Resident Fish Abundance Monitoring Program

2006

Prepared for:

Canadian National Railway Company
CN Environment
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SUMMARY

On August 5, 2005, the Cheakamus River was affected by an accidental discharge of sodium hydroxide (NaOH) following a train derailment in the Cheakamus canyon approximately 15 km north of Squamish, British Columbia. Although the product did not persist in the system, it caused mortalities to invertebrates and fish in the river at the time of the spill. Soon after, efforts were made to assess and document immediate impacts of the spill on the ecosystem. The Cheakamus Ecosystem Recovery Plan (CERP) was developed to recommend restoration and monitoring strategies for implementation for species affected by the NaOH spill. In addition, the CERP identified recovery targets for several species where sufficient background information was available to provide defensible comparisons to historic abundance. The plan is based on an adaptive management approach and outlines a number of monitoring programs initiated in 2006; some of these will be carried out for several years to assess the success of the restoration strategies and identify when recovery targets are met.

The Resident Fish Abundance Monitoring Program (RAMP) was implemented in an effort to assess the recovery of fish population abundance in the anadromous section of the river (downstream of the barrier at km 16.8) which was affected by the spill. Species of principal concern for the RAMP include sculpin (*Cottus sp.*), lamprey (*Lampetra sp.*), threespine stickleback (*Gasterosteus aculeatus*), cutthroat trout (*Oncorhynchus clarkii*), and bull trout (*Salvelinus confluentus*). These species were targeted because there was limited background information available to form the basis of recovery targets.

Pre-spill estimates of adult steelhead abundance from repeated snorkel surveys and calibrated observer efficiency estimates was identified as the most defensible recovery target for steelhead trout (*Oncorhynchus mykiss*) abundance. However, steelhead trout spend several years rearing in freshwater and as juveniles the resident form of this species (rainbow trout) cannot be distinguished from the juvenile steelhead. Therefore the CERP identified replication of historic electrofishing surveys and comparison of rainbow trout abundance to historic density estimates as a potential secondary measure of recovery for rainbow trout/steelhead. Replicating historic sampling sites and methods targeted at rainbow trout also provided a basis of comparison for other species captured at these locations.

Sampling was conducted from September 11 to 29, 2006 along the Cheakamus River mainstem (reaches 1 to 8), as well as in side channels and in Brohm River. Fish were captured by minnow trapping (250 sites), electrofishing (27 sites) and seining (4 sites). Sites were selected based on accessibility, suitability for each sampling method and habitat preferences of target species. Rainbow trout distribution extended throughout the entire sampling area (up to 15 km from the confluence with the Squamish River). Cottids were captured in the mainstem only up to river km 6.85 (with 85% caught within the first 3 km), lamprey from km 2 to 9, while threespine stickleback were only captured in Emerald Forest Creek. Rainbow trout accounted for 61% of the total electrofishing catch, while lamprey and sculpin accounted for 21% and 2.9% respectively. Measured densities (number of fish per 100 m^2 unit, or "fpu") ranged from 2 to 255 fpu for rainbow fry (highest densities found in riffles, with cobble substrate), 0 to 31 fpu for cottids, and 0 to 273 fpu for lamprey (highest densities found in sites specifically chosen for their suitability).

Based on length-frequency distributions, all but 5 rainbow trout captured in the Cheakamus River were age 0+ (fork length ≤85 mm), and there was a proportionally greater percentage of larger rainbow trout in side channel sites. The mean condition factor of rainbow trout (n=886) was 1.05. Cottids captured in the mainstem (n=95) appeared to belong mainly to one cohort, possibly two (average total length 84 mm); while no clear cohorts could be determined for lamprey (average total length 77 mm).

Comparison to past studies indicates rainbow trout recruitment has occurred in areas where they were observed historically, although with observed differences in age class structure and relative densities. Relative densities of cottids in 2006 were lower than reported in past studies and their distribution also differed, as no sculpin were captured above km 6.85. Limited historic data are available on lamprey in the Cheakamus River, however densities measured in 2006 were greater than any recorded historically for this area.

The results from the 2006 sampling efforts will serve as an additional reference point for the assessment of recovery in subsequent years.

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 (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 wells (Triton 2007a). The product did not persist in the environment, as evidenced by the return to normal pH levels within several hours of the derailment.

The Cheakamus Ecosystem Restoration Technical Committee (CERTC) - composed 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 coordinate the subsequent recovery of fish populations in the Cheakamus River. CN is funding several ongoing monitoring studies including the Non-Anadromous Reach Fish Abundance Monitoring Program (Triton, 2007b) and the Resident Fish Abundance Monitoring Program (RAMP). In addition to studies targeted at fish, several projects were undertaken to assess other impacts and monitor recovery. These studies included assessment of water quality after the spill (Triton 2007a), a screening level assessment of ecological effects (Triton, 2007c), assessment of impacts to benthic invertebrates (Stamford *et al*., 2008) and monitoring of benthic invertebrate recovery (Triton, 2008).

This report summarizes the survey results of the Resident Fish Abundance Monitoring Program (RAMP) conducted on the Cheakamus River in September 2006. The information collected represents the first sampling season of a multi-year program, will serve as an additional reference point from which recovery will be assessed in subsequent years, and will be used to determine when densities reach a point of equilibrium (detailed in Section 1.3).

1.2 Study Area

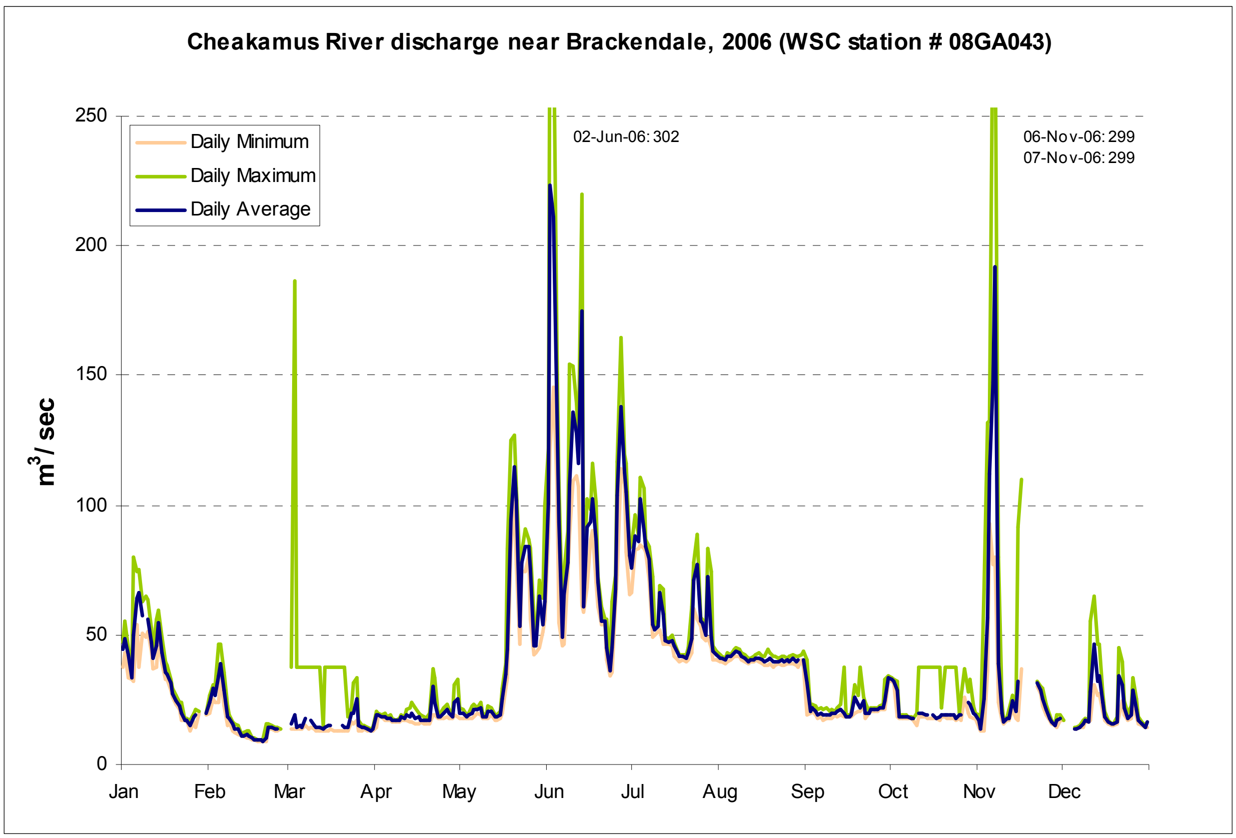
The Cheakamus River is one of the largest tributaries to the Squamish watershed, draining a 1,070 km^2 area of the Coastal Mountain range in southwestern BC (Northwest Hydraulic Consultants, 2000). The river flows 47 km from its headwaters in Garibaldi Provincial Park, through the Daisy Lake Reservoir to its confluence with the Squamish River, approximately 26 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 fishes such as sculpin, salmonids, lamprey and stickleback. A series of impassable falls 17 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 18.6, approximately two kilometres upstream of the first impassable falls at river km 16.8 (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).

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 valley. Diversion volumes and power production vary with both climate and regulation, as determined by the Cheakamus River Water Use Plan (Marmorek and Parnell, 2002). Daily discharges to the Cheakamus River in 2006 are shown in Figure 1-3. Changes in discharge reflect the influence of weather related effects such as snow or rain run-off with the exception of the maximum daily discharge peak in March, which has been attributed to a mechanical or electronic malfunction in the gauge station

Figure 1-1. Cheakamus River discharge near Brackendale, 2006



Source: Water Survey of Canada (preliminary data; B. Wilson, BC Hydro, written communication, 2007).

The study area encompasses the mainstem of the Cheakamus River from the confluence with the Squamish River (km 0) to the anadromous barrier (km 16.8; reaches 1 to 8, henceforth referred to as the "anadromous reach"), a number of natural and man-made side channels, and Brohm River.

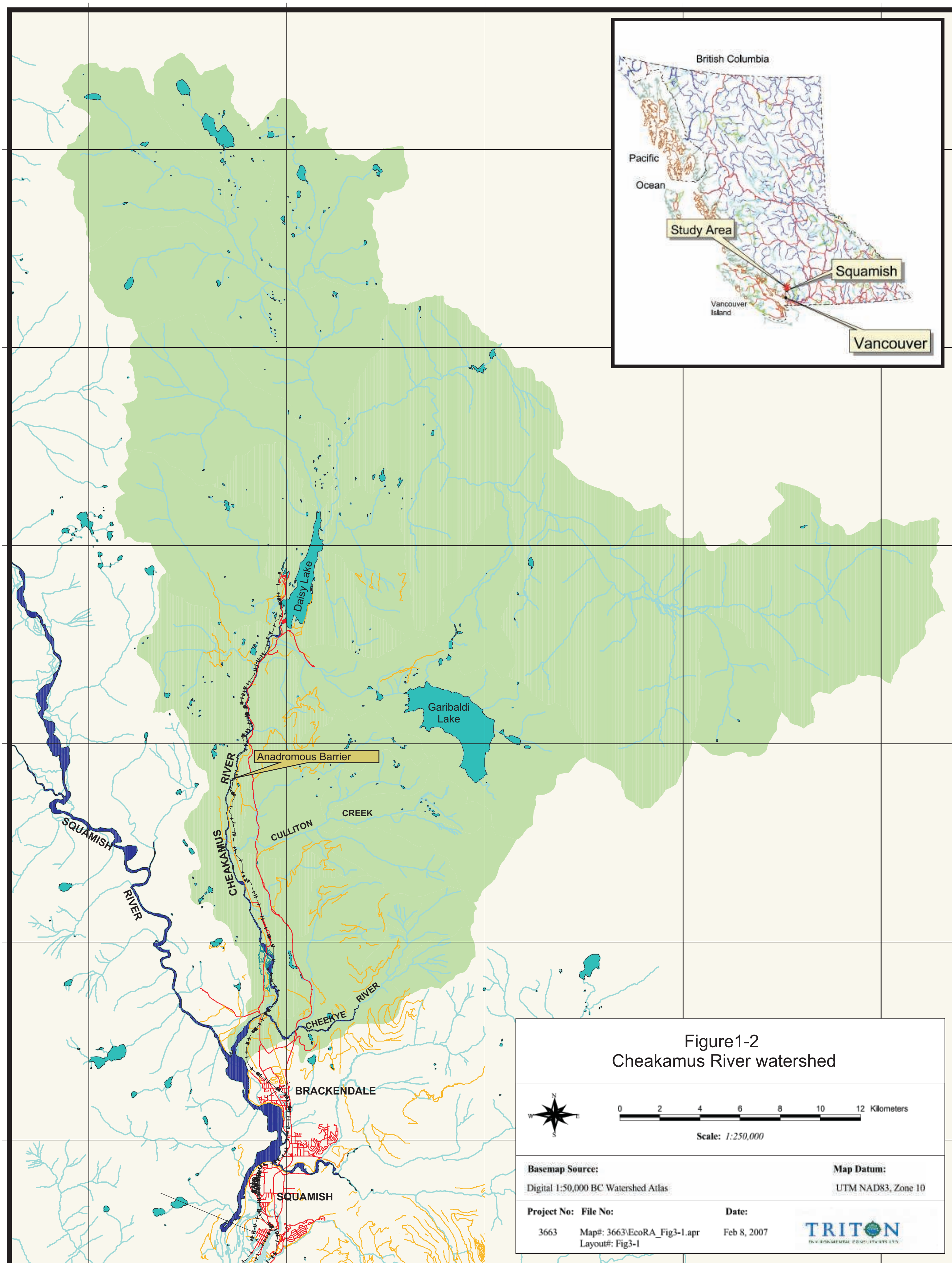
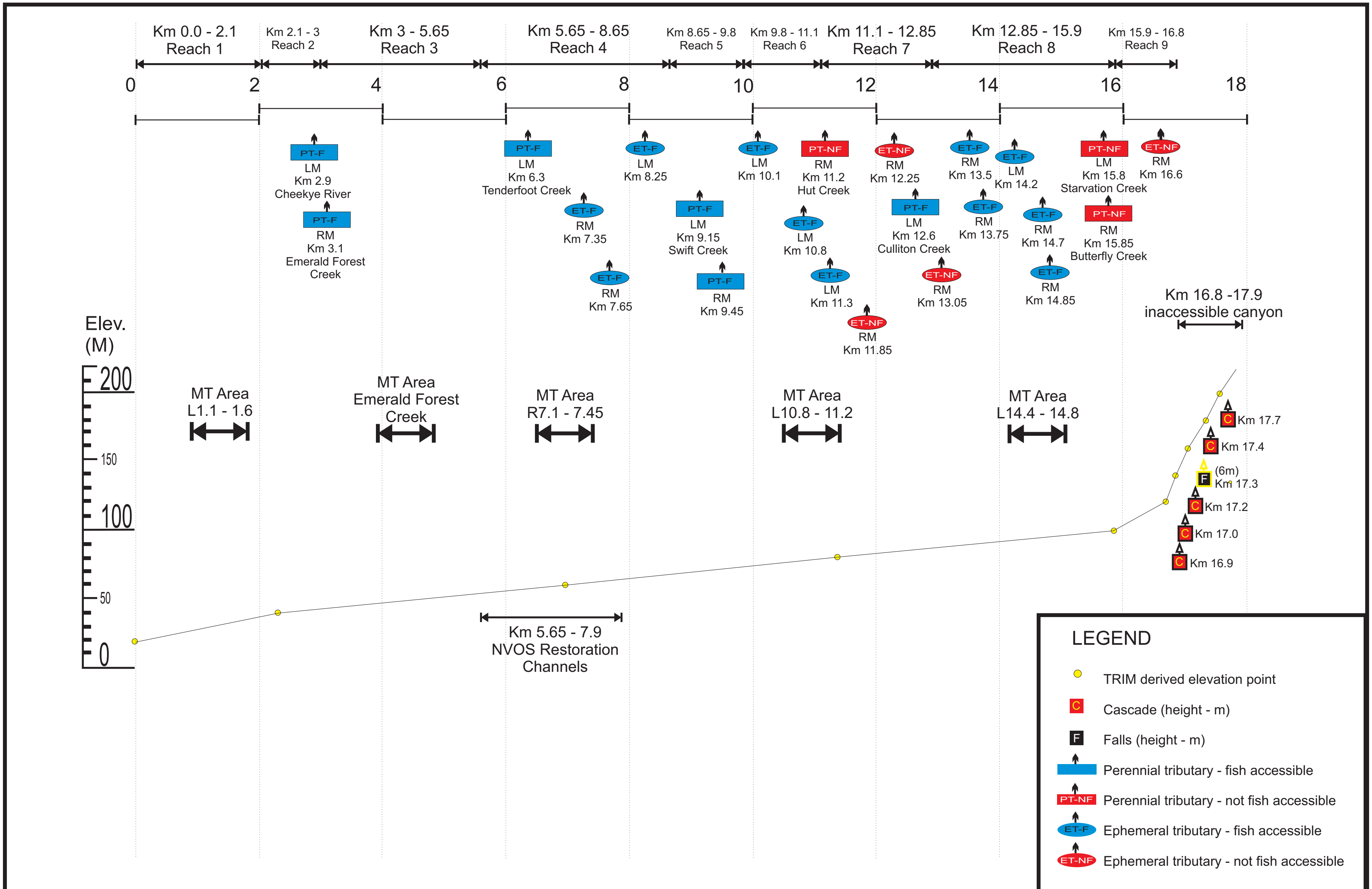


Figure1-2
Cheakamus River watershed



Resident Fish Abundance Monitoring Program, 2006

Map # RAMP Fig 1-3

Created by: J.Thorlacius 19 June 2007
Revised by: P. Frederiksen 29 Feb 2008
Source: Triton Environmental

FIGURE 1-3. PROFILE VIEW OF THE CHEAKAMUS RIVER ANADROMOUS REACH

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1.3 Program Rationale

The main purpose of the Resident Fish Abundance Monitoring Program is to monitor the natural recovery of target fish populations in the anadromous reach of the Cheakamus River. These include sculpin (*Cottus sp.*), lamprey (*Lampetra sp.*), threespine stickleback (*Gasterosteus aculeatus*), cutthroat trout (*Oncorhynchus clarkii*), bull trout (*Salvelinus confluentus*), and rainbow trout (*Oncorhynchus mykiss*). With the exception of rainbow trout, little data exist on the target species in the Cheakamus River (see Appendix 2), hence recovery is difficult to assess based on pre-existing information, and initial recovery targets could not be established.

The program's rationale and methods were developed to monitor the recovery of fish communities in the affected area while acknowledging this knowledge gap. The methodology has two main assumptions:

1. There is no residual effect to the physical habitat and therefore no associated limitation to fish recovery in the affected area; and,

2. The system will naturally recover to a state of equilibrium.

These assumptions are based on the concept of *homeostasis* - the tendency of a system to maintain a dynamic equilibrium. Also known as *equilibrium population density*, the model assumes the system has the capacity to restore equilibrium following a disturbance (Ludwig *et al*., 1997). Recovery should be reflected by some changes in the measured parameters (*e.g.,* fish abundance) over time. In a stream environment, there may be some variations in abundance, reflected in inter-annual fluctuations in spawning and rearing conditions. The important point is the *magnitude* or direction of change should be toward increasing abundance until abundance begins to reach a point of equilibrium and stabilizes as recovery proceeds.

Temporal variability will be 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 will be assessed using a multivariate analysis of the time-series data (*e.g.,* 2006 data with subsequent years), and comparing results to available data from previous studies.

Program Objective

The primary objective of this ongoing program is to monitor recovery of the affected fish community. Recovery will be assessed (recovered, recovering or unchanged) on a yearly basis by comparing changes in fish densities, distribution, age class composition and condition to those of previous program years and past studies. The parameters being evaluated to measure recovery are:

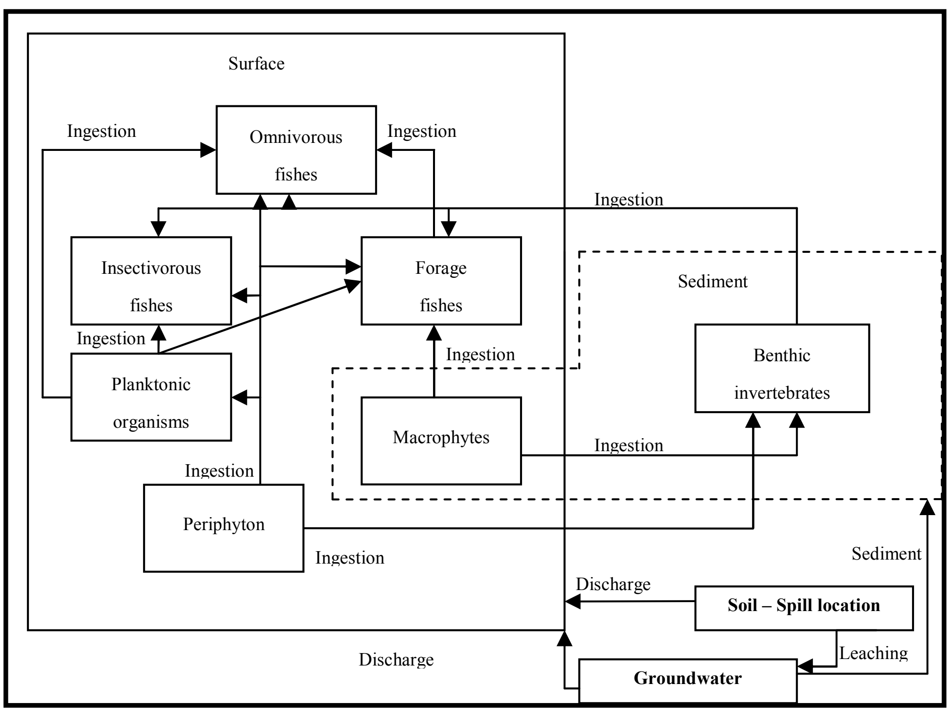
- Relative abundance (assessment of fish densities and spatial distribution, from river km 0 to the anadromous barrier);
- Length-frequency distributions (to assess distribution of cohorts, or age groups); and,
- General condition of fish (based on length and weight, and condition indices).

Other information may also be used, complementary to the aforementioned parameters. For example, the presence of young of year fish (*e.g.,* salmonid fry, lamprey ammocoetes or sculpin larvae) would be indicative of successful adult spawning. Information from other concurrent studies and unpublished reports is also being reviewed on an ongoing basis in an effort to identify defensible comparisons for measuring recovery (*e.g.,* MoE file data on rainbow trout biomass, and information from BC Hydro WUP monitoring programs). All of this information will be considered in combination with the overall program objective outlined above. The assessments undertaken in 2006 will serve as an additional reference point from which to evaluate the recovery of affected species in subsequent years, using a weight of evidence approach (*i.e.,* available information from multiple sources will be considered when determining if recovery has been achieved).

1.4 Conceptual Model

Rivers are complex ecosystems, with numerous components interacting in many different ways. An "ecosystem approach" is thus a central consideration when assessing how such a system may have been impacted by a particular event. Although the RAMP focuses primarily on fish populations, a study of the effects of the spill at the ecosystem level was conducted in 2006 (Triton, 2007c) to look at sources of impact (stressors) and possible species impacted (potential receptors). The information on stressors and potential ecological receptors (aquatic communities) was integrated into the development of a visual description or conceptual model outlining how NaOH could have affected the ecosystem (Figure 1-4).

Figure 1-4. Potential aquatic NaOH exposure pathway from point source to fish



Source: *Screening Level Assessment of Ecological Effects following an Accidental Release of Sodium Hydroxide into the Cheakamus River, BC*. Triton Environmental Consultants Ltd. 2007c.

2.0 Methods

2.1 Information Reviewed

A literature review was conducted to determine the availability of pre-spill data from the Cheakamus River. The following resources were consulted:

- DFO: WAVES catalogue
- MoE: EcoCat, Fisheries Information Summary System (FISS)
- UBC: ASFA (Aquatic Sciences and Fisheries Abstracts, BIOSIS, Web of Science)
- Canadian Journal of Fisheries and Aquatic Sciences (CJFAS)
- North American Journal of Fisheries Management (NAJFM)
- Transactions of the American Fisheries Society
- Bridge Coastal Fish & Wildlife Restoration Program
- Grey literature and unpublished consultants reports
- Other relevant online information

Personal communications with various organizations:

- Ministry of Environment
- BC Hydro
- InStream Fisheries Research Inc.

2.2 Target Species

A brief overview of life history information for target species is provided in Appendix 2. The RAMP targets fish populations with information gaps identified during the literature review conducted in preparation of the Cheakamus Ecosystem Recovery Plan (CERP; Triton, 2006). Species identified as primary targets for abundance monitoring were:

- Bull trout (*Salvelinus confluentus*)
- Coastrange and prickly sculpin (*Cottus aleuticus and C. asper -CC*)
- Coastal cutthroat trout (*Oncorhynchus clarkii clarkii* -CT)
- Pacific and western brook lamprey (*Lampetra tridentate, L. ayresii* and *L. richardsoni -L*)
- Threespine stickleback (*Gasterosteus aculeatus -TSB*)

During sampling for the RAMP, captured fish were identified to species with the exception of sculpin and lamprey. Due to difficulties in consistently differentiating *Cottus aleuticus* and *C. asper* in the field, captured sculpins were categorized at the family level (Cottids). The same level of identification was used for lamprey ammocoetes as they are difficult to visually identify in the field. Opportunities for species differentiation of ammocoetes based on morphology is under investigation. Adults were identified based on oral disc morphology (McPhail, 2007).

Rainbow/steelhead trout (*O. mykiss*) was deemed a good indicator species 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. To ensure consistency with previous sampling efforts in the system (van Dishoeck, 2000, 2002; van Dishoeck and Horne, 2002), no distinction was made between resident rainbow trout and anadromous steelhead trout. All *O. mykiss* are referred to as rainbow trout in this report.

While bull trout are included as a target species in the RAMP, their low abundance in previous surveys in the Cheakamus River suggests electrofishing may not provide the most defensible measure of recovery. Therefore, bull trout abundance is also being assessed through an adult enumeration program using information from radio telemetry of specific individuals to calibrate observer efficiency from snorkel surveys (Melville and McCubbing, 2006). This information is expected to allow information from historical snorkel surveys to be used to develop a defensible recovery target for adult bull trout abundance. Information from both projects will be considered by CERTC to determine the most defensible recovery target for bull trout (Triton, 2007d).

The following species were part of the incidental catch. 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 sampling programs (Triton, 2006).

- Chinook Salmon (*Oncorhynchus tshawytscha*)
- Coho Salmon (*O. kisutch*)

2.3 Site Selection

Site selection was based on a review of information from existing fish abundance surveys and from aerial photographs, as well as habitat preference of target species, knowledge gained from field reconnaissance surveys, and local knowledge of the Cheakamus River. Following the information review, a series of sites were selected which included historic sampling locations (*e.g.,* van Dishoeck, 2000 and 2002), and new sites identified for other target species (Photos 2 and 3).

A site naming system was established to identify sampling locations by river margin and river km: *e.g*., R1.5 = right margin, at 1.5 km from the confluence with the Squamish River. Reference distances along the Cheakamus River are based on distances measured in an upstream direction from its confluence with the Squamish River (km 0) using Geographic Information System (GIS) mapping tools and Terrain Resource Information Mapping (TRIM) information. Sites were selected along the river mainstem, natural side channels, man-made side channels and tributaries (Table 2-1; Figure 2-1).

Sites were selected based on accessibility and suitability for each sampling method as well as habitat preferences of target species. Some sites were chosen to replicate sampling conducted in past studies and allow comparison of results to pre-spill data. Mainstem sites (reaches 1 to 8) were selected mainly on the presence of cobble and boulder substrate, which provide a variety of velocity gradients and suitable habitat for several target species (*e.g.,* sculpins, cutthroat, and char). Other sites in natural and man-made side channels were chosen for their suitability for other target species (*e.g.*, muddy/sandy side channels are commonly used by lamprey). The monitoring program is based on a comparison of measured fish densities in preferred habitats and not a total population estimate. Therefore site stratification, to ensure proportional sampling of all habitat types, was not undertaken.

Table 2-1. Site sampled during the RAMP, September, 2006

Stream	Reach	Margin	River Km*	Site Location	Site Type	Sampling Method
Cheakamus River	1	R	0.3	Mainstem	O	EF
		L	1.5	Mainstem	O	EF, MT, SN
	2	R	2.1	Mainstem	O	EF
		R	2.9	Mainstem	O	EF
	3	R	3.5	Mainstem	O	EF
		R	3.6	Mainstem	C	EF
		R	5.35	Mainstem	O	EF
	4	R	6.7	Back channel	O	EF
		L	6.85	Mainstem	O	EF
		R	7.15	Side channel / Mainstem	O	EF, MT, SN
		L	8.4	Mainstem	C	EF
	5	L	8.6	Side channel	C	EF
		L	8.65	Mainstem	C	EF
	6	R	10.6	Side channel	C	EF
		R	10.65	Side channel	O	EF
		L	10.8	Side channel	O	EF, MT, SN
	7	L	11.1	Side channel	C	EF
		L	11.15	Mainstem	C	EF
		R	11.9	Mainstem	C	EF
		R	11.95	Mainstem	O	EF
	8	R	13.6	Mainstem	O	EF
		L	14.4	Mainstem	O	EF, MT
		L	14.8	Mainstem	C	EF, SN
		L	15.15	Mainstem	O	EF
	4	Gorbuscha Channel		Side channel	C	EF
		Emerald Forest Creek		Side channel	C, O	EF, MT
Cheekye River		Brohm River		Upstream (3.1 km from confluence)	C	EF
		Brohm River		Downstream (0.7 km from confluence)	C	EF

* Distance (km) from the confluence with Squamish River (km 0). R = right bank; L = left bank; O = open electrofishing site; C = closed electrofishing site; EF = electrofishing; MT = minnow trapping; SN = seining.

Two sample 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. Brohm River was selected because it is part of the Cheakamus River watershed, has been sampled in previous years using the same methods as employed in the Cheakamus River (*e.g.,* van Dishoeck, 2000, 2002; van Dishoeck and Horne, 2002), and for its potential as a reference site.

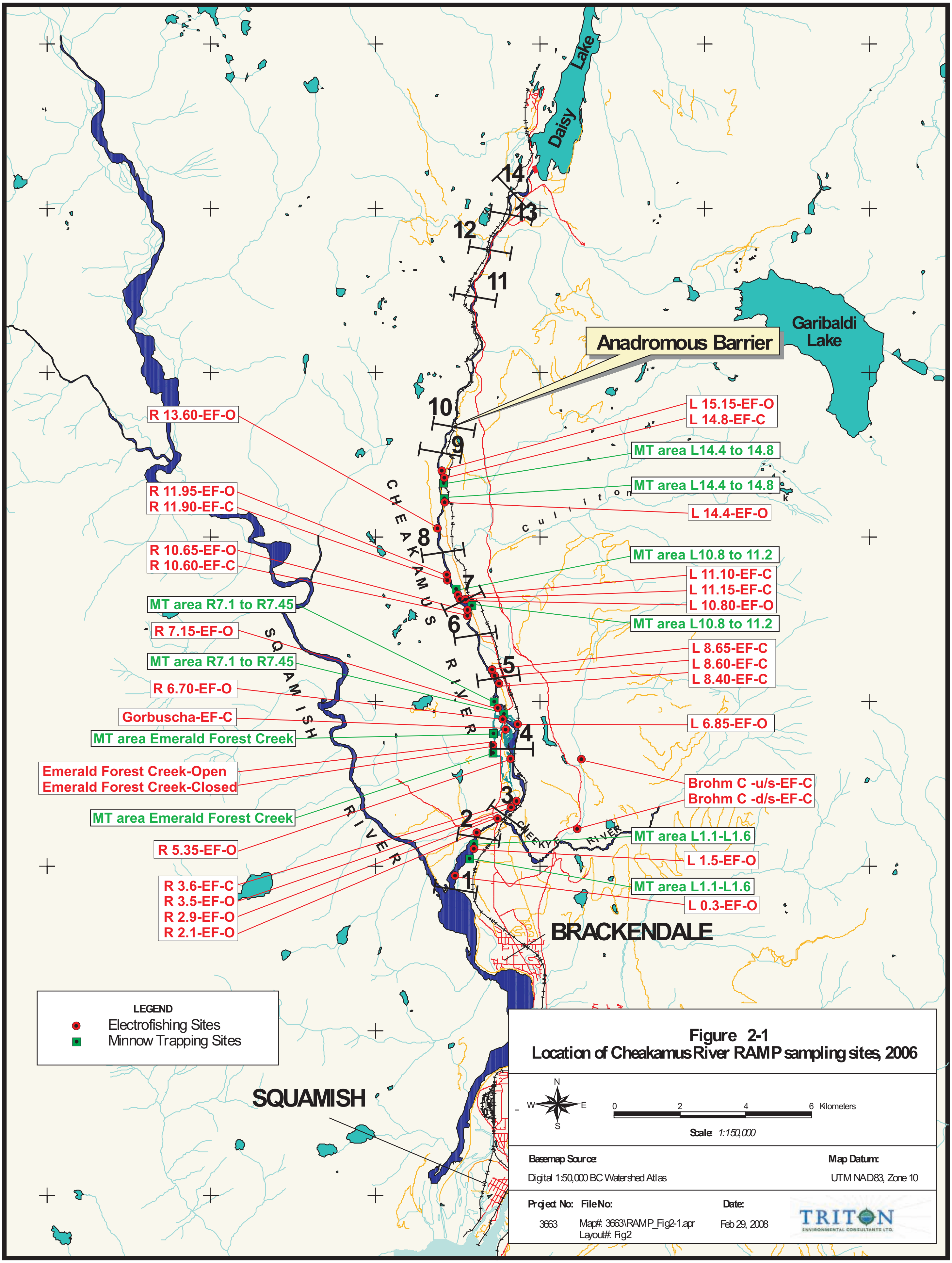


Figure 2-1
Location of Cheakamus River RAMP sampling sites, 2006

2.4 Physical Habitat

Site characteristics, as well as hydrological and water quality data, were collected for each electrofishing site (Table 2-2) and similar, although less-detailed data were collected for minnow trapping and seining sites. Site characteristics were measured with electronic instruments (calibrated to manufacturers' 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). For ground estimates survey crews discussed parameters in order to arrive at a consensus and minimize variation associated with subjective assessments.

Table 2-2. Electrofishing site characteristics measured, Cheakamus River, 2006

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)	% Sand	GE
Temperature (°C)	Hanna Combo Meter (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
Turbidity (cm)	GE		

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

Photographs were taken at each sampling area to show habitat features and sampling 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 3.

Depth and Velocity Profiles

Depth and velocity profiles were measured at transects within 24 of the 29 electrofishing sites. One transect per site was surveyed at a location representative of flow and depth characteristics (Photo 4). 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.

2.5 Fish Sampling

Sampling was conducted from September 11 to 29, 2006, by a four-person crew. Electrofishing, minnow trapping and seining were the three methods selected. Snorkelling and angling were discounted due to the size and habitat preferences of target species, difficulties in replicating observer efficiency and likelihood of variable visibility conditions between surveys. Sampling methods were chosen to emulate those of previous studies on the Cheakamus River (Sneep, 2001; van Dishoeck, 2000, 2002; van Dishoeck and Horne, 2002) and the sampling period was also chosen based on the timing of these same studies. Sampling was conducted by a four-person sampling crew over a period of approximately 20 days (flow and stage permitting).

Captured fish were lightly anaesthetized with clove oil and then identified to species, 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 using an electronic balance (Photo 5). Fish were allowed to recover in aerated buckets, after which time they were released back into the river near the vicinity of capture. No live fish were sacrificed for voucher specimens and the very few inadvertent mortalities were recorded.

2.5.1 Electrofishing

Twenty-seven electrofishing sites were established along the Cheakamus River mainstem and side channels, as well as two in Brohm River (Table 2-1). Locations of the electrofishing sites are shown in Figure 2-1. 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. Electrofishing site selection criteria included but were not limited to:

- Cover (abundance of boulder, pool, undercut bank, etc)
- Velocity (variation provided by cover features)
- Depth (no greater than 1.5 m)
- Safe wading and access for survey crew

All sites were sampled with triple-pass depletion to maximize total catch and allow for density calculations. Each pass consisted in one methodical sweep in an upstream direction. Crews strived to maintain a consistent sampling effort among passes and sites (*e.g.*, by monitoring the electrofisher counter). Thirteen enclosed sites were established mainly in shallow, low velocity areas with relatively easy access. Sites were isolated with a 30 m by 0.25-inch square mesh seine net with floats at the top and a lead line at the bottom. It was not possible to enclose all electrofishing sites with stop nets because of steep banks, proximity of streamside vegetation, velocities and/or large uneven substrate (boulder or large cobble), which may have allowed fish to bypass nets. Open pass electrofishing was used in 16 sites where the use of stop nets was deemed inefficient or dangerous. Flagging was placed along the shoreline to delineate the upstream and downstream boundaries during sampling. The length of the anode pole and in some cases natural features (such as boulders) were used as references to delineate and maintain the width of open sampling sites.

2.5.2 Minnow Trapping

Minnow trapping areas were chosen based on accessibility and habitat suitability for target species. Minnow traps were set overnight (for up to 24 hours), along five 500 m long sections of the Cheakamus River mainstem and side channels (Photo 6; Figure 2-1). Traps were baited with salmon roe (approximately 5 g/ trap) and approximately 10 traps were set per 100 m of stream length, totalling 50 traps per sampling area. 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. 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 bull trout. Trap site selection criteria included but were not limited to:

- Presence of cover (*e.g.,* large woody debris (LWD), pool, undercut bank or boulder)
- Velocity (suitable to avoid fish impingement in trap)
- Depth (minimum of 20 cm to insure traps were submerged)
- Safe access for survey crew

The following data were recorded for each minnow trap (field data forms in Appendix 4):

- UTM coordinates
- Set/retrieval date and time
- Hydraulic unit type (*e.g.,* riffle, pool, run) representative of the area in the trap vicinity
- Measured trap depth (m): from substrate to surface
- Cover type near trap location, and estimated proximity to cover (m)
- Presence/absence of bait remaining after each set
- Fish species, number, length, weight

Minnow trapping was used as a complementary sampling method and provided a valuable, low-cost method to sample habitat where electrofishing was not practical, as well as confirmation of species and age class information obtained by electrofishing. Overnight sampling may also allow the capture of fish exhibiting nocturnal or crepuscular feeding habits, such as sculpins (McPhail, 2007).

2.5.3 Seining

Four seining sites were established along the Cheakamus River. Seining (using either beach seine or pole seine) was conducted in an effort to target newly emerged fish in backwater areas. At each site a minimum of three and typically five passes were conducted with the seine net and results were pooled from all passes. As with minnow trapping, seining was identified as a complementary sampling method to electrofishing, possibly capturing different species or age classes. Therefore results are not meant to be taken as stand-alone data to assess recovery.

2.6 Data Compilation and Analyses

Project-specific data forms were developed to ensure consistent data collection at each sampling site (Appendix 4). The data collected were then analysed to provide information on:

- Habitat quality in sampled areas;
- Catch per unit effort for minnow trapping, expressed as fish/trap (CPT);
- Densities and adjusted densities, expressed as fish per unit (fpu), where one unit equals 100 m^2, based on electrofishing data (see formulae Section 2.6.1);
- Length and weight; and,
- Condition factor (K) for salmonids (see formula in Section 2.6.3).

2.6.1 Catch and Densities

Electrofishing

Electrofishing data were used to calculate relative density estimates for juvenile rainbow trout and other species. Site density estimates were calculated using maximum likelihood estimates (MLE; Zippin, 1956; Seber, 1982) generated by the software MicroFish 3.0 (Van Deventer, 1989). The maximum likelihood estimate (MLE) 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). *Measured densities* (population estimate divided by sampled area) were converted to fish per unit (fpu), where one unit equals 100 m^2.

Adjusted densities were calculated for rainbow trout fry, 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. Thus, a 100 m^2 site may be reduced to 60 m^2 of "usable area" for rainbow trout fry, and 40 m^2 for parr, based on the habitat suitability indices of each age class and depth and velocity characteristics obtained from a representative transect. The adjusted densities are then calculated from the catch divided by the usable area. This method considers some of the differences in habitat conditions (depth and velocity) between sites, and from year to year, allowing for a standardized comparison.

Only densities for rainbow trout fry 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 also affect density. As juveniles become larger, habitat use is more strongly influenced by the presence of suitable cover features and substrate size. The adjustment of parr densities based on depth and velocity characteristics is less reliable and not recommended (Ptolemy, 2007: oral comm.), and therefore, it was not calculated for this study.

Minnow Trapping

Trap soaking times varied from 19 to 22 hours. Studies conducted by Swales (1987) indicated a decrease in trap efficiency over time, and therefore 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 suggested it was 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 sample efficiency over time could not be quantified, field crews endeavoured to standardize soak times as much as possible between sampling locations. The catch per unit effort was then standardized as overnight sets, and catch rates for minnow traps were calculated as the number of fish per trap (catch per trap; CPT).

2.6.2 Length-Frequency Distributions & Age Classes

Growth of juveniles over time should result in different length class distributions from year to year, thus age class delineation is typically based on examination of length-frequency data and scale readings from a sub-sample of specimens collected during the time of sampling, to confirm the age length-frequency relationship.

Age classes for this program were assigned based on the observed modes in length-frequency and correlated by comparing age distribution to data collected on rainbow trout in the Cheakamus (van Dishoeck and Horne, 2002; McCubbing *et al.,* 2006). Previous studies have demonstrated lengths of young of the year (age 0+) rainbow inhabiting the Cheakamus in late summer (August to September) range from 20 to 75 mm fork length. The size limits for age 1+, however, are more contentious, varying from 76 to 115 mm (van Dishoeck and Horne, 2002) or from 83 to 175 mm (McCubbing *et al*., 2006). Variations in fish length between years may be reflective of environmental factors such as temperature (which may affect emergence time and growth rates), or may be density related (which may be affected by increased competition among larger fish). Inter-annual variations may also be a function of sampling time as the length of young of year fry may change considerably from August to September. Age class delineation for fry and 1+ rainbow based on length-frequency distribution was considered to be consistent with information reported for other studies in the Cheakamus River. Age class delineation was less reliable for older parr (2+ and 3+) due to a smaller sample size.

Length-frequency distributions were generated for cottids, lamprey and rainbow trout. Age classes were assigned, when possible, based on the observed modes in length-frequency.

2.6.3 Condition Factors

Fish condition may reflect habitat quality and food availability, especially in the case of juveniles, whose somatic condition is directly linked to food availability. Monitoring fish condition over time was considered a good indicator of changes in habitat quality, food availability and potentially in fish population recovery, depending on the degree of egress.

The physical condition of rainbow trout was calculated based on length and weight measurements 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:

$$K = (W*FL^{-3}) *10^{5}$$

where W = weight (g)
FL = 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: oral comm.). As a result, caution should be applied when utilizing condition indices to make assumptions concerning fish "health". These indices, however, provide a good method to evaluate and monitor changes in general population condition over time.

3.0 Results

3.1 Site Characteristics

3.1.1 Electrofishing Sites

Site characteristics were described based on criteria outlined in the Reconnaissance (1:20,000) Fish and Fish Habitat Inventory, Standards and Procedures (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. When site parameters could not be quantitatively measured, survey crews discussed site characteristics and attempted to arrive at a consensus in order to minimize this subjective variability. However, as parameters such as habitat unit types and percent cover or substrate cannot be objectively quantified, comparisons between sites based on these characteristics should be tempered with some caution, particularly when variation is small or if there is overlap between parameters (*e.g.,* riffle/pool vs. pool/riffle).

Site characteristics were collected from 27 electrofishing sites on the Cheakamus River, including 5 natural and 2 man-made side channel sites, as well as from 2 sites on Brohm River (a tributary of the Cheekye River; Figure 2-1; Table 2-1). Detailed site characteristics, depth-velocity profiles and a photograph of each site are provided in Appendix 3.

Hydraulic Unit Types

Half of the electrofishing sites consisted of a single hydraulic unit type (HUT), whereas the other half consisted of two or more (although only the primary and secondary types were recorded). Riffle dominated mainstem electrofishing sites (62% overall), while non-turbulent waters (run, glide and pool) characterized the remainder of mainstem sites (Figure 3-1). Side channel sites (both natural and man-made) were characterized as pool (50% overall), as well as riffle and glide. The upstream site in Brohm River was characterized as riffle/pool and the downstream site was characterized as run.

Depth/Velocity Profiles

Depth and velocity transects were measured at 26 electrofishing sites (Appendix 3). Mainstem sites were in deeper water and lower velocities than side channel and Brohm River sites (Figure 3-2). Water depth averaged 0.23 m in mainstem sites, 0.17 m in natural side channel sites, 0.19m in man-made side channel sites and 0.17 m in the Brohm River sites. Mean velocities recorded along the mainstem transects ranged from 0.06 to 0.25 m/s, with a maximum velocity of 0.67 m/s recorded at the L14.4 site. The mean velocities in the natural side channel sites ranged from 0.15 to 0.25 m/s, with a maximum velocity of 1.00 m/s at the L10.8 site. The mean velocity in Emerald Forest Creek and Brohm River was 0.17 m/s, with a maximum velocity of 0.70 m/s in the upstream Brohm River site. No transects were measured at the R6.7, R7.15 and the Gorbuscha channel site, as no velocity was observed.

Figure 3-1. Percent hydraulic unit types at electrofishing sites

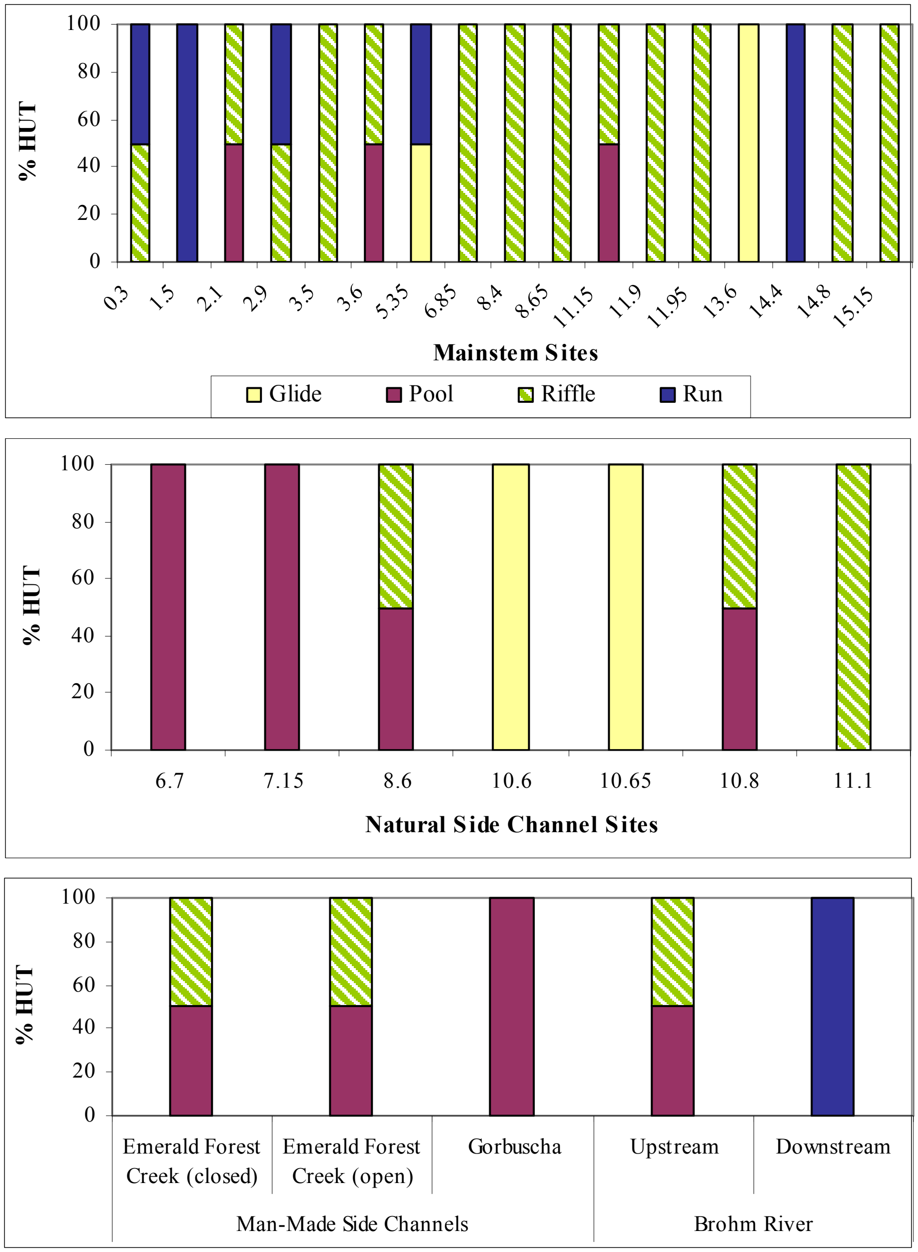
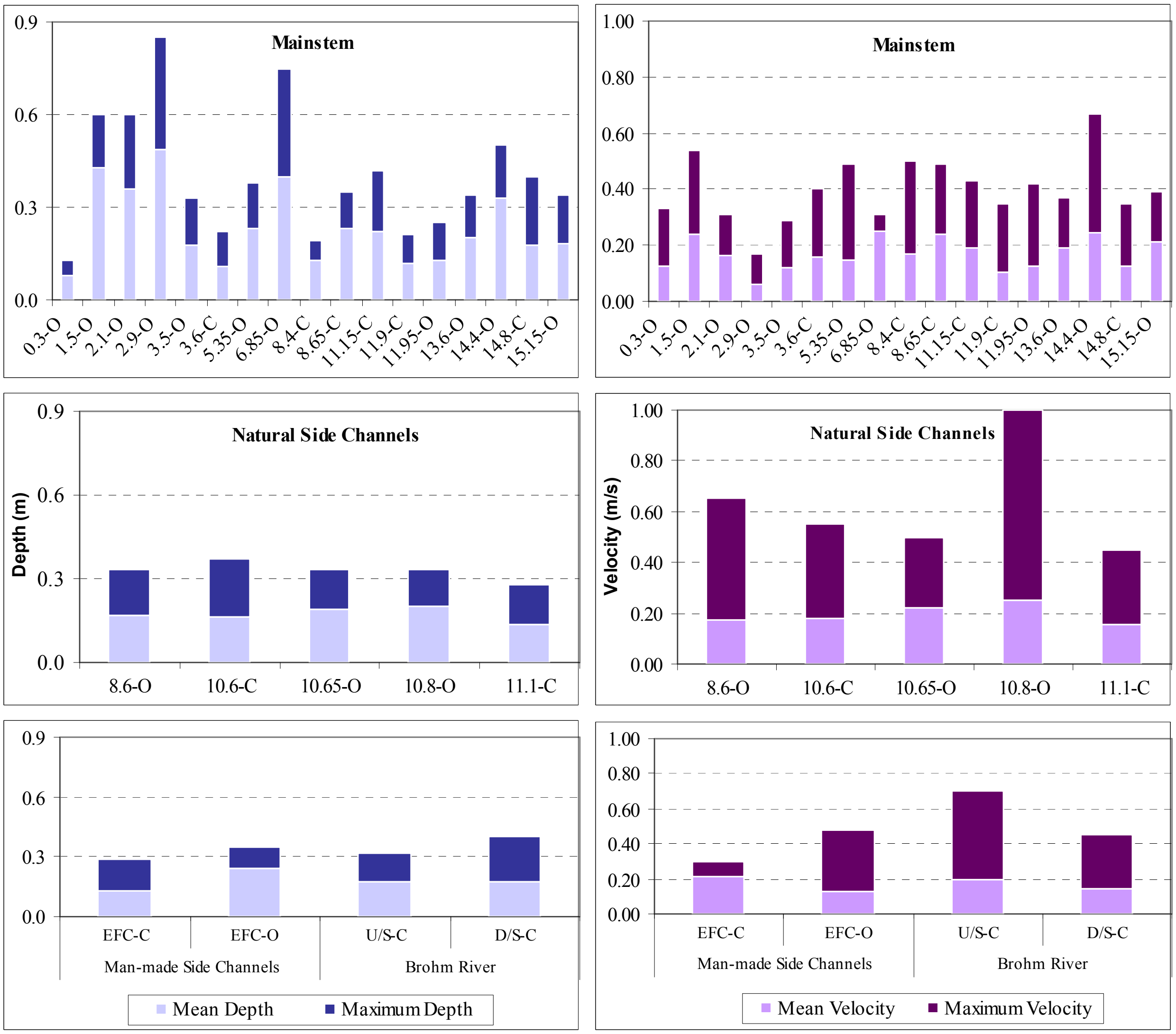


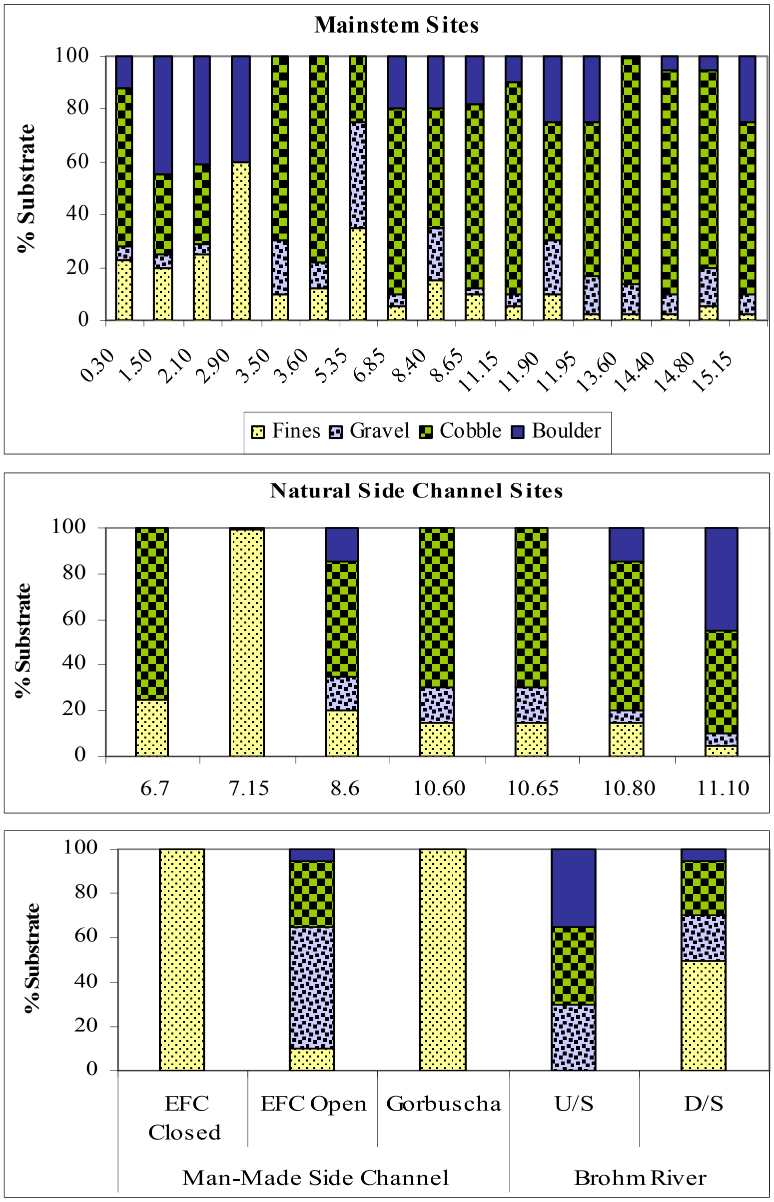
Figure 3-2. Depth and velocity measurements in electrofishing sites



Substrate

Mainstem sites were dominated by cobble (57% - average cover among 17 sites), while boulder (17%), fines (15%) and gravel (11%) comprised the remaining substrate (Figure 3-3). Natural side channel sites were dominated by fines and cobble (approximately 77%), while man-made side channel sites were dominated by fines (approximately 70%). In Brohm River, the upstream and downstream sites were characterized by boulder and gravel or boulder and cobble, respectively.

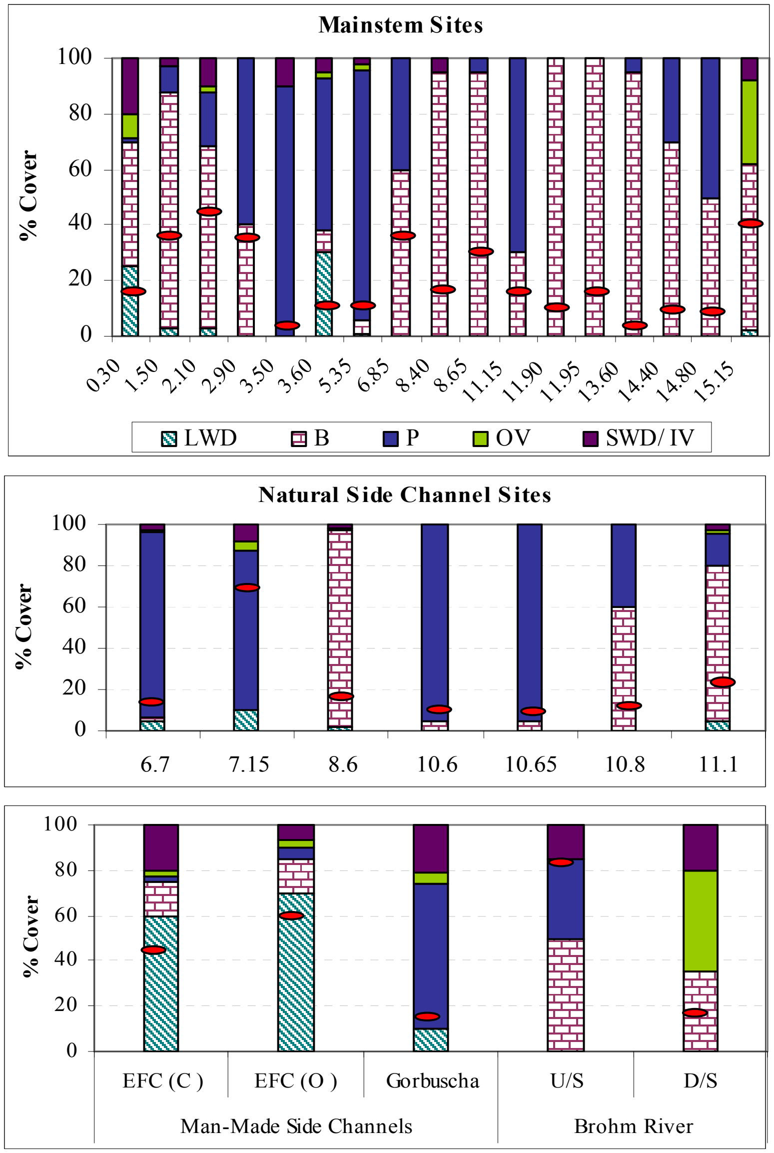
Figure 3-3. Percent substrate by type at electrofishing sampling sites



Cover

Estimated total cover per site varied between 5% and 85%, with 23 out of 29 sites containing between 10% and 35% total cover (Figure 3-4). The three sites with estimated total cover above 50% encompassed a large pool area (R7.15), an enhanced habitat area with dense large woody debris (LWD; Emerald Forest Creek-open), and a dense boulder field (Brohm River-upstream). Boulders and pools provided most of the available instream cover in mainstem sites (comprising approximately 90% of available cover). Pools and boulders provided 43% and 30% of the cover, respectively, in the natural side channel sites. LWD provided the majority of cover in Emerald Forest Creek and pools dominated the Gorbuscha site. In Brohm River, the majority of cover was provided by boulders in the upstream site and by overstream vegetation in the downstream site.

Figure 3-4. Relative percent of each cover type in electrofishing sites



Note: Red dot represents estimated total percent cover available at each site.

3.1.2 Minnow Trapping Sites

Table 3-1 presents a summary of minnow trapping site characteristics in the four minnow trapping areas along the Cheakamus River and the one in Emerald Forest Creek. The characteristics of individual minnow trapping sites are provided in Appendix 5. Mean trap depth varied between areas, ranging from 0.38 m to 0.60 m. Traps were set relatively evenly among glide, pool, riffle and run habitat (between 55 and 67 traps/hydraulic unit type). Cover was provided mainly by boulders (45%) and large woody debris (LWD: 29%). All minnow traps were set in low to no velocity sites to avoid fish impingement and stress on captured individuals.

Table 3-1. **Summary of habitat characteristics for minnow trap sampling areas, 2006.**

Trap Data	Left Km 1.1-1.6	Right Km 7.1-7.45	Left Km L10.8-11.2*	Left Km 14.4-14.8	Emerald Forest Creek
Total no. traps retrieved	49	50	50	49	50
Mean trap depth (m)	0.38	0.60	0.41	0.53	0.45
SD	*0.14*	*0.43*	*0.16*	*0.25*	*0.24*
Min	*0.2*	*0.2*	*0.13*	*0.3*	*0.25*
Max	*0.9*	*1.5*	*0.9*	*1.3*	*1.40*
No. traps / HUT					
Pool	0	15	18	9	20
Glide	4	18	0	29	11
Run	30	12	12	0	13
Riffle	15	5	18	11	6
No. traps / Cover type					
Boulder	47	17	20	17	10
LWD	0	18	8	10	36
SWD	1	5	6	12	0
Cutbank	1	4	8	8	2
Overstream vegetation	0	1	7	2	1
Pool	0	5	1	0	1

SD: Standard deviation; * Habitat Unit Type data not recorded for 2 traps.

3.1.3 Water Quality

Daily *in situ* water quality measurements were collected at minnow trapping and electrofishing sites. Hanna HI98129 Combo meters (calibrated daily) recorded similar conditions in all three minnow trapping areas where measurements were collected. The mean water temperature in mainstem areas was 10.8°C, while it was 11.1°C in Emerald Forest Creek. Conductivity varied by 20 µS between minnow trapping area R7.1-7.45 and L14.4-14.8 (40µS and 60µS, respectively), and was 40 µS in Emerald Forest Creek.

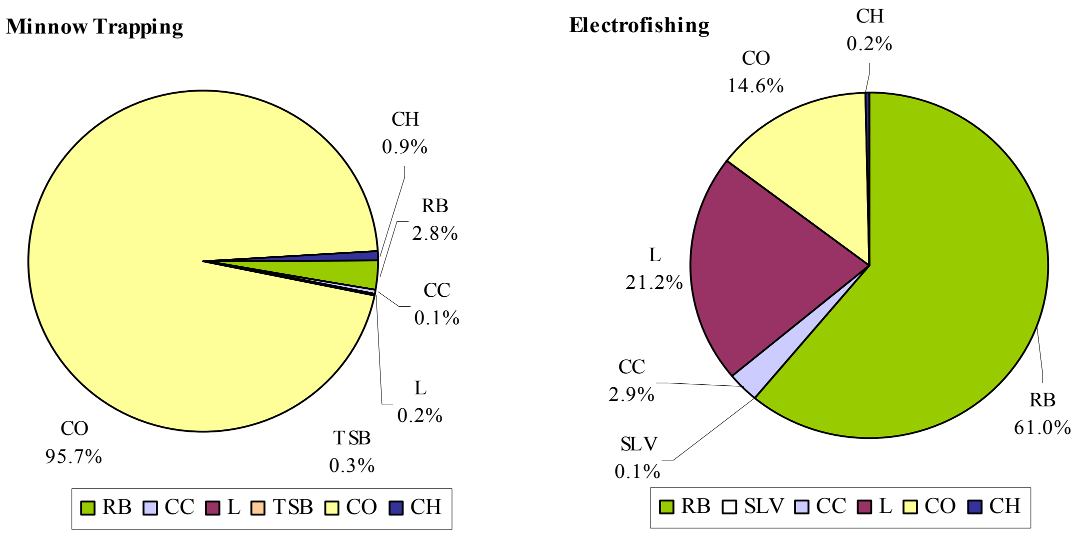
Temperature, pH and conductivity were similar among electrofishing sites, with some variations between the mainstem and side channel sampling sites (Appendix 6). Temperatures ranged between 8.6°C and 13.9°C and were highest in side channels. All pH values (7.32 to 8.12) fell within the range of recommended values for the protection of freshwater life (CCME, 2007; MoE, 1998). Conductivity ranged between 30 µS and 65 µS. Additional information regarding background water quality of the Cheakamus River is also available in Triton, 2006 and 2007a.

3.2 Catch Distribution

The total catch in the Cheakamus River mainstem, side channels and tributaries during the September 2006 sampling period was 5,664 fish. Electrofishing accounted for 3,248 fish, minnow trapping for 2,348 and seining for 68. Target species accounted for 51% of total catch: 2,096 rainbow trout, 694 lamprey, 98 cottids, 7 threespine stickleback and 2 bull trout. The remaining catch was composed of 2,219 coho and 18 chinook salmon.

With the exception of threespine stickleback (only captured by minnow traps) and bull trout (only captured by electrofishing), the two methods yielded similar species, although in different ratios (Figure 3-5). Coho accounted for approximately 96% of the minnow trapping catch, while rainbow trout accounted for the majority (61%) of fish captured by electrofishing.

Figure 3-5. Percent catch by sampling method, 2006



RB: rainbow trout, CC: sculpin, L: lamprey, TSB: threespine stickleback, CO: coho, CH: chinook, SLV: char.

3.2.1 Electrofishing

Twenty-seven electrofishing sites were sampled along the Cheakamus River during the 2006 survey, resulting in 3,248 fish captured in the mainstem and side channel sites (individual site data are provided in Appendix 7). The electrofishing catch consisted of approximately 85% target species: rainbow trout accounted for the majority (72%), while bull trout, cottids and lamprey accounted for the remaining 13% (Table 3-2). Coho and chinook accounted for approximately 15% of the total electrofishing catch (479 fish).

Table 3-2. Electrofishing catch composition for target species (excluding Brohm River), 2006

Site Type	RB		CC		L		SLV		Total Catch
	Catch	% Catch	Catch	% Catch	Catch	% Catch	Catch	% Catch	
Open (n=16)	1,176	71.45	94	5.71	375	22.78	1	0.06	1,646
Closed (n=11)	806	71.77	1	0.09	315	28.05	1	0.09	1,123
Combined	**1,982**	**71.58**	**95**	**3.43**	**690**	**24.92**	**2**	**0.07**	**2,769**

In Brohm River, 38 rainbow trout were captured in the upstream site and 176 were captured in the downstream site. No other species were caught in Brohm River.

3.2.2 Minnow Trapping

Although minnow traps captured approximately 42% of the total 2006 catch, target species accounted for only 3.3% of the minnow trapping catch (Figure 3-5) and 1.4% of the total catch (all methods combined). Most rainbow trout (83%) were captured within minnow trapping area L14.4-14.8 (Table 3-3). Cottids were only captured in area L1.1-1.6 and threespine stickleback, in Emerald Forest Creek. No target species were captured at area L10.8-11.2. Individual catch per trap data are provided in Appendix 5. The catch per trap (CPT) for target species varied between 0 and 1.12, with an average CPT of 0.32.

Table 3-3. Minnow trapping catch composition for target species, Cheakamus River, 2006

Area	No. of Traps	RB		CC		L		TSB		Total Catch
		Catch	CPT	Catch	CPT	Catch	CPT	Catch	CPT	
L1.1 to 1.6	49	9	0.18	3	0.06	1	0.02	0	0	13
R7.1 to 7.45	50	1	0.02	0	0	1	0.02	0	0	2
L10.8 to 11.2	50	0	0	0	0	0	0	0	0	0
L14.4 to 14.8	49	55	1.12	0	0	1	0.02	0	0	56
EFC	50	1	0.02	0	0	1	0.02	7	0.14	9
Total	**248**	**66**	**0.27**	**3**	**0.01**	**4**	**0.02**	**7**	**0.03**	**80**

Coho and chinook accounted for approximately 97% of the total minnow trap catch (Figure 3-5). Chinook were only captured at site L10.8-11.2 (n=22), while coho were the most abundant species captured in all trapping areas (n=2,246) and accounted for 96% of the total minnow trapping catch. The mean CPT for coho was 9.06 and 0.09 for chinook.

3.2.3 Seining

In-stream obstacles (boulders, LWD, etc.) and turbidity limited the effectiveness and ability to seine in many areas. Some areas initially identified as good potential seine sites turned out to have large obstructions or other site characteristics which limited the sampling crews' ability to effectively sample sites targeted by this method (*i.e.,* seining was attempted at other locations and abandoned after encountering obstructions). A total of 68 fish were captured in 18 seine sets (average 3.7 fish/set), which accounted for 1.2% of the total 2006 catch, of which 71% were rainbow trout, 25% coho and 4% chinook (Table 3-4). The five sets conducted near km 14.6 accounted for 90% of all fish captured by seining.

Table 3-4. Seining catch composition, 2006

Site	No. of Sets	RB	CO	CH	Total Catch
L1.1	3	0	1	0	1
R7.3	5	0	0	0	0
L10.8	5	0	3	3	6
L14.6	5	48	13	0	61
Total	**18**	**48**	**17**	**3**	**68**

3.3 Population Parameters

Length-frequency distributions and length-weight relationships were generated for cottids, lamprey and rainbow trout, whereas the low number of char and threespine stickleback limited the ability to apply this analysis to these species. Length-frequency distribution was used in an effort to assign age groups based on length classes. Condition was also assessed for rainbow trout. The individual lengths and weights of fish measured in 2006 are presented in Appendix 8.

3.3.1 Habitat Use

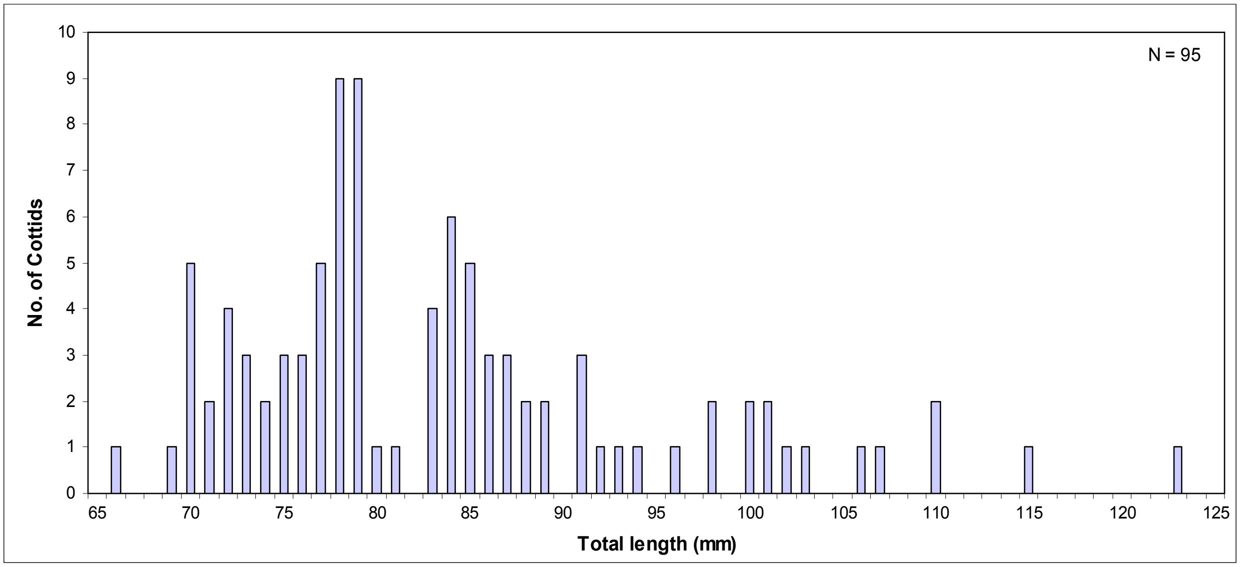
Habitat quality may impact fish growth in various ways. Certain factors, such as hydrology and water quality, can influence fish distribution and growth rate. Five main HUTs were recorded in the mainstem and side channel electrofishing sites: riffle, glide, run, riffle/pool and riffle/run. Since the type of habitat may affect the growth rates of fish and may introduce spurious variations in analyses, the influence of HUTs on rainbow trout and lamprey abundance was examined (catch for these species were sufficiently high to allow analyses). Five variables were measured for each HUT: water temperature, water depth, conductivity, velocity and pH. These were reduced to one variable accounting for 84% of the variance among HUTs. Based on this variable, glides and riffles and riffle/run/pools formed two distinct groups. These two groups were then used as covariates when analyzing each species length/weight relationship to account for the potential influence of these factors. Lengths and weights were only pooled across hydraulic units after verifying there was no interaction between these parameters. Further details of this analysis are provided in Appendix 9.

3.3.2 Cottids

The mean total length of cottids in September 2006 was 84 mm ± 12 mm SD (n = 95, median 80 mm). Based on the length frequency analysis in Figure 3-6 it is difficult to draw conclusions about age class distributions for cottids in this study. While it appears there are at least two age classes (*e.g.,* fish 65 to 90 mm and fish greater than 90 mm), the two peaks, at 78 to 79 mm and at 84 mm, may also suggest two different cohorts. However, these peaks could also be species-related (with prickly sculpins reported to be larger in size).

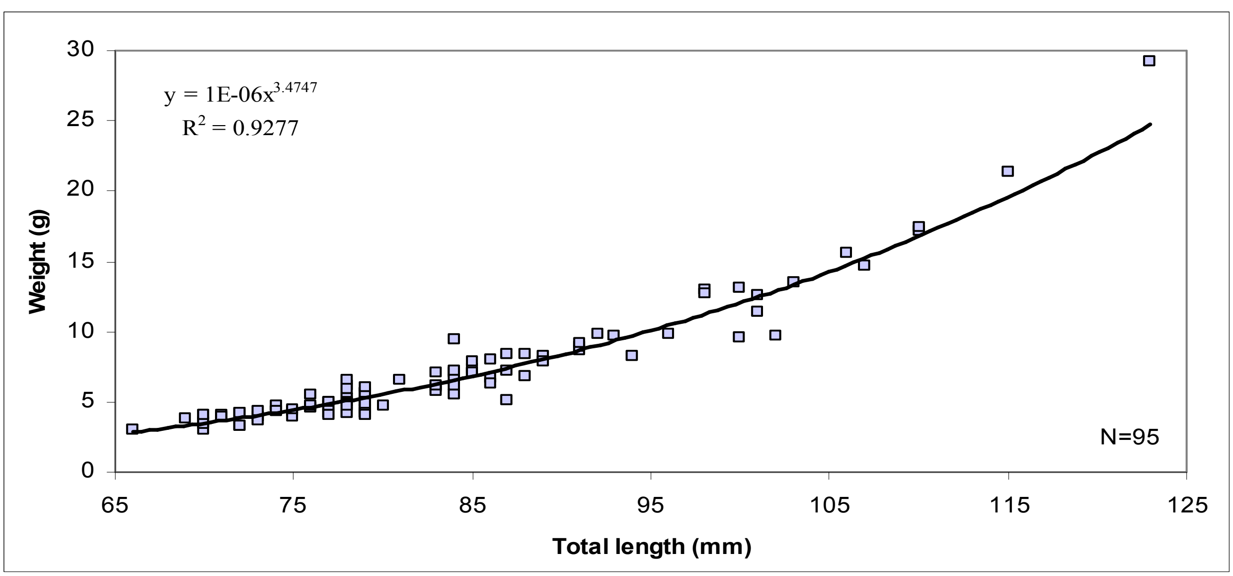
Based on other studies and measured lengths of cottids captured in 2006, the cottid population in the Cheakamus River appears to be composed of second year fish and older. Ringstad and Narver (1973) reported mean total lengths of 57.0 mm and 65.5 mm for age 2 *C. aleuticus* and *C. asper* respectively (Vancouver Island, in August). Wydoski and Whitney (2003) reported mean total lengths of 48 to 71 mm for second year coastrange sculpin and 86 mm for prickly sculpin (West coast of United States, sampling period not specified; spring/summer).

Figure 3-6. Length-frequency distribution of cottids captured by electrofishing, 2006



The weight of cottids measured in this study varied between 3 g and 29 g, with an average of 7.1g ± 7 g SD. Figure 3-7 shows the length/weight relationship of cottids based on data from September 2006.

Figure 3-7. Length/weight relationship of cottids captured by electrofishing, 2006

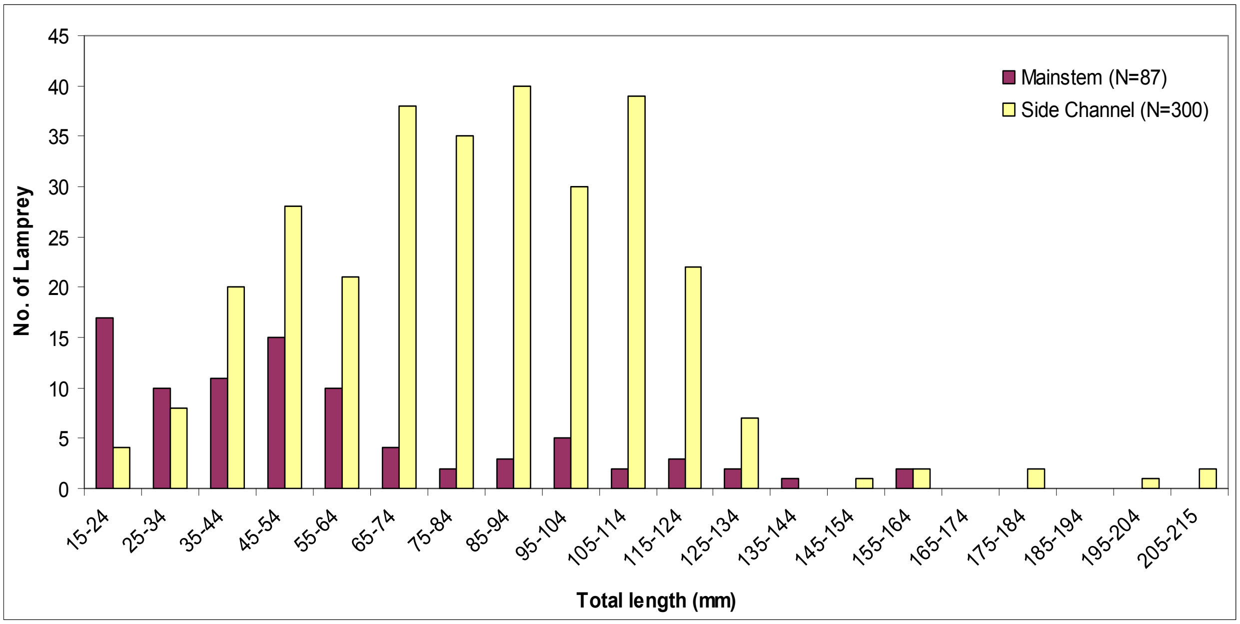


3.3.3 Lamprey

A total of 387 lamprey were measured for total length (mm) and 177 were weighed (0.01 g). All but four fish were ammocoetes (Photo 7 and 8). Measured ammocoetes varied between 16 and

159 mm in length (mean = 56 mm ± 35 mm SD) in mainstem sites, and between 18 and 215 mm (mean = 83 mm ± 31 mm SD) in side channel sites (Figure 3-8; Appendix 8).

Figure 3-8. Length-frequency distribution of lamprey captured by electrofishing, mainstem vs. side channel sites

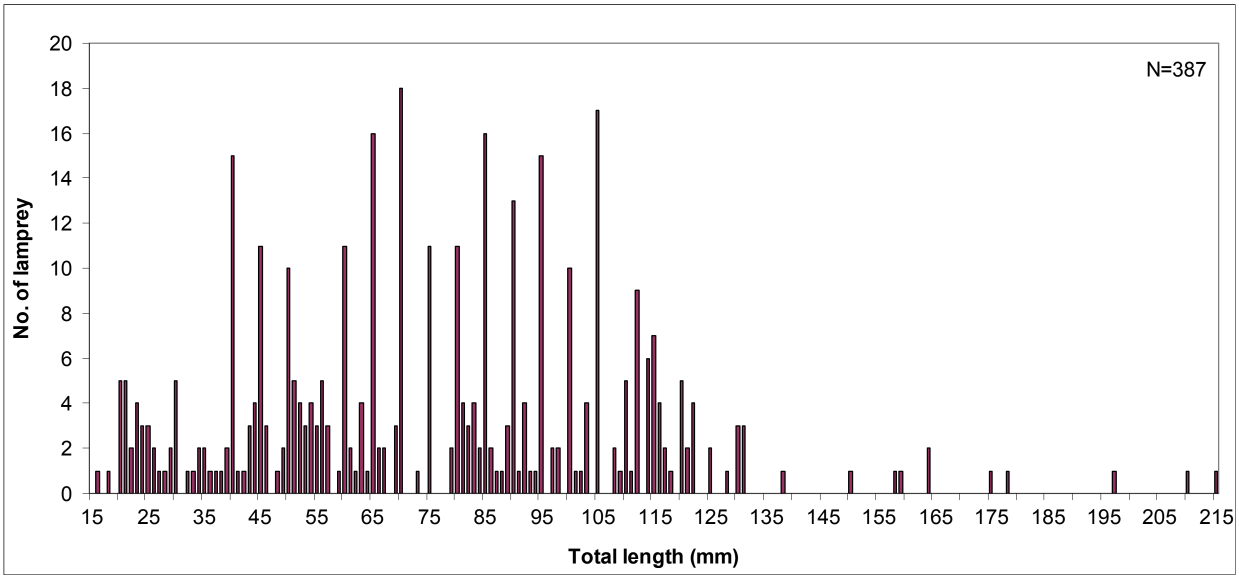


Four adult (eyed) lamprey were captured during the 2006 sampling season. Lengths varied between 159 and 210 mm. One specimen was identified as western brook lamprey (*Lampetra richardsoni*), based on morphometric characters described in McPhail (2007): two blunt supraoral teeth, no median tooth on tongue and blunt cusps on infraoral tooth bar (Photo 9), combined with a length of 159 mm. Another specimen was identified as a potential river lamprey (*L. ayresii*), based on the sharper appearance of the two supraoral teeth (compared to the above-mentioned specimen; Photo 10) and a total length of 210 mm; McPhail (2007) indicated western brook lamprey rarely exceed 160 mm. However, this specimen may also have been a newly transformed – albeit large – western brook lamprey, as macropthalmia (newly metamorphosed lamprey) of this species can present the oral disc characteristics of the river lamprey (*i.e.,* sharp cusps) for up to three weeks following transformation (Beamish, 2008, oral comm.). The other two specimens could not be identified. One individual identified as a Pacific lamprey (*L. tridentata*) was captured in May 2006 during preliminary sampling to identify sites for resident fish abundance monitoring at site L0.30 (Photo 11 and 12, Triton data on file). In addition the presence of Pacific lamprey was established by McCubbing *et al.* (2006; Section 4.1.2).

Since ammocoetes could not be identified to species, length-frequency distribution was not used to try to ascertain age classes. However, length-frequency distribution of lamprey from both mainstem and side channel sites was combined to examine the general distribution of size classes and to see if there were any gaps in size classes (Figure 3-9). Species-specific information on size at age for lamprey was not identified for the Cheakamus River. A literature review was undertaken to identify if length information from other systems could be used to develop age class delineations from the length-frequency information.

McPhail (2007) reported average lengths of young-of-year (YoY) Pacific lamprey as 10 to 25 mm in August and 18 mm (14 to 21 mm) for western brook lamprey in September. Based on this information, it is clear YoY lamprey were captured in 2006, although the size distinction between YoY and older fish is not clear (Figure 3-9) and the species represented is unknown.

Figure 3-9. Length-frequency distribution of lamprey captured by electrofishing, all sites, 2006

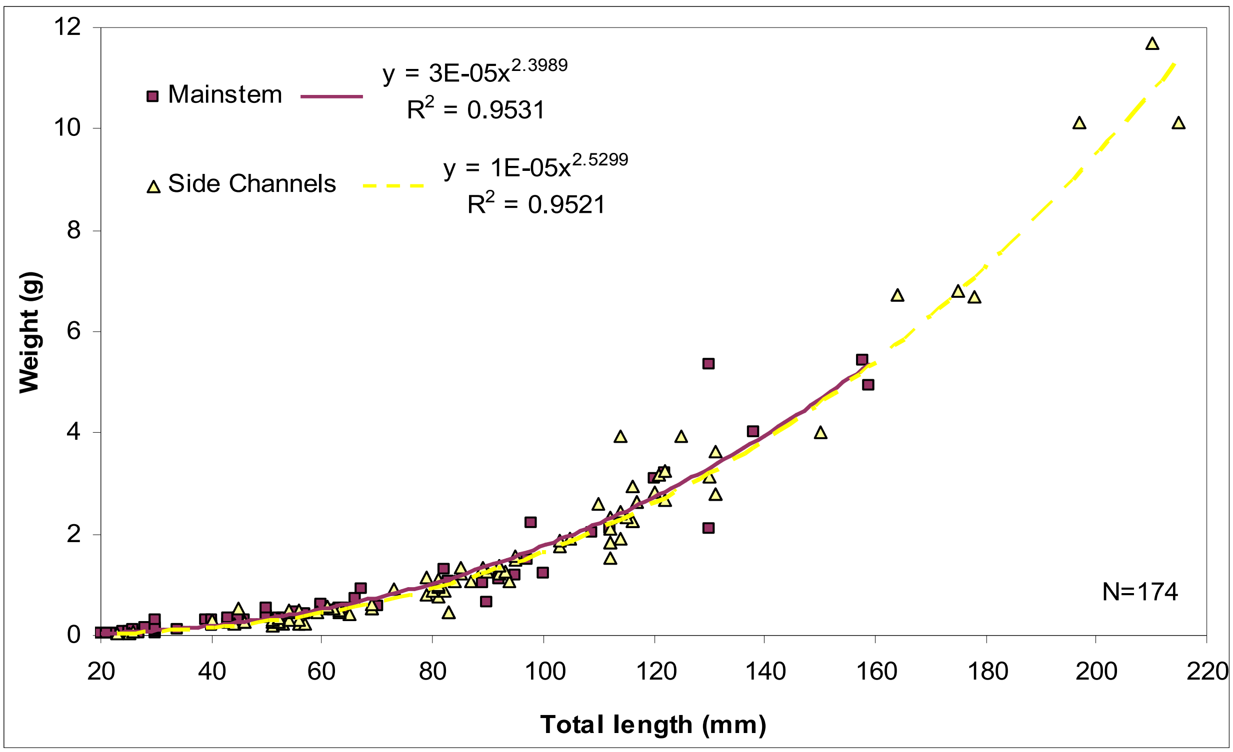


Beamish and Levings (1991) indicated the metamorphosis of most Pacific lamprey (captured during spring outmigrations) into the adult form occurs around the age of 4 or 5 years, at average lengths of 120 to 140 mm. However, the age also varied between 4 and 8 years. Based on examination of statoliths and lengths from a limited sample of Pacific lamprey ammocoetes (n=33), Beamish and Levings (1991) identified mean lengths at age of: 60 mm - age 2; 80 mm - age 3; 115 mm - age 4; 115 mm - age 5; and 119 mm - age 6. The long river residency period and variations in age of adults also suggest considerable variation in growth rates of ammocoetes. McPhail (2007) reported average lengths for pre-metamorphosis Pacific lamprey ammocoetes of 120 to 176 mm and reported the average size of young adults entering salt water as 130 mm. The average length of western brook lamprey ammocoetes has been reported to vary between 115 and 120 mm (McPhail, 2007). The length of ammocoetes is also known to vary among populations, but is rarely reported to exceed 150 mm (McPhail, 2007). In summary, the literature indicates considerable variation in the size and age of ammocoetes for both species, and McPhail (2007) suggests this makes the length-frequency method unreliable for aging older Pacific lamprey ammocoetes. Discerning other age classes based on the length-frequency distribution is also complicated by the difficulties in distinguishing between the two species of lamprey present in the Cheakamus River and variations in reproductive timing and growth rates even within species.

In summary, the length-frequency distribution of lamprey captured in 2006 does not show distinct cohorts (Figure 3-9) or gaps in size classes. Based on the literature reviewed, lamprey in the Cheakamus River would be expected to have similar YoY (15 to 40 mm), and metamorphosis size ranges (>120 mm). The size of ammocoetes captured in 2006 encompassed this entire range, suggesting multiple age classes from YoY (*e.g.,* 15 to 40 mm) up to ammocoetes approaching the age of metamorphosis (*e.g.,* >120 mm) were present, in addition to adults.

Weights of lamprey captured in mainstem sites ranged between 0.03 g and 5.42 g (n=75 fish; mean = 0.77 g ± 1.21 g SD), and between 0.03 g and 11.69 g in side channel sites (n=99 fish; mean = 1.87 g ± 2.16 g SD). The length-weight relationship for lamprey captured in the mainstem and side channels is shown in Figure 3-10.

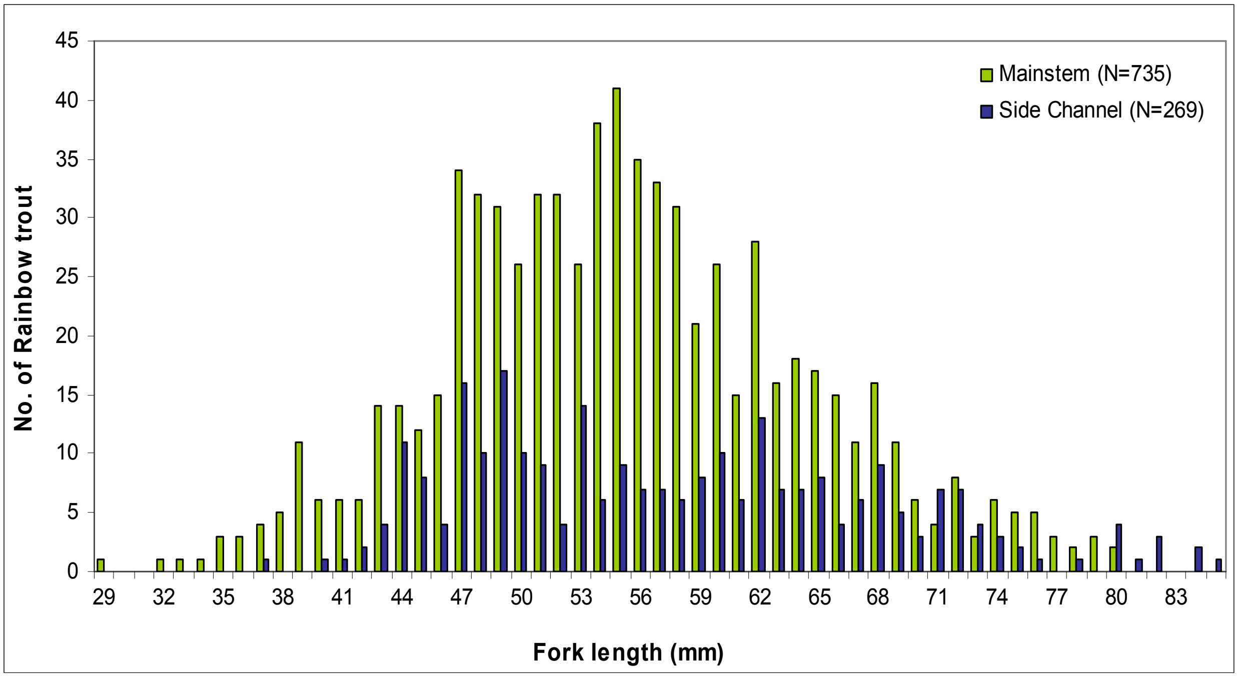
Figure 3-10. Length/weight relationship of lamprey captured by electrofishing, 2006



3.3.4 Rainbow Trout

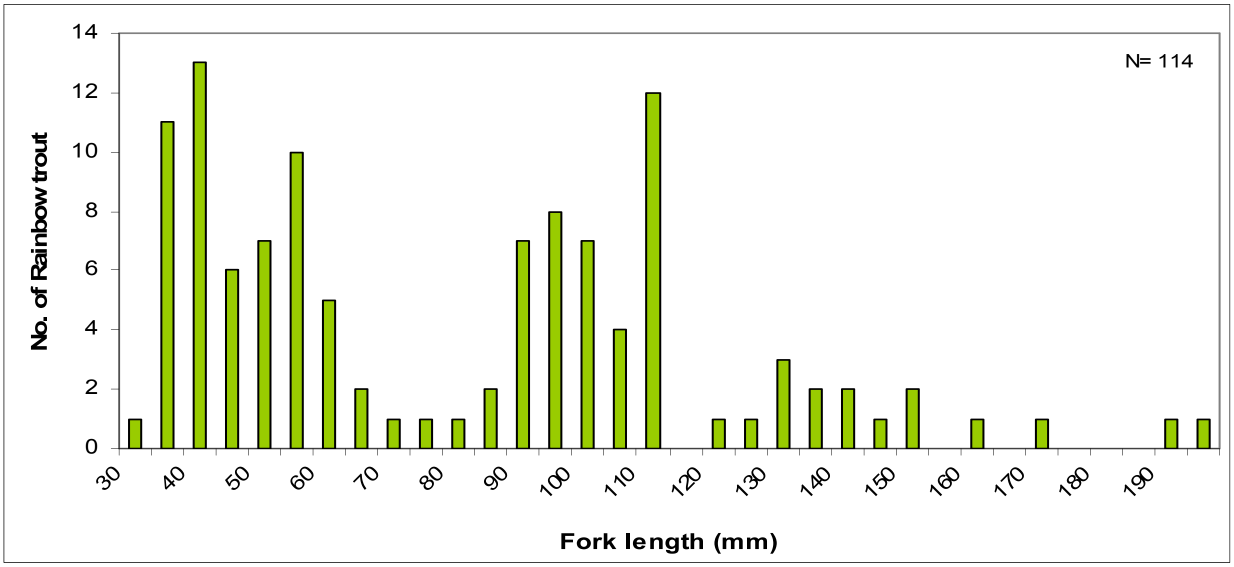
A sub-sample of 1,004 rainbow trout fry (age 0+; fork length ≤ 85 mm) was measured for fork length. The length-frequency distribution of rainbow trout captured in mainstem sites was significantly different than fish captured in side channel sites (Kolmogorov-Smirnov D test = 0.13, P< 0.004). Due to this statistical difference, length-frequency information for these sites is shown separately (Figure 3-16). Rainbow trout fry in the mainstem averaged 55 mm in length ± 9 mm SD (median 55 mm), whereas they averaged 58 mm ± 10 mm SD (median 57 mm) in side channels. Only three rainbow trout with a length greater than 85 mm (96 to 128 mm) were captured in the mainstem, and two (99 to 199 mm) in the side channels. These fish were classified as parr and were not included in the length-frequency distribution shown in Figure 3-11.

Figure 3-11. Length-frequency distribution of rainbow trout fry (0+) captured by electrofishing, 2006



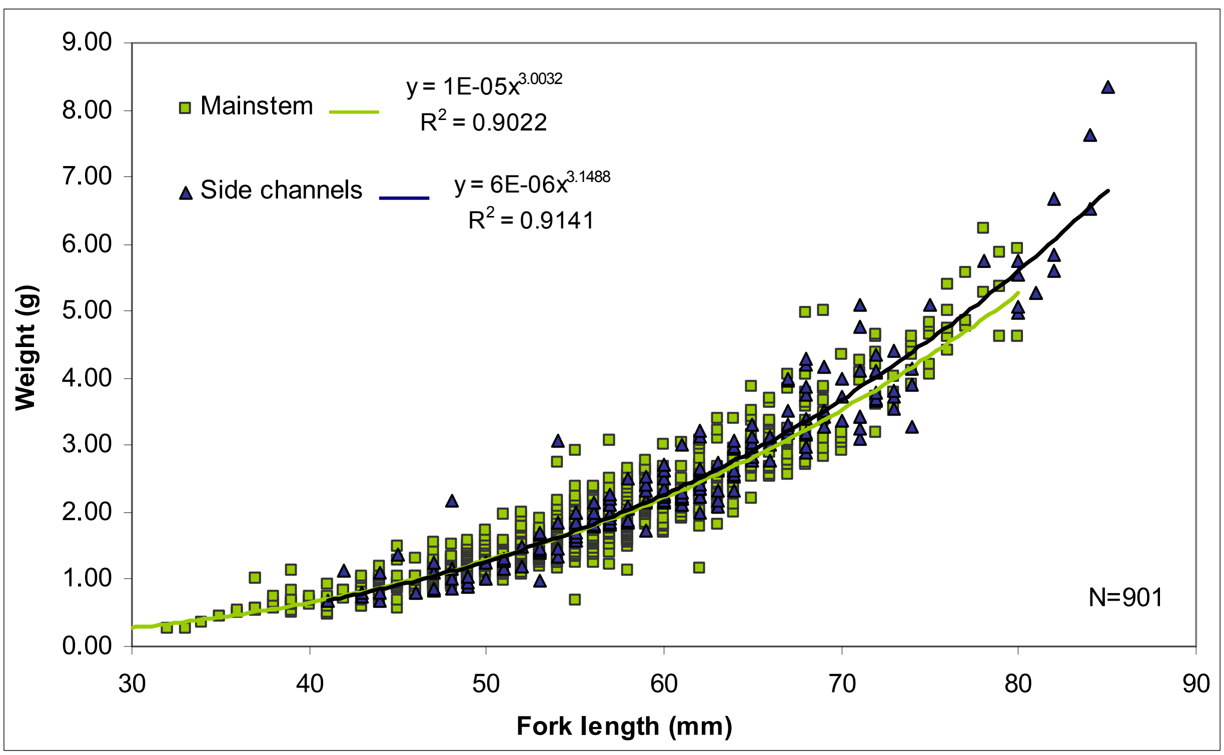
Rainbow trout captured in Brohm River showed wider variation in lengths and based on length-frequency distribution (Figure 3-12), rainbow trout were classified as 0+ fry (≤ 74 mm); 1+ (75 to 119 mm); 2+ (120 to 154 mm); and 3+ (≥ 155 mm). Within sites in Brohm River, rainbow trout captured in the upstream site were larger (n=38; mean = 114 mm ± 30 mm SD), than in the downstream site (n=76; mean = 66 mm ± 32 mm SD).

Figure 3-12. Length-frequency distribution of rainbow trout captured in Brohm River, 2006



A total of 901 Cheakamus River rainbow trout fry were weighed (720 captured in the mainstem and 181 in side channels). Weights averaged 1.91 g in mainstem sites (±1.01 g SD) and 2.70 g in side channel sites (± 1.35 g SD). Length/weight relationship trends were similar between mainstem and side channels (Figure 3-13).

Figure 3-13. Length/weight relationship of rainbow trout captured by electrofishing



The condition factor (K) of individual rainbow trout fry captured in the Cheakamus River watershed varied from 0.71 to 1.65. However, the mean conditions from mainstem and side channel sites, as well as from Brohm River, were similar (Table 3-5).

Table 3-5. Condition factor (K) of rainbow trout captured by electrofishing, 2006

Sites	Sample size	Mean	Min.	Max.	*SD*
Mainstem	711	1.04	0.71	1.65	*0.15*
Side Channel	178	1.06	0.76	1.51	*0.14*
Cheakamus River (all sites)	**889**	**1.04**	**0.71**	**1.65**	***0.15***
Brohm River	114	1.06	0.73	1.30	*0.11*

Note: Condition values below 0.7 and above 1.7 were excluded (n=12).

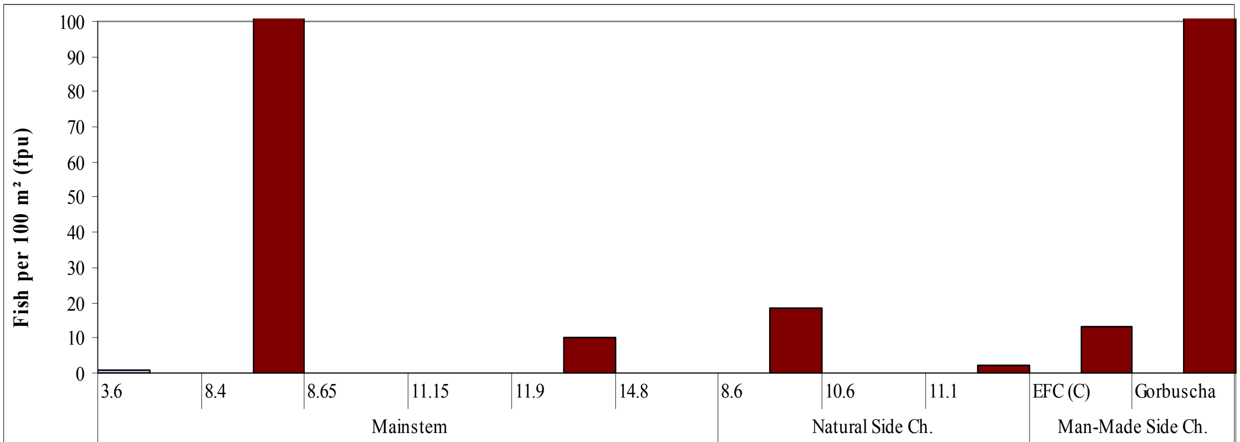
3.4 Estimated Densities – Closed Sites

Densities were calculated for cottids, lamprey, rainbow trout, and coho salmon, based on electrofishing data only. Catch, population estimates and calculated densities for individual sites are provided in Appendix 10.

3.4.1 Cottid and Lamprey

Only one sculpin was captured in enclosed electrofishing sites (site R3.6). Lamprey were captured at two mainstem closed sites and four side channel sites. Figure 3-14 shows lamprey densities were highest at site L8.4 (189 fpu) and in the Gorbuscha side channel site (237 fpu). The estimated lamprey density at site L8.4 seems unlikely considering the site's large substrate and moderate velocity, and is the result of the maximum likelihood adjustment based on an abnormal catch rate (*i.e.,* a similar catch on each pass; n=21, 18, 18). A density of 57 fpu, based on the catch value, seems more appropriate for site conditions. Stone *et al.* (2002) observed a positive correlation between lamprey abundance and percent fines, as well as a negative correlation between abundance and velocity. The Gorbuscha side channel site was selected for its percentage of fine substrate (*i.e.,* 100%; *c.f.* Figure 3-3) and low velocity (*c.f.* Figure 3-2), indicative of suitable lamprey habitat. The Emerald Forest Creek site had a similar substrate composition, but the estimated density for lamprey was only 13 fpu. This difference in densities between the two sites may be attributable to higher water velocity at the EFC site. Due to non-descending removal patterns for sites R11.9 and Emerald Forest Creek, population estimates could not be generated, thus lamprey densities were calculated based on total catch divided by area.

Figure 3-14. Distribution of cottid and lamprey densities (fpu) in closed electrofishing sites, 2006



	3.6	8.4	8.65	11.15	11.9	14.8	8.6	10.6	11.1	EFC (C)	Gorbuscha
Cottids	1	0	0	0	0	0	0	0	0	0	0
Lamprey	0	189[1]	0	0	10[2]	0	19	0	2	13[2]	237

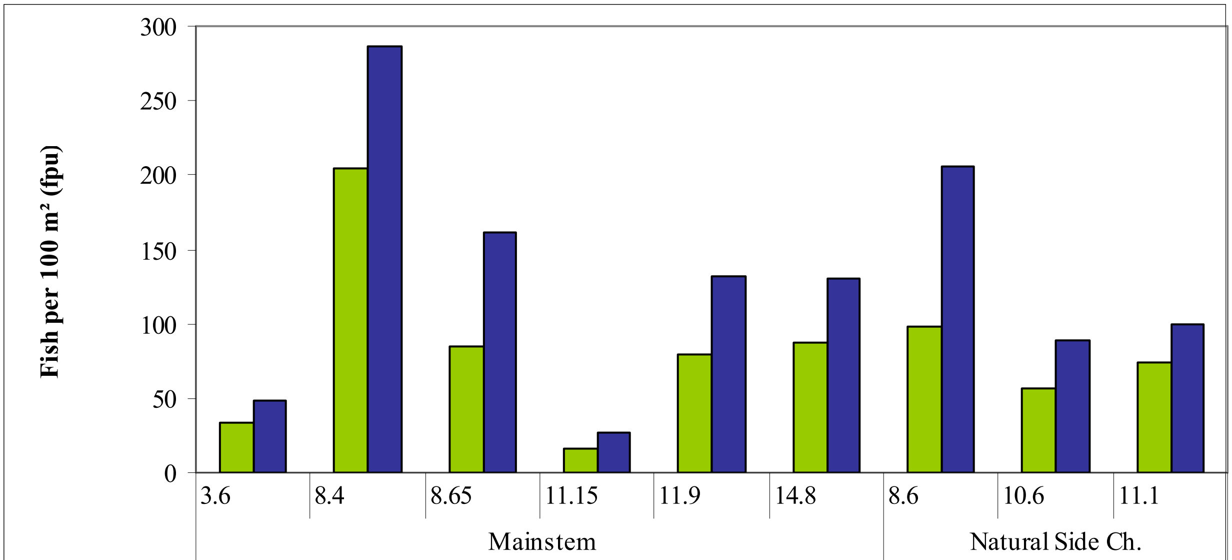
[1] Density calculated is unlikely, due to a high standard error on the population estimate.
[2] Population estimates could not be generated due to non-descending removal pattern: densities based on catch data.

3.4.2 Rainbow Trout

Measured densities for rainbow trout fry captured in closed electrofishing sites averaged 82 fpu. The highest density (205 fpu) was found in site L8.4, and the lowest (16 fpu), in site L11.5 (Figure 3-15). Densities were not calculated for parr, as only five 1+ fish were captured by electrofishing (details in Section 3.3.4).

Densities for rainbow trout fry were adjusted for "probability of use" (Section 2.6.1), based on depth/velocity transects measured at each electrofishing site and habitat suitability curves (HSC; Ptolemy, 2001). According to the habitat suitability curves, the greatest probability of use (P=1) for rainbow trout fry occurs at depths between 0.05 and 0.25 m and velocities between 0.07 and 0.12 m/s. The percentage of "usable area" in closed electrofishing sites varied between 47.9% and 75.2%, with an average of 63.4% (Appendix 10). Adjusted densities for rainbow fry averaged 131 fpu, ranging from 27 to 286 fpu (Figure 3-15). Sites with small differences between measured and adjusted densities (*e.g.*, sites R3.6 and L11.15) represent areas where measurements from the depth/velocity transect indicate conditions were more suitable for rainbow trout fry. Inversely, sites with large variations between measured and adjusted densities (*e.g.*, sites RL8.65 and L8.6) indicate habitat conditions were less suitable for rainbow trout fry, based on the measured parameters.

Figure 3-15. Rainbow trout fry measured and adjusted densities in closed electrofishing sites, 2006



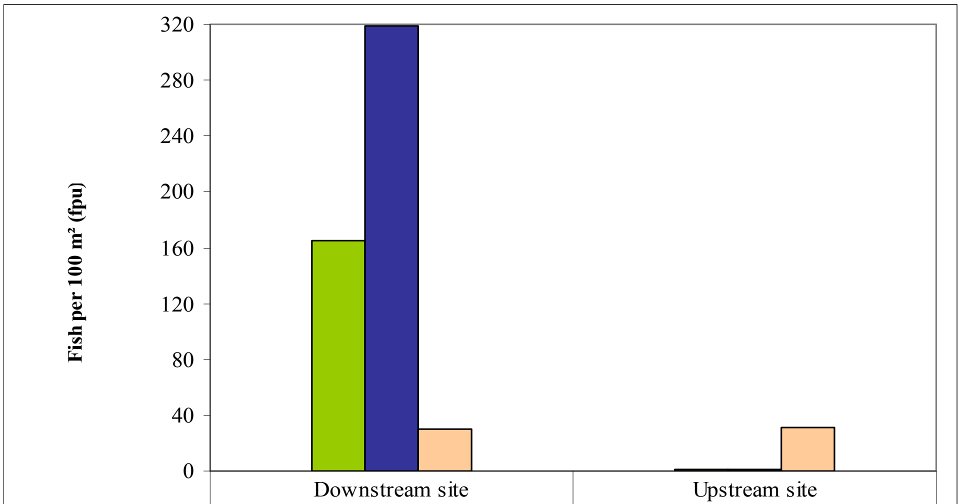
	Mainstem 3.6	Mainstem 8.4	Mainstem 8.65	Mainstem 11.15	Mainstem 11.9	Mainstem 14.8	Natural Side Ch. 8.6	Natural Side Ch. 10.6	Natural Side Ch. 11.1
Measured fpu	34	205	85	16	80	88	99	57	75
Adjusted fpu	48	286	161	27	132	130	206	88	99

Note: Man-made side channel sites (Emerald Forest Creek and Gorbuscha) were excluded as they were not selected for rainbow trout preferred habitat, but for other species, such as threespine stickleback and lamprey.

3.4.3 Brohm River

Measured and adjusted densities of rainbow trout fry in Brohm River were greater at the downstream site than the upstream site, even though the measurements from the depth/velocity transect suggested the percentage of usable area (*i.e.*, habitat conditions for fry) was similar at both sites (52% downstream and 54% upstream; Figure 3-16). Parr densities in both sites were similar.

Figure 3-16. Distribution of rainbow trout densities in Brohm River, 2006

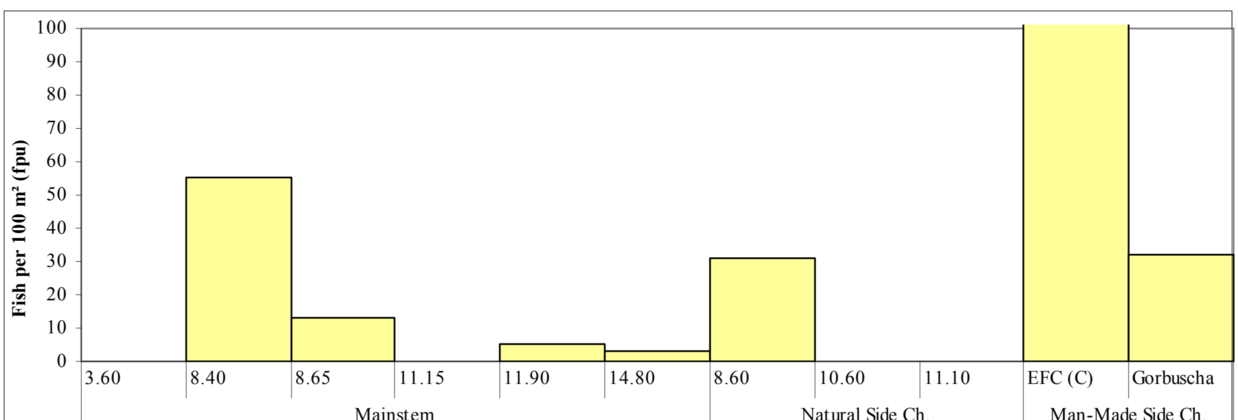


	Downstream site	Upstream site
Measured fry fpu	165	1
Adjusted fry fpu	319	2
Measured parr fpu	30.0	30.8

3.4.4 Other Species

Coho were part of the incidental catch (Section 2.2), and were not targeted by the RAMP. However because they accounted for a substantial portion of the total electrofishing catch (almost 15%), measured densities were also calculated and reported in this section. Individual data for coho (and chinook) is provided in Appendix 5 and 7. Coho measured densities in enclosed electrofishing sites averaged 41 fpu, ranging from 0 to 308 fpu (Figure 3-17).

Figure 3-17. Distribution of coho densities (fpu) in closed electrofishing sites, 2006



	Mainstem						Natural Side Ch.			Man-Made Side Ch.	
	3.60	8.40	8.65	11.15	11.90	14.80	8.60	10.60	11.10	EFC (C)	Gorbuscha
Coho	0	55	13	0	5	3	31	0	0	308	32

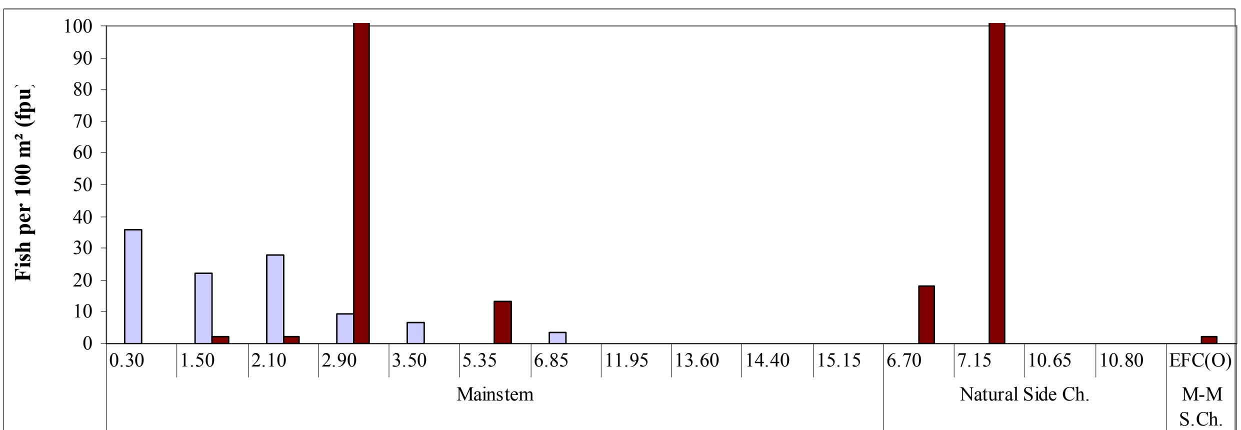
3.5 Estimated Densities – Open Sites

3.5.1 Cottid and Lamprey

The highest cottid densities were found in the three most downstream electrofishing sites (between km 0.3 and 2.1; mean of 27 fpu) and no cottids were captured by electrofishing upstream of site R6.85 or in side channel sites (Figure 3-18).

The highest estimated lamprey densities were recorded in mainstem site R2.9 (128 fpu) and side channel site R7.15 (288 fpu; Figure 3-18). Substrate at site R2.9 consisted of 60% fines, with a mean depth of 0.49 m and mean velocity of 0.06 m/s (*c.f.* Figure 3-2 and 3-3). Substrate at site R7.15 was 99% fines, and was described as a pool with no observed velocity. Although no association between lamprey presence and measured velocities was identified in the Cheakamus River, field observations did indicate lamprey were captured in low velocity habitats near the shoreline.

Figure 3-18. Distribution of cottid and lamprey densities in open electrofishing sites, 2006



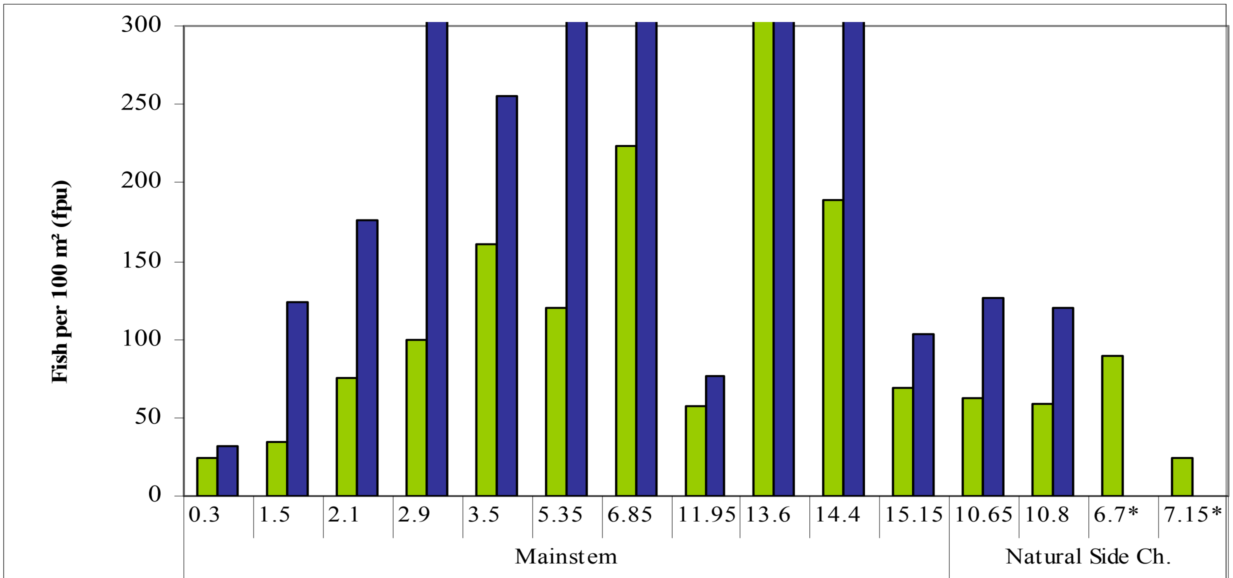
	0.30	1.50	2.10	2.90	3.50	5.35	6.85	11.95	13.60	14.40	15.15	6.70	7.15	10.65	10.80	EFC(O)
Cottids	36	22	28	9	7	0	3	0	0	0	0	0	0	0	0	0
Lamprey	0	2	2	128	0	13	0	0	0	0	0	18	288	0	0	2

3.5.2 Rainbow Trout

Measured densities for rainbow trout fry captured in open electrofishing sites averaged 110 fpu. The highest density (358 fpu) was recorded at site R13.6, and the lowest (24 fpu) at site L0.3 and side channel site 7.15 (Figure 3-19); the latter two sites were in fact selected to target cottids and lamprey, respectively.

The percentage of "usable area" in open electrofishing sites varied between 28.3% and 82.6%, with an average of 52.0% (Appendix 10). Adjusted densities for rainbow fry captured in open electrofishing sites averaged 245 fpu, ranging from 32 to 597 fpu (Figure 3-19).

Figure 3-19. Rainbow trout fry measured and adjusted densities in open electrofishing sites, 2006



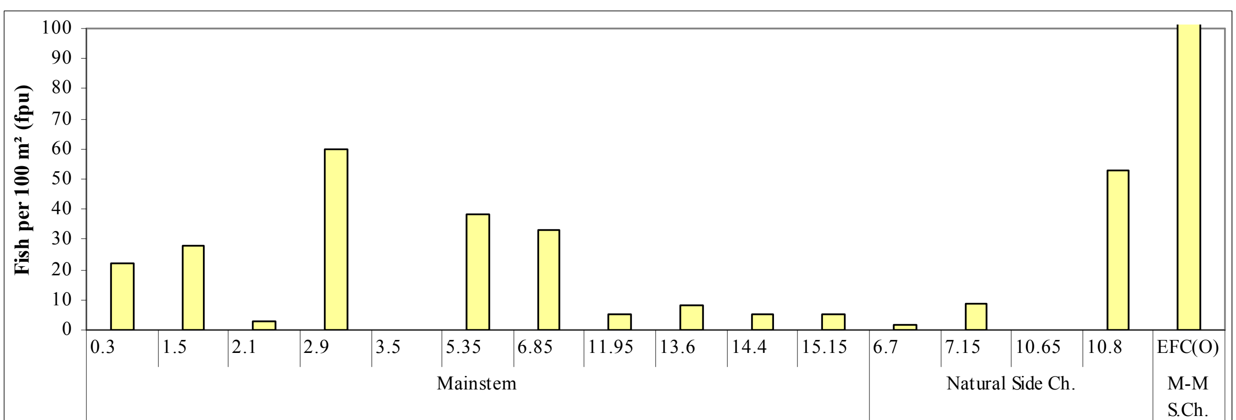
	0.3	1.5	2.1	2.9	3.5	5.35	6.85	11.95	13.6	14.4	15.15	10.65	10.8	6.7*	7.15*
Measured fpu	24	35	75	100	161	120	223	57	358	189	69	63	59	89	24
Adjusted fpu	32	124	176	338	256	375	597	76	433	423	103	127	120		

*Adjusted densities were not calculated for side channel sites R6.7 and R7.15, as depth/velocity profiles were not measured (see Section 3.2.1).

3.5.3 Other Species

Coho measured densities in open electrofishing sites averaged 25 fpu, ranging from 0 to 135 fpu (Figure 3-20). As for enclosed sites, the greatest density was recorded for Emerald Forest Creek.

Figure 3-20. Distribution of coho densities (fpu) in closed electrofishing sites, 2006



	0.3	1.5	2.1	2.9	3.5	5.35	6.85	11.95	13.6	14.4	15.15	6.7	7.15	10.65	10.8	EFC(O)
Coho	22	28	3	60	0	38	33	5	8	5	5	2	9	0	53	135

4.0 Discussion

The RAMP was established to describe the post-spill abundance of resident juvenile and adult fish in the Cheakamus River in order to measure recovery and determine if or when population levels reach pre-spill abundance levels or densities reach a state of equilibrium. 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. Where no such information is available, data collected in 2006 will be used as reference for the assessment of recovery in subsequent years. The September 2006 sampling represents the program's first year.

The following section presents a preliminary assessment of fish recovery in the Cheakamus River based on results of the 2006 sampling program and on comparison - where possible - with pre-spill information.

4.1 Pre-Spill Studies

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 (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).

Van Dishoeck (2000, 2002) and van Dishoeck and Horne (2002) conducted studies of juvenile rainbow trout densities from 1999 to 2001. The program was designed to develop a population indexing system for steelhead in the Squamish River drainage. Juvenile rainbow trout densities were estimated from triple pass depletion electrofishing in sites enclosed with stop nets. Depth/velocity transects were used to measure habitat characteristics and estimate probability of use in order to "adjust" measured densities. These reports also presented limited data from the capture of "non-target" fish such as char, lamprey and cottids.

Sneep (2001) assessed the distribution of juvenile salmonids in the Cheakamus River through minnow trapping, seining and snorkel floats from September 1999 to July 2000. Among the fish captured during the study were rainbow trout (representing 7.7% of the total salmonid catch), cutthroat trout, Dolly Varden and unidentified cottids.

McCubbing *et al.* (2006) studied fish populations of the Cheakamus River following the 2005 derailment. Data were collected on impacted fish in the mainstem, side channels and restoration channels and post-spill surveys collected information on densities and distribution of survivors. It was estimated approximately 90% of juvenile rainbow trout representing four age classes were affected, and survivorship of resident fish - including cottids and lamprey - was deemed limited.

4.2 2006 Monitoring Results

4.2.1 Cottids

Cottids collected in early August during the 2005 post-spill assessment (McCubbing *et al.,* 2006) ranged from 47 to 132 mm, which should represent juveniles and adults present in the river. However, no young of year (YoY) sized sculpin were captured. There are several potential causes for this: smaller fish could have been overlooked, as volunteers collecting mortalities may have had a natural tendency to pick up the larger specimens over the smaller ones; smaller fish may also have been lodged in the substrate and difficult to observe or collect; furthermore, Ringstad and Narver (1973) suggested YoY (both coastrange and prickly sculpin) may spend a year in the estuary before migrating upstream in late August into habitat where adults are found.

Sculpins captured during the September 2006 surveys varied between 66 mm and 124 mm, indicating at least second year fish and over, regardless of the species (Section 3.3.2). Average length at mainstem electrofishing sites varied little (Table 4-1), ranging from 81 mm (site R2.1) to 88 mm (site L1.5). Average sculpin length at site L1.5 was consistent with values reported by van Dishoeck (2000) and van Dishoeck and Horne (2002) for the site.

Table 4-1. Sculpin average length, Cheakamus River mainstem electrofishing sites, 2000, 2001 and 2006

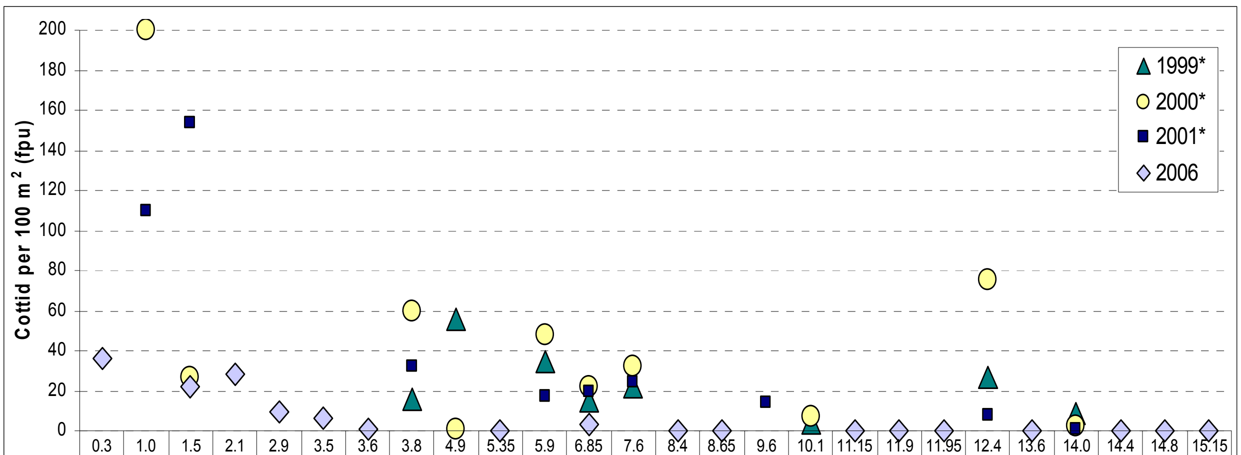
Site (river km)	van Dishoeck 2000	van Dishoeck and Horne 2001	RAMP 2006
0.3	-	-	83 (32)
1.0	80 (103)	87 (79)	-
1.5	86 (27)	85 (118)	88 (22)
2.1	-	-	81 (27)
2.9	-	-	82 (7)
3.5	-	-	85 (5)
3.6	-	-	84 (1)
3.8	74 (43)	74 (34)	-
4.9	77 (1)	-	-
5.9	99 (115)	102 (31)	-
6.85	96 (18)	98 (20)	87 (1)
7.6	92 (35)	95 (22)	-
9.6	-	105 (13)	-
10.1	96 (7)	-	-
12.4	102 (66)	108 (12)	-
14.0	87 (1)	132 (1)	-

Note: Values in parentheses represent sample size (# of fish).

In summary, there was insufficient existing information available to determine whether age class composition has changed in relation to pre-spill conditions.

Results indicate measured densities in 2006 were lower than those reported by van Dishoeck for the 1999, 2000 surveys, and by van Dishoeck and Horne for the 2001 surveys (Figure 4-1). The distribution of cottids in the Cheakamus River also appears to have changed. In the above-mentioned studies, cottids were captured along the Cheakamus River up to the most upstream site (at km 14), whereas in 2006 no cottids were captured upstream of the km L6.85 site. Most cottids were captured in riffle and run, over cobble/boulder substrate, in areas with moderate to high velocities and depths ranging from 0.20 m to 1.0 m.

Figure 4-1. Cottid densities, Cheakamus River mainstem electrofishing sites, 1999-2001 and 2006



	0.3	1.0	1.5	2.1	2.9	3.5	3.6	3.8	4.9	5.35	5.9	6.85	7.6	8.4	8.65	9.6	10.1	11.15	11.9	11.95	12.4	13.6	14.0	14.4	14.8	15.15
▲ 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	36		22	28	9	7	1			0		3		0	0			0	0	0		0		0	0	0

* van Dishoeck (2000, 2002) and van Dishoeck and Horne (2002). Note: Empty cells represent sites not sampled for each year.

Considering the impact the spill had on cottid populations in the river, the low abundance and reduced distribution of cottids was not unexpected. In the days following the incident, 2,437 dead cottids were collected (with many more observed but not collected due to the large number of fish, velocity, turbidity and time constraints), and post-spill surveys suggested a 94% reduction in cottid density (McCubbing *et al*., 2006). The 2006 monitoring program captured a total of 98 sculpins in 6 sites, indicating either the survival of a few individuals, or the beginning of a re-colonization process from other systems (*e.g.,* tributary streams or the Squamish River watershed), or a combination of the two scenarios. Results from ongoing monitoring efforts in 2007 are expected to provide more information on the mechanisms contributing to recovery of cottids in the Cheakamus River.

4.2.2 Lamprey

A total of 694 lamprey were captured in the Cheakamus River mainstem from river km 1.5 to km 12, as well as in the Mykiss (R7.15) and Gorbuscha side channels. The highest densities were found in low velocity side channels with sandy/silty bottom. These results are consistent with those of Torgersen and Close (2004), who suggested lamprey prefer velocities ranging between 0.05 and 0.15 m/sec, which provide a steady influx of food while promoting the deposition of soft sediments needed for burrowing. Beamish and Levings (1991) also found Pacific lamprey ammocoetes in the fine sediments of backwater areas of streams, and Stone *et al.* (2002) showed a positive correlation between lamprey abundance and fine sediment and a negative correlation with increasing velocities.

Total length varied between 16 and 215 mm, indicating the presence of multiple age classes (*i.e.,* YoY, juvenile ammocoetes, and possibly young adults) in the Cheakamus River. Lamprey captured in side channel sites were on average longer and heavier than those captured in mainstem sites.

Pre-spill information on lamprey in the Cheakamus River is incidental from studies focusing on steelhead/rainbow trout and could not be used as baseline for comparison. Van Dishoeck (2000, 2002) and van Dishoeck and Horne (2002) reported a total of only 9 lamprey (not identified to the species level; mean lengths 152 to 174 mm) captured from Cheakamus River mainstem sites in three years of sampling. In the days following the spill, 162 dead lamprey were collected: 9 of the larger fish (>150 mm) were identified to species (Pacific lamprey). Measured lamprey (n=144) ranged from 38 to 337 mm (mean = 129.9 mm ± 52.9 mm 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 within the sampled area, the number observed but not collected, and the fact no lamprey were captured during the post-spill sampling (McCubbing *et al.*, 2006). Based on the low abundance of lamprey observed in historic sampling and in post-spill survival assessments targeted at other species, McCubbing *et al*. (2006) suggested current and historic sampling methodologies (*i.e.,* electrofishing and minnow trapping) were inefficient in the capture of lamprey.

The increased abundance of lamprey in similar mainstem sites between information reported in 1999 to 2001 and results from 2006 may be more reflective of target species and observer efficiency, than an actual increase in abundance. Since sampling methods between these periods were similar (*i.e.,* electrofishing), and lamprey were captured by electrofishing in 2006, it is clear electrofishing is an effective method of capturing lamprey. During the 1999 to 2001 studies and the post-spill survival assessments, sampling crews were targeting rainbow trout and any lamprey capture and recording was incidental. Sampling crews may not have noticed the presence of lamprey ammocoetes, which are bottom-oriented and will often burrow back into the substrate after disturbance. Observations in 2006 indicated the sampling crews' efficiency at capturing lamprey increased as they became more accustomed to looking for lamprey movements, especially in pockets of sediment deposition along the shoreline in mainstem sites.

The capture of multiple age/size classes (YoY, ammocoetes, and adult lamprey) and abundance of lamprey observed in the Cheakamus River in 2006 is encouraging. The presence of YoY juveniles in September 2006 also suggests breeding has taken place in the Cheakamus River since the spill (Section 3.4.3). In general, sampling information in 2006 suggests numerous individuals survived the effects of the spill and the impacts on lamprey were not as severe as estimated by McCubbing *et al*. (2006).

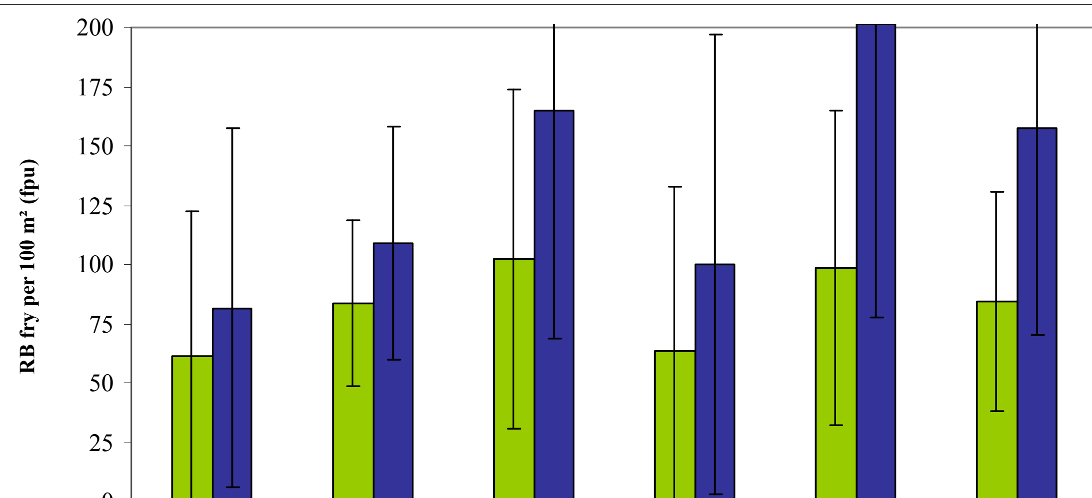
Lamprey were captured throughout the anadromous section of Cheakamus River in 2006, but it is not clear what the pre-spill abundance of each species was and how this compares to the current population. While it may not be possible to determine with certainty when or if populations reach pre-spill abundance, further sampling is planned to confirm the presence of ongoing breeding and multiple overlapping age classes as evidence of population stability.

4.2.3 Rainbow Trout

Juvenile rainbow trout were captured at every sampling site along the Cheakamus River mainstem and side channels (with the exception of Gorbuscha), with all three sampling methods [electrofishing (open and closed), minnow trapping and seining]. A total of 2,091 fry and 5 parr were captured. Fry captured in mainstem and side channel sites averaged 55 mm (± 9 mm SD) and 58 mm (± 10 mm SD), respectively. Condition factor (Fulton's K) varied between 0.71 and 1.65, and averaged 1.04 (± 0.15 SD).

Mean measured and adjusted densities of all closed sites were within the range of similar sites sampled in other years (Figure 4-2). Sites with the highest measured densities were dominated by riffle/pool over cobble substrate, with cover provided primarily by boulder and pools. Mean measured and adjusted densities for closed sites in 2006 were greater than values reported by van Dishoeck (2000) for the 1999 survey, but lower than values reported for the 2000 and 2001 surveys (van Dishoeck, 2002; van Dishoeck and Horne, 2002; Figure 4-2). Estimated steelhead escapement also varied between years and was lowest in 1999 and 2000 (Korman *et al*., 2007; Figure 4-2).

Figure 4-2. Geometric means and 95% confidence intervals for measured and adjusted rainbow trout fry densities, Cheakamus River, 1999-2001 and 2006



	van Dishocek 1999 Closed (N=8)	van Dishoeck 2000 Closed (N=10)	van Dishoeck and Horne 2001 Closed (N=9)	Triton 2006 Closed (n=6)	Triton 2006 Open (n=11)	Triton 2006 Combined (n=17)
Measured fpu	61.46	83.62	102.27	63.66	98.51	84.44
Adjusted fpu	81.62	109.09	164.72	100.31	201.73	157.64
Escapement*	191	90	305	255		

Juvenile rainbow trout distribution was also examined by comparing densities (mean and adjusted) by river section. Four river sections were identified based on discussions with the BC Ministry of Environment. These river sections represent large scale variations in habitat and rearing conditions influenced by factors such as gradient, substrate, channel morphology and tributaries. The four rivers sections were:

- Km 0 to 3 – Squamish River to Cheekye River confluence – characterized by larger substrate and higher gradient than other sections, and water quality influenced by Cheekye River;
- Km 3 to 9 – Cheekye River confluence to an area 2 km upstream of the Bailey bridge – characterized by shallower gradient with a large proportion of gravel substrate and several enhanced restoration channels (groundwater and river fed);
- Km 9 to 12.6 – Km 9 to Culliton Creek confluence – characterized by higher gradient and larger substrate than the previous section, with water quality influenced by Culliton Creek (*i.e.,* glacially turbid in summer and early fall); and,
- Km 12.6 to Km 17 – Culliton Creek to anadromous barrier – characterized by moderate gradient and a combination of gravel and boulder substrates with few side channels, and water quality influenced by Daisy Lake Dam.

Although the number of sites sampled has not been consistent between years or river sections, the highest mean and adjusted densities have been encountered between river km 3 and km 9 (Table 4-2). Sampling results in 2006 showed a similar trend to observations in previous years (*i.e.,* sampling effort as well as mean and adjusted densities were highest between km 3 and 9).

Table 4-2. Geometric means for measured and adjusted densities of rainbow trout fry by river section, Cheakamus River, 1999-2001 and 2006

	Measured densities				Adjusted densities			
River section (Km)	van Dishoeck 1999 Closed	van Dishoeck 2000 Closed	van Dishoeck and Horne 2001 Closed	Triton 2006 Closed	van Dishoeck 1999 Closed	van Dishoeck 2000 Closed	van Dishoeck and Horne 2001 Closed	Triton 2006 Closed
0 - 3	N/A	50.55	76.62	N/A	N/A	71.94	146.83	N/A
n	0	2	2	0	0	2	2	0
SD	N/A	*27*	*33*	N/A	N/A	*49*	*61*	N/A
3 - 9	65.35	110.11	189.06	83.99	90.43	137.76	281.68	130.26
n	5	5	4	3	5	5	4	3
SD	*50*	*47*	*93*	*88*	*85*	*66*	*118*	*119*
9 - 12.6	78.13	75.46	52.15	35.73	85.17	102.76	78.04	59.70
n	2	2	2	2	2	2	2	2
SD	*141*	*76*	*82*	*45*	*151*	*122*	*128*	*74*
12.6 - 17	28	71	60	88	45	88	108	130
n	1	1	1	1	1	1	1	1
SD	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Although the effects of the spill on rainbow trout in the river at the time of the spill were considerable (estimated losses greater than 90%; McCubbing *et al.*, 2006), rainbow trout fry in 2006 were captured in all areas of the river historically occupied by this species. This may be due to the anadromous component of the population (*i.e.,* steelhead). Prior to the 2005 spill, juvenile rainbow trout in the Cheakamus River would have included progeny from both anadromous and non-anadromous individuals. The life histories of these individuals may have overlapped among individuals and their progeny (*e.g.,* some progeny of adult steelhead may have residualized and some progeny of resident fish may have become anadromous). 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 captured in September 2006. The reduction in resident rainbow trout spawners and reduced recruitment from this component of the population may also explain some of the difference between densities between 1999 to 2001 and September 2006. In addition, spill impacts are the most obvious explanation for the reduction in rainbow trout parr in 2006 compared to previous years.

As a result of reduced environmental pressures (*e.g.,* reduced competition and predation) it is also possible rainbow trout fry will experience higher survival rates compared to historical levels to assist in the recovery of this species. Further sampling efforts in subsequent years of the RAMP is expected to provide more information on survival rates by providing comparisons of fry and parr abundance between years.

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), juvenile densities in this system in 2006 would not have been affected by the spill. In addition, since it was sampled in years prior to the spill, it can be used as a temporal comparison of changes in rainbow trout density.

Rainbow trout were the only species captured in Brohm River in 2006 and based on length frequency analysis the population was composed of age classes 0+ to 3+ (Figure 3-12). The mean measured density for rainbow trout fry in 2006 was lower than densities measured between 2000 and 2004 (van Dishoeck, 2002; van Dishoeck and Horne, 2002; Hanson and Hryhorczuk, 2005), while parr densities appear to be similar (Table 4-3). This decrease in fry density may be associated with natural inter-annual variations, or with the unavoidable variation in site-specific density (given only two sites were sampled for each of the compared studies). In 2006, one site had a measured density for rainbow trout fry of 120 fpu, while the other site had a measured density of only 2 fpu for rainbow trout fry. Since the variation between measured densities in a similar number of sampling sites (two) in other years (2000 to 2002) was less obvious, site-specific conditions would appear to be the cause of the lower mean densities in 2006. When the one 2006 site was removed the mean measured density of rainbow trout fry was similar to previous years (Table 4-3).

Table 4-3. Rainbow trout mean measured/adjusted densities, Brohm River, 2000-04 and 2006

Age Class	van Dishoeck 2000 (Triple pass) (2 sites)	van Dishoeck and Horne 2001 (Triple pass) (3 sites)	Hanson and Hryhorczuk 2002 (2-pass depletion) (2 sites)	Hanson and Hryhorczuk 2003 (2-pass depletion) (2 sites)	Hanson and Hryhorczuk 2004 (2-pass depletion) (2 sites)	Triton 2006 (Triple pass) (1 site)[1]
Measured Density						
0+	134.4	119.2	220.5	155.5	69.0	164.5
1+	27.6	10.9	n/a	n/a	n/a	30.0[2]
2+	6.4	4.9	n/a	n/a	n/a	
3+	2.1	0	n/a	n/a	n/a	n/a
Adjusted Density						
0+	194.8	164.9	299.0	219.5	122.0	319.1

1. The 2006 Upstream site on Brohm River was excluded as results were not considered representative of potential rainbow trout productivity for the system.
2. 1+ and 2+ fish combined.

4.2.4 Bull Trout

There were only two char (identified in the field as bull trout) captured at two sites in 2006, and therefore distribution in the Cheakamus River could not be assessed. The two sites, one along the mainstem and the other in a side channel, were characterized by riffle/pool, with moderate water velocities over cobble, with boulder cover. Char often use areas near substrate dominated by cobble and boulder, allowing them to inhabit low-velocity areas of riffle habitat (Bonneau and Scarnecchia, 1998).

The effects of the spill on char are uncertain due to the lack of information available on their abundance and life history in the Cheakamus (McCubbing *et al.*, 2006). A total of 9 juvenile char were reported by van Dishoeck (2000, 2002) and van Dishoeck and Horne (2002) in all three survey years. Abundance and recovery of bull trout in the Cheakamus River is also being evaluated using adult radio telemetry and calibrated snorkel surveys (Melville and McCubbing, 2006).

4.2.5 Threespine Stickleback

In 2006, seven threespine stickleback were captured by minnow trapping in Emerald Forest Creek only. Emerald Forest Creek is an enhanced watercourse supplemented by surface water from the Cheakamus River delivered through a man-made intake (Melville, 2006). The channel is characterized by riffle/pool, with a mix of fine and gravel substrate, and LWD, SWD and overstream vegetation providing cover. This trapping area provided typical stickleback habitat requirements of plant cover, debris and sandy/muddy substrate with low velocities. Minnow trapping was the only successful sampling method, which corroborates similar assessments in past research programs in other systems (Hyatt and Ringler, 1989; Larson and McIntire, 1993).

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, and 2002; van Dishoeck and Horne, 2002). Although only two dead stickleback were collected during the 2005 assessment, several live fish were observed (McCubbing *et al.*, 2006). As stickleback are known to inhabit backwater areas (*i.e.,* pools, finer sediment, organic debris, slower velocities) as opposed to gravel/cobble and higher velocities mainstem areas, it was suggested live fish captured post-spill may have originated from the river's off-channel areas.

4.2.6 Cutthroat Trout

No cutthroat trout were captured during the 2006 sampling program. Only one dead fish was recovered during the post-spill assessment (McCubbing *et al.*, 2006).

4.2.7 Other Species

Juvenile chinook and coho salmon were captured with all three sampling methods, in both mainstem and side channel sites. Thirty chinook were captured in sites characterized mainly by riffle/run, dominated by boulder and cobble, with velocities ranging from 0.15 to 0.24 m/s. It was estimated 50% of the 2005 adult chinook population was affected by the spill (McCubbing *et al.*, 2006).

Due to the timing of the 2005 spill, adult coho returns were not expected to be affected (McCubbing *et al.*, 2006) and this was reflected in the large number of coho fry captured in 2006. Minnow traps were the most effective method of capture: 96% of total coho catch, averaging 9 fish per trap.

4.3 Conclusions

Based on the 2006 results from the Resident Fish Abundance Monitoring Program, the following conclusions can be made:

- The composition of the fish community was similar to that reported in previous studies indicating recruitment is occurring and the physical habitat has the capacity to support the same species as it did before the spill;
- Data collection in 2006 did not refute the estimated impact assessment by McCubbing *et al*. (2006) for sculpin: the low number of fish captured and limited distribution appears to corroborate the impact assessment;
- Cottid densities were lower than reported in previous surveys and the species' distribution was limited to the downstream reaches of the river (km 0.3 to 8.65, reaches 1 to 5);
- Multiple age classes of lamprey were captured and in greater abundance than previously reported, suggesting the species were not impacted by the spill to the extent estimated in the 2005 assessment;
- Mean measured and adjusted densities of rainbow trout fry captured at closed electrofishing sites in 2006 were lower than values reported by van Dishoeck and Horne

for the 2001 survey, although the estimated escapement was also lower in 2006 than 2001;

- Rainbow trout parr abundance was lower 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;
- Although it is not possible to determine the timing or rate for recovery based solely on the 2006 surveys, results suggest natural recovery has started.

4.4 Recommendations

The program follows an adaptive approach and therefore the methods used will 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:

- Minnow trapping – The location of individual minnow trapping sites should be re-evaluated in an effort to target preferred habitats and capture a greater percentage of target species.
- Seining – Additional sites should be identified and sampled in 2007.
- Water Quality parameters – *In situ* water quality parameters should be measured and recorded through the day during the setting and retrieval of minnow traps.
- Cottids –While cottids are not a commercially or recreationally important species, they may contribute to the abundance of other species in ways not currently understood, therefore the mechanisms and limitations of recovery should be further investigated:
    - Conduct further literature searches to identify characteristics which will allow effective visual species identification;
    - Conduct DNA testing of a sub-sample to clarify questions about species composition in the river;
    - Identify additional mainstem sites with habitat characteristics suitable for cottids in the lower river to better track the upstream progression of cottid re-colonization;
    - Consider marking strategies to obtain information about species distribution and migration patterns, through subsequent recaptures; and,
    - Consider adding sampling sites in tributaries to assess the potential for recruitment from tributaries.
- Lamprey – While lamprey are not a commercially or recreationally important species they may contribute to the abundance of other species in ways not currently understood, therefore the mechanisms and limitations of recovery should be further investigated:
    - Conduct further literature searches to identify characteristics which may allow for visual species identification at the ammocoete life stage;
    - Collect voucher specimens from a variety of sampling locations and size classes for laboratory species identification;

- Increase photo-documentation of adults' oral disc for consistent and reliable species identification; and,
- Identify additional sampling locations with habitat characteristics suitable for lamprey to better document their distribution and abundance.

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PHOTOGRAPHS

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