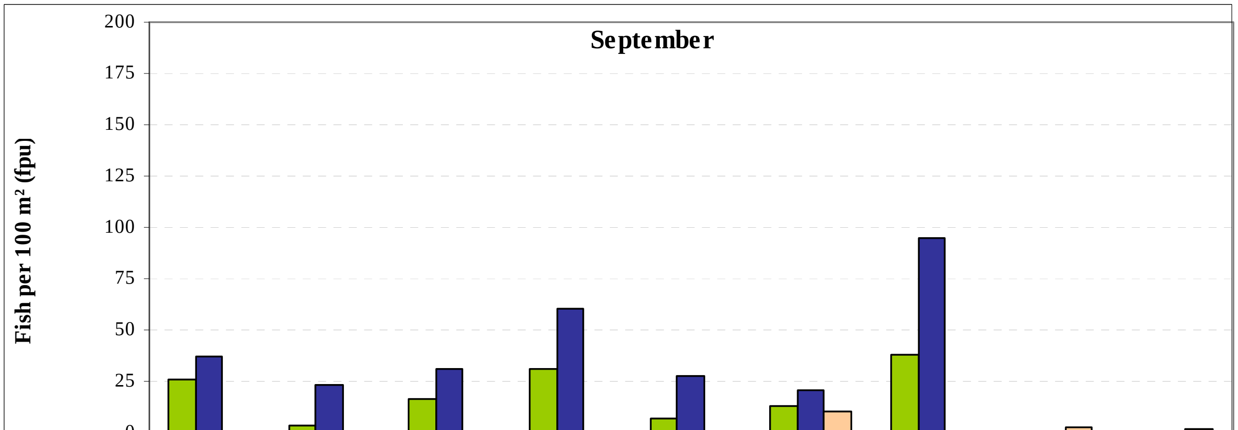
The percentage of "usable area" averaged 40% in April (ranging from 11% to 71%) and 46% in September (ranging from 13% to 70%; Appendix 2). Adjusted densities ranged from 0 to 252 fpu (mean = 57 fpu ± 78 SD) in April and from 0 to 95 fpu (mean = 33 fpu ± 30) in September (Figure 3-23). Adjusted underyearling densities at sites L7.85, L9.03 and R10.35 in April were large due to useable area values below 15% (Appendix 2).

Rainbow trout parr were captured in 14 of 22 open electrofishing sites in April and in four (4) of nine (9) sites in September (Figure 3-20). Parr measured densities ranged from 0 to 10 fpu for both sampling periods, with the highest densities recorded in Culliton Creek L0.2 (in April) and Cheekye River L0.00 (in September).

Figure 3-20. Rainbow trout measured and adjusted densities (fpu), open electrofishing sites, 2008



	0.032	0.38	1.80	2.15	2.75	CR0.00	CR1.05	3.45	3.55	4.35	7.35	7.85	8.15	9.03	10.35	11.05	11.65	12.55	CC0.2	CC0.3	14.25	15.6
Measured UY	24	30	2	11	10	1	3	8	4	0	6	26	17	42	32	23	0	25	0	0	22	21
Adjusted UY	34	60	8	31	19	4	11	20	7	0	40	236	28	252	221	53	0	61	0	0	82	81
Measured parr	2	1	1	2	2	2	1	0	5	0	0	0	0	0	4	5	1	0	10	2	1	0



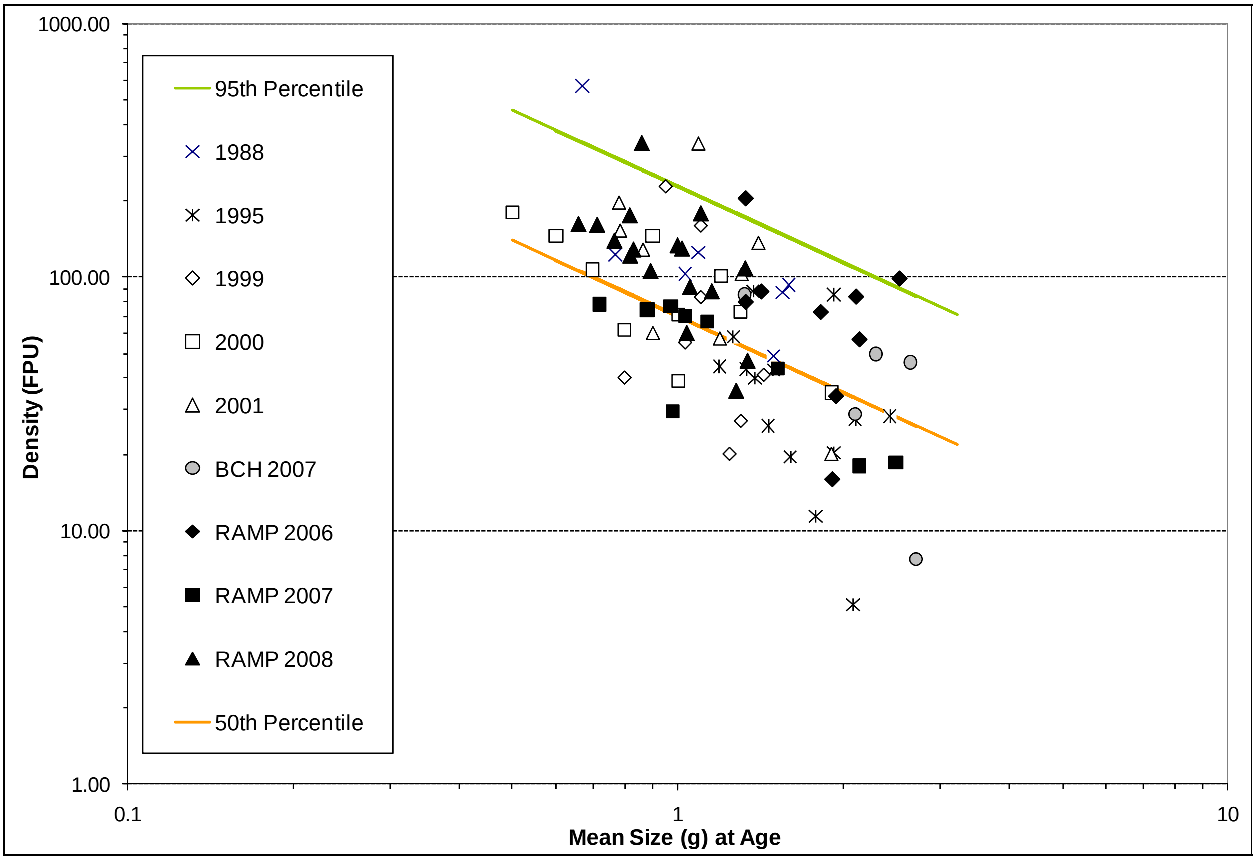
	0.032	1.8	2.15	2.75	3.55	CR 0.00	11.05	CC0.2	CC0.3
Measured UY	26	3	16	31	7	13	38	0	0
Adjusted UY	37	23	31	61	28	21	95	0	0
Measured parr	0	0	0	0	0	10	1	3	2

Note: UY= underyearlings. Moody's Pond 5.75, Gorbuscha 6.45, Mykiss 7.71(back channel) and Emerald Forest Creek 7.95 were excluded as these sites did not target rainbow trout, but other resident species such as lamprey, stickleback or sculpin.

3.4.7 Rainbow Trout Biomass

For comparative purposes, biomass was only calculated from site-specific mean size-at-age and density measurements at closed electrofishing sites (Triton, 2009a). In 2008, the biomass of rainbow trout fry ranged from 45.8 to 298.0 g/100 m^2 (geometric mean of 109.51 g/100 m^2; 0.5 coefficient of variation; Figure 3-21). Biomass values for 2008 were greater than those recorded in 2007 and within the range of natural variation reported in past studies (Ptolemy, 2008 written comm.).

Figure 3-21. Scatter plot of measured densities by mean size at age for rainbow trout fry, Cheakamus River (1988, 1995, 1999-2001, 2006-2008)



3.4.8 Other Target Species

Electrofishing catch data for each species per site are available in Appendix 7 and individual lengths and weights, in Appendix 9.

The largest measured density of threespine stickleback was recorded in September, at Moody's Pond 5.75 (237 fpu, n = 61). This site (part of a made-made complex of side channels) was sampled because it provides preferred rearing habitat and suitable nursery conditions for this species, as evidenced by 77% of the fish captured being less than 30 mm in total length (Photo 7) (average adult size 35 to 60 mm TL: McPhail, 2007). Adult sticklebacks were also captured by electrofishing at the following sites: MPC 5.75 (n = 25), L15.55 (n = 1) and L15.6 (n = 2) in April and R7.1 (n = 1) in September. Numerous adults were also captured by minnow trap (Section 3.5).

Bull trout and cutthroat trout were also captured by electrofishing. Bull trout were observed in three mainstem sites (one fish at L7.85, L9.03, and L11.7) and in both Culliton Creek sites (CC0.20, n = 5 and CC0.30, n = 3) in April. In September, bull trout were captured in two mainstem sites (L11.7, n = 1 and L12.6 n = 2), in the two enhanced side channels (sites R7.1 and L8.65, n = 1 in each), as well as in both Culliton Creek sites (n = 8 in each site). Only one cutthroat trout was captured, in Brohm River (BR0.72) in September 2008.

3.4.9 Incidental Catch

Coho, chinook, chum and pink salmon (fry and parr) were part of the incidental catch, and therefore not utilised in this program to assess river recovery (Section 2.1). Given these species accounted for 44% of the total electrofishing catch in April and 17% in September, their distribution and densities are considered as additional indicators of habitat health. A total of 21 pink salmon were also captured in April 2008 (2007 was an "off" brood years for pink salmon on the Cheakamus River). Individual lengths and weights are available in Appendix 9 and a summary of densities by species for each sampling period and site is presented in Appendix 12.

3.5 Minnow Trapping – Catch per trap (CPT)

Minnow traps captured approximately 30% of the total catch in 2008, however, target species accounted for only 2.6% of the catch (Figure 3-1). Each survey area (n = 5) was sampled with 50 traps, in April and September. Individual catch data and site characteristics for each minnow trapping site are provided in Appendix 6.

Coho salmon represented 91% of the total minnow trap catch, followed by rainbow trout, representing 5.6% (Table 3-4) and both species were captured in all five survey areas. Sculpins (seven coastrange and one prickly sculpin) were only captured in the km 1.75 to 2.25 survey area (correlating to the area of greatest abundance for these fish). Threespine sticklebacks were captured in all minnow trap survey areas: the highest CPT values (0.46 and 0.32) were recorded in Emerald Forest Creek in September and Farpoint Channel in April, respectively. All but six threespine sticklebacks captured by minnow traps were adults (50 to 73 mm; mean = 57 and 61 mm in April and September respectively; n = 61), which may be a result of the minnow trap mesh size (*i.e.*, 6 mm square mesh). The minnow trap catch also included 3 bull trout in September.

Table 3-4. Minnow trapping catch per trap (CPT), Cheakamus River, 2008

Survey area	Period	CAL	CAS	BT	TSB	RB UY	RB parr	CO
Km 1.75 to 2.25	*April*	0.10	0.02	0.00	0.02	0.24	0.02	0.06
	September	0.04	0.00	0.00	0.00	0.16	0.02	1.68
Km 7.65 to 8.25	*April*	0.00	0.00	0.00	0.32	0.16	0.20	1.44
	September	0.00	0.00	0.00	0.30	0.30	0.06	3.60
Km 11.45 to 11.75	*April*	0.00	0.00	0.00	0.00	0.30	0.12	0.74
	September	0.00	0.00	0.06	0.04	0.24	0.14	0.94
Km 14.95 to 15.45	*April*	0.00	0.00	0.00	0.00	0.64	0.02	0.50
	September	0.00	0.00	0.00	0.02	0.48	0.14	3.38
Emerald Forest Creek	*April*	0.00	0.00	0.00	0.20	0.02	0.00	3.56
	September	0.00	0.00	0.00	0.46	0.00	0.02	5.82

CAL: coastrange sculpin, CAS: prickly sculpin, BT: bull trout, TSB: threespine stickleback, RB: rainbow trout (UY: underyearling), CO: coho

4.0 Discussion

The Resident Fish Abundance Monitoring Program (RAMP) was established to describe the post-spill abundance of resident juvenile and adult fish in the Cheakamus River in order to measure recovery. Recovery is being assessed by comparing fish distribution, densities and condition in the section of the river affected by the spill, to available pre-spill data, as well as to results from previous survey years. Fish populations in the lower reaches of the Cheakamus River (below the barrier located between reach 9 and 10; Figure 1-2) have been studied for many years and baseline data does exist for rainbow trout, as well as for other resident species such as bull trout, sculpin and lamprey, however data concerning these species were often incidental and therefore limited (McCubbing and Melville, 2000; Sneep, 2001; van Dishoeck, 2000, 2002, van Dishoeck and Horne, 2002; Melville, 2005; Melville and McCubbing, 2005; and McCubbing *et al.*, 2006). Where no baseline information is available, data collected in 2008 was compared to RAMP 2006 and 07 survey results only. The 2008 surveys represent the program's third year.

4.1 Electrofishing Catch - 2006 to 2008

As in 2007, sampling in 2008 was conducted in both April and September. The number of electrofishing sites surveyed was reduced in April 08 from September 07, and further reduced in September 08 to avoid known spawning areas, and increase sampling efficiency by focusing on preferred habitat of target species. Most sites sampled in 2008 were in the same location as - or in close proximity to - those also surveyed the previous year. A greater number of electrofishing sites were closed in September 08 than during previous surveys (n = 20 in September 08, compared to approximately 15 in past surveys). In 2008, target species represented a greater percentage (52%) of the total electrofishing catch than in 2007 (32%). Generally, catch values for target species increased between survey years with a few exceptions. Table 4-1 provides an overview of the electrofishing catch for target species over each survey year. Inter-year comparisons for each species are further analyzed in the following sections.

Table 4-1. Target species electrofishing catch, Cheakamus River and tributaries, 2006-08

Sampling Period/ Year	CC	L	TSB	BT	RB UY	RB PARR	*Total Catch*
APR 2007 EF (n = 34)	33	331	1	7	432	32	***829***
APR 2008 EF (n = 39)	107	739	27	11	465	50	***1,399***
SEP 2006 EF (n = 27)	95	690	0	2	1,977	5	***2,767***
SEP 2007 EF (n = 41)	181	1,019	76	22	923	75	***2,274***
SEP 2008 EF (n = 30)	316	682	62	20	2,036	90	***3,206***

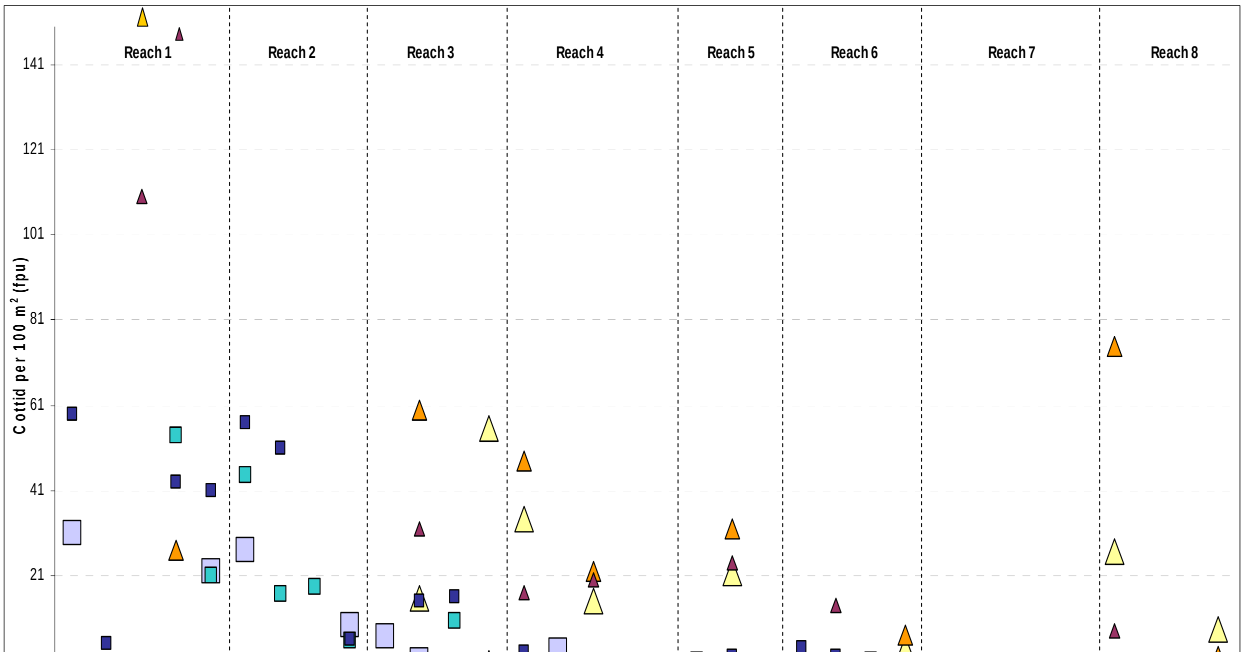
Note: UY= underyearlings. Catch values exclude Brohm River data.

4.2 Sculpins

Based on visual identification in the field, fewer prickly sculpins were captured in 2008 (n = 5) than in 2007 (n = 13) and all were captured within the first two reaches of the river. Although the ratio of coastrange to prickly sculpins in the Cheakamus River previous to the spill is unknown, of the 499 sculpins sampled for length and weight during the 2005 post-spill assessment, McCubbing *et al.*, (2006) visually identified 207 fish as coastrange sculpin and 15 as prickly sculpin, representing a 14:1 ratio. Prickly sculpins were recovered only from sites close to or at the confluence with the Squamish River, while coastrange sculpins were recovered from the confluence up to the Brackendale gauge pool, near river km 6 (McCubbing *et al.*, 2006).

Historically, sculpins have been captured on the Cheakamus River as far upstream as river kilometre 15.35 (van Dishoeck 2000, 2002; van Dishoeck and Horne, 2002), as well as in the non-anadromous reaches (Clark, 1989 unpublished). Although data recorded by van Dishoeck (2000, and 2002) and van Dishoeck and Horne (2002) regarding sculpins was mainly incidental (and fish were not identified to species), the authors observed the highest measured densities (up to 200 fpu) in the river's lower reaches (Figure 4-1), with considerable inter-annual variation over a period of three years (*i.e.*, 1999 to 2001). In 2008, the upstream distribution - and associated abundance - of sculpins continued to increase from the first two years of the Program: the upper-most boundary where sculpins were captured was at km 12.6 in 2008, compared to km 11.3 in 2007, and km 7.5 in 2006 (Figure 4-1).

Figure 4-1. Sculpin measured densities and distribution, Cheakamus River all electrofishing sites, fall 1999-2001 and 2006-2008



	0.03	0.38	1.65	1.95	2.15	2.75	2.8	3.45	3.55	4.15	4.30	5.45	5.97	7.05	7.5	7.95	8.65	8.9	9.03	9.05	9.30	10.35	11.1	11.3	11.45	11.7	11.9	12.5	12.55	12.6	14.1	14.25	15.05	15.35
1999											16		56	34		15				22					4						27			8
2000			200	27							60		1	48		22				32					7						75			2
2001			110	154							32			17		20				24			14								8			1
2006	31				22	27			9	7	1		0		3					0	0								0	0		0	0	
2007				54	21	45	17	18	6		0	10	0	0		0		0	1	0			0	1		0	0	0	0	0	0			
2008	59	5		43	41	57	51		6		15	16	1	3	1	1	1			2		4	2	1		0				1		0	0	

Note: Year 1999-2001 = van Dishoeck (2000, 2002) and van Dishoeck and Horne (2002); years 2006-08 = RAMP, September data only. Empty cells represent sites not sampled for each year. Four additional sites, sampled between 2006 and 2008 (km 15.45 to 15.8) are not shown on this figure (no sculpins captured).

Measured densities of sculpin in the fall of 2008 were greater than those observed in 2006 and 2007 (for all but two sites; Figure 4-1). Densities recorded during the 2006 to 2008 surveys were greater in the lower river, which is consistent with results from past studies. In 2008, densities in the lower reaches (1 to 3) of the river were approaching the range of those reported between 1999 and 2001 for the same area, while densities in the upper reaches (4 to 8) remained below historical values. Factors other than the spill, such as the 2003 flood and other events may have also had a negative impact (the extent of which remains unknown) on sculpin populations in the Cheakamus River and contributed to lower densities.

The literature suggests sculpins migrate upstream throughout their life: Brown *et al*. (1995), for example, found a significant correlation between mean (and minimum) lengths of coastrange sculpins with distance from the ocean. A similar trend can be found on the Cheakamus River, in the data reported by van Dishoeck (2000, and 2002) and van Dishoeck and Horne (2002), as well as in the RAMP 2007 and 2008 surveys. In September 2008, the minimum length of coastrange sculpins increased in association with distance from the confluence: 52 mm, 47 mm, 65 mm, 85 mm, 114 mm, 87 mm and 119 mm in reaches 1 to 7, respectively.

There is also evidence mature sculpins undertake a pre-spawning downstream migration each year (Ringstad and Narver, 1973; McPhail, 2007), however the extent of this migration is not well understood. Although sculpin movements in the Cheakamus River have not been studied in the past, data from the BC Hydro rotary screw traps located near river km 5.5 suggest an increase in downstream movement of sculpins during the months of April and May (Melville, 2008 verbal comm.). In 2008, fewer sculpins were captured and at fewer sites in the Cheakamus River during April surveys than in September (for similar sampling sites and effort). Furthermore, the upstream distribution of sculpins in April was reduced compared to that in September, and a similar pattern was identified in 2007. Breeding males and females were also captured in the river’s lower reaches in April. Males displayed a dark body and an orange trim along the edge of the first dorsal fin (Photo 3; McPhail, 2007). A number of fish with an enlarged abdomen (assumed to be gravid females) were observed and two specimens had visible eggs (Photo 4). This information supports the scenario of a spring downstream migration for at least a portion of the population (either to the lower river or possibly to the Squamish River and estuary).

Although it is not known where Cheakamus River sculpins spawn, the literature suggests a portion of the population (prickly, and possibly coastrange) could be spawning in brackish water (*i.e.*, in the Squamish estuary). Larval sculpins have also been reported to drift downstream at night, late spring to early summer (Ringstad and Narver, 1973; Brown *et al.*, 1995; White and Harvey, 2003). Furthermore, Ringstad and Narver (1973) have suggested a number of young-of-year (both coastrange and prickly sculpin) may spend a little over a year in the estuary before migrating upstream (in late August) into habitat where adults are found. It is not known if a similar life history is shared by the Cheakamus River sculpin populations; however, it could explain why no larva or young-of-year have been observed in the river. The smallest sculpin recorded during the 2008 surveys - and smallest to-date in the anadromous reaches - was 47 mm in total length, indicating the majority of fish sampled were at least age 2 and older, regardless of the species (Section 3.3.1). Smaller coastrange sculpins (26 and 31 mm) were captured, in October 2008, near km 22 in the non-anadromous portion of the Cheakamus River (Triton, 2009): similarly, no sculpin smaller than 47 mm was recorded during post-spill assessment in 2005 (McCubbing *et al.*, 2006).

These results support the hypothesis of re-colonization from downstream (as opposed to recruitment from local spawning or larval drift from reaches above the impacted area). Although the rate of upstream migration is unknown, a marking program initiated in September 2007 may provide some answers in future years. Re-capture of marked fish could provide information regarding sculpin movements (*i.e.*, evidence of upstream/ downstream migration and rate of re-colonization) within the river.

The presence of the two species and age/ size classes, as well as the abundance of sculpins observed in the lower reaches of the Cheakamus River, along with the continued expansion of their distribution in the upper reaches in 2008 is encouraging. While it may not be possible to determine with certainty when or if populations reach pre-spill abundance, results from the 2006 to 2008 surveys suggest recovery appears to be progressing.

4.3 Lamprey

A total of 1,273 lamprey were captured in the Cheakamus River during the 2008 surveys: all were ammocoetes, except for three, which were newly transformed adults (macropthalmia). Field identification of lamprey ammocoetes - which can be challenging as all three species known to inhabit the system have very similar morphology at this stage - was attempted for all fish captured in September, based on the examination of pigmentation on the caudal ridge: clear for Pacific lamprey; dark for western brook/river lamprey (Beamish, 2008 verbal comm.). A total of 519 fish were identified as western brook/river lamprey and 113 as Pacific lamprey: both species were found in greater abundance where they were sympatric (Figure 3-18).

Pre-spill information on lamprey in the Cheakamus River is incidental, from studies focusing on steelhead/rainbow trout. Van Dishoeck (2000, 2002) and van Dishoeck and Horne (2002) reported a total of nine lamprey (not identified to the species level; mean lengths 152 to 174 mm) captured from mainstem sites, over three sampling years. In the days following the spill, 162 dead lamprey were collected: nine of the larger specimens were identified to species (all Pacific lamprey), and measured lamprey (n = 144) ranged from 38 to 337 mm (mean = 129.9 mm ± 52.9 SD; McCubbing *et al.*, 2006). Total lamprey mortalities were estimated to be in excess of 5,000 individuals, based on the number of mortalities recovered and fish observed but not collected, and results from post-spill sampling (*i.e.*, no lamprey were captured in the surveys). However, a low confidence was attributed by the authors to the impact estimate, due to uncertainties regarding the efficiency of methods used for the lamprey survivorship assessment (McCubbing *et al.*, 2006).

In 2008, as in the previous two years of the RAMP, the highest lamprey densities were found in side channel sites, selected for their low velocity and sandy/silty substrate (*i.e.*, preferred lamprey habitat). These results are consistent with Torgersen and Close (2004) who suggested lamprey prefer velocities ranging between 0.05 and 0.15 m/sec, providing a steady influx of food while promoting the deposition of soft sediments needed for burrowing, as well as with Beamish and Levings (1991) who found Pacific lamprey ammocoetes in the fine sediments of backwater areas of streams. Thus, the absence of lamprey in the sampling conducted in 2005 for the impact assessment (McCubbing *et al.*, 2006) may have been a factor of site selection, and not of electrofishing sampling efficiency for these fish. Table 4-2 shows inter-annual variations in lamprey densities in four sites along the Cheakamus River, from 2006 to 2008. Although pre-spill densities for these sites are unknown (and no literature was identified suggesting expected lamprey densities), it appears these population are healthy, as ammocoetes (of multiple age classes) have been repeatedly captured in abundance.

Table 4-2. Measured lamprey densities (fpu) in four targeted sites, Cheakamus River, September 2006-08

Site	2006 (all species)	2007 (all species)	2008	
			western brook/river	Pacific
L1.8 side channel	n/a	6	124*	20
R3.55 mainstem	128	251	125	22
Gorbuscha 6.45 side channel	237	142	135	30
Mykiss 7.75 back channel	288	347*	898	68
Mean	**218**	**133**	**321**	**35**
CV (%)	*38*	*92*	*120*	*64*

* Density calculated based on catch due to a high standard error for the population estimate generated by the MLE (caused by non-descending removal pattern).

Total length for ammocoetes varied between 16 and 183 mm, indicating the presence of multiple age classes in the Cheakamus River, from young-of-year to newly-transformed juveniles (age 5 western brook/river lamprey, or age 6 or 7 Pacific lamprey; McPhail, 2007). Pacific lamprey were larger on average than western brook/river ammocoetes (Figure 3-8 and 3-12). Discerning age classes based on the length-frequency distribution is complicated by the difficulties in distinguishing between the three species of lamprey present in the Cheakamus River and variations in reproductive timing and growth rates even within species. The literature indicates considerable variation in the size and age of ammocoetes, making the length-frequency method unreliable for aging older ammocoetes (McPhail, 2007).

The repeated capture of multiple species and age/size classes, as well as the abundance of lamprey observed in the Cheakamus River in 2008 is encouraging. The continued presence of YoY and juveniles also suggests breeding has taken place in the Cheakamus River since the spill (Section 3.3.2). While it may not be possible to determine with certainty when or if populations reach pre-spill abundance, results from the 2006 to 2008 surveys suggest the impacts on lamprey were not as severe as estimated by post-spill assessments (McCubbing *et a*l., 2006) and recovery appears to be well underway.

4.4 Rainbow trout

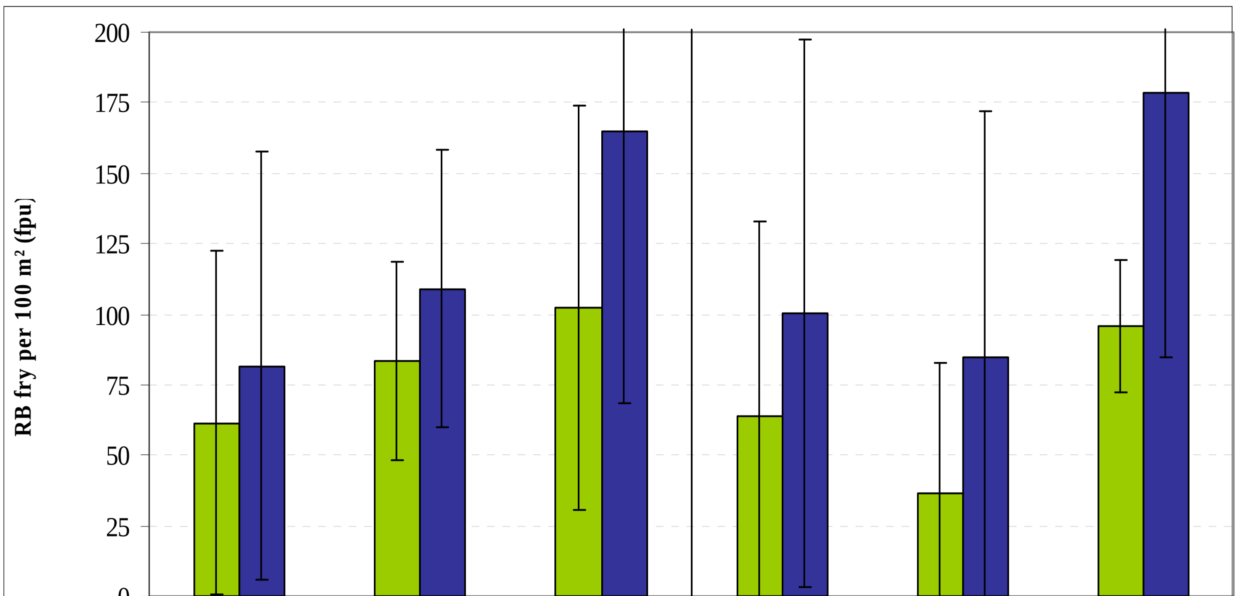
A total of 2,587 rainbow trout underyearlings and 235 parr were captured in the Cheakamus River and tributaries during the 2008 surveys (excluding Brohm River). Rainbow trout were recorded at every electrofishing site targeting this species (with the exception of site R4.3, in

April only), and in all five minnow trap sampling areas. Multiple age classes (young-of-year to parr estimated to be age 3+) were observed and the mean condition of captured rainbow was indicative of fish in good health.

Rainbow fry

The mean measured density for rainbow fry captured in September 2008, in mainstem, closed electrofishing sites was the highest recorded value for the RAMP to-date, despite a lower steelhead escapement estimate than in the previous year (Figure 4-2). The 2008 fall fry density was also within the range reported for the 1999 to 2001 surveys (van Dishoeck, 2000, 2002 and van Dishoeck and Horne, 2002), and the adjusted density surpassed all past values.

Figure 4-2. Geometric means and 95% confidence intervals for measured and adjusted rainbow trout densities, Cheakamus R. mainstem, closed electrofishing sites, fall 1999-2001 and 2006- 08



	1999 (N=8)	2000 (N=10)	2001 (N=9)	RAMP 2006 (n=6)	RAMP 2007 (n=8)	RAMP 2008 (n=18)
Measured fry	61.46	83.62	102.27	63.66	36.69	95.57
Adjusted fry	81.62	109.09	164.72	100.31	84.52	178.79
Escapement*	191	90	305	255	585	239

Note: Sampling year 1999, 2000 from van Dishoeck (2000, 2002); 2001 from van Dishoeck and Horne (2002).
* Escapement estimates from Korman (2008).

Rainbow parr

In 2008, parr-sized rainbow trout up to 236 mm fork length in April and 194 mm in September were captured, suggesting multiple age groups were present in the Cheakamus River: van Dishoeck and Horne (2002) identified the upper limit of age 1+ parr at 115 mm (September), however, results from scale reading (McCubbing et al., 2006; August surveys) indicated large overlaps between age 1+, 2+ and 3+ rainbow trout. Rainbow parr were captured at 14 (out of 18) mainstem, closed electrofishing sites, and in greater numbers than in 2006 and 2007. Mean measured density in the fall of 2008 was also higher than those reported for 1999 to 2001 and for the first two years of the RAMP (Table 4-3).

Table 4-3. Mean measured densities for rainbow parr captured in closed mainstem electrofishing sites, Cheakamus River, fall 199-2001 and 2006-2008

Sampling year	1999 (n=8)	2000 (n=10)	2001 (n=9)	RAMP 2006 (n=6)	RAMP 2007 (n=8)	RAMP 2008 (n=18)
Mean (fpu)	**2.75**	**3.70**	**0.18**	**0.13**	**2.39**	**4.36**
CV (%)	*207.51*	*129.96*	*300.00*	*244.95*	*94.06*	*122.40*

Note: Sampling year 1999, 2000 from van Dishoeck (2000, 2002); 2001 from van Dishoeck and Horne (2002).

Although the effects of the spill on rainbow trout in the river at the time of the incident were considerable (estimated losses greater than 90%; McCubbing *et al.,* 2006), rainbow trout were captured in all areas of the river historically occupied by this species, in all three years of the monitoring Program. Recovery (*i.e.,* juvenile recruitment) is suspected to be, in part, a result of the anadromous (*i.e.,* steelhead) component of the rainbow trout population since steelhead adults contributing to these brood years were not affected by the spill. Historical measurements of juvenile rainbow trout abundance in the Cheakamus River included progeny from both anadromous and non-anadromous individuals. After the spill, the resident population would have suffered a reduction in spawners in 2006, while adult steelhead in the ocean at the time of the spill would have returned to spawn in the river during the spring of 2006, providing recruitment of fry in 2006 fry, and thus 2007 parr. Since the life histories of anadromous and resident individuals may overlap (*e.g.,* some progeny of adult steelhead may "residualize" and some progeny of resident fish may become anadromous), each population may contribute to the recovery of the other.

Brohm River

The assessment of fish densities in Brohm River was not a specific objective of the RAMP. However, as Brohm River is a tributary of the Cheekye River, and thereby the Cheakamus River (Figure 1-1), rainbow trout populations in this system would not have been directly impacted by the spill and since the stream was sampled in years prior to the spill, it provides a useful temporal comparison of changes in rainbow trout densities.

Mean measured densities of rainbow trout fry in 2007 and 2008 were below values reported for 2000 to 2004 (van Dishoeck, 2002; van Dishoeck and Horne, 2002; Hanson and Hryhorczuk, 2005), however parr densities in all three years of the RAMP were similar to the 2000 value and greater than the 2001 value (Table 4-4). Given the low number of sites historically sampled, these differences among years could be, in part, an effect of site selection.

Table 4-4. Geometric mean for rainbow trout densities, Brohm River, fall 2000-04, 2006-08

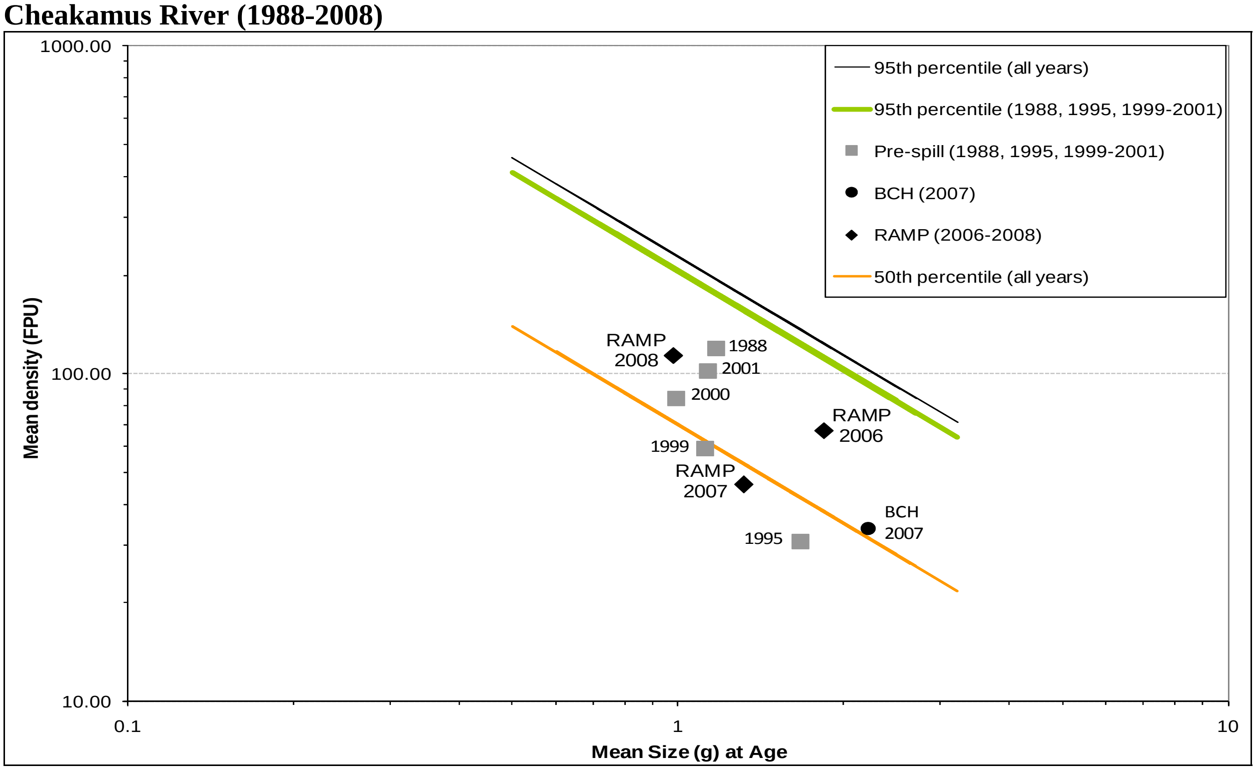
Survey year (No. sites)	2000[1] (n=2)	2001[2] (n=3)	2002[3] (n=2)	2003[3] (n=2)	2004[3] (n=2)	RAMP 2006 (n=2)	RAMP 2007 (n=2)	RAMP 2008 (n=2)
Fry Measured Density								
FPU	147.1	122.3	164.8	121.1	47.5	164.5[4]	26.0	39.6
CV (%)	*40.4*	*50.9*	*125.7*	*113.8*	*148.7*	*N/A*	*5.7*	*40.9*
Fry Adjusted Density								
FPU	194.4	198.2	224.9	177.2	85.5	319.1[4]	60.2	85.0
CV (%)	*48.4*	*35.9*	*123.9*	*103.3*	*143.9*	*N/A*	*59.2*	*110.7*
Parr Measured Density								
FPU	37.8	12.6	N/A	N/A	N/A	30.4	25.2	36.1
CV (%)	*48.6*	*46.4*	N/A	N/A	N/A	*1.9*	*45.2*	*95.5*

[1] van Dishoeck (2002), three-pass depletion; [2] van Dishoeck and Horne (2002), three-pass; [3] Hanson and Hryhorczuk (2005), two-pass; [4] Site km 3.09 in 2006 was excluded, as only one fry was captured.

Rainbow Trout Biomass Recovery Target

Information from historical surveys of rainbow trout was used to generate a secondary recovery target based on site biomass calculated from the yearly mean density and weight of fry. The biomass recovery target was identified as being between 50.0 and 133.6 g/unit area (*i.e.*, grams/100 m^2). Figure 4-3 shows yearly pre- and post-spill mean biomass values, with 95th and 50th percentile limits (based on non-impacted years). Mean rainbow trout fry biomass for September 2008 (geometric mean of 109.51 g/100 m^2; 0.5 coefficient of variation) was greater than the 2007 value and within the recovery target range.

Figure 4-3. Scatterplot of yearly geometric mean rainbow fry density by mean size-at-age for the Cheakamus River (1988-2008)



4.5 Bull Trout

A total of 34 bull trout were captured in the Cheakamus River and tributaries during the 2008 surveys (n = 2 in 2006 and n = 37 in 2007). A similar distribution to 2007 was recorded in 2008: ten bull trout were captured in the Cheakamus River (mainly in the upper reaches; Appendix 6 and 7) and the remaining fish, in the two Culliton Creek sites. Captured bull trout were 53 to 158 mm in length, suggesting multiple age classes.

The effects of the spill on the bull trout population are uncertain due, in part, to the low number of juvenile fish captured during previous surveys. A total of only 9 juvenile char (recorded as Dolly Varden) were reported between 1999 and 2001 by van Dishoeck (2000, 2002) and van Dishoeck and Horne (2002). While juvenile bull trout are included as a target species in the RAMP, their low abundance in historical surveys in the Cheakamus River makes this parameter difficult to use as a defensible measure of recovery. Therefore, adult abundance has been identified as the most defensible recovery target, although information from both projects is considered by CERTC to assess recovery of bull trout (Triton, 2009b).

Adult abundance is being assessed using information from radio telemetry of specific individuals to calibrate observer efficiency during snorkel surveys (Melville and McCubbing, 2006; Ladell *et al*., 2007 and 2009). The calibrated observer efficiency can then be applied to historical snorkel survey data and used to develop a defensible recovery target for adult bull trout. Preliminary information from these surveys suggests adult bull trout overwinter in the Cheakamus River but most fish emigrate from the river by July and may spawn in the Squamish River, although some bull trout also spawn in the Cheakamus River. This could explain the low number of juveniles historically captured in the river, relative to the number of adults observed during spring snorkel surveys targeted at steelhead.

Although more juvenile bull trout were captured in 2008 compared to historic surveys, the results are difficult to compare due to the low number of fish captured. Sampling in 2008 did capture juvenile bull trout - in preferred habitats - representing multiple age classes, indicating recruitment is occurring and recovery is underway. Several projects are also underway which are providing more information about bull trout life history in the Cheakamus River. The results of all these programs continue to be evaluated to assess bull trout recovery.

4.6 Threespine Stickleback

In 2008, 156 threespine stickleback were captured in the Cheakamus River - a similar catch to 2007 (n= 166). Although a few adults were observed in the mainstem (in pool areas), the majority of threespine sticklebacks (YoY, juveniles and adults) were captured in Moody's Pond (by electrofishing) and Emerald Forest Creek (including Farpoint Intake, near km 7.65; by minnow trap). Both areas are part of a complex of man-made side channels, with multiple large pools, low-to-no velocity and abundant cover (LWD, SWD, instream and overstream vegetation), providing preferred stickleback habitat.

No quantified pre-spill information on threespine stickleback distribution or abundance in the Cheakamus River was identified. No stickleback were reported captured in mainstem sites targeted at rainbow trout fry from 1999 to 2001 (van Dishoeck 2000, 2002; van Dishoeck and

Horne, 2002). Only two dead stickleback were collected during the 2005 assessment, and several live fish were observed during post spill surveys (McCubbing *et al.*, 2006). Pre and post spill information examined and collected to-date would seem to confirm stickleback in the Cheakamus River prefer off-channel habitats not affected (or to a lesser degree) by the pulse disturbance associated with the spill. While few stickleback have been captured or observed in mainstem habitats, the species appears to be abundant in areas identified as preferred habitat, and is represented by multiple age classes.

4.7 Cutthroat Trout

As in the past two survey years, no cutthroat trout were captured in the Cheakamus River in 2008: one fish was captured in Brohm River (BR0.72), in September (n = 3 in 2007). Evidence collected from various monitoring programs indicates cutthroat trout are not abundant in the Cheakamus River, as very few cutthroat trout were captured in pre-spill electrofishing or salmon migration trapping studies (van Dishoeck, 2000 and 2002; van Dishoeck and Horne, 2002; Sneep, 2001; Melville, 2005; and Melville and McCubbing, 2006). During their 1999 to 2001 surveys, van Dishoeck (2000, 2002) and van Dishoeck and Horne (2002) reported no cutthroat in the Cheakamus River and only two in Brohm River. In addition, only one cutthroat trout mortality was collected during the emergency impact assessment (McCubbing *et al.*, 2006). Information from other literature reviewed also suggests the Cheakamus River does not provide preferred habitat for cutthroat trout. Depth, cover, substrate and velocity play a strong role in the type of habitat cutthroat select (Heggens *et al.*, 1991). Although the microhabitat preferences of juvenile cutthroat and juvenile rainbow and steelhead trout are similar, cutthroat are more often found in smaller drainages (*e.g.,* <13 km^2) or small tributaries to larger drainages (Slaney and Roberts, 2005). The effects of the spill on the cutthroat population are uncertain as historical information suggests cutthroat trout juveniles seldom use the Cheakamus River.

4.8 Incidental Catch

Several species were also captured as part of the incidental catch including, chinook, chum, coho and pink salmon. Due to their seasonal migration patterns (*i.e.*, some of these species leave the river as fry after emergence in the spring), the abundance of these fish varied with the sampling time of year. While data on abundance, along with fish lengths and weights were recorded during the RAMP, recovery of these species is being measured through other monitoring programs (Triton, 2006). This information, therefore, has not been analyzed in detail or compared to past survey years. However, the ongoing presence, relative abundance and distribution of these species (compared to past surveys), combined with evidence of fish being in good condition, are supporting indications the river is recovering from the affects of the spill.

5.0 Conclusions

Based on the 2008 results from the Resident Fish Abundance Monitoring Program (RAMP), the following conclusions have been drawn:

- The composition of the fish communities in 2008 was similar to that reported in previous studies, indicating the physical habitat has the capacity to support the same species as it did before the spill;
- Sculpin densities remained lower than reported in previous surveys and their distribution (*i.e.*, the upstream limit of capture) was limited compared to the historical range;
- The upstream-most capture location of sculpins has increased from km 7.5 in 2006 to km 11.3 in 2007 and km 12.6, suggesting a (natural) progression of upstream recolonization by sculpins;
- The capture of multiple species and age/size classes, as well as the abundance of lamprey observed in the Cheakamus River in 2008 corroborate information from 2006 and 2007 and indicate lamprey were not impacted by the spill to the extent estimated in the 2005 assessment;
- The low number of threespine stickleback captured in mainstem habitats between 2006 and 2008, as well as during historical surveys indicates the mainstem does not provide preferred habitat for this species;
- The abundance of threespine stickleback captured in off-channel habitats - less affected by the spill - and the multiple age/size classes in these habitats indicate the spill impacts on stickleback were less severe than on other species;
- Abundance of juvenile bull trout has historically been low in the Cheakamus River. However, between 2006 and 2008 they were captured in similar mainstem, side channel and tributary habitats as historically reported, indicating spawning and recruitment of juveniles is occurring;
- Few cutthroat trout have been captured in historical surveys of the Cheakamus River, or in 2006 to 2008, suggesting the river does not provide preferred habitat for this species;
- Mean measured and adjusted densities of rainbow trout fry captured in mainstem, closed electrofishing sites in 2008 were higher than 2006 and 2007 values, as well as the 1999 and 2000 values (van Dishoeck, 2000 and 2002), despite the population estimate for adults in spring 2008 being below the recovery target (Triton, 2008c);
- Rainbow trout parr abundance in 2008, based on mean measured densities, was greater than observed in past RAMP surveys and than historical estimates;
- The average condition of captured rainbow trout was consistent with conditions reported in other studies, and was reflective of fish in good health; and,
- Although it is not possible to determine the timing or rate for recovery based solely on the 2006 to 2008 surveys, results suggest natural recovery is underway.

6.0 Recommendations

The Resident Fish Abundance Monitoring Program follows an adaptive management approach and the methods used will, therefore, continue to be evaluated for their efficacy in achieving the program objectives. Based on a review of methodologies and results, some adjustments were identified to the sampling protocols, which will be considered for implementation in the future, including:

- Discontinuing pole seining, as this sampling method is not providing the anticipated information on young of year for target species; and,
- Adding one or more sites in Brohm River targeting rainbow trout fry, to allow better comparison to past surveys.

7.0 References

Albrecht, Debbie. 2008. Written communication from BC Hydro, Generation Operations. Water Survey of Canada (preliminary data). Email communication to Triton Environmental Consultants summarizing discharges and water levels in Cheakamus River from January 1 – December 31 2008.

Allen, K.R. 1969. Limitations on production in salmonid populations in streams, p. 3-18. In T.G. Northcote [ed.] Symposium on salmon and trout in streams. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

Beamish, R.J. and J.H. Youson. 1987. Life history and abundance of young adult *Lampetra ayresii* in the Fraser River and their possible impact on salmon and herring stocks in the Strait of Georgia. Can. J. Fish. Aquat. Sci. 46: 420-425.

Beamish, R.J. and C.D. Levings. 1991. Abundance and freshwater migrations of the anadromous parasitic lamprey, *Lampetra tridentata*, in a tributary of the Fraser River, B.C. Canadian Journal of Fisheries and Aquatic Sciences, 48:1250-1263.

Beamish, R.J. 2008. September 4th, 2008. Verbal communication. Discussion regarding lamprey adult and larval identification based on morphology.

Beamish, R.J. and J. Wade. 2009. May30th, 2009. Verbal communication. Field sampling and discussion regarding ammocoetes identification based on morphology.

Bovee, K.D. 1978. Probability-of-use criteria for the family Salmonidae. Co-operative Instream Flow Service Group, Fort Collins, Colorado. Instream Flow Information Paper No. 4.

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Co-operative Instream Flow Service Group, Fort Collins, Colorado. Instream Flow Information Paper No. 12.

Brown, L.R., Matern, S.A. and P.B. Moyle. 1995. Comparative ecology of prickly sculpin *Cottus asper*, and coastrange sculpin, *C. aleuticus*, in the Eel River, California. *Envir. Biol. of Fishes* 42: 329-343.

Campbell, Peter. 2007. Verbal communication June 2007. Discussion regarding use of habitat condition indices to asses fish health.

Canadian Council of Ministers for the Environment (CCME). 2007. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Update 7.0.

Cheakamus Ecosystem Restoration Technical Committee (CERTC). 2009. [Internet]. Website consulted February 05, 2009. Available from; http://www.certc.ca/monitoring_programs.shtml

Clark, B.J. 1989. The Assessment of the Recreational Fishery Potential of the Cheakamus River Upstream of the Anadromous Barrier: Progress in 1988. Regional Fisheries Report Unpubl. MS., Ministry of Environment, Surrey, BC.
Hanson A. and Hryhorczuk C. 2005. Squamish River juvenile steelhead sampling - Brohm River, and Ashlu, High Falls, Kaitlin, Mashiter Shovelnose, and UNN#1(W) Creeks, Fall 2002 2004. Prepared for Greg Wilson, Ministry of Water Land and Air Protection

Heggens, J., Northcote, T.G., and A. Peter. 1991. Seasonal habitat selection and preferences by Cutthroat Trout (*Oncorhynchus clarki*) in a small, coastal stream. Canadian Journal of Fisheries and Aquatic Science. 48: 1364-1370.

Korman, J. 2008. Cheakamus River Steelhead Adult Abundance, and Juvenile Habitat Use and Abundance Monitoring. Prepared for B.C. Hydro Power Authority.

Kostow, K. 2002. Oregon Lampreys: Natural History Satatus and Problem analysis. Oregon Department of Fish and Wildlife.

Johnston, N.T. and P.A. Slaney. 1996. Fish habitat Assessment Procedures. Province of British Columbia Watershed Restoration Technical Circular 8: 97p.

Ladell, J., J. Korman, and C. Melville. 2007. Cheakamus River char radio telemetry and enumeration program, 2007 annual report. Prepared for Canadian National Railway Company.

Ladell, J., J. Korman, and D.J.F. McCubbing. 2009. Annual report for the Cheakamus River bull trout radio telemetry and enumeration program, Prepared for CN Environment.

Marmorek, D. and I. Parnell. 2002. Cheakamus River Water Use Plan Report of the Consultative Committee. Prepared on behalf of Cheakamus River Water Use Plan Consultative Committee.

McCubbing, D.J.F., C.C. Melville, G Wilson, and M. Foy. 2006. Assessment of the CN sodium hydroxide spill August 5th, 2005 on the fish populations of the Cheakamus River. Final Draft. Prepared by InStream Fisheries Research, Inc. for Ministry of Environment and Fisheries and Oceans Canada. March 1st, 2006.

McCubbing, D.J.F. and C.C. Melville. 2000. Chinook Spawning Migration in the Cheakamus River from Radio Tracking Observations in the Summer of 1999. Prepared by InStream Fisheries Research, Inc. for BC Hydro.

McPhail, J.D. 2007. The Freshwater fishes of British Columbia. The University of Alberta Press. Edmonton, AB. 696 pp.

Melville, C. 2005. Cheakamus steelhead fry emergence timing summer 2005. Prepared by InStream Fisheries Research, Inc. Prepared for BC Hydro, Burnaby, BC.

Melville, C.C. and D.J.F. McCubbing. 2005. Assessment of the 2004 juvenile salmon migration in the Cheakamus River, using rotary traps. DRAFT. Prepared for BC Hydro. Prepared by InStream Fisheries Consultants Ltd.

Melville, C.C., and DE. McCubbing. 2006. Proposal: Use of radio telemetry to calibrate observer efficiency and monitor recovery of Cheakamus River char (*Salvelinus sp.*) using pre and post spill snorkel surveys, Final Draft. Prepared for Canadian National Railway Company.

Melville, C.C. 2008. Verbal communication Discussion regarding sculpin catch from rotary screw traps (RSTs) data.

Melville, C.C., and DE. McCubbing. 2008. Cheakamus River Water Use Plan Monitoring Program: Juvenile Salmonid Outmigration Enumeration Assessment, Spring 2007. Prepared by InStream Fisheries Consultants Ltd.

Meeuwig, M.H., and J.M. Bayer. 2005. Morphology and aging precision of statoliths from larvae of Columbia River Basin lampreys. N. Am. J. Fish. Manage. 25: 38-48.

Ministry of Environment (MOE). 2008. Fisheries Inventory Data Queries. Website consulted August 26, 2008. http://a100.gov.bc.ca/pub/fidq/speciesQuery.do

Ministry of Environment (MOE). 1998. British Columbia Approved Water Quality Guidelines (Criteria) 1998 Edition, updated August 2006.

Northwest Hydraulic Consultants. 2000. Analysis of channel morphology and sediment transport characteristics of the Cheakamus River. BC Hydro Ref No. CMS-MRPHLGY. Prepared for BC Hydro.

Ptolemy, R.A. 1993. Maximum salmonid densities in fluvial habitats in British Columbia. p. 223-250. In: L. Berg and P.W. Delaney, editors. Proceedings of the Coho Workshop, Nanaimo, B.C., May 26-28, 1992.

Ptolemy, R. 2001. Depth/ velocity transect data analysis spreadsheet. Developed by Poul Bech, Ron Ptolemy, and Rob Knight, B.C. Environment, Fisheries Section, May 1994 and modified by Harlan Wright, British Columbia Conservation Foundation, January 2003, using February 2001 WUP HSI curves and Generic Insect curves from Stalnaker and Arnette, 1976.

Ptolemy R.A., M Ramsay, D Peard, and D Sollitt, 2006. Results of Steelhead Stock Monitoring (1988-2006) in the Bella Coola River and Implications for Population Recovery. Prepared for: Ministry of Environment, Fish & Wildlife Science and Allocation, Williams Lake, British Columbia, and Habitat Conservation Trust Fund, Victoria, British Columbia

Ptolemy, Ron. 2007. Verbal communication July 2007. Discussion regarding the application of the depth/velocity transect data analysis spreadsheet to calculate weighted useable area for rainbow trout fry and parr.

Ptolemy, Ron. 2008. Written comm. Information collected for BC Hydro during the 2007 juvenile habitat use and abundance monitoring surveys and analyses of biomass data from historical electrofishing surveys in the Cheakamus River.

Ptolemy, Ron. 2008. Verbal communication September 3, 2008. Field demonstration of standard MoE methods for enclosed, triple-pass electrofishing sampling.

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Resource Inventory Committee (RIC). 1999. Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Site Card Field Guide. Errata 1 (Mar 2000); Errata 2 (Apr 2001); Errata 3 (Mar 2004). Prepared for Forest Renewal BC.

Richards, J.E., R.J. Beamish, and F.W.H. Beamish. 1982. Description and keys for ammocoetes of lampreys from British Columbia, Canada. Can. J. Fish. Aquat. Sci. 39: 1484 – 1495.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin Fisheries Research Board of Canada. 191. 382pp.

Ringstad, N.R. and D.W. Narver. 1973. Some Aspects of the Ecology of Two Species of Sculpin (*Cottus*) in a West Coast Vancouver Island Stream. Manuscript Report Series No. 1267. Fisheries Research Board of Canada.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. MacMillan Publishing Co. Inc., New York.

Slaney, P. and J. Roberts, 2005. Coastal Cutthroat trout as sentinels of lower mainland watershed health, An action plan for coastal cutthroat trout conservation, restoration and recovery. Prepared for Ministry of Water Land and Air Protection.

Stone, J. J. Pirtle, and S Barndt. 2002. Evaluate habitat use and population dynamics of lampreys in Cedar Creek. Bonneville Power Association Contract #200001400, Annual report for 2001, US Fish and Wildlife Service, Columbia River Fisheries Program Office, Habitat and Natural Production Team

Sneep, J. 2001. Cheakamus River juvenile salmonid distribution assessment September 1999 to July 2000. Cheakamus River Water Use Plan Data Report. Prepared for BC Hydro. 41pp.

Swales, S. 1987. The use of small wire-mesh traps in sampling juvenile salmonids. Aquaculture and Fisheries Management, 18:187-195

Taylor E.B. and J.L. Gow. 2008. Molecular Species Identification and Population Structure Analysis of Sculpin (Pisces: Cottidae) species in the Cheakamus River, British Columbia. Prepared for Triton Environmental Consultants Ltd., August 2008.

Teal Solutions. 2005. Draft Environmental Emergency Remediation Plan, CN Rail Derailment Garibaldi Mile 58.5, August 8th 2005. 16p.

Torgersen, C.E. and D.A. Close. 2004. Influence of habitat heterogeneity on the distribution of larval Pacific lamprey (*Lampetra tridentata*) at two spatial sites. Freshwater Biology, 49: 614-630.

Triton Environmental Consultants Ltd. 2006. Cheakamus Ecosystem Recovery Plan (CERP), 2006. Submitted to the Cheakamus Ecosystem Restoration Technical Committee (CERTC) by Triton Environmental on behalf of Canadian National Railway Company. November 2006.

Triton Environmental Consultants Ltd. 2007a. Water Quality Assessment following an Accidental Release of Sodium Hydroxide. Final Report prepared for the Cheakamus Ecosystem Recovery Technical Committee, September 2007.

Triton Environmental Consultants Ltd. 2007b. Screening Level Assessment of Ecological Effects following an Accidental Release of Sodium Hydroxide into the Cheakamus River, BC. Final Report prepared for the Cheakamus Ecosystem Recovery Technical Committee, February 2007.

Triton Environmental Consultants Ltd. 2008a. Cheakamus River Benthic Invertebrate Recovery Monitoring Program, 2005. Final Report prepared for the Cheakamus Ecosystem Recovery Technical Committee, April 2008.

Triton Environmental Consultants Ltd. 2008b. Resident Fish Abundance Monitoring Program, 2006. Final Report prepared for the Cheakamus Ecosystem Recovery Technical Committee, November 2008.

Triton Environmental Consultants Ltd. 2008c. Cheakamus Ecosystem Recovery Plan (CERP), 2008 – Three-year Review. Submitted to the Cheakamus Ecosystem Restoration Technical Committee (CERTC) by Triton Environmental on behalf of Canadian National Railway Company. October 2008.

Triton Environmental Consultants Ltd. 2009a. Resident Fish Abundance Monitoring Program, 2007. Final Report prepared for the Cheakamus Ecosystem Recovery Technical Committee, June 2009.

Triton Environmental Consultants Ltd. 2009b. Cheakamus Ecosystem Recovery Plan, Annual Review 2009. Draft report in preparation for Canadian National Railway Company, in cooperation with Cheakamus Ecosystem Restoration Technical Committee.

Van Deventer, J.S. 1989. Microcomputer Software System for Generating Population Statistics from Electrofishing Data--User's Guide for MicroFish 3.0. USDA Forest Service, General Technical Report INT-254. 29pp.

van Dishoeck, P. 2000. Squamish River System Juvenile Steelhead Sampling Program. Squamish, Cheakamus, Mamquam and Elaho Rivers, and Shovelnose Creeks. October 1999. Prepared by Aquatic Resources Ltd for Ministry of Environment, Lands and Parks, Surrey BC. ARL Report No. 337-2. 90pp.

van Dishoeck, P. 2002. Squamish River System Juvenile Steelhead Sampling Program. Brohm, Cheakamus, Mamquam and Squamish Rivers, Ashlu, Chuck Chuck, Highfalls, Kaitlin, Mashiter and Shovelnose Creeks. September 2000. Prepared by Aquatic Resources Ltd for Ministry of Water, Land and Air Protection, Surrey BC. ARL Report No. 369-1. 50pp.

van Dishoeck, P. and B. Horne. 2002. Squamish River System Juvenile Steelhead Sampling Program. Brohm, Cheakamus and Mamquam Rivers, Ashlu, Highfalls, Kaitlin, Mashiter, Shovelnose and Spring Creeks. September 2001. Prepared by Aquatic Resources Ltd for the Ministry of Water, Land and Air Protection, Fish and Wildlife Science and Allocation Surrey, BC. ARL Report No. 436-1, 2002. 47pp

Wydoski R.S. and R.R. Whitney. 2003. Inland Fishes of Washington, 2^{nd} ed. Singapore: University of Washington Press. 98-99p.

Zippin, C. 1956. An evaluation of the removal method of estimating animal populations. Biometrics, 12: 163-189.

APPENDIX 1

PHOTOGRAPHS

APPENDIX 2

ELECTROFISHING SITE DESCRIPTIONS AND DEPTH/VELOCITY PROFILES

APPENDIX 3

FIELD DATA FORMS

APPENDIX 4

SUMMARY OF ELECTROFISHING SITE CHARACTERISTICS

APPENDIX 5

SUMMARY OF MINNOW TRAPPING SITE CHARACTERISTICS

APPENDIX 6

MINNOW TRAP HABITAT AND CATCH DATA

APPENDIX 7

ELECTROFISHING CATCH DATA

APPENDIX 8

SEINING CATCH DATA

APPENDIX 9

LENGTH, WEIGHT AND CONDITION DATA

APPENDIX 10

RESULTS FROM ANALYSES OF LENGTH FREQUENCY DISTRIBUTIONS WITH MIX

APPENDIX 11

RESULTS FROM ANALYSES OF RAINBOW TROUT LENGTHS BY SAMPLING METHOD

APPENDIX 12

SUMMARY OF DENSITIES FOR NON-TARGET SPECIES