Lemon Creek Spill: Biological Monitoring Program - Final Report

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Project 615438

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EXECUTIVE SUMMARY

SNC-Lavalin Inc. (SNC-Lavalin) has prepared the following final report detailing the findings from the last round of monitoring efforts on Lemon Creek and Slocan River that was initiated in late 2013 in response to the Lemon Creek Jet-A1 fuel spill incident that occurred on July 26, 2013. This report focuses solely on those programs in which the endpoints had not yet been achieved as per the interim monitoring report, dated May 7, 2014 and Ministry of Environment acceptance letter dated July 24, 2014. The following programs discussed herein include the:

- Slocan River Off-Channel Fish Mark Recapture and Fish Community Program;
- Slocan River Rainbow Trout Population Analysis;
- Lemon Creek Bull Trout Redd Survey;
- Lemon Creek Fish Abundance and Community Recovery Monitoring Program; and
- Benthic Invertebrate Community Recovery Monitoring Program.

The fish community structure of select off-channel habitats of the Slocan River downstream of Lemon Creek were similar in terms of species composition, species dominance, and species richness and displayed an increasing trend in relative abundance between 2013 and 2014. Even though an increase in abundance was observed, it was difficult to ascertain whether the increase was related to initial declines in fish numbers as a result of the spill or simply natural variability. In our opinion, we believe the latter is a more likely scenario. Based on the results from the 2013/2014 mark-recapture program, we believe that the modified endpoints have been achieved.

Rainbow Trout population data collected from the Slocan River in 2013 and 2014 displayed a decreasing trend in abundance that was similar to that observed since 2010. Data observed post-spill suggest population levels still remain within the natural variation exhibited in the population prior to the spill. Given the consistent trends in the Rainbow Trout population since 2006, post-spill data suggest that the observed decrease is likely attributed to natural variability of the species and are not indicative of an effect to the population as a result of the spill. In our opinion the population of Rainbow Trout in the Slocan River system appear to be stable, and believe this endpoint has been achieved.

Data collected during the Bull Trout redd surveys conducted in 2013 and 2014 indicate that successful Bull Trout spawning occurred in upper Lemon Creek and tributaries post-spill. Redds, and juvenile and adult Bull Trout, were documented in 2014, providing evidence that Bull Trout migration through the exposure area to upstream spawning habitat was not being impeded. The lack of suitable spawning habitat observed in the upper reaches of the Lemon Creek watershed was likely the limiting factor to the spawning success of the Bull Trout.

Results from the Lemon Creek fish abundance and community recovery monitoring program indicated that there has been a recovery of community structure in Lemon Creek over one year after the spill event. Relative abundance, diversity, composition, and age structure results all indicated that fish are recovering and is further supported from the results of other monitoring programs (i.e., suitable water quality, abundance of invertebrates (fish food), and continuation of critical life stages such as spawning).

The fish community in Lemon Creek was likely dissimilar to reference sites in the lowest reach of Lemon Creek prior to the spill due to different habitats and the proximity to Slocan River and Slocan Lake. Thus, a recovery of all 4.9 km of downstream impacted channel to exactly match the species assemblage, diversity and density of the reference sites is likely a false assumption. When scaled back to account for the morphologically similar reaches that end at the Highway 6 crossing, our data suggest that recovery has progressed to levels that may be within levels of natural variation. This would be in line with the intent of the Biological Monitoring Plan endpoint.

Results from the benthic invertebrate monitoring program indicated that while the invertebrate assemblage in Lemon Creek was initially impacted by the spill, recovery was evident, as exhibited by the results from a number of components of a weight of evidence approach (biometrics, non-parametric ordination [ANOSIM], regression models [Before/After-Control/Impact {BACI} and Generalized Linear Mixed Model {GLMM}], and Reference Condition Approach [River Invertebrate Prediction and Classification System {RIVPACS} and *Benthic Analysis of Sediment* {BEAST}]). In summary, it appears that while the jet fuel spill initially impacted the benthic invertebrate community at sites downstream of the spill location on Lemon Creek, they have since recovered to reference site levels. We therefore believe that the endpoint has been met for Lemon Creek.

Benthic invertebrate results from the Slocan River data were less clear. Evaluation of taxonomic data did not provide a clear indication that invertebrates had been impacted by the jet fuel. Based on the weight of evidence, results suggest that there was no obvious impact on the benthic community structure at exposure sites in Slocan River in October 2013 or October 2014 and that results most likely represent natural variability rather than a direct effect from the jet fuel spill.

Given the findings from the fish and benthic invertebrate monitoring programs, results suggest that the Lemon Creek and Slocan River aquatic ecosystems were displaying resiliency in the wake of a moderately acute impact. The nature of the effects and the recovery shown in the results (e.g., benthic invertebrates) is not entirely unexpected given our understanding of the environmental fate and transport of the spilled product. It is our opinion that based on the findings from each biological monitoring program, the list of remaining (modified) endpoints has been achieved.

ACKNOWLEDGEMENTS

SNC-Lavalin would like to acknowledge the following individuals for their technical input and reviews of earlier drafts of the Lemon Creek Spill Biological Monitoring Program Report, including: Robyn Roome (MoE), Jolene Raggett (MoE), Carrie Morita (MoE), Jeff Burrows (MFLNRO), Dr. Carl Schwarz (SFU), and Dr. Laurie Ainsworth (PhiStat Consulting).

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DEFINED TERMS

°C – degree Celsius

API – American Petroleum Institute

BC – British Columbia

BMP – Biological Monitoring Plan

CDC – Conservation Data Centre

COSEWIC – Committee on the Status of Endangered Wildlife in Canada

CPUE – catch per unit effort

EFC – Executive Flight Centre Fuel Services Inc.

EIA – Environmental Impact Assessment

EMP – Environmental Management Plan

EPA – U.S. Environmental Protection Agency

FSR – Forest Service Road

g - gram

GPS – Global Positioning System

ID – identification

km – kilometre(s)

LNAPL – light non-aqueous phase liquid

LWD – large woody debris

m – metre(s)

MFLNRO – BC Ministry of Forests, Lands and Natural Resource Operations

mm – millimetre(s)

MoE – BC Ministry of Environment

Perry's Bridge – Perry's Back Road Bridge

PAH – polycyclic aromatic hydrocarbon

PHC – petroleum hydrocarbon

RISC – Resource Information Standards Committee

SARA – Species at Risk Act

DEFINED TERMS (Cont'd)

SCAT – Shoreline Clean-up Assessment Technique

SNC-Lavalin – SNC-Lavalin Inc.

UTM – Universal Transverse Mercator

WB – Winlaw Bridge

YOY – young-of-the-year

1 INTRODUCTION

On behalf of Executive Flight Centre Fuel Services Ltd. (EFC), SNC-Lavalin Inc. (SNC-Lavalin) has prepared the following report detailing the findings from biological programs outlined in the Biological Monitoring Plan (BMP), developed in response to the Lemon Creek Jet-A1 fuel spill incident that occurred on July 26, 2013. This report specifically covers those biological programs that were not completed or achieved the endpoint at the time of the interim report, dated May 7, 2014. Programs for which endpoints were achieved at the time of the interim report (Water & Sediment and Fish Tissue programs) are not covered in this report.

1.1 Jet A-1 Fuel Background

Jet A-1 fuel is a liquid mixture primarily composed of kerosene and contains aliphatic and aromatic petroleum hydrocarbon (PHC) parameters comprised of six to sixteen carbon atoms (in the C_6-C_{16} carbon range). Kerosene's environmental fate is based on the individual components of the mixture itself. Methods for examining the environmental fate of jet fuels as a whole product are limited; instead the fates of individual hydrocarbon components are typically examined. Dissolution, adsorption, volatilization, and degradation are the primary factors affecting the transport and fate of Jet A-1 fuel in the environment. The fate of the spilled material is dependent on environmental conditions (e.g., climate, soil type). In addition to the physical-chemical properties of Jet A-1 fuel, organism-specific mechanisms (e.g., metabolism, excretion) determine the degree of uptake and accumulation of the spilled material in plants and animals.

1.1.1 Overview of Jet A-1 Fuel Persistence and Biodegradation

Jet A-1 fuel falls under the category of non-persistent oils (Group 1). Group 1 oils, when spilled in water (e.g., rivers) will partition as: 80% lost through natural dissipation, 10% recoverable floating oil, and 10% oil on shore (US Environmental Protection Agency [EPA] 2009). In terms of a relative ranking for different fuel spills on the basis of acute toxicity and persistence, Table 1.1 provides findings from the Washington Department of Ecology. Jet A fuel has the lowest acute toxicity and a low persistence in the environment (persisting on the order of days to weeks) (SNC-Lavalin 2013a).

Table 1.1: Relative ranking scores of acute toxicity and persistence for various types of oil spills

Oil Class	Acute Toxicity[a]	Persistence[b]
Kerosene-type Jet Fuel	1.4	1
Gasoline	5	1
No. 2 Fuel Oil	2.3	2
Bunker C	2.3	5

[a] Ranks for acute toxicity are based on a scale of 0–5 (0 is least harmful, 5 represents the most harmful effect).

[b] Ranks for persistence are based on an integer scale of 1–5, where the anticipated persistence levels are classified as 1: days-weeks, 2: 1 month to 1 year, 3: 1–2 years, 4: 2–5 years, and 5: 5–10 years or more.

Provided there are sufficient nutrients present for microbial communities, the components of kerosene can be significantly biodegraded to carbon dioxide and water, especially under aerobic conditions (API 2010). Lower molecular-weight linear alkanes are most readily biodegraded; however, they tend to partition to air where they are subject to photolysis. Following a spill, the microbial community composition in the impacted area may change to select for microbes that can degrade the introduced compounds (API 2010), which may explain the increased incidence of algae observed in pockets of Lemon Creek and Slocan River several weeks post-spill.

1.1.2 Summary: Environmental fate and transport of Jet A-1 fuel

Following a release of Jet A-1 fuel, the individual components will disperse and partition according to their individual physical-chemical properties. Since the product is highly volatile and a light non-aqueous phase liquid (LNAPL), most of its components would disperse on the surface of the water and tend to volatilize quickly; it is predicted that 30% to 35% of the volume released would volatilize in one day and 100% would have volatilized in 9 to 12 days (SNC-Lavalin 2013a). Residence times in the atmosphere would be relatively short due to indirect photo degradation reactions. In water, hydrolysis is not likely to be an important degradation process.

As the liquid product migrated downstream, some LNAPL and related contaminants would tend to accumulate in slower moving reaches of the creek and/or river and come into contact with river bank sediments. Some components, such as three-ring polycyclic aromatic hydrocarbons (PAH) and longer chain PHCs, may bind to organic material (i.e., organic carbon – wood debris, leaves, peat, etc.), partition to the sediment, and eventually be biodegraded.

It is duly noted that it is likely some partitioned components of Jet A-1 fuel may still be present in the aquatic environment. However, given the scientific knowledge around the persistence, biodegradation, and environmental fate of the Jet fuel it is anticipated that the majority of product constituents have been removed from the environment and any remaining product will continue to attenuate.

For more in-depth details regarding the persistence, bioaccumulation, biodegradation, and environmental fate and transport of Jet A-1 fuel, please refer to the Spill Response Environmental Impact Assessment report (SNC-Lavalin 2013a).

1.2 Purpose of Biological Monitoring Plan (BMP)

The key objective of the overall BMP was to ensure that the potential short-term, moderate, and longer-term (prolonged) effects to human and environmental health are effectively assessed, mitigated if necessary, and monitored for recovery. As the plan was carried out, each program reviewed its short-, medium-, and long-term objectives.

The BMP was also updated, as needed, based on the outcome of each proposed field sampling event. Shoreline Cleanup and Assessment Technique (SCAT) records and reporting (where available) have been utilized to coordinate the proposed monitoring locations and have added value on the identification of any potential new monitoring locations. The BMP was proposed to be adaptive and continually improved/refined as results were received and evaluated. Of note, select endpoints were modified in July 2014. Further detail is provided below in Section 2.1.

2 OBJECTIVES

The objectives of the Biological Monitoring Plan were to:

1) assess and document the distribution and concentrations of residual contaminants associated with the spill in water, sediment, and fish to determine the extent of the impacts and to ensure all potentially impacted human and ecological receptors (endpoints) are identified and evaluated; and
2) assess and monitor the effect of the spill on key biological (primarily aquatic) indicators (endpoints) as well as recovery of those indicators that were (or potentially were) impacted.

2.1 Identification of Recovery Endpoints

An endpoint is a measured response of a receptor to a stressor and can be measured in a toxicity test or field assessment.

Endpoints were established through consultation with provincial agencies (Ministry of Environment [MoE], Ministry of Forest Lands and Natural Resources [MFLNRO]), First Nations (Canadian Columbia River Inter-tribal Fisheries Commission), and fisheries professionals (Mirkwood Ecological Consultants) with knowledge of the Slocan River system. The endpoints recognize pertinent findings from the emergency response phase, physical and biological features that are highly valued in the region, and the importance for effectively monitoring the status and recovery of aquatic health post-spill.

Select endpoints characterized in the original version of the BMP were modified in July 2014 based on findings from initial field programs. The proposed modifications (detailed in SNC-Lavalin 2014a) were subsequently approved by MoE shortly thereafter. Thus, these revisions were applied to pertinent biological programs in this report. For details regarding the proposed modifications including rationale, please refer to SNC-Lavalin (2014a). The modified aquatic biota endpoints for the riverine environment are presented in Table 2.1 along with the criteria used for selecting the endpoints.

Table 2.1: Modified Endpoints for the Biological (Aquatic) BMP

Component	Endpoint	Rationale and criteria for selection
Fisheries Resources	Fish community metrics (abundance, diversity, community, and health) in braided side-channels of the Slocan River are stable over temporal and spatial scales.	The majority of deceased fish collected during the emergency response were located within the braided side-channels of Slocan River just downstream from the Lemon Creek confluence. Given that the majority of fish were recovered from the side-channel habitat, it is assumed that the fish assemblage within these channels were the most impacted as a result of the spill.

Table 2.1 (Cont'd): Modified Endpoints for the Biological (Aquatic) BMP

Component	Endpoint	Rationale and criteria for selection
Fisheries Resources (Cont'd)	Population estimates of Rainbow Trout in select off-channel habitat are stable over temporal and spatial scales.	Rainbow Trout populations of the Slocan River have been in decline, but more recent studies have suggested population recovery. Previous studies of Slocan River index sites found the highest numbers of Rainbow Trout near Lemon Creek, about half as many fish at Winlaw, about one quarter as many fish at Crescent Valley, and lowest numbers of fish at Passmore and Slocan Park (Oliver 1999). Population monitoring has been ongoing, including post-spill; however, insufficient funds has prevented the analysis of current and historic data.
	Bull Trout migration and spawning in the Lemon Creek system have not been adversely impacted.	Bull Trout are a blue-listed (species of concern) fish species in BC (BC Conservation Data Center). No Bull Trout mortalities were collected during seven days of post-spill salvages. However, the system is believed to be a highly productive spawning area and likely provides habitat for other life stages.
	Fish abundance and community structure in Lemon Creek are similar to reference (non-impacted) sites.	Lemon Creek is one of, if not, the most diverse and productive watercourses for fish species in the Slocan River system. It is home to several important fish species including Bull Trout (Blue-listed), Rainbow Trout, Mountain Whitefish, sculpin spp including Shorthead Sculpin (Species At Risk Act [SARA]-listed), and Umatilla Dace (also SARA-listed). The lower 4 kilometres of Lemon Creek were the most highly impacted from the spill based on SCAT data/results and deceased fish specimens collected during salvage.
Lower Trophic Level Dynamics	Similar abundance, diversity, and distribution of benthic invertebrates in affected and reference areas as well as regional data (where feasible).	Benthic invertebrate community structure represents an important ecosystem health indicator and well as an indication of aquatic recovery post- impact event.

Aquatic impacts and recovery as a result from, and post-clean up of, this type of fuel spill has previously been studied by Guiney et al. (1987) and the American Petroleum Institute – Petroleum HPV Testing Group (API 2010).

The HPV Chemical Test Program of the American Petroleum Institute (API 2010) included acute toxicity endpoints for freshwater fish, freshwater invertebrate, and freshwater alga for jet fuel/kerosene category. The substances in the Jet fuel/kerosene were found to produce a similar range of toxicity for each of the three trophic levels (API 2010) and there is sufficient data on the ecotoxicity of jet fuel and kerosenes to demonstrate moderate acute toxicity to aquatic organisms. This is predicted because the majority of constituents in kerosenes are neutral organic hydrocarbons that act in a common mode of action termed “non-polar narcosis”, which is brought about by disruption of biological membrane function (van Wezel and Opperhuizen 1995). Thus, it was anticipated that any chronic toxicity effects or impacts to species, populations, or communities of these organisms to be low.

The above product information, results from the emergency response and Environmental Impact Assessment (EIA), extensive literature, and local knowledge/expertise was evaluated prior to selecting monitoring components and further supplemented those modifications made to select endpoints.

The following sections summarize the findings from developed monitoring programs to meet the above objectives (and endpoints) to carry out each program.

3 WATER AND SEDIMENT ASSESSMENT PROGRAM

Based on May 2014 analytical results, concentration of hydrocarbons were non-detectable in surface water and sediment samples collected from two locations on Lemon Creek where residual sheen was observed, as well as a water sample collected from a local resident's (Mr. Hulbert) shallow drinking water well. Furthermore, the remaining 18 locations, including six (6) along Lemon Creek and 12 along Slocan River that were sampled and analyzed also contained non-detectable concentrations of hydrocarbons in surface water and sediment, as well as porewater samples collected along the Slocan River.

Groundwater impacts along Lemon Creek and/or the Slocan River are not expected based on May 2014 surface water/sediment results. It appears that the flushing/clean-up efforts were effective in reducing the amount of Jet A1 fuel along Lemon Creek and the Slocan River. As well, spring freshet conditions appear to have aided in the flushing process, which is inferred to have mobilized residual jet fuel trapped beneath boulders and cobbles within Lemon Creek, allowing for further product attenuation. Based on this information, it was recommended that no further remediation in Lemon Creek and Slocan River was required at that time. In addition, all samples collected and analyzed as part of the May 2014 freshet sampling event contained non-detectable concentrations of hydrocarbons, indicating that the end-points have been achieved. Therefore, it was proposed not to proceed with the fourth and final monitoring and sampling event for Lemon Creek and the Slocan River for the end of July 2014. BC MoE approved the discontinuation of the Water/Sediment monitoring based on the July 24, 2014 memo requesting modifications to the overall BMP. General field observations documenting conditions along Lemon Creek and Slocan River as part of the Biological Monitoring Program are provided in Appendix I.

4 FISH TISSUE ASSESSMENT PROGRAM

As per the May 2014 interim monitoring report (SNC-Lavalin 2014b), fish tissue results from Mountain Whitefish (*Prosopium williamsoni*) indicated that PAH levels were similar between samples collected from the Lemon Pool and the Little Slocan/Slocan River confluence site located approximately 30 km downstream.

Data generated from the fish tissues analyzed from whole samples collected in October 2013 indicated the PAH profile would not be considered similar to the released product, as most of the associated PAH compounds in Jet A1 fuel were non-detectable. Based on extensive scientific literature, teleost fish are capable of metabolizing PAHs readily, which was supported by the laboratory results that exhibited multiple non-detect and/or very low PAH levels in the fish tissues three months after the spill occurred. Furthermore, fish in the Slocan River system have been subjected to other ‘historical’ inputs, which are not associated with Jet A1 fuel. Even with historical inputs and the release of Jet A1 fuel, PAH levels remain negligible, suggesting fish in the Slocan watershed are effective at metabolizing PAHs they encounter.

The observed presence of phenanthrene in sampled tissues was likely an artifact in the Slocan system. Phenanthrene is a compound that occurs naturally (and is typically associated with forest fires) and levels recorded in Mountain Whitefish from the Slocan River are similar to natural levels documented in other systems with no industrial development or anthropogenic stressors (e.g., Taylor et al. 1998). Detected PAHs were well below those described by Alberta Environmental Protection as safe for human consumption, or risk to fish or wildlife species that consumed those fish (Sosiak 1998). Based on the weight of evidence, the observed presence of phenanthrene does not appear to be a concern to fish health or human/wildlife consumption. Further, PAH levels found in Mountain Whitefish tissue from the Lemon Pool were similar to the reference site, while the PAH profile in tissue is dissimilar to the released product. Consequently, the endpoint for this program was reached and subsequently approved by BC MoE and MFLNRO.

5 SLOCAN RIVER OFF-CHANNEL FISH COMMUNITY MONITORING

As per the "*Environmental Monitoring Plan – Biological Programs*" (BMP), the Slocan River off-channel fish community monitoring program was designed to address several key endpoints established through consultation with provincial agencies, First Nations, local stakeholders and fisheries professionals. The original established endpoints of the program included:

1) Population estimates of Mountain Whitefish in select off-channel habitat were not significantly adversely impacted; and
2) Fish abundance and community structure in braided off-channels of the Slocan River were similar to mortality counts in the same area and are temporarily consistent and stable.

The intent of the mark-recapture program was to characterize the post-spill fish assemblage and provide salmonid population estimates in select off-channel habitats on the Slocan River. The majority of deceased fish collected during the emergency response were recovered in off-channel braided habitats of the Slocan River downstream of the Lemon Creek confluence. Given that the majority of deceased fish were juvenile Mountain Whitefish, it was initially hypothesized that they were the most abundant species inhabiting Slocan River off-channel habitats at the time of the spill, and, thus, were selected as the target species for the mark-recapture program. The proposed endpoints summarized above and in the SNC-Lavalin Biological Monitoring Plan (SNC-Lavalin 2013b) were formed based on this premise.

Data collected from three field seasons (fall 2013, summer 2014, and fall 2014) confirmed that our initial hypothesis (i.e., Mountain Whitefish are the most abundant fish in off-channel habitat) was likely false and the original endpoints could not be appropriately monitored and achieved. Consequently, an alternate hypothesis was formulated and the endpoints modified to more effectively monitor for potential fish-related effects.

SNC-Lavalin issued a memorandum to MoE requesting proposed modifications to the original BMP (SNC-Lavalin 2014a). In that memo it was recommended that Rainbow Trout (Oncorhynchus mykiss) replace Mountain Whitefish as the focused species for the Mark-Recapture Program. Subsequently, the MoE and MFLNRO agreed that the specific change request was reasonable and supported by sound rationale (SNC-Lavalin 2014c).

Based on the modifications made to the Mark-Recapture Program, the endpoints were adjusted to address the following hypotheses:

1) Population estimates of Rainbow Trout in select off-channel habitat are stable over temporal and spatial scales; and

2) Fish community metrics (i.e., fish abundance, diversity, community and health) in braided side-channels of the Slocan River are stable over temporal and spatial scales.

5.1 Objectives Based on Modified Endpoints

The objectives of the modified Mark-Recapture Program were to:

1) Calculate population estimates of Rainbow Trout in select off-channel habitats on the Slocan River, compare data to historical Rainbow Trout population data for the Slocan River mainstem, and evaluate the stability and resilience of Rainbow Trout post-spill; and
2) Characterize fish community metrics in select braided off-channel habitat on the Slocan River.

5.2 Methods

5.2.1 Study Locations

5.2.1.1 Sample Sites

A summary of the sampling program conducted in 2013/2014 (Table 5.1) and supplemented with site location maps (Figure 5.1 – 5.4) is provided below.

Table 5.1: Timeframe and rationale for sampling events conducted on the Slocan River as part of the mark-recapture program

Year	Month	Location	Site Name	Sampling Objective
2013	October	Larsen	Mainstem	• Rainbow Trout Population Estimate • Fish Community • Mountain Whitefish Presence/Absence
			Off-channel	
		Drake	Upper	
			Lower	
		Lower Lemon Creek/Slocan River Side-Channel	Channel 1	• Fish Community • Mountain Whitefish Presence/Absence
			Channel 2	
2014	July	Upper Lemon Creek/Slocan River Side-Channel	Site 1	• Mountain Whitefish Presence/Absence
			Site 2	
		Lower Lemon Creek/Slocan River Side-Channel	Channel 1	
	October	Larsen	Mainstem	• Rainbow Trout Population Estimate • Fish Community • Mountain Whitefish Presence/Absence
			Off-channel	
		Drake	Upper	
			Lower	

Four off-channel habitats were sampled; Larsen, Drake, and lower and upper Lemon Creek/Slocan River side-channels (Figure 5.1). In each of the off-channel habitats mentioned above, two sites were sampled within each location (e.g., Drake – Upper and Lower).

The Larsen off-channel habitat is located on the Slocan River approximately 2.3 km downstream of the Lemon Creek confluence. Larsen included two sampling areas; a left bank mainstem channel, and side-channel habitat located on an island (Figure 5.2). The sampled mainstem channel was relatively wide (<30 m), contained deep pools (>2 m to 3 m deep), with scattered large woody debris (LWD) structures along the margins. Cobble, gravel and fines were the most abundant substrate observed in the mainstem. The side-channel habitat consisted of multiple small channels (<5 m) with an abundance of LWD structure. The channels were mostly shallow (<1 m deep) but did include several 2 m deep pools. With the abundance of woody debris in the channels, water flow was relatively slow. As such, fines were the most common substrate observed. Gravel and cobble were present in areas containing slightly higher flows.

Drake is located considerably farther downstream (19.0 km) than the Larsen off-channel habitat (Figure 5.3). The area was divided into an Upper and Lower section and channel widths ranged from 10 m to15 m. Upper Drake was relatively shallow (<1.5 m deep) and contained a moderate amount of cover in the form of small woody debris (SWD) and LWD. Fines were the dominant substrate observed; however, small gravel and cobble patches were also present. Lower Drake contained little to no woody debris for cover, but did include some larger substrate that fish associated with. Unlike the Upper Drake section, Lower Drake offered deeper habitat (>2 m deep) with considerably coarser substrate. Undercut banks and overhanging vegetation was relatively scarce throughout both channels.

The bottom end of the Lemon Creek/Slocan River side-channel is located approximately 500 m upstream from the Larsen off-channel habitat (Figure 5.4). Two separate channels were sampled in the lower Lemon Creek/Slocan River side-channel; Channel 1 and Channel 2. At the time of the study, Channel 1 was the longer of the two and comprised short riffle and shallow glide sections interspersed with the occasional run. The area sampled included some undercut banks and overhanging vegetation with little to no woody debris. There was a mix of cobble, gravel and fine substrate throughout the sampled area. Channel 2 was considerably shorter and was a slower moving channel. The lower velocity channel consisted mostly of fines (~80%) and offered marginal fish habitat cover in the form of woody debris and the occasional cutbank.

Upper Lemon Creek/Slocan River side-channel was sampled at the anniversary of the spill and included two sample locations relatively close to one another (Figure 5.4). Both locations were similar in terms of habitat, channel morphology and available cover. Channel widths ranged between 5 m and 8 m in both areas, and consisted of run/riffle/pool habitat. The channel was relatively shallow (<1.5 m deep) and included overhanging vegetation, occasional woody debris and undercut banks that acted as fish cover. Substrate was also consistent between sites and predominantly consisted of gravel and cobble, while areas of lower velocity contained fines.

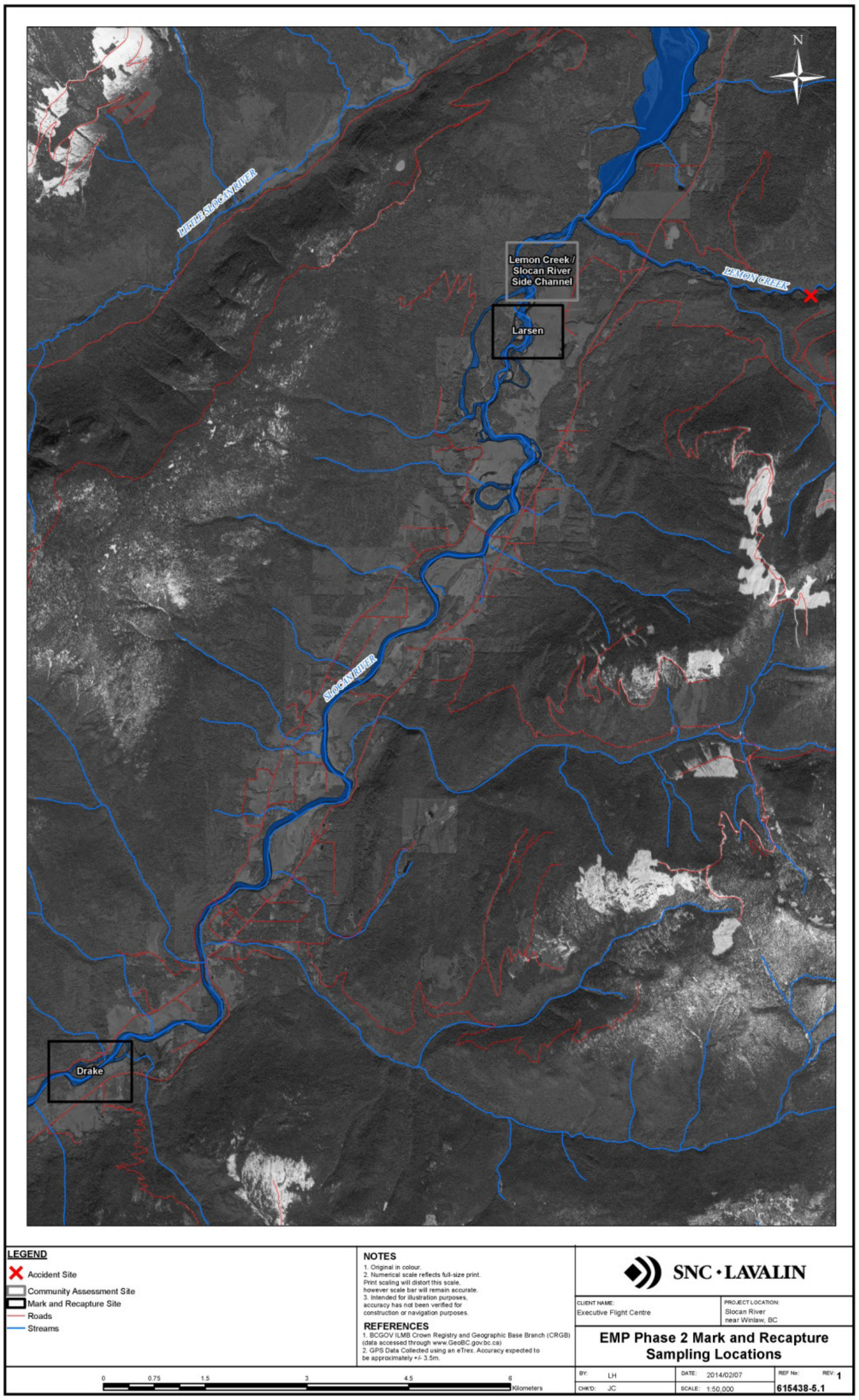


Figure 5.1: Overview map showing the four locations sampled during the mark-recapture program

Figure 5.2: Map showing the two mark-recapture sites (main channel and side-channel) at Larsen

Figure 5.3: Map showing the two mark-recapture sites (upper and lower) at Drake

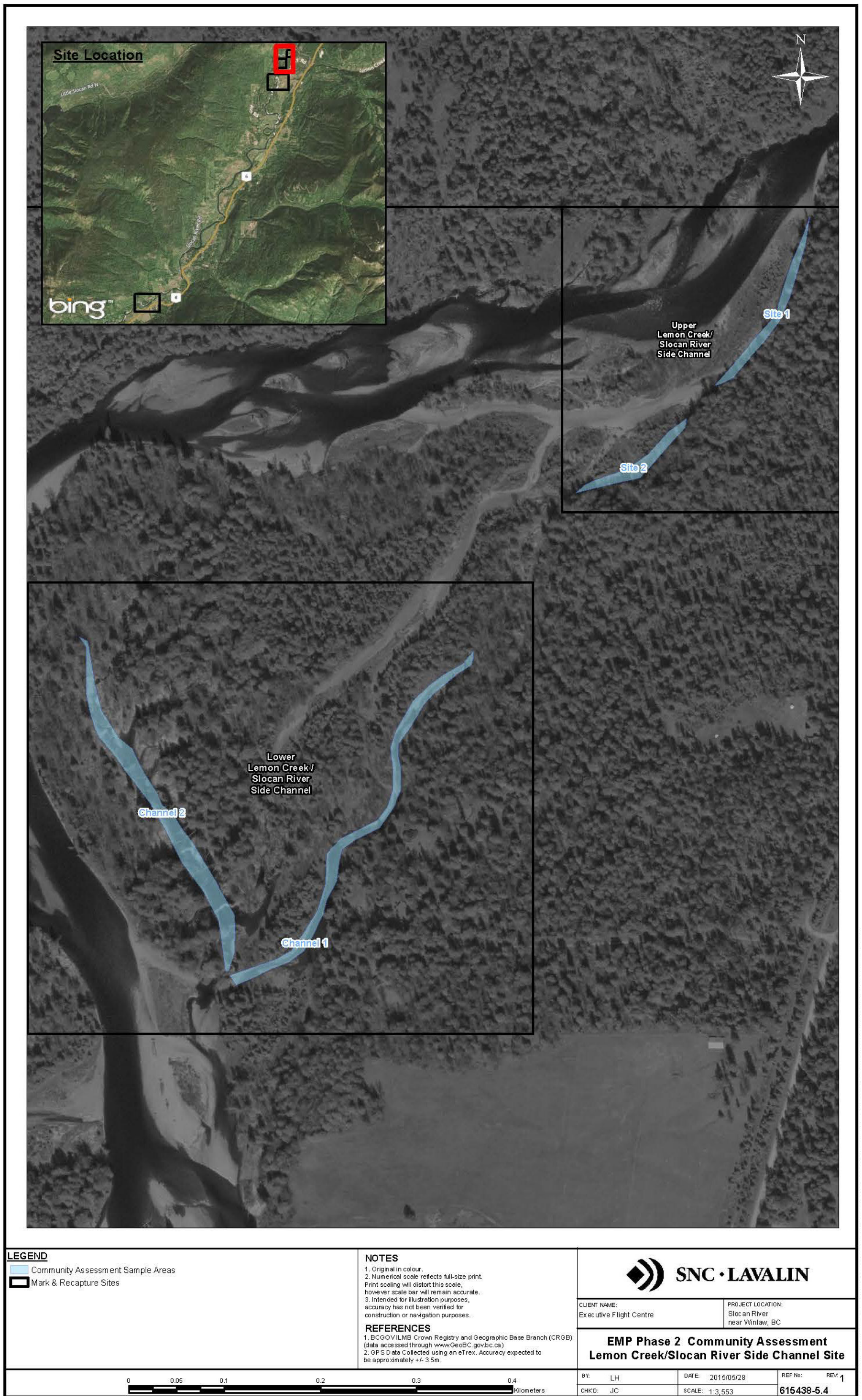


Figure 5.4: Map showing Upper and Lower Lemon Creek/Slocan River Side-channel sites

5.2.2 Fish Collection

5.2.2.1 Fish Community and Rainbow Trout Population Sampling

Rainbow Trout population estimates and fish community data was collected in 2013 and 2014 from two locations; the off-channel habitat at Larsen and Drake. Fish community data was also collected with the same amount of effort for Lower Lemon Creek/Slocan River side-channel in 2013 with the intention that Mountain Whitefish were to be captured. Since Mountain Whitefish were not captured at this location in 2013, additional sampling was conducted in 2014 that attempted to target Mountain Whitefish presence/absence. Thus, only a small subset of incidental fish catch data was processed in 2014.

Each of the locations was sampled using a backpack electrofisher. In an attempt to capture as many Rainbow Trout as possible, two passes were conducted with the electrofisher at both sites at each location. The electrofisher settings, number of seconds fished and UTM coordinates of the upstream and downstream extent of the site were recorded. Electrofishing was conducted in a safe manner in shallow water and in areas containing suitable fish habitat (i.e., woody debris, margins of deep pools, boulders, undercut banks, overhanging vegetation).

All fish caught were placed in a five gallon pail and anesthetized with Alka-Seltzer tablets. During the first day of the mark-recapture program, all fish caught were identified, weighed (g) and measured to fork length (mm). Only Rainbow Trout were marked with an adipose fin clip for the program. A small fraction of the adipose (enough to make a positive identification on the recapture day) was removed using surgical scissors. Photographs were taken of each species of fish captured during the program. Once all required data was obtained, fish were placed in a recovery bucket containing an aerator. To further reduce the amount of stress on the fish, some fish cover was added to the recovery pail. All fish were subsequently released in the vicinity of point of capture.

After approximately 48 hours, crews returned and sampled the same area as the first day. Unlike the first day, crews only retained Rainbow Trout and released all other species of fish caught. Rainbow Trout were placed in a pail and anesthetized as previously described. All trout retained were inspected for a clipped adipose fin. Marked fish were recorded as re-captures and fish not previously caught were weighed (g) and measured to fork length (mm). Fish were placed in a recovery pail and released near the point of capture.

As described above, Mountain Whitefish were not captured in 2013 at Larsen, Drake or Lower Lemon Creek/Slocan River side-channel. Further opportunistic sampling was conducted in 2014 to confirm the presence/absence of Mountain Whitefish at a time when water levels were similar to when the spill occurred in off-channel habitat and to validate the 2013 findings.

5.2.3 Data Analyses

5.2.3.1 *Fish Community Data*

Although additional fish community data is available, analyses will only focus on data collected from Larsen and Drake off-channel habitat. Remaining data was collected at other locations opportunistically as sampling efforts targeted Mountain Whitefish and only a small subset of fish were identified, weighed and measured.

Given the relatively low numbers of individuals caught during the program, catch data from sites within each location were combined (e.g., Drake catch data includes Upper and Lower site). All catch data from 2013 and 2014 were examined in terms of species diversity and relative abundance over a spatial and temporal scale. Species composition at each location was compared using a pie chart based on relative abundance numbers.

Length frequency graphs were developed for species when n >30 individuals were caught. In the case of Rainbow Trout, length frequency graphs were developed regardless of number of individuals captured. In addition to the graphs, condition factor was also calculated for Rainbow Trout at each location using an equation reflecting allometric growth (slope of 3.024) derived by Simpkins and Hubert (1996). Simpkins and Hubert (1996) derived their equation based on Rainbow Trout data collected in lotic systems across Canada. Condition factor is widely used in fisheries and general fish biology studies as a means to describe the condition of that individual (Nash et al. 2006). An average fish in good condition will have a condition factor close to 1.

5.2.3.2 *Population Data*

Given the relatively low number of recaptures, Rainbow Trout catch data was combined from each site at each respective location. Population estimates for Rainbow Trout were obtained from Larsen and Drake off-channel habitat using a closed population model: specifically the modified Petersen estimate (Chapman 1951). The modified Petersen estimate is represented by the formula provided below:

$$N \approx \frac{(K+1)(n+1)}{k+1} - 1$$

Where:

N= Number of animals in the population

K= Number of animals marked on the first visit

n= Number of animals captured on the second visit

k= Number of recaptured animals that were marked

Sample calculations also included an approximately unbiased variance using the equation below:

$$\mathrm{var}(N) = \frac{(K+1)(n+1)(K-k)(n-k)}{(k+1)(k+1)(k+2)}.$$

The modified Petersen estimate is consistent with other population estimate studies conducted in the Columbia River (e.g., Rawding and Cochran 2007).

5.3 Results

5.3.1 Fish Community

5.3.1.1 Larsen

Nine species were caught in Larsen off-channel habitat in both 2013 and 2014 (Table 5.2, 5.3). Umatilla Dace was only captured in 2014, whereas Prickly Sculpin were only collected in 2013. The presence of Umatilla Dace is of particular interest due to the relatively high numbers of individuals collected compared to any other site or year. Similar between years, Rainbow Trout and Torrent Sculpin were the most dominant species in 2013 and 2014 and accounted for 58% and 51% of the total catch, respectively (Figure 5.5). Number of fish caught were also considerably higher in 2014 (328 individuals) than in 2013 (136 individuals). Length frequency plots for Torrent Sculpin and Umatilla Dace suggest that a wide range of age classes (cohorts) and life stages are present (Figure 5.6). Length frequency data for Northern Pikeminnow suggest the vast majority of individuals captured were juveniles. Rainbow Trout frequency plots are provided in the Rainbow Trout catch data section discussed below.

Table 5.2: Species diversity, relative abundance and fork length of fish caught in 2013 in the Larsen off-channel habitat location

Species	Common Name	Number Caught	Fork Length (mm)		
			Min	Max	Mean
Oncorhynchus mykiss	Rainbow Trout	41	63	269	110
Cottus rhotheus	Torrent Sculpin	38	56	122	84
Catostomus macrocheilus	Largescale Sucker	17	46	131	81
Ptychocheilus oregonensis	Northern Pikeminnow	12	68	116	79
Rhinichthys cataractae	Longnose Dace	9	33	89	56
Cottus sp.	Sculpin sp.	9	48	70	55
Cottus asper	Prickly Sculpin	7	50	92	78
Catostomus catostomus	Longnose Sucker	2	57	95	76
Richardsonius balteatus	Redside Shiner	1	-	106	106

Table 5.3: Species diversity, relative abundance and fork length of fish caught in 2014 in the Larsen off-channel habitat location

Species	Common Name	Number Caught	Fork Length (mm)		
			Min	Max	Mean
Cottus rhotheus	Torrent Sculpin	100	24	143	74
Oncorhynchus mykiss	Rainbow Trout	70	51	161	84
Ptychocheilus oregonensis	Northern Pikeminnow	68	34	135	71
Rhinichthys umatilla	Umatilla Dace	30	47	86	60
Rhinichthys cataractae	Longnose Dace	27	36	66	51
Cottus sp.	Sculpin sp.	15	25	68	46
Catostomus catostomus	Longnose Sucker	9	80	124	99
Catostomus macrocheilus	Largescale Sucker	7	44	59	49
Richardsonius balteatus	Redside Shiner	2	38	90	64

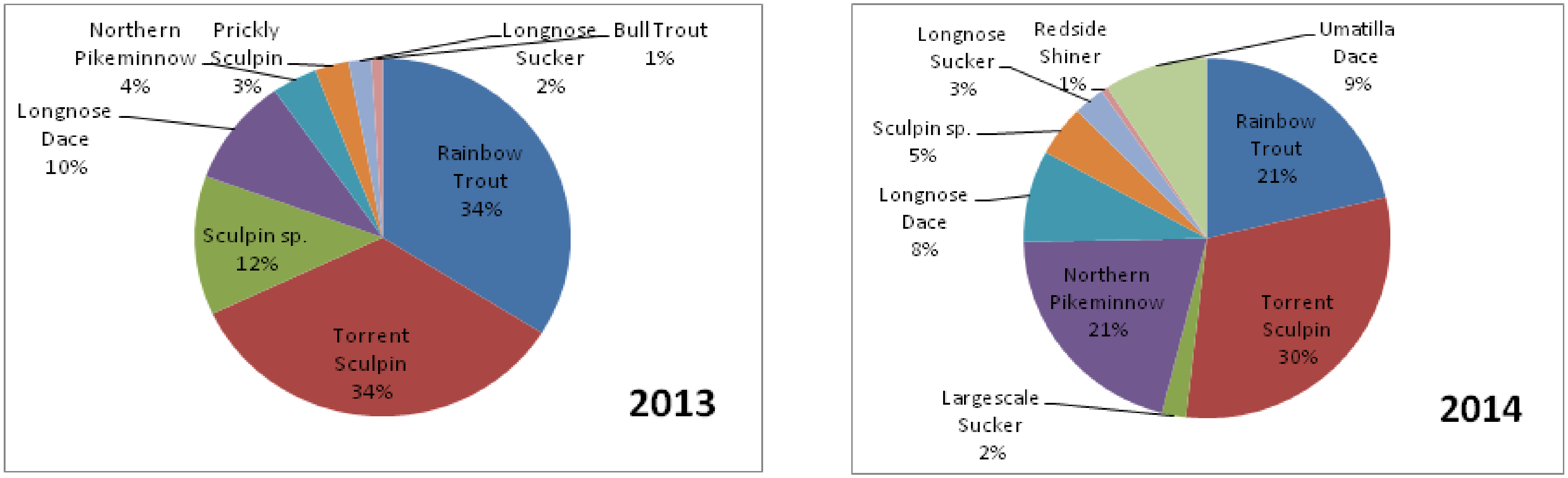


Figure 5.5: Pie chart displaying respective species percentage of total catch in Larsen off-channel habitat in 2013 and 2014

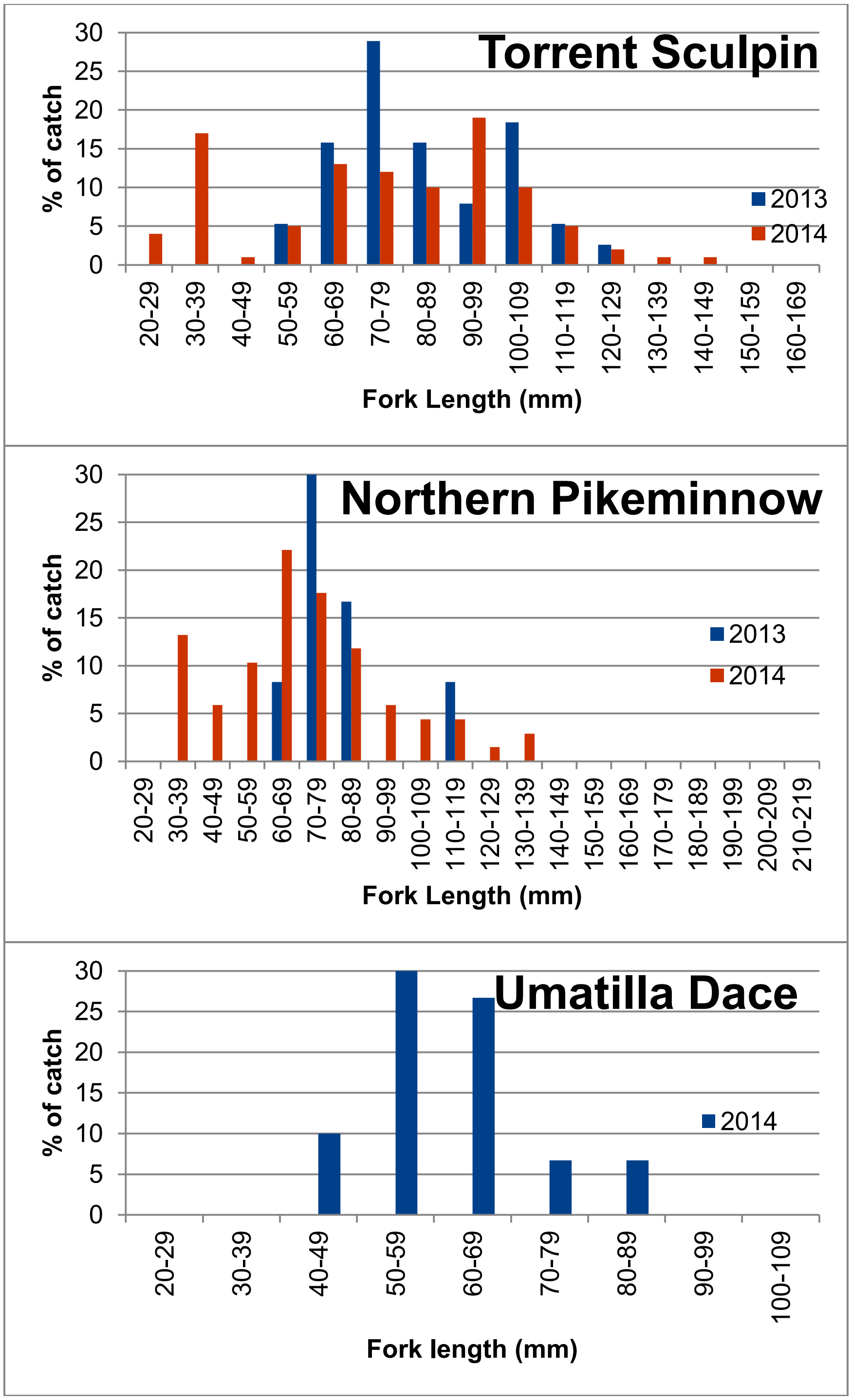


Figure 5.6: Length frequency percentage plots of most abundant species caught at Larsen off-channel habitat. Note: Umatilla Dace were not captured in 2013.

5.3.1.2 Drake

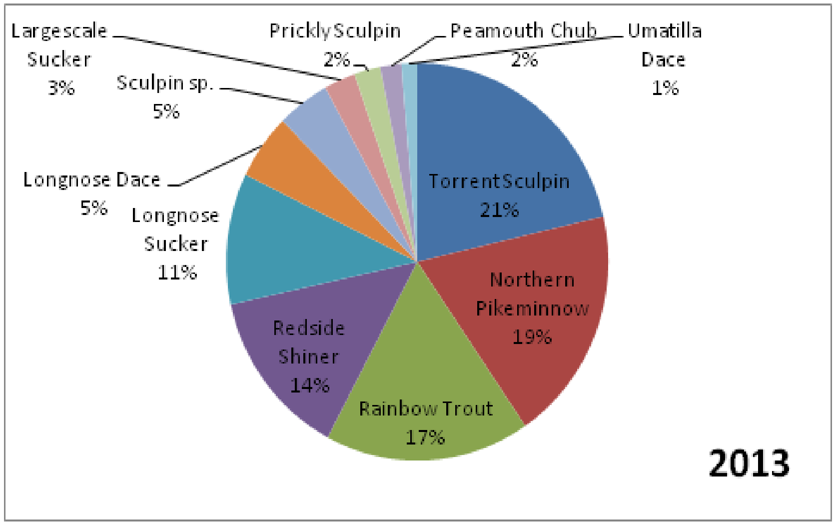
A total of 11 and 10 species were captured at the Drake off-channel habitat in 2013 and 2014, respectively (Table 5.4, 5.5). Although Peamouth Chub was collected in 2013 in low numbers, none were caught or observed at Drake in 2014. Similar between years, the four most abundant species at Drake were Torrent Sculpin, Northern Pikeminnow, Rainbow Trout and Redside Shiner (Figure 5.7). These four species accounted for 71.6% (2013) and 70.8% (2014) of the total catch. Length frequency plots for Torrent Sculpin and Redside Shiner suggest that a wide range of age classes (cohorts) and life stages are present (Figure 5.8). Length frequency data for Northern Pikeminnow suggests that the vast majority of individuals captured were juveniles. Rainbow Trout frequency plots are provided in the Rainbow Trout catch data section discussed below.

Table 5.4: Species diversity, relative abundance and fork length of fish caught in 2013 in the Drake off-channel habitat location

Species	Common Name	Number Caught	Fork Length (mm)		
			Min	Max	Mean
Cottus rhotheus	Torrent Sculpin	48	24	138	73
Ptychocheilus oregonensis	Northern Pikeminnow	43	50	213	83
Oncorhynchus mykiss	Rainbow Trout	39	57	305	97
Richardsonius balteatus	Redside Shiner	31	36	123	83
Catostomus catostomus	Longnose Sucker	24	78	178	116
Rhinichthys cataractae	Longnose Dace	12	34	93	55
Cottus sp.	Sculpin sp.	10	48	71	59
Catostomus macrocheilus	Largescale Sucker	6	82	119	93
Cottus asper	Prickly Sculpin	5	38	126	90
Mylocheilus caurinus	Peamouth Chub	4	37	96	69
Rhinichthys umatilla	Umatilla Dace	3	63	78	76

Table 5.5: Species diversity, relative abundance and fork length of fish caught in 2014 in the Drake off-channel habitat location.

Species	Common Name	Number Caught	Fork Length (mm)		
			Min	Max	Mean
Cottus rhotheus	Torrent Sculpin	88	20	126	66
Ptychocheilus oregonensis	Northern Pikeminnow	71	40	110	69
Richardsonius balteatus	Redside Shiner	46	34	111	74
Oncorhynchus mykiss	Rainbow Trout	31	59	336	106
Catostomus macrocheilus	Largescale Sucker	29	89	180	125
Catostomus catostomus	Longnose Sucker	26	54	152	111
Cottus sp.	Sculpin sp.	20	29	73	57
Rhinichthys cataractae	Longnose Dace	11	28	73	50
Rhinichthys umatilla	Umatilla Dace	9	46	110	61
Cottus asper	Prickly Sculpin	2	67	120	94



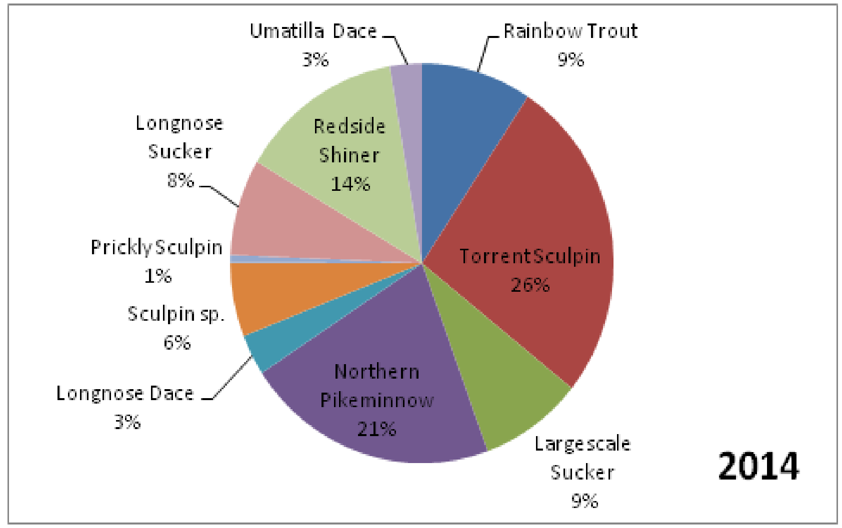


Figure 5.7: Pie chart displaying respective species percentage of total catch in Drake off-channel habitat in 2013 and 2014

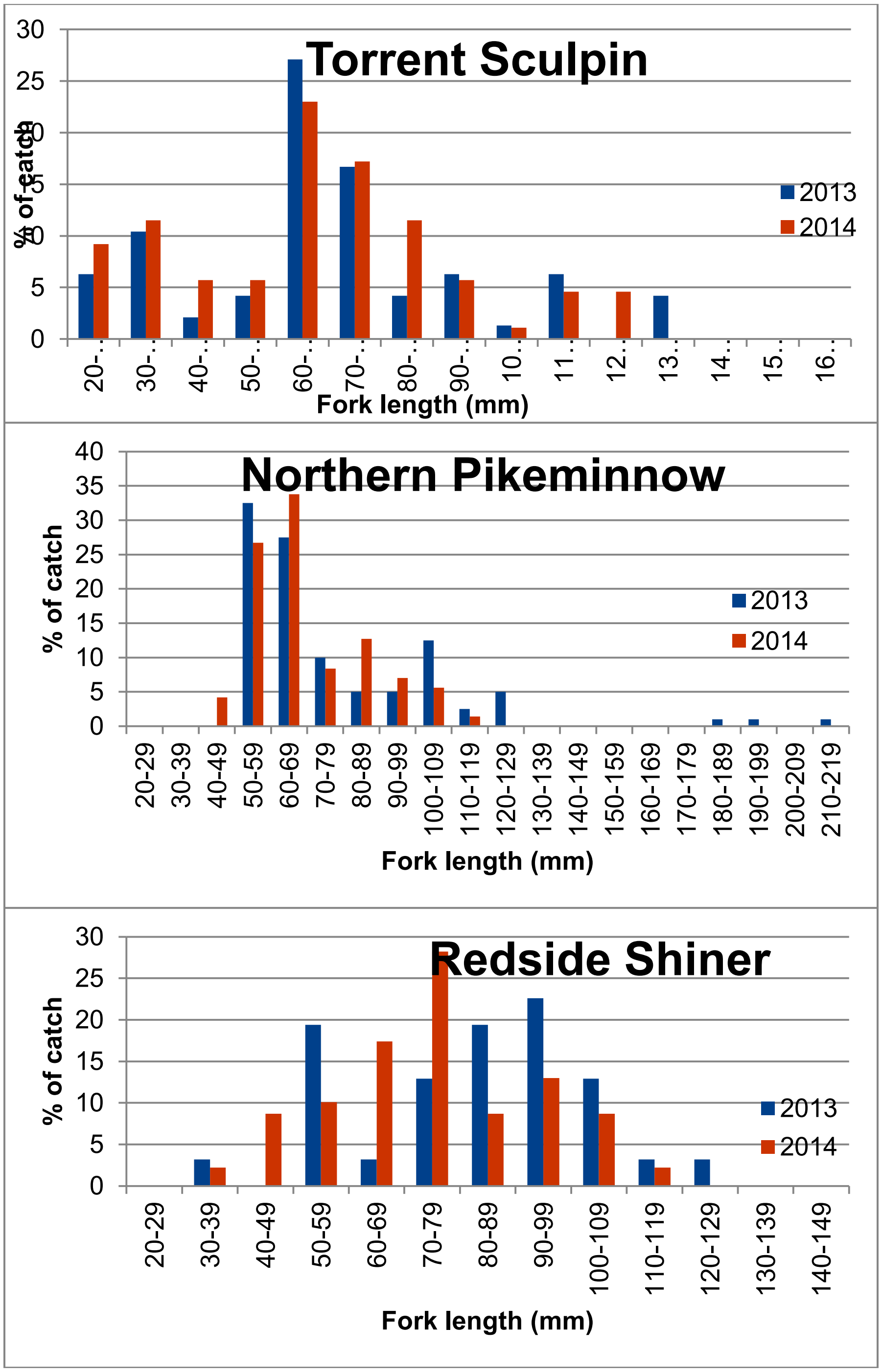


Figure 5.8: Length frequency percentage plots of most abundant species caught at Drake off-channel habitat

5.3.1.3 Lower Lemon Creek/Slocan Side-Channel

In 2013, eight species were caught in the Lemon Creek/Slocan River side-channel, with Rainbow Trout and Torrent Sculpin being the most abundant accounting for 68% of the total catch (Figure 5.9, Table 5.6). Bull trout (*Salvelinus confluentus*) was also captured at this site.

The off-channel habitat was only sampled once in 2014 (July) with the intention of conducting a reconnaissance for Mountain Whitefish presence when water levels were similar to when the spill occurred. Incidental by-catch was opportunistically sampled, but since sampling effort was not similar to that applied in 2013, comparison of species diversity and relative abundance between years was problematic. Only five species of fish were processed from the Lower Lemon Creek/Slocan River off-channel habitat in 2014, and two of these species (Longnose Dace and Sculpin sp.) accounted for 72.8% of the total catch (Table 5.7). Aside from Rainbow Trout, Torrent Sculpin was the only other species of fish where greater than 30 individuals were caught. The length frequency plot for Torrent Sculpin suggests that catches were comprised of juvenile and adult cohorts (Figure 5.10).

Table 5.6: Species diversity, relative abundance and fork length of fish caught in 2013 in the Lower Lemon Creek/Slocan River off-channel habitat location

Species	Common Name	Number caught	Fork Length (mm)		
			Min	Max	Mean
Oncorhynchus mykiss	Rainbow Trout	35	67	235	113
Cottus rhotheus	Torrent Sculpin	35	61	116	89
Cottus sp.	Sculpin sp.	13	50	90	65
Rhinichthys cataractae	Longnose Dace	10	32	123	80
Ptychocheilus oregonensis	Northern Pikeminnow	4	70	91	80
Cottus asper	Prickly Sculpin	3	79	100	90
Catostomus catostomus	Longnose Sucker	2	85	105	95
Salvelinus confluentus	Bull Trout	1	-	185	185

Table 5.7: Species diversity, relative abundance and fork length of fish caught in 2014 in the Lower Lemon Creek/Slocan River off-channel habitat location

Species	Common Name	Number caught	Fork Length (mm)		
			Min	Max	Mean
Rhinichthys cataractae	Longnose Dace	19	81	103	69
Cottus sp.	Sculpin sp.	5	59	88	71
Cottus rhotheus	Torrent Sculpin	4	78	125	98
Rhinichthys umatilla	Umatilla Dace	4	49	72	58
Cottus asper	Prickly Sculpin	1	-	98	98

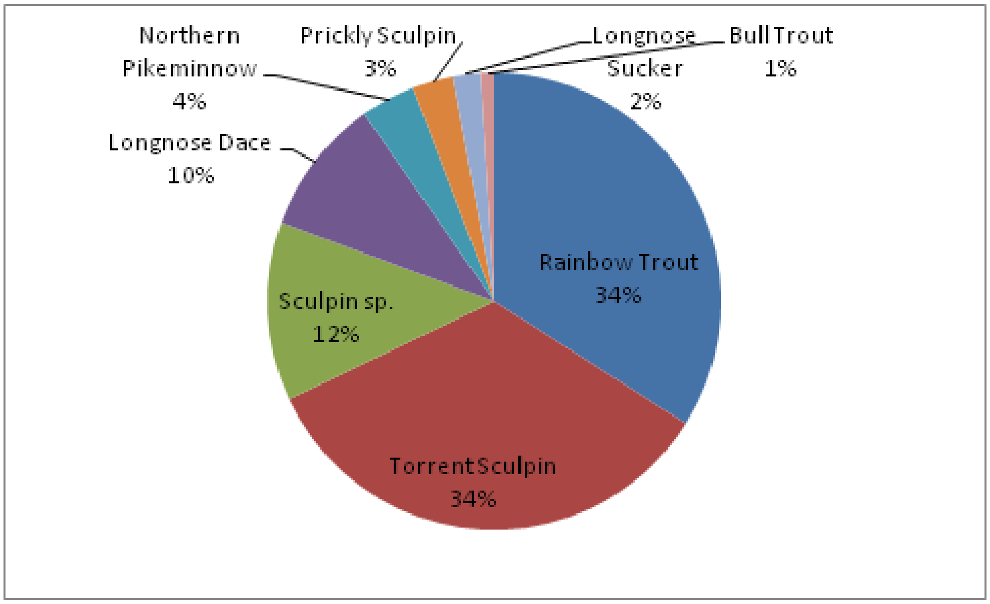


Figure 5.9: Pie chart displaying respective species percentage of total catch in Lower Lemon Creek/Slocan River off-channel habitat in 2013

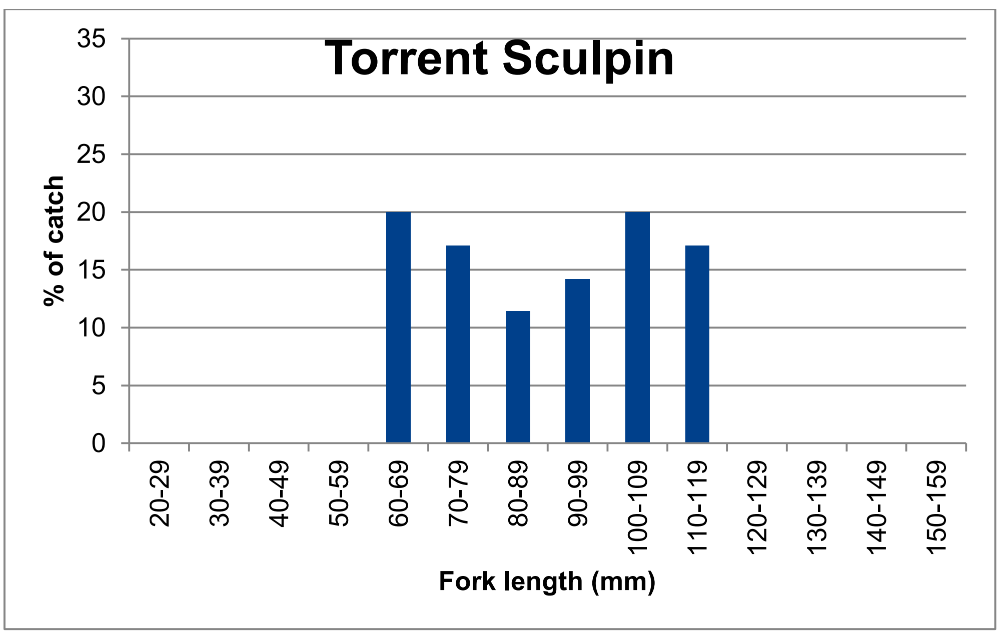


Figure 5.10: Length frequency percentage plots of Torrent Sculpin caught at Lower Lemon Creek/Slocan River off-channel habitat in 2013

5.3.1.4 Upper Lemon Creek/Slocan Side-Channel

Since the side-channel was dry when the program was initiated in October 2013, July 2014 was the first time that the upper Lemon Creek/Slocan River side-channel was sampled. The off-channel habitat was sampled on the anniversary of the spill with the intention of locating Mountain Whitefish. Considering that the program focused on the collection of Mountain Whitefish, incidental by-catch was only opportunistically sampled. Sample collections revealed seven species of fish were present, of which Torrent Sculpin and Longnose Dace accounted for 56.7% of the total catch (Table 5.8, Figure 5.11).

Table 5.8: Species diversity, relative abundance and fork length of fish caught in 2014 in the Upper Lemon Creek/Slocan River off-channel habitat location.

Species	Common Name	Number caught	Fork Length (mm)		
			Min	Max	Mean
Cottus rhotheus	Torrent Sculpin	18	50	125	94
Rhinichthys cataractae	Longnose Dace	16	57	108	71
Cottus sp.	Sculpin sp.	9	14	79	55
Cottus asper	Prickly Sculpin	6	61	110	83
Oncorhynchus mykiss	Rainbow Trout	5	32	54	45
Rhinichthys umatilla	Umatilla Dace	4	45	65	55
Ptychocheilus oregonensis	Northern Pikeminnow	2	52	58	55

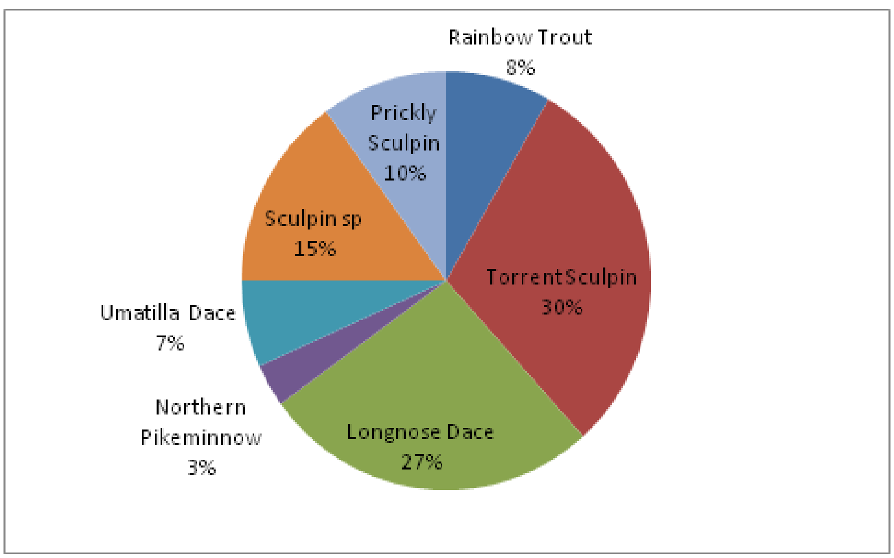


Figure 5.11: Pie chart displaying respective species percentage of total catch in Upper Lemon Creek / Slocan River off-channel habitat in 2014

Rainbow Trout Catch Data

Length Frequency

Length Frequency histograms were plotted for Rainbow Trout caught in 2013 and 2014 at Larsen (Figure 5.12), Drake (Figure 5.13) and Lemon Creek/Slocan River side-channel (Figure 5.14). As the majority of Rainbow Trout caught in off-channel habitat were young of the year and in the 1+ age class (Figures 5.12 to 5.13), low numbers of mature Rainbow Trout were captured during the mark-recapture program. Although a relatively small sample size of Rainbow Trout was collected over both years, there appears to be a small increase in the number of 50 mm to 89 mm at Drake in 2014 and a decrease in the number of larger individuals (Figure 5.12). Data from Drake suggests that the size structure is similar between 2013 and 2014 (Figure 5.13). Sampling efforts in 2014 within Lemon Creek/Slocan River side-channel focused on the capture of Mountain Whitefish thus incidental fish community by-catch was only opportunistically processed. As such, fork lengths of Rainbow Trout were not completed in 2014.

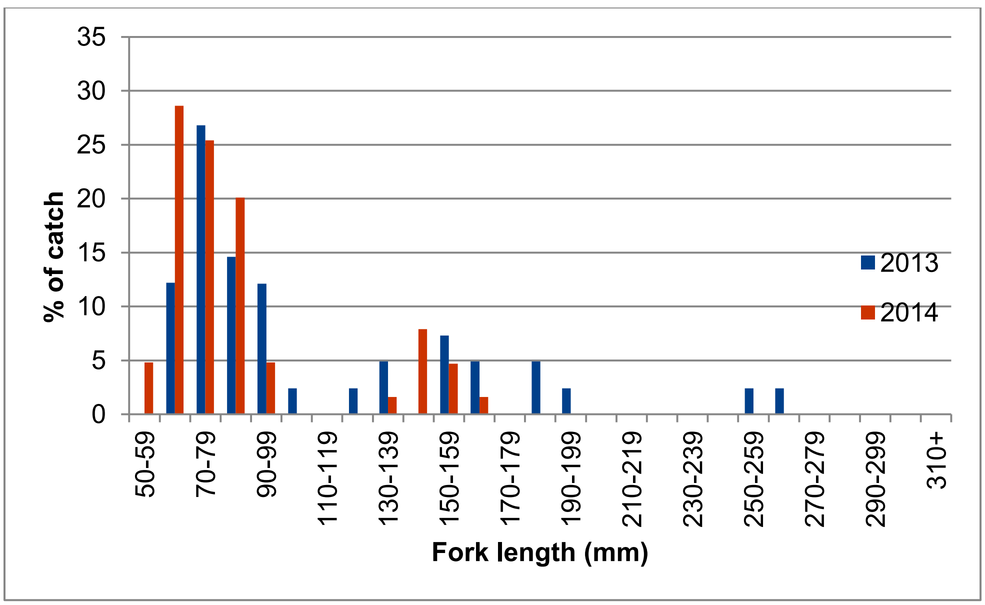


Figure 5.12: Length frequency percentage plots of Rainbow Trout caught at the Larsen off-channel habitat

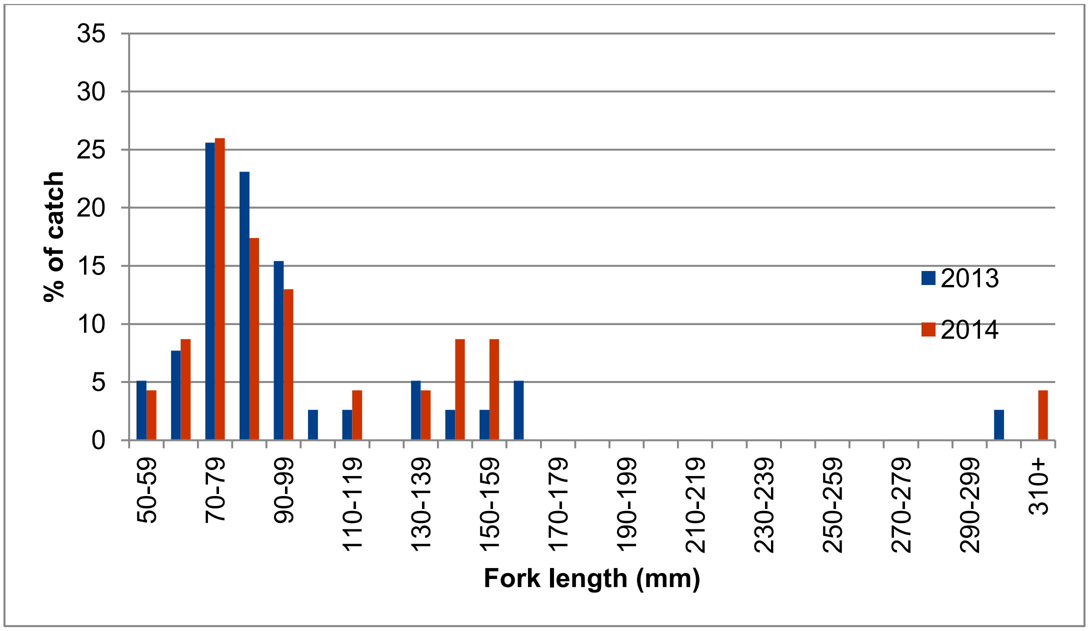


Figure 5.13: Length frequency percentage plots of Rainbow Trout caught at the Drake off-channel habitat

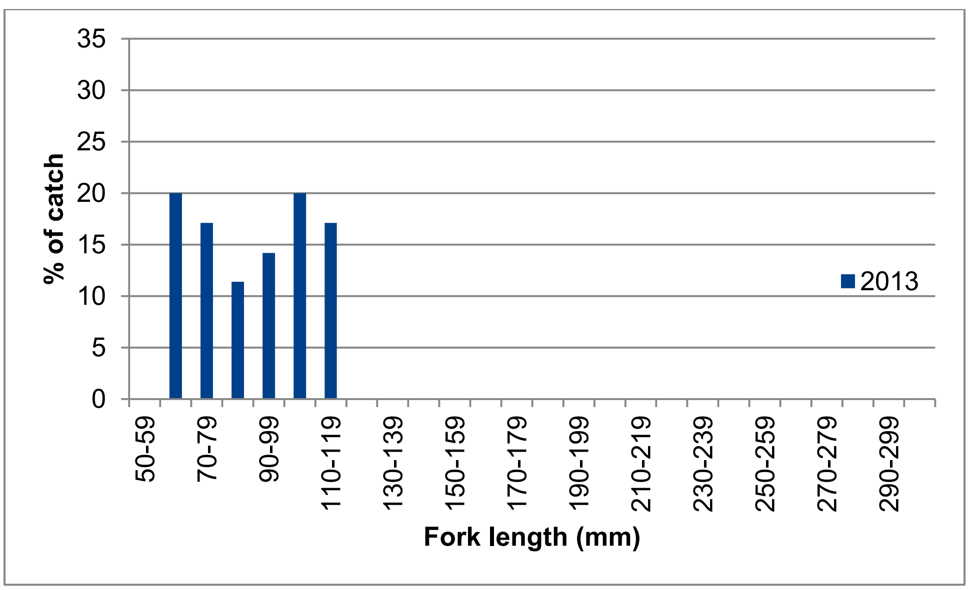


Figure 5.14: Length frequency percentage plots of Rainbow Trout caught at the Lower Lemon Creek/Slocan River side-channel habitat. Note: This site was not sampled in 2014

Condition Factor

Condition factors of Rainbow Trout appear to be relatively similar for each site between years, with a slightly higher mean condition factor observed in 2013 (Table 5.9). Even though the mean was higher in 2013, maximum values were higher in 2014. Note: Sampling did not occur in October 2014 in Lemon Creek/Slocan side-channel.

Table 5.9: Condition factor calculated from Rainbow Trout collected during the mark-recapture program using an equation derived by Simpkins and Hubert (1996).

Location	Number of fish caught		2013		2014	
	2013	2014	Mean	St. E*	Mean	St. E*
Drake	39	31	0.95	0.010	0.92	0.032
Larsen	41	70	0.96	0.009	0.97	0.016
Lemon/Slocan Side-channel	35	-	0.97	0.011	-	-

* indicates standard error
– Lemon/Slocan Side-channel not sampled in 2014

5.3.2 Population and CPUE Data

Rainbow Trout CPUE (fish/1000 seconds) and population estimates suggest that density and abundance of Rainbow Trout is higher in Larsen than Drake in 2013 and 2014 (Table 5.10). Results also suggest a slight decline in the abundance of juvenile Rainbow Trout between both sample years.

Table 5.10: Rainbow Trout CPUE and population estimates in 2013 and 2014 for Larsen and Drake off-channel habitat

Location	2013		2014	
	CPUE (Fish per 1000 seconds)	Population estimate	CPUE (Fish per 1000 seconds)	Population estimate
Drake	2.9	116 (75-157)*	2.6	61 (46-76)*
Larsen	3.9	199 (95-303)*	5.8	186 (137-235)*

Note: Numbers included in the estimates are rounded to the nearest integer
*Numbers in parentheses correspond to the 95% confidence interval

5.4 Discussion

The original endpoints described in the BMP were established based on the assumption that Mountain Whitefish were abundant in off-channel habitat in the Slocan River. However, Mountain Whitefish were never captured during the 2013/2014 sampling program suggesting that utilization of the Slocan River off-channel habitat by Mountain Whitefish is very low. Considering that some sampling was conducted at flows similar to when the incident occurred, it is likely that the deceased Mountain Whitefish collected during the emergency response were flushed into the off-channel habitat. Seasonal use of off-channel habitats by Mountain Whitefish is well documented in the literature. In late summer, juvenile Mountain Whitefish migrate out of the off-channel habitat (shallow and low velocity) to much deeper and faster water that is typically associated with the mainstem river (McPhail and Troffe 1998). Juveniles are associated with areas adjacent to adult habitats, usually concentrating where riffles break over a deeply scoured pool. These areas are typically not easily accessible and are often difficult to effectively sample with an electrofisher.

The absence of Mountain Whitefish from our study program is also supported by the findings from a Slocan River side-channel study conducted by Mirkwood Ecological Consultants in spring and summer 2010. Results from the study (Mirkwood Ecological Consultants 2010) show a decreasing trend in numbers of Mountain Whitefish utilizing off-channel habitats between spring freshet and summer. Mountain Whitefish were documented in eight of the ten back-channels sampled during spring freshet, whereas only three of them contained Mountain Whitefish in summer. Additional information supporting the absence of Mountain Whitefish in off-channel habitat includes further work conducted by Mirkwood Ecological Consultants in Slocan River. Shortly after the spill incident in 2013, a snorkel survey of Lemon Creek/Slocan River confluence pool was conducted and approximately 800 Mountain Whitefish were observed. Although fish were not categorized by length, all life stages of Mountain Whitefish were present in the mainstem (pers. comm. Peter Corbett 2015). To further support the presence of the juvenile lifestage in the mainstem Slocan River, juveniles have been observed from 2007 and 2014 as part of the monitoring the effectiveness of habitat structures in lower Slocan River (Mirkwood Ecological Consultants 2014). Consequently, the absence of Mountain Whitefish from off-channel habitat during the 2013/2014 study program was most likely due to their seasonal habitat preference for the Slocan River mainstem.

With the absence of Mountain Whitefish, the mark-recapture program focused on the characterization of the fish community and Rainbow Trout population estimates in select off-channel habitats (Larsen and Drake) over two sampling seasons.

Fish inhabiting Larsen off-channel habitat at the time of the jet fuel spill would have been subjected to higher exposure than fish inhabiting Drake. Our findings suggest that species richness is similar between years at each respective location; however, there appears to be a slightly higher diversity and relative abundance of fish at the Drake off-channel habitat. Although there are some small differences between sites with respect to species richness and relative abundance, there are also a number of similarities in the fish assemblage at each site:

1) An overall increasing trend in relative abundance was observed at both locations in 2014;
2) Species composition is similar between sites and years;

3) Dominant species found at both sites include Torrent Sculpin, Rainbow Trout and Northern Pikeminnow;
4) Length frequency percentage plots of most dominant species are similar between sites and often include a variety of life stages (i.e., YOY, juvenile, adult);
5) Increasing presence of Umatilla Dace (listed as Threatened Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 2010c) and of special concern (SARA) at both sampling locations (particularly Larsen) in 2014; and
6) Condition factors of Rainbow Trout were similar between sites and sample years.

Species composition (i.e., dominant species) of the off-channel habitats sampled in 2013 and 2014 are noticeably similar to the species composition of the deceased fish recovered during the emergency response following the spill incident. With the exception of Mountain Whitefish, Sculpin and Rainbow Trout were the most abundant species documented in the off-channel habitat. Given the absence of Mountain Whitefish supported by their documented seasonal preference shift to mainstem river habitat, deceased individuals were likely washed into the off-channel habitat. Thus, we believe that Mountain Whitefish were not actively utilizing the off-channel habitat at the time of the spill. With this in mind, the most abundant individuals collected during our sampling program coincide with the most abundant species collected during the emergency response. Condition factor of Rainbow Trout captured during the program fall in line with an average conditioned fish, and data suggests that condition factor is similar between sites with no apparent overall decreasing trend.

Rainbow Trout are recreationally important in the Slocan River watershed and were the second abundant fish species recovered during the emergency response. The importance of Rainbow Trout to the Slocan River system is well documented by other studies that have characterized and monitored population size, growth and reproduction. Our population estimates and CPUE results suggest that numbers of Rainbow Trout are higher in Larsen than that observed in Drake off-channel habitat. A small decline in population estimates and CPUE was detected between 2013 and 2014 at Drakes, while an increase in CPUE was observed at Larsens. Although our population data is site specific, the general decline is similar to what has been documented in snorkel surveys in 2013 and 2014 in the mainstem Slocan River (Mirkwood Ecological Consultants 2013, 2014). Snorkel surveys can be a relatively precise sampling method for enumerating salmonids, specifically larger bodied individuals. Smaller bodied individuals are considerably more difficult to enumerate given the habitat they occupy, cryptic behavior and their ability to hide amidst structure. Even though snorkel surveys enumerated Rainbow Trout <200mm, the proportion of juveniles <100 mm accounted for can very simply be underestimated. Consequently, the information gathered from the mark-recapture study (which targeted juvenile Rainbow Trout <200mm) complements the ongoing snorkel survey findings. Of the deceased fish collected during the emergency response, all Rainbow Trout salvaged were <200 mm, suggesting that larger juvenile and adult Rainbow Trout were likely unaffected. Given the consistent trend in juvenile and adult Rainbow trout population data since 2006, data would suggest that the observed decreases are likely attributed to natural variability in the species and are not indicative of a considerable effect as a result of the spill.

5.5 Conclusion

The fish community structure of select off-channel habitats were similar in terms of species composition, species dominance, species richness and showed an increasing trend in relative abundance between 2013 and 2014. Abundance numbers of Umatilla Dace, a species listed under COSEWIC (threatened) and SARA (species of concern), also increased in both off-channel habitats in 2014. Being a listed species, the overall abundance of Umatilla Dace in off-channel habitats post-spill suggests that the spill did not have a considerable effect on the species. Rainbow Trout condition factor was relatively stable between years and sites and suggests that the condition of Rainbow Trout is average. In addition, overall relative abundance of fish caught in each off-channel habitat considerably increased in 2014. Even though there is an increase in abundance, it is difficult to ascertain whether the increase in abundance is related to declines in fish numbers as a result of the spill or simply natural variability. In our opinion, we believe the latter is a more likely scenario.

Rainbow Trout mark-recapture data are consistent with trends observed from Slocan River mainstem Rainbow Trout population data suggesting the trends observed fall well within the natural variability of the Slocan River Rainbow Trout population since 2006. There is no evidence to suggest that the spill had a sizeable effect on the Slocan River rainbow trout population(s).

Based on the results from the 2013/2014 mark-recapture program, we believe that the modified endpoints have been achieved, which are:

1) Population estimates of Rainbow Trout in select off-channel habitat have remained stable over a temporal and spatial scale; and
2) Fish community metrics (abundance, diversity and community structure) in braided side-channels of the Slocan River have shown resilience and are stable over temporal and spatial scale.

Our data speaks to the resiliency of fish species inhabiting the Slocan River. Even after the perturbation caused by the spill, the Slocan River system has been able to maintain its ecological integrity based on our data with respect to species composition, species richness and dominance as they appear to have remained similar to pre-spill conditions.

6 SLOCAN RIVER MAINSTEM RAINBOW TROUT POPULATION ANALYSIS

As per the BMP, this section was prepared by Mirkwood Ecological Consultants. The purpose of this section was to evaluate and compare the historical adult Rainbow Trout population in the Slocan River with the adult Rainbow Trout population post-spill.

6.1 Introduction

Since the early 80's, Rainbow Trout (*Oncorhynchus mykiss*) abundance in the Slocan River has been monitored using snorkel surveys. Since 2006, these surveys have been completed annually (with the exception of 2012) producing reliable population estimates and trend data. A full river survey was completed in the fall of 2013 after the fuel spill occurred, and again in 2014, giving an opportunity to investigate impacts post spill and to compare these estimates to pre spill data.

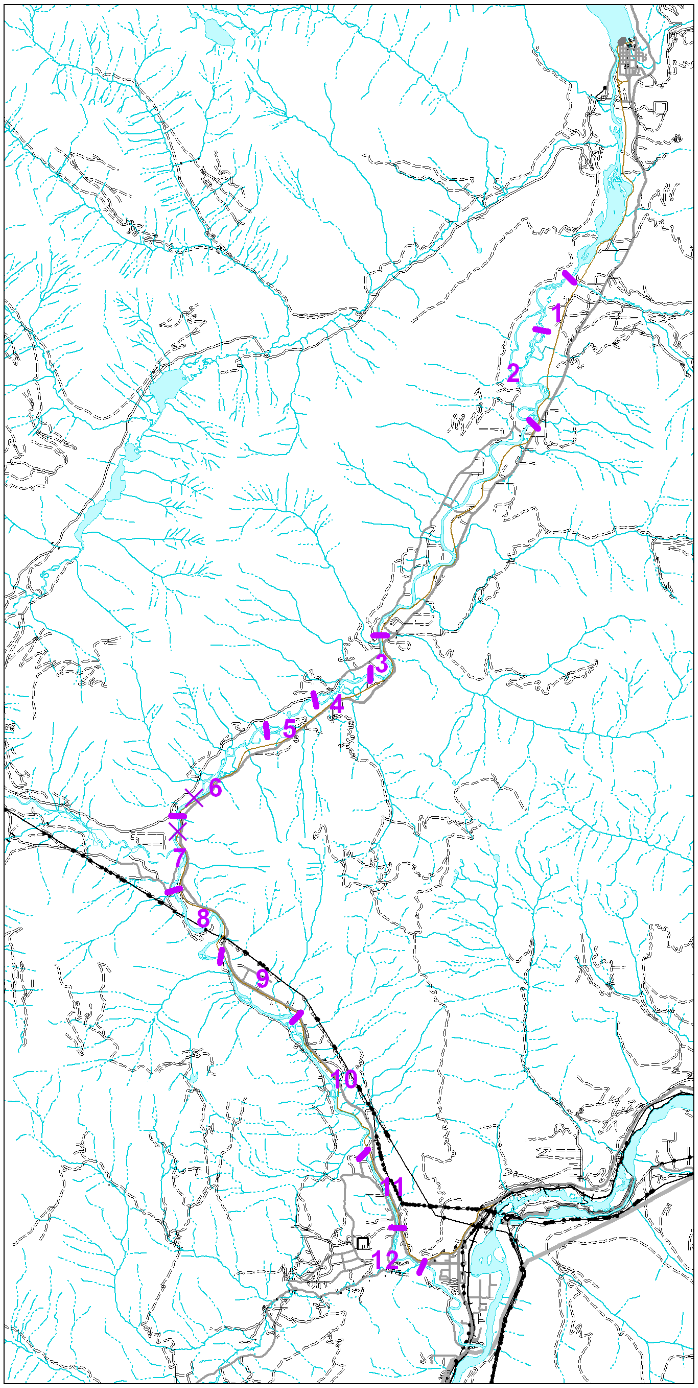
6.2 Methods

The river was stratified into reaches with a population assessment completed for each reach. Figure 6-1 shows the delineation of each reach along the Slocan River.

Traditionally these assessments were performed using five (5) swimmers (observers) with two (2) passes per reach (Oliver 2001). In recent years, a 2-swimmer method has been employed. On a number of instances, both methods were used so that a detection factor could be developed between the two methods thereby standardizing the data and making the results interchangeable. Differences were measured between the 2 methods by fork length and a factor determined for each size class. These were then applied to the entire data set to standardize all of the results since 1996. Adjustment factors by age class are presented in Table 6-1.

Table 6-1: Adjustment factors by size class (fork length) used on the Slocan River to compare 5 swimmer data to 2 swimmer data

Fork Length (cm)	< 20	20+	30+	40+	50+
Adjustment Factor	1.7	1.4	1.3	1.2	1



Slocan River
Trout Enumeration
Reaches

1 Lemon
2 Goat
3 Winlaw
4 Cougar
5 Ehlers
6 Lumberyard
7 Passmore
8 Horseshoe
9 Slocan Park
10 Kosiancic
11 Straight 8
12 Crescent Valley

Bold Text = Index Site

Structures

Val 1
Val 2

1 : 180,000

Figure 6-1: Survey reach delineation on the Slocan River

6.3 Results

Snorkel surveys were conducted in September 2013 and 2014. A comparison of 2013 and 2014 results with the previous six surveys pre-spill is represented in Figure 6-2 below. Results are for the upper Slocan River only, from the Lemon reach down to the Ehlers reach (see Figure 6-1).

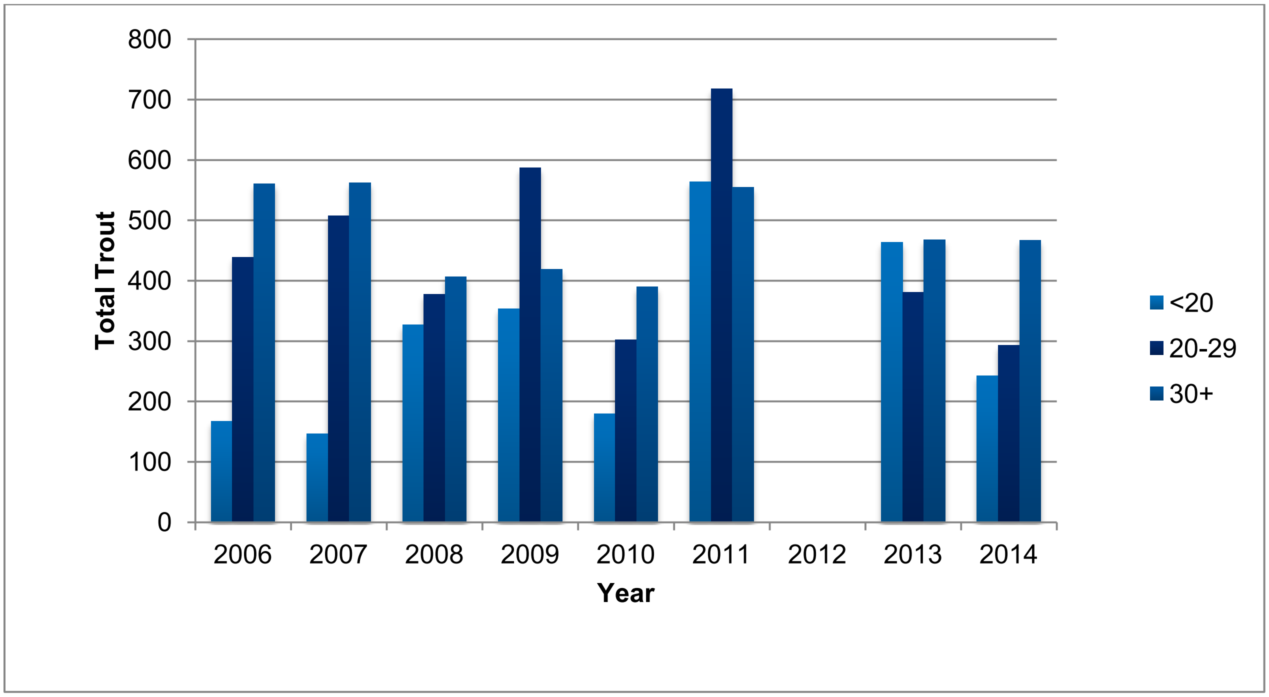


Figure 6-2: A comparison of total trout by year in the upper reaches of the Slocan River (Lemon to Ehlers) by fork-length class (cm). Note that there is no data available for 2012

The total number of trout observed was placed into bins representing the various life- stages or cohorts of Rainbow Trout in the Slocan River and are described in table 6-2 below.

Table 6-2: Fork-length class compared to age class and life-stage of Rainbow Trout in the Slocan River

Fork-length Class (cm)	Age Class (years)	Life Stage
<20	1+ and 2+	fry, fingerling
20-29	3+	Juvenile
30+	4+ or older	Adult

6.4 Discussion

When all of the upper reaches are considered, Rainbow Trout abundance in 2013 and 2014 appears to be experiencing a downward trend in all age classes over the last six years (Figure 6-2 above). While the Rainbow Trout population is lower than in previous years, it is still falls in line with the natural variability observed from pre-spill data. When only the two upper reaches (directly downstream of Lemon Creek) are examined (Figure 6-3), data for all years follow the same abundance trends as the rest of the river, with the exception of 2013 and 2014. There is a considerable decrease in younger age classes of Rainbow Trout after 2011, but the numbers are similar to 2010, suggesting that the population numbers fall in line with what has been historically documented.

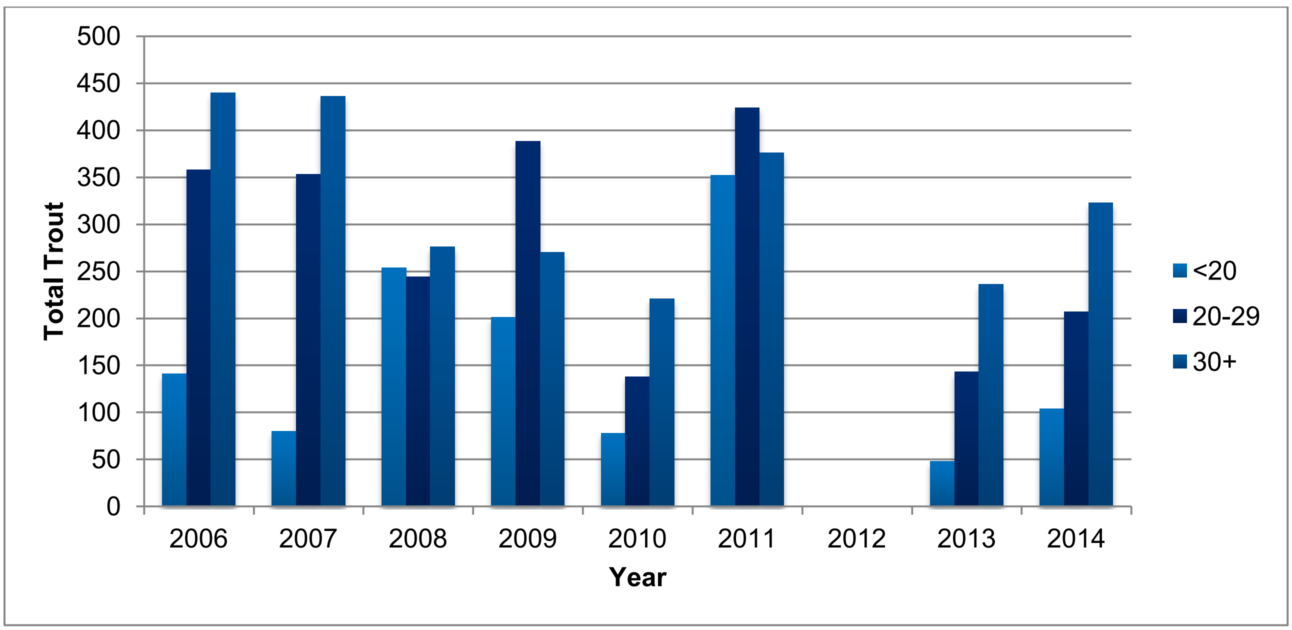


Figure 6-3: A comparison between years by fork-length (cm) in the two reaches below Lemon Creek (Lemon and Goat)

Overall, data suggests that the upper two sites typically accounted for a high percentage of the total number of Rainbow Trout in Slocan River (Figure 6-4). However, data collected since 2010 suggests the upper two sites account for a smaller percentage of the total abundance than in previous years. It should also be taken into consideration that there is no data for 2012. The absence of this data can skew the visual interpretation of the data when observing the graphs, resulting in what would appear to be a more noticeable decline between pre and post spill than what may have occurred.

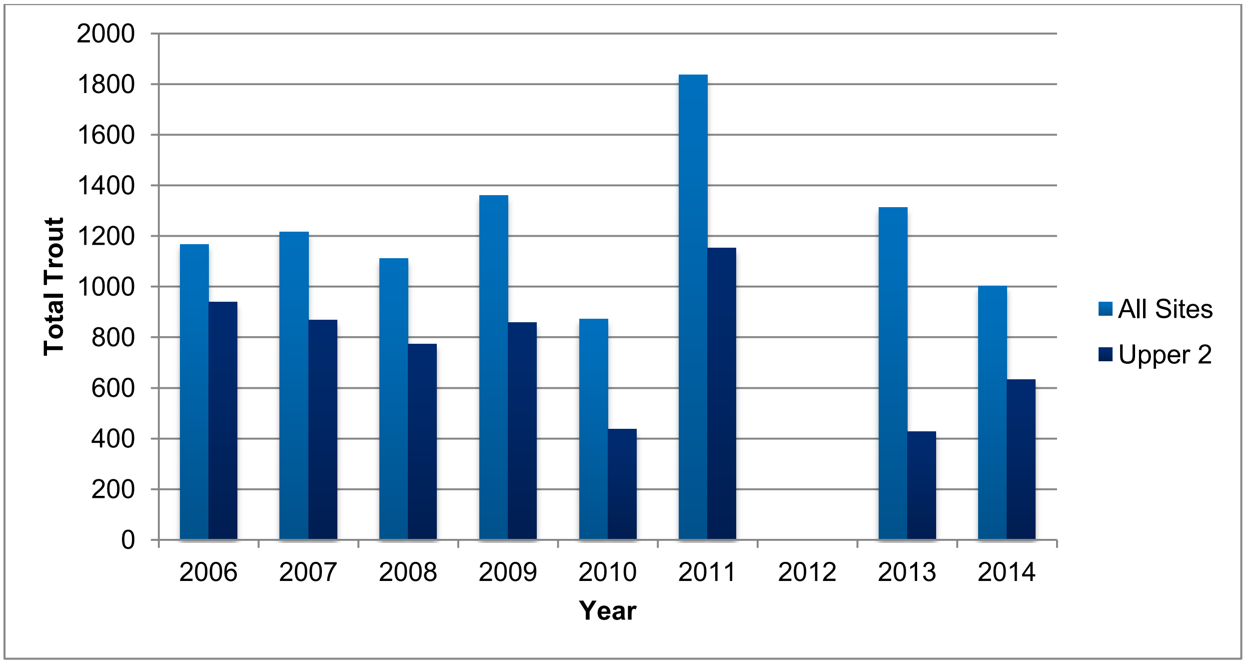


Figure 6-4: Total fish abundance by year between all of the sites (Lemon to Ehlers) and the upper two sites below Lemon Creek (Lemon and Goat)

6.5 Conclusion

Rainbow Trout population data collected in 2013 and 2014 suggests that there is a decreasing trend since 2010. Even though there appears to be a decrease, post-spill population levels still remain within the natural variation exhibited in the population and is not indicative of any sizeable effect as a result of the Jet A1 fuel spill.

7 BULL TROUT REDD SURVEY

7.1 Introduction

Bull trout (*Salvelinus confluentus*) are an iteroparous large char salmonid native to the lower Columbia drainage. They have specific habitat requirements and are particularly sensitive to habitat alteration and degradation and as such have been used as an 'indicator' species for the health of aquatic ecosystems. In light of recent population declines and extirpation throughout systems in the United States and significant population declines in areas of British Columbia Bull Trout have been designated as a blue listed species by the BC Conservation Data Centre. There exists an adfluvial population of Bull Trout in Slocan Lake. This population has been isolated as a result of hydroelectric developments in the region. There has been no research conducted on this population of Bull Trout until 2013 when Mountain Water Research completed redd surveys on several creeks and tributaries located off the northern portion of the lake and Mirkwood Ecological Consultants conducted redd surveys in the Lemon Creek system. There is a lack of research on abundance and therefore conservation status of this isolated population is unknown.

7.2 Background

The selection of these Lemon Creek survey sites was to address concerns about Bull Trout spawning success in relation to the fuel spill in Lemon Creek.

There is no previous data on Bull Trout spawning in Lemon Creek or tributaries, however, as part of a larger 1:20,000 Fish Reconnaissance Report, Mirkwood Ecological Consultants conducted electrofishing surveys in 1996 within the Lemon Creek system and found Bull Trout were present. Juvenile Bull Trout were electrofished in the upper reaches of Lemon Creek (above the spill site), Holmsen Creek and Monument Creek. Sexually mature Bull Trout were observed in the upper reaches of Lemon Creek above Crusader Creek and in Monument and Holmsen creeks. The report attests there is a probable adfluvial Bull Trout population existing within the Lemon Creek system (Addison et al. 1996).

Prior to conducting the 2013 and 2014 Bull Trout redd surveys, Mirkwood Ecological Consultants completed annual snorkel float surveys on the Slocan River. On September 26th, 2013 and September 17th, 2014, eight and 14 mature Bull Trout, respectively, were observed staging in the Lemon pool directly south of the mouth of Lemon Creek (Corbett, pers. com).

In 2013, a mature Bull Trout was found deceased with accompanying egg mass on the west bank. In 2014, illegal angling in both Lemon Creek and the Lemon pool on the Slocan River was documented. Poaching has been noted as an issue of concern as locals have been observed poaching fish from the Lemon pool. The fishing regulations for the Slocan River permit catch and release of trout and char with only Mountain Whitefish retention. Lemon Creek is closed to fishing and has been for over the past two decades.

7.3 Methods

7.3.1 Site Description

Located in the lower Columbia River drainage in Southeast British Columbia, Lemon Creek is a tributary of the Slocan River. The creek originates in the southern Selkirks Kokanee mountain range and flows for 26.5 km until it reaches the Slocan River. Lemon Creek is a fourth order stream with moderately steep gradients and dominated by plunge pool/riffle habitat. Boulder is the dominant substrate, while cobble and gravel are less abundant. Lemon Creek has numerous small first and second order tributaries, of which five were surveyed in 2013 and 2014; Monument Creek, Holmsen Creek, Unnamed Creek, Crusader Creek and Dunnet Creek. Smaller unnamed tributaries were also surveyed over a short distance as habitat features restricting access to Bull Trout were present. Other tributaries, (e.g., Chapleau Creek) were not assessed due to the lack of spawning potential and very steep gradients. In 2013, watercourses were surveyed in an upstream to downstream direction, typically beginning at documented fish barriers down to the confluence with the Slocan River. Given the lack of suitable spawning habitat for Bull Trout in the lower reaches of Lemon Creek, the 2014 survey only focused on the upper reaches of Lemon Creek and previously surveyed tributaries.

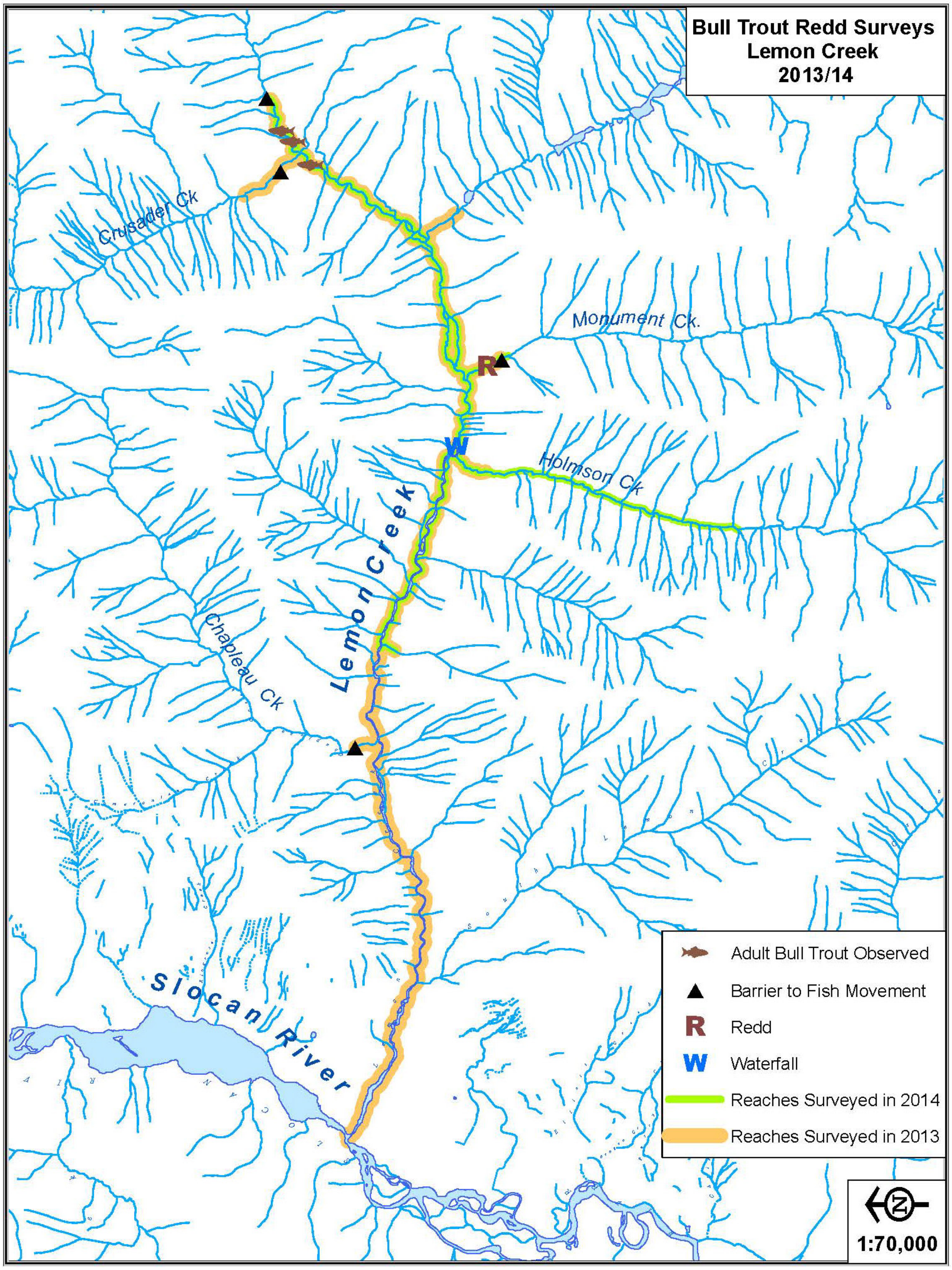


Figure 7-1: Map of Lemon Creek and tributaries surveyed in 2013 and 2014.

7.3.2 Survey Timing

Redd count surveys were conducted from October 14, 2013 to October 23, 2013, and from September 12, 2014 to October 7, 2014. Regional timing of Bull Trout spawning has been documented between the end of August and the end of October. Sampling in 2013 coincided with the end of the regional spawning window and, in theory, provided an opportunity to observe the greatest number of redds. Weather conditions prior to the survey included heavy intermittent precipitation. However, during the redd surveys, weather conditions were clear with no precipitation. In-stream visibility during the surveys was optimum. In 2014, Bull Trout redd surveys coincided with Mountain Water Research's survey period on watercourses in the northern portion of Slocan Lake. Weather conditions throughout the surveys were a mixture of clear and overcast days with no precipitation.

7.3.3 Redd Surveys

In 2013, two 2-person crews walked in a downstream direction from fish barriers to locate redds. As the mainstem of Lemon Creek is proportionately larger than its tributaries both crews split up and walked on the south bank and north bank. Redds were geo-referenced with a handheld Garmin GPS 76 unit. Additional habitat features were recorded: redd size, substrate characteristics and proximity to fish barrier. At the redd site, two pictures were taken using a digital camera. In 2014, survey methods were modified as one person on each crew wore a dry suit with snorkel and swam pools large enough to hold spawning Bull Trout. All suitable spawning and holding habitat was assessed and all mature and juvenile Bull Trout were documented.

7.3.3.1 Redd Identification

Redds were positively identified based on the size of the pit, the shape of the excavated pit often described as dish-shaped (Andrusak and Langston 2012) and a noticeable pit lip or wall of deposited gravel on the upstream side of the excavation. The presence of cleaned loose small gravel substrate deposition within the pit was used as a primary identifier.

The size of the pit is an important factor for consideration as Bull Trout often dig 'test pits' in which they do not deposit eggs (Andrusak 2010). These pits are smaller in size and lack the deposition of homogenous un-embedded small gravel within the pit.

7.4 Results

In 2013, redd surveys were completed by October 23rd with approximately 28 km of stream assessed. Only one redd was identified during the survey; in Monument Creek, a third order tributary to Lemon Creek located above the spill site (Figure 7-1). In 2014, redd surveys were completed by October 7th with approximately 22 km of stream assessed. No redds were identified. Three mature Bull Trout were observed in the upper reaches of Lemon Creek (above the 11 km waterfalls). All mature Bull Trout observed were solitary and located in different pools. Less than 20 juvenile Bull Trout were documented within the upper reaches of the Lemon Creek system.

7.5 Discussion

Mountain Water Research observed spawning Bull Trout and redds in the upper tributaries of Slocan Lake in September/October 2013 and 2014. In September 2013 and 2014, sexually mature Bull Trout were staging in the Lemon Creek/Slocan River confluence pool. Even though Bull Trout were observed near Lemon Creek at the end of September, only one redd was identified in 2013, while no redds were identified in 2014

The low number of redds in the system could be attributed to the lack of available suitable spawning habitat. Suitable spawning habitat was limited during the survey periods. There appears to have been a significant hydrological event that occurred over the last few years, thereby reducing large quantities of LWD (large woody debris) from the mainstem of Lemon Creek. Particularly lacking was perpendicular LWD which creates gravel substrate deposition zones in the thalweg providing suitable un-embedded gravels with sufficient interstitial water flow required for successful Bull Trout spawning.

In addition to the lack of suitable spawning habitat, the observation of few juveniles and three mature Bull Trout during the 2014 survey suggests that the adult Bull Trout population utilizing Lemon Creek and tributaries is low.

7.6 Conclusion

Based on the Bull Trout redd surveys (2013 and 2014), data indicates that successful Bull Trout spawning has occurred in upper Lemon Creek and tributaries post spill. Redds, and both juvenile and adult Bull Trout have been documented in 2014 providing evidence that Bull Trout migration through the impact area to upstream available habitats is not being impeded. Given the recent surveys, the lack of suitable spawning habitat observed in the upper reaches of the Lemon Creek watershed is likely the limiting factor to the spawning success and population viability of Bull Trout.

8 LEMON CREEK FISH ABUNDANCE AND COMMUNITY RECOVERY PROGRAM

8.1 Introduction

As per the "*Environmental Management Plan – Biological Programs*" (BMP), the Lemon Creek fish abundance and community recovery monitoring program was initiated to quantify fish abundance, distribution and composition following the spill event, in relation to upstream reference sites as an indicator of ecosystem recovery.

This chapter provides a summary of data analyses conducted for the Lemon Creek fish community sampling program. The study area encompasses approximately 6 km of the lowermost fish bearing reaches of Lemon Creek, from its confluence with the Slocan River. To assess recolonization, the information from impacted reaches (seven sites) was compared to upstream reference sites (three sites) and to the limited baseline data available for species distribution and relative abundance.

8.2 Background

The fish populations and community inhabiting both Lemon Creek and the Slocan River system were adversely affected as a result of the Jet-A1 fuel spill, based on the evidence of fish mortalities collected during the emergency response. The approximately 4.9 km of Lemon Creek channel downstream of the incident site received the full effects of the fuel spill event, with no significant off-channel refuge habitat downstream of the spill. Deceased Mountain Whitefish (n=15) and Shorthead Sculpin (n=2) were collected from Lemon Creek. In total, 261 fish were collected from the Slocan River system, with the majority comprised of Mountain Whitefish (n=155), followed by Torrent Sculpin (n=26), and Rainbow Trout (n=19). The juvenile life stage accounted for a smaller portion of deceased fish collected from Lemon Creek, in comparison to fish salvaged from Slocan River. It is possible that salvaged fish in Lemon Creek may not have accounted for some that may have been swept downstream due to the fast-flowing waters in Lemon Creek, thus contributed to a portion of the mortalities downstream of the confluence with Slocan River. Information collected from baseline review suggests the presence of up to 12 fish species that could inhabit Lemon Creek. Considering the possible transport of deceased fish from the system, an account of the fish community in Lemon Creek needed to be characterized.

During the emergency response, live fish were also observed in some of the same areas where fish mortalities were collected, indicating that not all of the fish in the watercourse were acutely impacted, or that other fish from locations uninfluenced by the fuel (e.g., from Slocan River upstream of the confluence with Lemon Creek, lower South Lemon Creek, or upstream of 4.9 km in Lemon Creek) could have migrated into the affected reaches (areas) fairly quickly post-incident.

In addition to the fish mortalities, extensive numbers of deceased benthic invertebrates were observed in both Lemon Creek and Slocan River, which could have influenced fish community structure. Environmental effects of the spill were documented in the Environmental Impact Assessment report (SNC-Lavalin 2013a).

The May 2014 sample set of the water and sediment monitoring program indicated the spill product was not persisting in Lemon Creek at levels that would exceed provincial standards for the protection of aquatic life, though there were remaining locations where disturbance to banks could induce a sheen or hydrocarbon odour remained detectable (SNC-Lavalin 2014b). Thus site chemistry indicated water quality was suitable for fish when sampling was conducted in summer and fall 2014.

8.3 Objective

Objectives that comprised the Biological Monitoring Plan (BMP; SNC-Lavalin 2013b) included assessment of key fisheries indicators (e.g., species-level, population-level, community-level) and detecting and identifying recolonization processes based on results from the assessment.

In collecting data to evaluate endpoints for fish community, the objectives of the sampling program were to:

1) Describe and compare the fish assemblage (species presence/absence, relative abundance) at select sites along a gradient from upstream of the spill site (non-impacted) down to the Slocan River confluence (impacted) in Lemon Creek;
2) Determine if fish abundance and community structure in Lemon Creek are similar to reference (non-impacted) sites; and
3) Indirectly establish whether Bull Trout migration and spawning in the Lemon Creek system have not been adversely impacted.

8.4 Methods

8.4.1 Literature Review

Baseline information and data were collected through a desktop review of available ecological and regulatory databases and search engines including local, regional and federal government sites, (e.g., iMap BC; HabitatWizard; EcoCat; BC Conservation Data Centre (BC CDC); and Species at Risk Public Registry (SARA). Historical fish inventory reports were collected and reviewed in order to aid in the monitoring program study design phase and for background information for data interpretation.

8.4.2 Study Design

The program's rationale and methods were developed to monitor the recolonization of fish populations in the affected area while considering the limited information available. The methodology had three main assumptions:

1) There were no residual effects to the physical habitat (i.e., the system's integrity) limiting fish recovery in the affected area.
2) Fish populations would naturally return to a state similar to upstream control sites, or normal variation.
3) Natural state community structure would be more similar to upstream reaches of Lemon Creek than Slocan River, thus no reference sites were established outside of Lemon Creek. This would require the impacted reaches to primarily be recolonized in a downstream direction.

Sampling took on a control-impact approach, with multiple upstream reference sites providing the 'control' conditions anticipated to have occurred pre-impact. For the purposes of this monitoring program, fish community recovery was defined as the impacted reach returning to similar abundance and diversity as seen in natural variation in the multiple upstream reference sites.

Assessment of fish abundance and community composition in the impacted reaches were completed by open site sampling. Closed sites were not feasible to implement in enough sites for repeatable and statistically meaningful comparison among sites. Seine nets could not effectively be used to block fish accessing or leaving the survey area during the survey due to water depths, flow velocities and in some cases site boundary dimensions.

The proposed timeline of the first sample event was initially delayed from fall 2013, since the October timing had potential to be disruptive to Bull Trout spawning. The sampling was rescheduled for April to characterize fish use of overwintering habitat in Lemon Creek prior to freshet. However, with localized and fairly limited overwintering habitat in Lemon Creek, sampling during this period would not add substantive value to understanding fish community abundance and distribution as well as effectively address the fish resource endpoint. Sampling would need to be timed for prior to Rainbow Trout and sculpin spawning, with potential concerns with water temperatures. After consultation with MoE and MFLNRO, field sampling was rescheduled for late July 2014 to coincide with the spill anniversary date and account for similar environmental conditions at the time of the spill. Actual start date was dependent on suitable site conditions when water levels had subsided to allow for more effective/safe sampling. The second sampling event occurred in early September (as described in the approved BMP) during lower flows, when fish had settled into their preferred summer rearing habitats.

8.4.3 Study Location

According to Aquatic Resources Limited (ARL 2000b), Lemon Creek is a straight-channel stream, with un-confined later channel movement, de-coupling between the hillslope and the channel, and occasional islands. This channel is comprised of either a riffle-pool or cascade-pool morphology. The mainstem was previously delineated as 12 distinctive reaches over 26 km, eight (8) of which are fish-bearing (Zimmer 1999). For approximately 1.5 km downstream of the incident site, Lemon Creek flows within a relatively narrow incised channel, which is characteristic of channels cut into bedrock. The final two (2) km of Lemon Creek is underlain by sands and gravels that are tens of metres thick, defined as an alluvial fan deposit, which serves as an aquifer (SNC-Lavalin 2013a). Bankful widths range from approximately 19 to 28 m. Aquatic Resources Limited (ARL 2000b) reported channel crown closure was between approximately 1% and 20%. Large woody debris was abundant and clumped together.

The confluence of Lemon Creek and Slocan River is located 7 km downstream of Slocan Lake, with the several hundred meters wide flood plain and ponded water habitat of the Slocan River ending immediately upstream of the confluence, and the start of the more confined, swift flowing braided gravel channel reach downstream.

Apart from the Little Slocan River, Lemon Creek is the second most significant tributary system to the Slocan River (Addison et. al. 1996). The colder water input from Lemon Creek is believed to be a major factor in fish productive capacity and survival in Slocan River during warm summer months when average water temperatures are well above 19°C, and consequently the Slocan River reach immediately downstream of the confluence with Lemon Creek has historically had the highest salmonid abundance (Arndt 1999; Oliver 1999). Lemon Creek may provide thermal refuge habitat for salmonids during summer months. Lemon Creek mainstem has an extensive amount of inhabited fish habitat (in excess of 20 km). The lower reaches of tributaries are used for spawning and rearing and all appear to support resident populations (Zimmer 1999). A set of falls at 17 km function as a barrier to upstream migration in the Lemon Creek mainstem. Side channel habitats are largely absent in the mainstem (Addison et al. 1996). As a result of proximity to both the braided gravel reach and Slocan Lake, the lower reaches of Lemon Creek have been noted to support a diverse population of fish that have access to these habitats (Zimmer 1999).

Lemon Creek downstream of the spill site consisted of at least two different reaches. The reach from the spill site downstream to the Highway 6 bridge, was characterized by fast-flowing waters, a confined channel, and relatively steep gradient. Downstream of the Highway 6 bridge to the confluence with the Slocan River, the watercourse was less confined, with bars and islands present, low gradient, and slower water velocities.

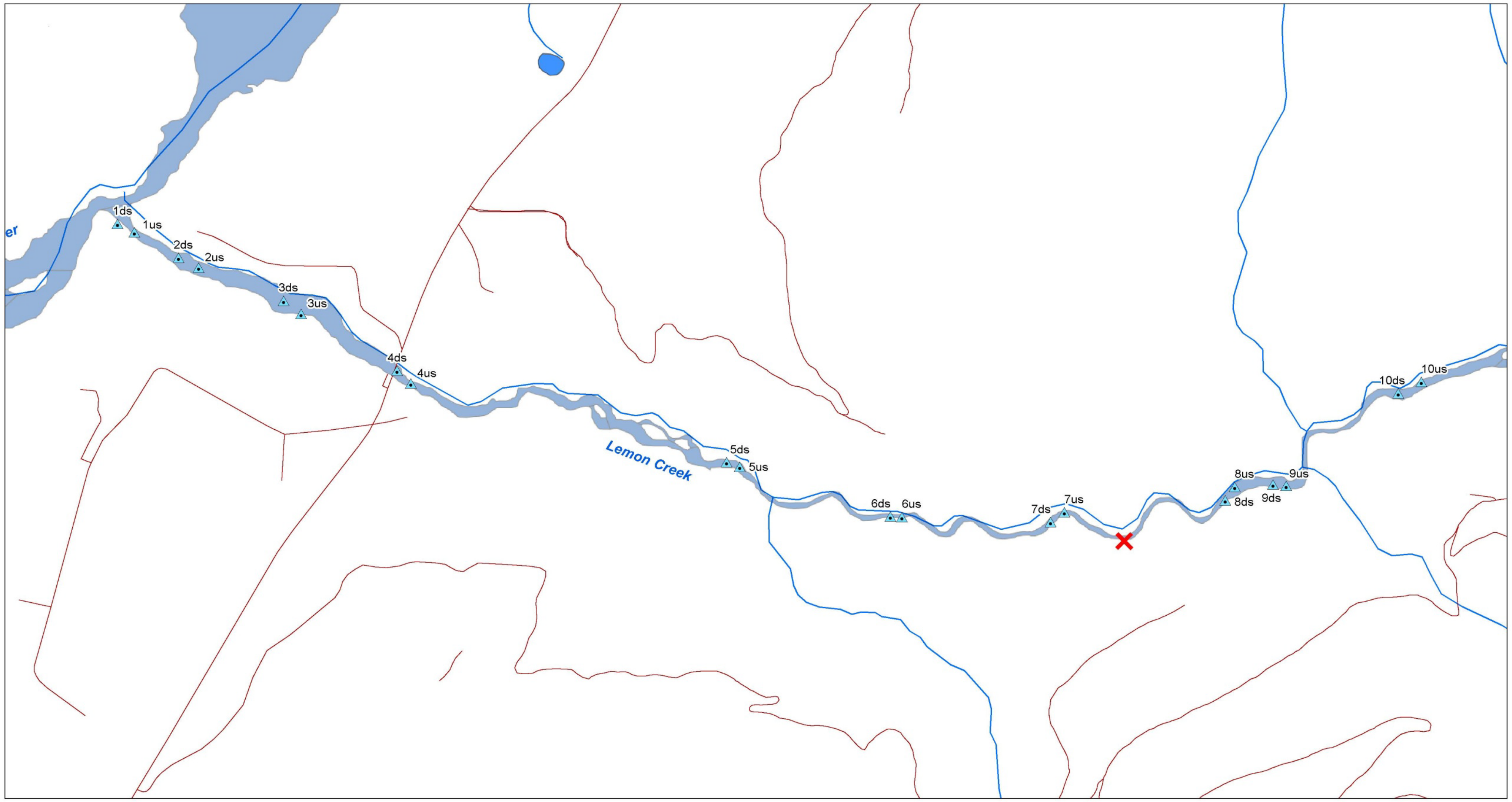
The study area encompasses approximately six (6) kilometres of the Lemon Creek mainstem, along with several minor side channel sites. Criteria for site selection of the 2014 electrofishing and minnow trap sampling sites, such as suitability for each sampling method, habitat preferences of target species.

Available habitat types in selected Lemon Creek mainstem habitat and braided/side channel habitat were sampled. By including these types of habitat, it was felt that a better understanding of fish distribution in Lemon Creek could be achieved. The side channel may provide refuge for smaller fish during higher flows, but the mainstem may provide suitable habitat at low flow (e.g., seasonal habitat shift).

Seven impact sites were sampled and three upstream sites in Lemon Creek were established as control sites (Figure 8-1). In the 7 impacted, there were 3 side channel sites established and 4 mainstem sites. For Non impacted (control) sites, 2 mainstem and 1 side channel sites were established. Nomenclature of each site was based on sequence from confluence to upstream, s= side channel, m= mainstem, and r= reference/ non-impacted site.

Surveys in 2014 were conducted during the period of late July/August and repeated in September. This timing coincides initially with the tail end of the descending limb of the freshet, equivalent water levels and discharge providing similar available habitat to what occurred at the time of the spill event, avoidance of sensitive spawning timing, and instream flow conditions conducive to sampling (Figure 8-2).

Hydrometric data provided in Figure 8-2 show daily average discharge in 2014 for Lemon Creek. The Environment Canada Water office station number 08NJ160 is located above South Lemon Creek (at 49°41’51” N, 117°27’00” W), approximately 2 km downstream of the incident site. Lemon Creek experiences an annual freshet with the onset of warm weather in the spring, and lasts until late July. Changes in discharge reflect the influence of weather-related effects such as snowmelt or rain run-off.



LEGEND

- Accident Site
- Fish Community Sites
- Roads
- Streams

NOTES

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.
4. Surface soil and excavation sample locations were taken in the vicinity of the accident site, however specific locations are not shown on figure.

REFERENCES 0 125 250 500 750 Meters

1. BCGOV ILMB Crown Registry and Geographic Base Branch (CRGB) (data accessed through www.GeoBC.gov.bc.ca)
2. GPS Data Collected using an eTrex. Accuracy expected to be approximately +/- 3.5m.

Service Layer Credits:

SNC·LAVALIN

CLIENT NAME: Executive Flight Centre

PROJECT LOCATION: Lemon Creek, BC Spill Site

EMP Phase 2
Fish Community Sample Locations

BY: LH	SCALE: 1:13,000	DATE: 2016/04/29	REF No: REV: 1
CHK'D: JAB	PROJ COORD SYS: NAD 1983 UTM Zone 11N		615438-005

Figure 8-1: Overview map showing sampling locations in Lemon Creek

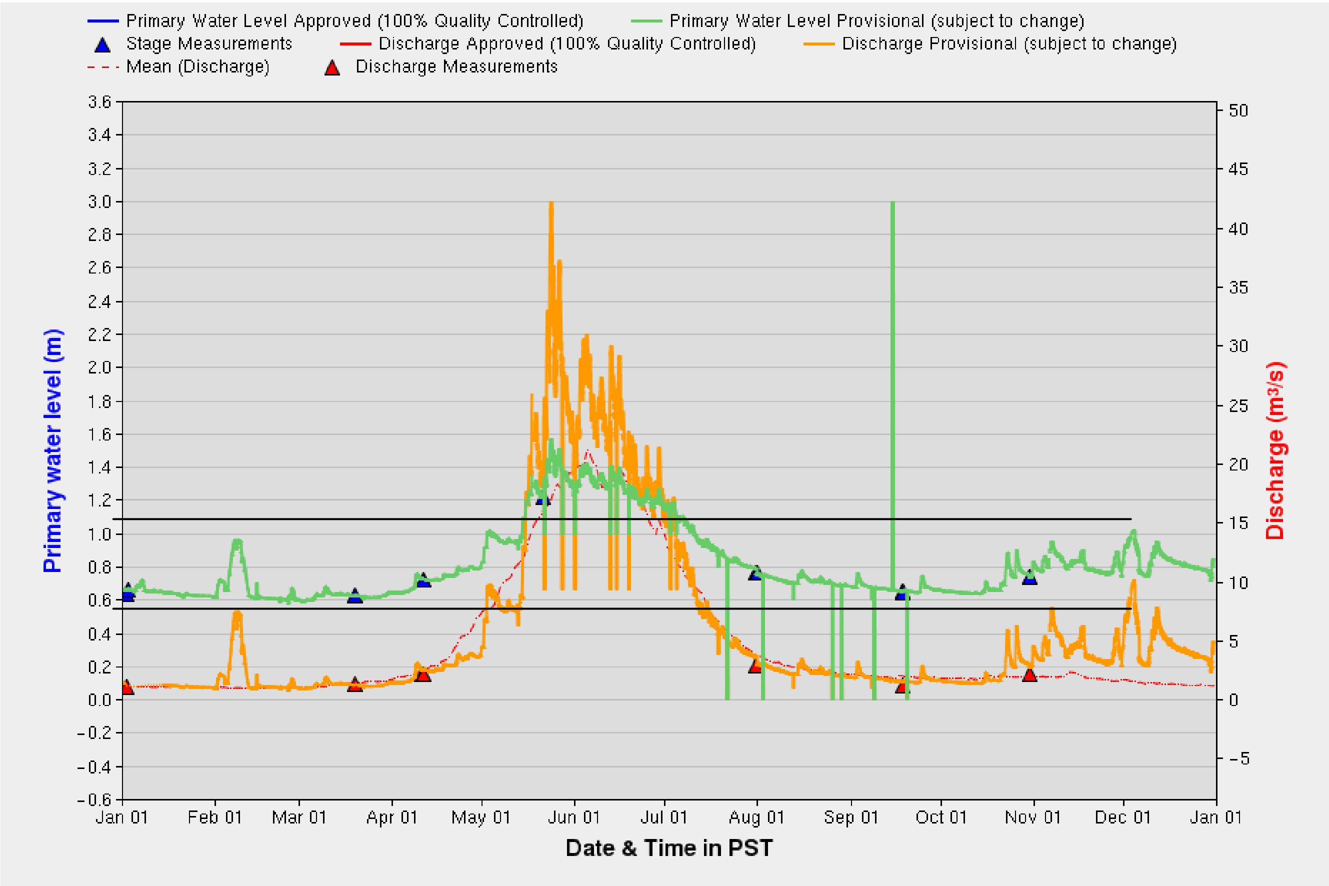


Figure 8-2: Hydrometric data for Lemon Creek in 2014, with approximate water level and discharge from the date of the incident July 26, 2013 (Lemon Creek above South Lemon Creek Monitoring Station)

8.4.4 Fish Data Collection

Sampling was completed in July/August (summer) and repeated in mid-September (fall) to sample a range of bar/bank edge habitats and assess juvenile distribution.

Electrofishing

Electrofishing was conducted during both sampling events. Sampling sites were selected to represent various habitat types within each site and were sampled by multiple pass removal to maximize opportunities for identifying species composition and fish densities in surveyed areas. Each electrofishing site was measured to nearest meter, geo-referenced using hand held GPS units, and marked with flagging tape at the upstream and downstream end for replication on future surveys. In-situ water quality parameters including temperature, conductivity, dissolved oxygen and pH were recorded at each site.

Electrofishing sites were established based on the presence of suitable cover, velocity and depth suitable for sampling, and habitat for target species (e.g., cobble and boulder substrate, which provide a variety of velocity gradients). Some basic approaches applied to electrofishing during biological sampling included: proceeding in an upstream direction to minimize disturbance to water not yet sampled and to reduce the likelihood of fish escapes; a minimum of 100 m^2 area sampled at each site; and, each pass consisted of an "ambush" upstream sweep (Triton 2006). As mentioned previously, closed sites could not be established with stop nets because of steep banks, proximity of streamside vegetation, high velocities and/or large uneven substrate. Sites were located a sufficient distance apart where activities would not affect other sample locations, particularly for sculpin or juvenile salmonids, which would not be expected to move far in a day. Effectiveness at catching fish of multiple sizes and age classes was apparent when comparing to minnow trapping.

Sampling occurred with a Smith-Root Inc. backpack electrofisher (Model LR-24). The electrofisher settings and the number of seconds fished were recorded. Other equipment included: dip net, gloves, waders, polarized sunglasses, hip-chain, Eslon tape measure, clinometer, compass, camera and thermometer.

Minnow Trapping

Minnow trapping was initially used as a complementary method prior to electrofishing, to corroborate species and age class information obtained by electrofishing, as well as to capture fish which may have nocturnal or crepuscular feeding habits, such as sculpin (McPhail 2007 in Triton 2008).

Minnow traps were set at an approximate density of 1 traps/10 m of stream length, or sufficient numbers to sample all pool habitat available in a sample site. The traps were baited with cat food and set overnight for 18 to 24 hours soak time. Trap locations were marked in the field and georeferenced using hand held GPS units.

Criteria for trap site selection included the presence of cover (e.g., LWD, pool, undercut bank or boulder); depth (minimum of 20 cm to ensure traps were submerged); velocity (suitable to avoid fish impingement in trap), and; safe access (Triton 2006). Any fish caught were identified, measured, tallied and released.

Very low catch rates in the summer sample set determined the sample method to be ineffective for statistically meaningful data collection. Minnow trapping was inefficient at capturing fish in Lemon Creek as little to no fish were caught. Of the fish captured, no additional species, size classes or age groups were caught in minnow traps versus electrofishing. Minnow trapping was discontinued during the first sample event.

Fish Data

All fish caught were placed in a five gallon pail and anesthetized with Alka-Seltzer tablets. All fish were identified to species (where possible in the field) using the field guide, "Field Key to The Freshwater Fishes of British Columbia", Columbia Region (McPhail and Carveth 1994). Captured fish were measured for length (to the nearest mm) and weight (g). The majority of fish weights are provided to 1/10 g; however, equipment malfunction required the use of a larger secondary scale which measured to the nearest gram. Once all required data was obtained, fish were placed in a recovery bucket containing an aerator. To further reduce the amount of stress on the fish the recovery pail was covered. After all three passes were completed; all fish were subsequently released in the vicinity of point of capture.

8.4.5 Data Analyses

Fish Community field data was assessed by comparing abundance, distribution and densities in the section of the river affected by the spill to upstream reference sites and available historical information. Data were compared between both sample periods.

Fish sampling field data were compiled to provide the following information:

- Species composition, distribution and diversity including number of species and % catch by species;
- Relative abundance and densities of fish (by species) in the sampling areas (expressed as fish / m^2);
- Catch Per Unit Effort (CPUE) for the most abundant species common to all sampled sites;
- Species level analysis of average fork length (mm), approximate age to length and length to frequency data of the most abundant species (i.e., n>20) or species of fisheries significance; and
- Species habitat selection preferences in surveyed areas were considered.

8.5 Results

8.5.1 Literature Review

The lower reaches of Lemon Creek support a diverse fish community, which may be related to the close proximity of a variety of habitats in the nearby Slocan River system. Some species may utilize lake, large river and stream habitats during their life cycle (Zimmer 1999). Up to 12 fish species have been documented in the Lemon Creek watershed (BC MoE 2015):

- Brook Trout
- Bull Trout
- Dace (general)

- Longnose Dace
- Mountain Whitefish
- Northern Pikeminnow
- Rainbow Trout
- Sculpin (general)
- Shorthead Sculpin
- Slimy Sculpin
- Torrent Sculpin
- Umatilla Dace

There was also indication of potential Kokanee spawning in lower Lemon Creek (Zimmer 1999), but there is no current record of the observation in the provincial database.

Three fish species documented in the Slocan River and its tributaries (Shorthead Sculpin, Columbia Sculpin, and Umatilla Dace) are currently listed provincially by the BC CDC and by COSEWIC. Additionally, Bull Trout are a provincially blue-listed species (Special Concern [formerly Vulnerable]) by BC CDC.

Information in literature is limited with respect to bull trout numbers, population dynamics, utilization, or timing within the Lemon Creek system. Mirkwood Ecological Consultants conducted electrofishing surveys in 1996 within the Lemon Creek system. Rainbow Trout were abundant in the lower reaches of Lemon Creek, while Bull Trout were more prevalent in upper reaches (Addison et al. 1996). Juvenile bull trout were electrofished in the upper reaches of Lemon Creek, Holmsen Creek and Monument Creek (Addison et al. 1996). Emergence of bull trout fry typically occurs in the late spring, and these fish may stay in their natal stream for 1 to 4 years (Baxter and McPhail 1996).

Zimmer (1999) completed a 1:20 000 reconnaissance of Lemon Creek drainage. Following established standards the stream was divided into 12 reaches labeled upstream from the confluence. Reaches 1 to 3 correspond to the areas sampled in 2014, with the impacted sites located in Reaches 1 and 2, and reference conditions sampled in Reach 3. Sampling occurred between August 24 and September 17, 1999, thus timing of survey was comparable. Reconnaissance sampling consisted of electrofishing and overnight sets of G-Type minnow traps. Unfortunately, sample effort was only included in tables describing effort in determining non-fish bearing status of upper stream reaches; therefore, their catch data was only used herein to compare fish distribution, community composition and relative abundance (Table 8-1).

Table 8-1: Historical studies collected from the Slocan River watershed showing sites, classification level of data presented and metrics used in the analysis section

Reference Document	Site	Reach	Species	Life Stage	Total Fish	Mean Length	Range of Lengths
Reconnaissance (1:20,000) Fish and Fish Habitat Inventory of Slocan Forest Products Ltd. Chart Area Selected Streams (Zimmer 1999)	Lemon Creek Mainstem (Reaches 1, 3 & 5)		BT	A	1	202	
			BT	J	1	99	
			BT	P	1	73	
			RB	J	14	155	112-193
			RB	P	9	79	60-97
		3	MW	J	1	182	
		1	EB	J	1	140	
		1,3	CRH	A	25	76	30-130
		5	CCN	A	6	83	33-110

Eastern brook trout were identified throughout the Lemon Creek watershed. This species competes aggressively with other salmonids for available resources and may eventually replace other species (Rieman and McIntyre 1993).

Torrent sculpin were the most abundant fish in Reach 1 of Lemon Creek (Zimmer 1999). Rainbow trout were the most abundant fish captured along with Bull Trout and Shorthead Sculpin in the cascade-pool channel in Reach 5. Shorthead Sculpin were also captured in the Summit Creek tributary to Lemon Creek. These were the only two sites Shorthead Sculpin were sampled within the Lemon Creek watershed at that time. Approximately 17 km upstream of Slocan River, a 4 m high waterfall in Reach 6 blocks the upstream migration of adfluvial bull trout. Potential spawning areas and rearing areas for these adfluvial fish were indicated to include all downstream areas of the mainstem, as well as accessible portions of the downstream tributaries. Resident populations of Bull Trout, Rainbow Trout, Slimy Sculpin have been reported immediately upstream of the falls (Wildstone 1995 in Zimmer 1999).

Rainbow trout fry have historically been stocked in Lemon Creek in 1939, 1950, and 1951 from the Nelson Hatchery; however, there are no reports of recent stocking (BC MoE 2015). A single lake in the headwaters of Lemon Creek, Crazy Jane Lake, has been stocked with Westslope (Yellowstone) Cutthroat Trout (O. clarki lewisi) at least twice in the past. The most recent data point indicated an observation of these fish in 1995 (BC MoE 2015). It is unknown if these fish persist; however, it is assumed all downstream areas may also support Westslope Cutthroat Trout.

The six major tributaries to Lemon Creek are third or fourth order streams varying in length from 6 km to 10 km. Each of the streams were either confirmed to contain Rainbow Trout, Bull Trout, Eastern Brook Trout and sculpin, or were considered fish bearing based on fish access (e.g., Nilsik Creek;

Addison et al. 1996). Holmsen Creek was noted among the most productive in the entire watershed for salmonids (Addison et al. 1996). Monument Creek was the only drainage with confirmed Bull Trout spawning in 2013.

Study Sites/Habitat Data

Site characteristics were assessed for each of the sample sites. Sample sites spanned at least two distinct morphological reaches, similar to what was determined in past 1:20 000 reconnaissance assessments (Zimmer 1999). The lowest reach is downstream of the Highway 6 crossing to the confluence with Slocan River, and consists of a reduced channel confinement and resultant widening of the stream bed. Zimmer (1999) indicated the average channel width of the lowest reach was 43.1 m and average gradient was 2%. Upstream of the Highway 6 crossing, the average channel width in the sampled reaches reduced to 18.0m.

Mesohabitat at the 10 sample sites in order of abundance was riffle, run, glide and pool. Total available cover was moderate (5 to 20%) at most sites, abundant (greater than 20%) at one of the sites (LC05S). The dominant cover type was associated with boulder, subdominant was pool. Other cover types, such as large and small woody debris, overstream vegetation and undercut bank accounted for a lower portion of total available cover in the sites sampled.

Substrate in the lower reach sampled sites was 55% cobble, 30% boulder, 10% gravel and 5% fines. Substrate in the upper reach sampled sites was 46% cobble, 37% boulder, 10% gravel and 7% fines.

8.5.2 Biological Data Collection - Community

Catch Distribution and Abundance

A total of 1,422 fish were captured in Lemon Creek mainstem and side channel sites during the summer and fall 2014 surveys. Electrofishing accounted for over 99% of the catch. The total number of species identified in the samples was ten. Members of the target salmonid species (Rainbow Trout, Bull Trout, and Mountain Whitefish) represented over 21% of total catch, and consisted of 299 fish. The remaining fish sample was comprised of 1,006 sculpin (general, Torrent, and Prickly), 102 dace (Umatilla and Longnose), 13 Northern Pikeminnow, and two (2) Largescale Sucker.

Within the seven impact sites, all ten species identified were present if both sample sets (seasons) are included. In the reference reach, the three non-impacted (control) sites contained three identified species (Rainbow Trout, Bull Trout, and sculpin sp.).

Table 8-2: Summary of total catch per species for each sample period

	Sampling Event	RB	BT	MW	CRH	NSC	LNC	UDC	CAS	CC	CSU	# species
Fish Caught	Summer	30	9	1	6	1	44	5	1	540	0	637
	Fall	243	14	2	7	12	31	22	0	452	2	785
Grand Total		**273**	**23**	**3**	**13**	**13**	**75**	**27**	**1**	**992**	**2**	**1422**

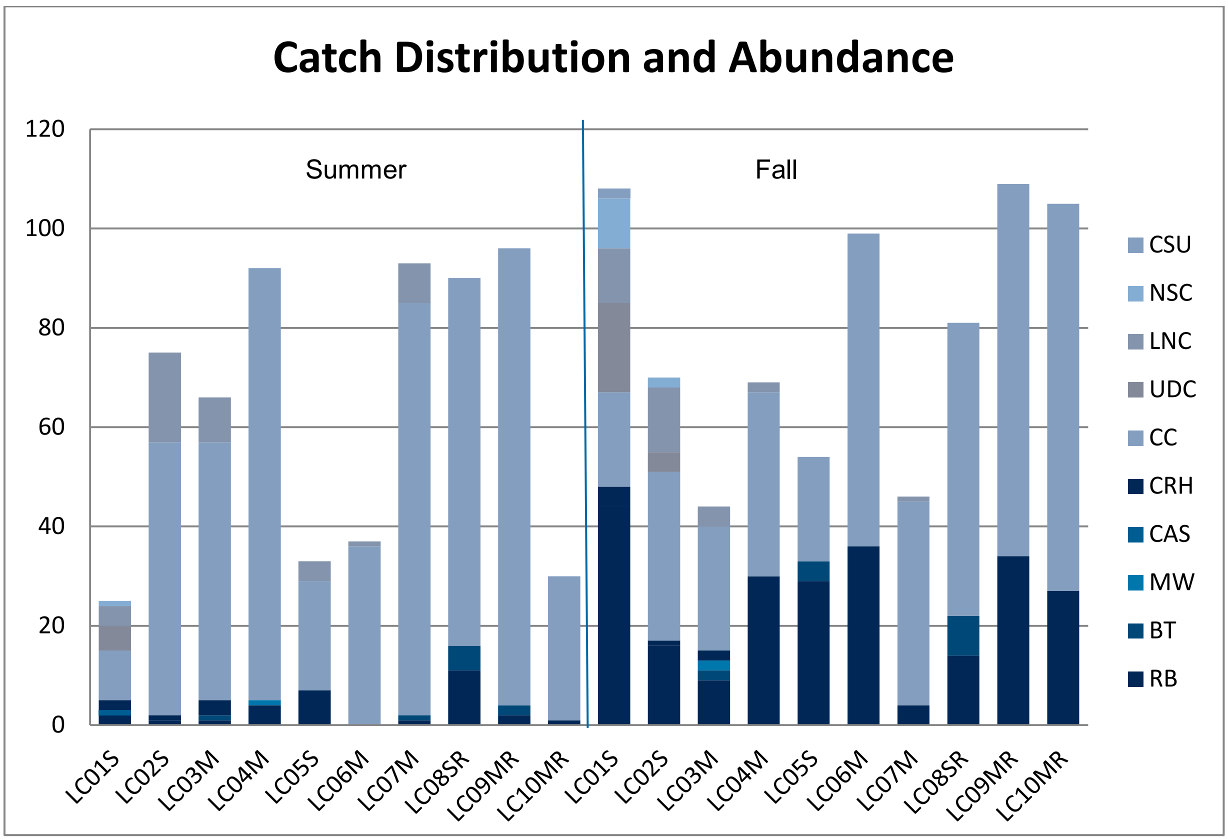


Figure 8-3: Lemon Creek fish distribution and abundance for all sites – summer and fall 2014

Unidentified sculpin were by far the most abundant species and were distributed in all sites for both sample events. Rainbow trout were present in low numbers during initial sampling, and substantially increased in abundance by the fall sampling period. There were a number of species only observed in the lower impact sites between the Highway 6 Bridge and Slocan River confluence. The distribution also showed variability among sites for abundance and species composition, particularly when comparing lower sites to the reference sites.

Diversity

The community diversity was indicated by species richness (i.e., the number of species per site, Figure 8-4). The sites in the upper reach, upstream of Highway 6, ranged from two to three species present. That is, diversity in the impacted sites from Site 4 to Site 7, were similar or greater in diversity than the upstream reference sites (sites 8 to 10). The sites in the reach downstream of the Highway 6 crossing (sites 1 to 3) increased in species richness towards the Slocan River confluence, with diversity threefold higher than the reference sites. This pattern appeared to be strengthening between the summer and fall sample periods.

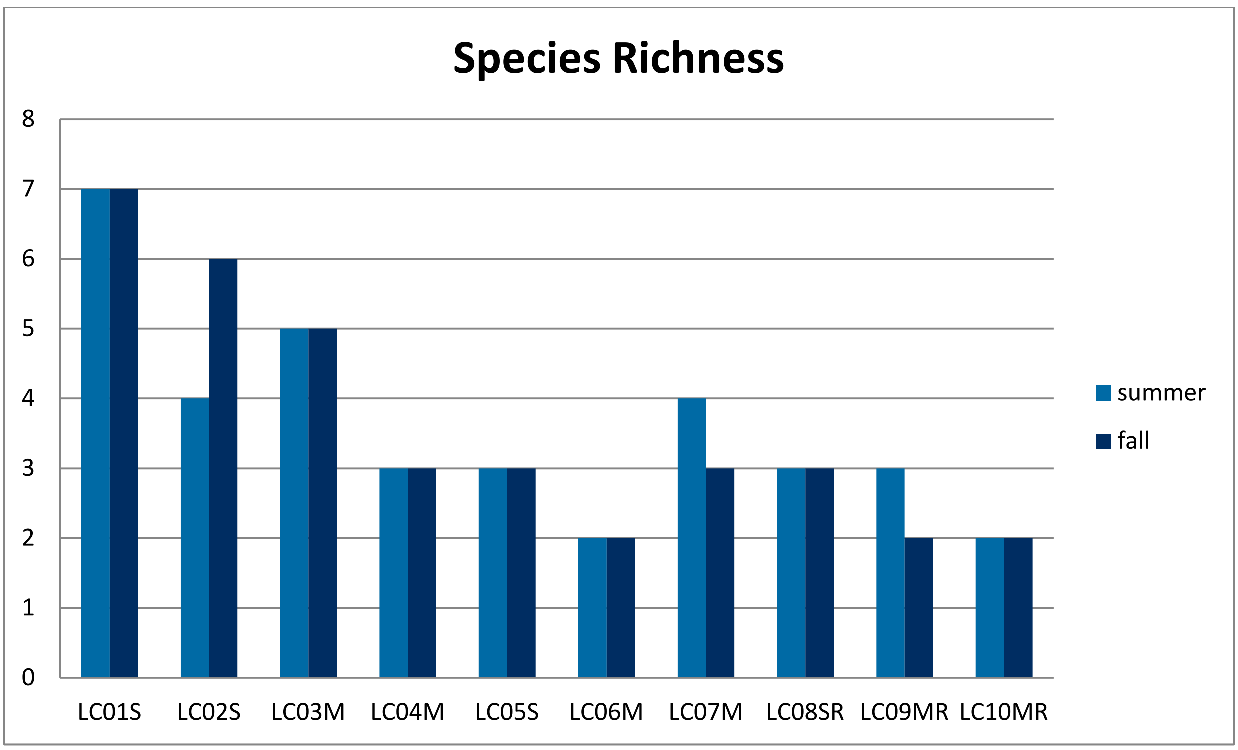
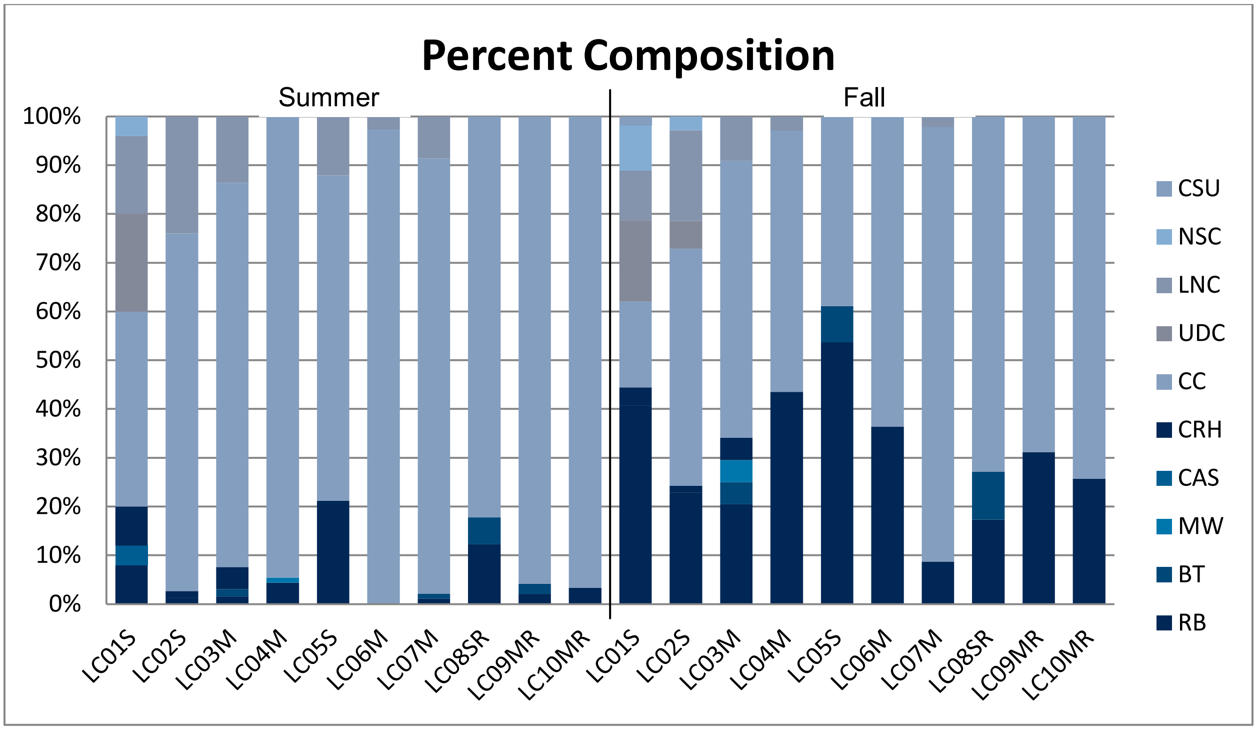


Figure 8-4: Lemon Creek Fish Species Richness – summer and fall 2014

Percent Composition

Unidentified sculpin was the most dominant species captured at all sites in the summer. Species diversity increased in an upstream to downstream direction (e.g., sites closest to the confluence with the Slocan River had a higher diversity than the site furthest upstream).



Note: CSU=largescale sucker, NSC=northern pikeminnow, LNC=longnose dace, UDC=umatilla dace, CC=sculpin (general), CRH=torrent sculpin, CAS=prickly sculpin, MW=mountain whitefish, BT=bull trout, RB=rainbow trout

Figure 8-5: Lemon Creek Fish Percent Composition – summer and fall 2014

Density/CPUE

Fish density is presented herein as a weighted catch per unit effort (CPUE), indicating catch rates to sample effort adjusted for sampled area to provide fish / effort / m^2. This assumes all sites are equally sampled. In this case 'effort' is seconds of electrofishing. Reference sites LC08SR and LC09MR exhibited higher fish densities during summer than fall sampling. Fall sampling indicated a similar high fish density at site LC06M, which is an impact site. The area closest to the spill would be expected to have the most similar habitat characteristics to the reference sites. Downstream densities were indicated to be lower, especially in the lower reach of Lemon Creek at sites LC01S1, LC03M and LC05S. However, natural variability in fish densities and corresponding sites did not appear substantially different than reference site 10, which suggested the present in the system.

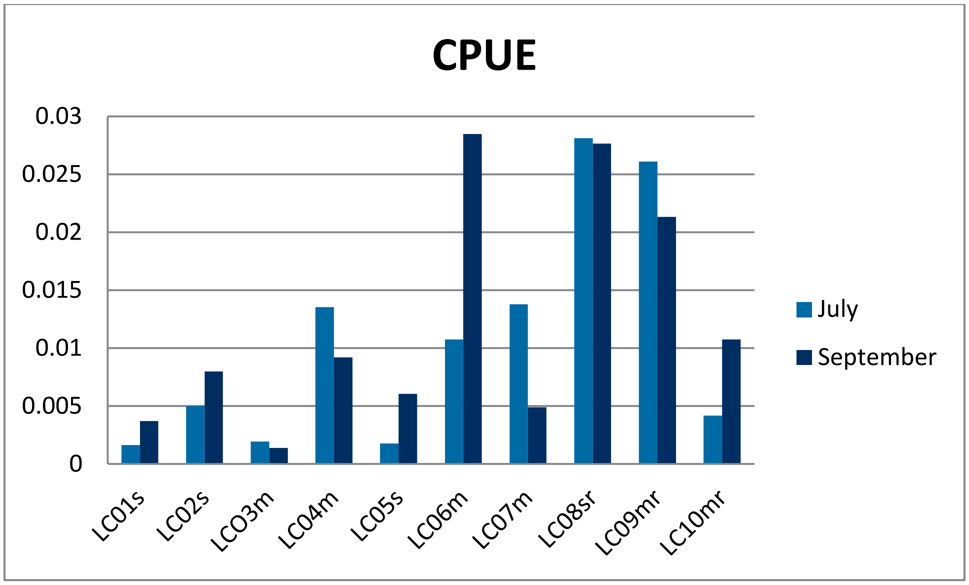


Figure 8-6: Lemon Creek Fish Catch Per Unit Effort – summer and fall 2014

8.5.3 Biological Data Collection – Species Level

Tables 8-3 and 8-4 provide a summary of species abundance and size classes represented in the impacted and reference sites for both sampling events. For most species, the size range indicates multiple age classes present in the sample sites. The most abundant species, or species with high fisheries value, are further analyzed below.

Table 8-3: Lemon Creek Fish Abundance and Size Class – Summer

Site	Species	Number Caught	Fork Length (mm)		
			Min	Max	Mean
Impact	Bull Trout	2	108	177	143
	Prickly Sculpin	1	116	116	116
	Sculpin sp.	345	31	116	70
	Torrent Sculpin	6	102	144	119
	Longnose Dace	44	62	120	89
	Mountain Whitefish	1	75	75	75
	Northern Pikeminnow	1	101	101	101
	Rainbow Trout	16	25	204	100
	Umatilla Dace	5	55	74	68
Reference	Bull Trout	7	46	222	111
	Sculpin sp.	195	33	105	65
	Rainbow Trout	14	29	95	72

Table 8-4: Lemon Creek Fish Abundance and Size Class – Fall

Site	Species	Number Caught	Fork Length (mm)		
			Min	Max	Mean
Impact	Bull Trout	6	62	263	131
	Sculpin sp.	240	17	110	62
	Torrent Sculpin	7	92	134	114
	Largescale Sucker	2	97	103	100
	Longnose Dace	31	52	129	80
	Mountain Whitefish	2	89	90	90
	Northern Pikeminnow	12	58	144	82
	Rainbow Trout	168	18	258	59
	Umatilla Dace	22	49	80	62
Reference	Bull Trout	8	64	119	83
	Sculpin sp.	212	17	105	61
	Rainbow Trout	75	28	177	57

8.5.3.1 Sculpin

Sculpin (cottids) were not anticipated to be a target species of study; however, further consideration of the sculpin data as an indicator of stream fish abundance and community recovery was supported for several factors. There were over three times as many sculpin collected (n=1003) as the next most abundant fish species (Rainbow Trout: n=273). Sculpin are not migratory and display strong site fidelity tending to live out their entire life history in one area (approximate individual range of up to 200 m for freshwater sculpins). Torrent Sculpin have been discussed as intolerant of poor water quality (Maughan and Laumeyer 1974; Hughes and Gammon 1987; Friesen and Ward 1996; Maret and MacCoy 2002), and unlikely to persist when faced with high levels of habitat degradation, thus they are a good indicator of water quality and habitat suitability over time. And finally, Shorthead Sculpin, a provincially blue-listed fish species, is known to inhabit Lemon Creek.

Of the combined total of 1006 cottids collected (Figure 8-7), 13 were identified as Torrent Sculpin and one as Prickly Sculpin. Identification was conducted in the field, based on visual observation of diagnostic traits. The field guide selected and used during the sampling program (McPhail and Carveth 1994) only included guidance to field identify two of the five sculpin species potentially present in Lemon Creek, hence the vast majority of sculpin were simply entered as general cottid species (CC). As sculpin were not considered the target species of study, the deficiency in the field key was not found until the field program was under way, when it was carried through all sampling to allow for comparable results. Sculpin were sorted by the characteristic of 'prickly' texture, then to additional characteristics to differentiate between Torrent and Prickly Sculpin. The remainder forms the bulk of the sculpin not identified to species, which could most likely be Slimy or Shorthead Sculpin, each of which were previously reported in the drainage, or in low potential Columbia Sculpin. Columbia Sculpin are present in the lower Slocan River near the confluence with Kootenay River, but have not been reported in Lemon Creek (BC MoE 2015; pers. comm. Crystal Lawrence 2015). The Kootenay/Slocan population of Columbia Sculpin has been estimated at roughly 100 individuals; however, this value was not obtained quantitatively (COSEWIC 2010a). Considering their relative rarity and no confirmed previous presence in Lemon Creek, it is unlikely the unidentified sculpin are Columbia Sculpin. Shorthead Sculpin are present in both Slocan River and Lemon Creek (BC MoE 2015). Populations appear to be locally abundant and stable within their range (COSEWIC 2010b).

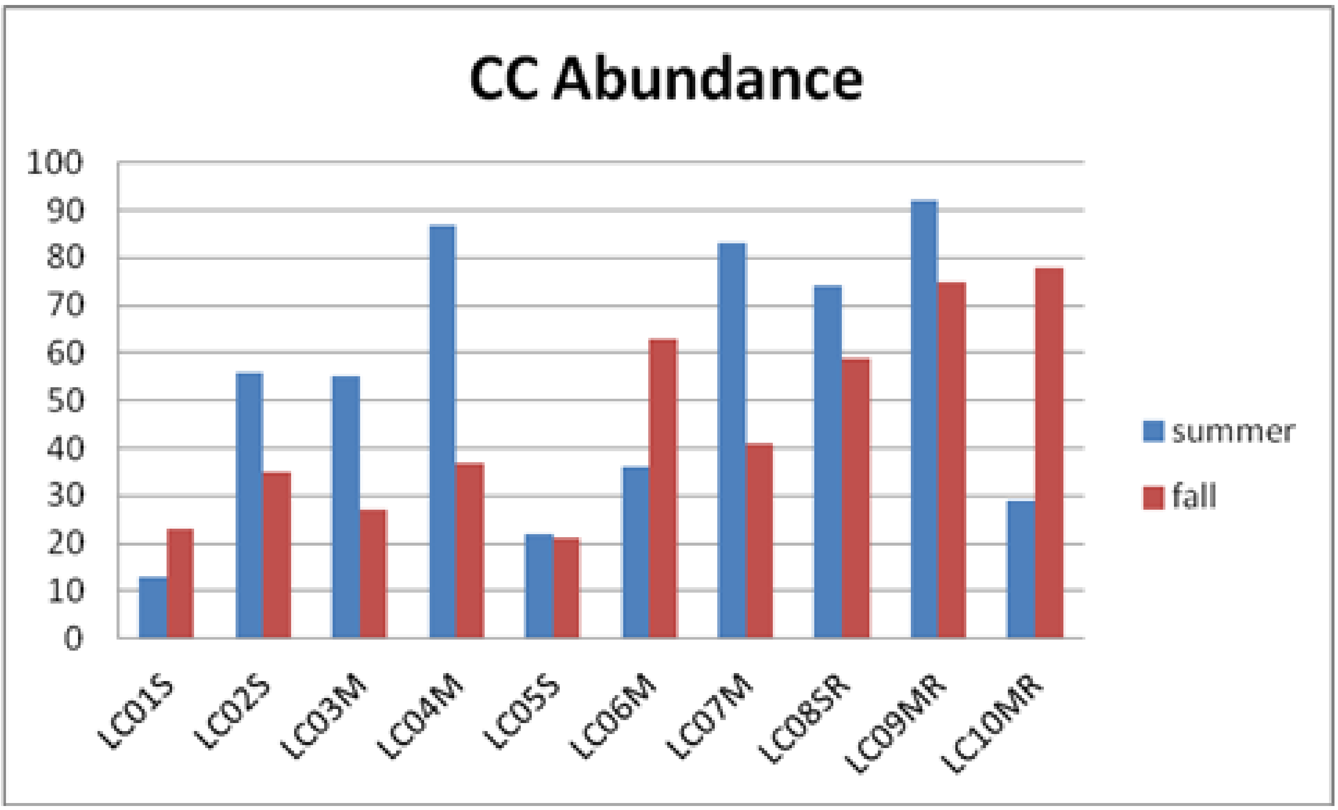


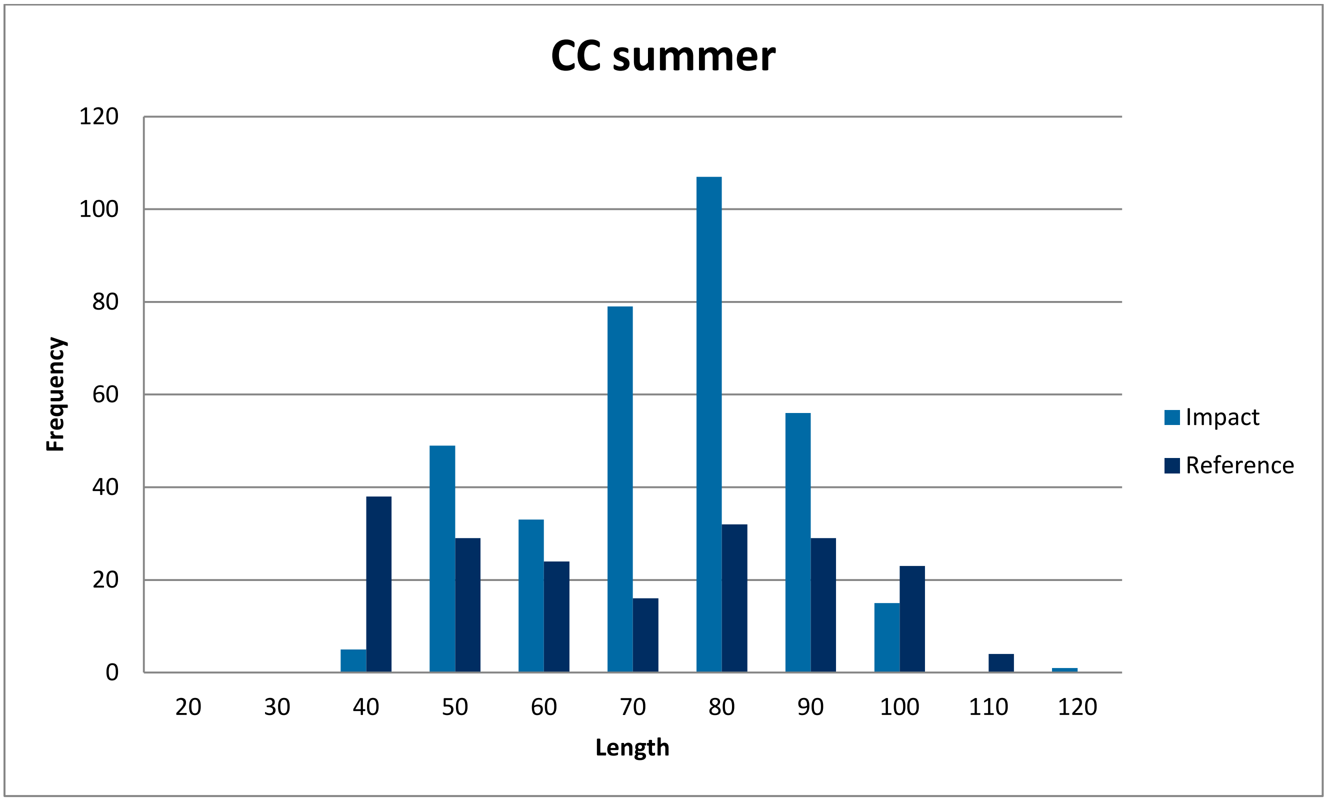
Figure 8-7: Lemon Creek Total Catch of Sculpin Species by Site – summer and fall 2014

Zimmer (1999) indicated Torrent Sculpin were only captured in Reaches 1 and 3 of Lemon Creek mainstem (i.e., the reaches being sampled in 2014), while Shorthead Sculpin were captured in the mid to upper drainage of Lemon Creek.

8.5.3.1.1 Biometric Parameters

Length-Frequency

Average total lengths (TL) of Sculpin captured in summer and fall of 2014 was 70 mm and 62 mm respectively. The length frequency chart for the summer combined set of all sampled sculpin does not indicate a clear correlation to age cohorts (Figure 8-8), but it did appear there was a difference in population age structure. The reference sites had small sized sculpin (30 mm to 40 mm age class) sampled in the summer which were largely absent from the impact sites. However, in the fall samples, sculpin fry (<30 mm) had emerged from the gravel and were sampled in higher numbers in the impact sites than in the reference sites, clearly indicating successful spawning and recruitment within the impacted sites.



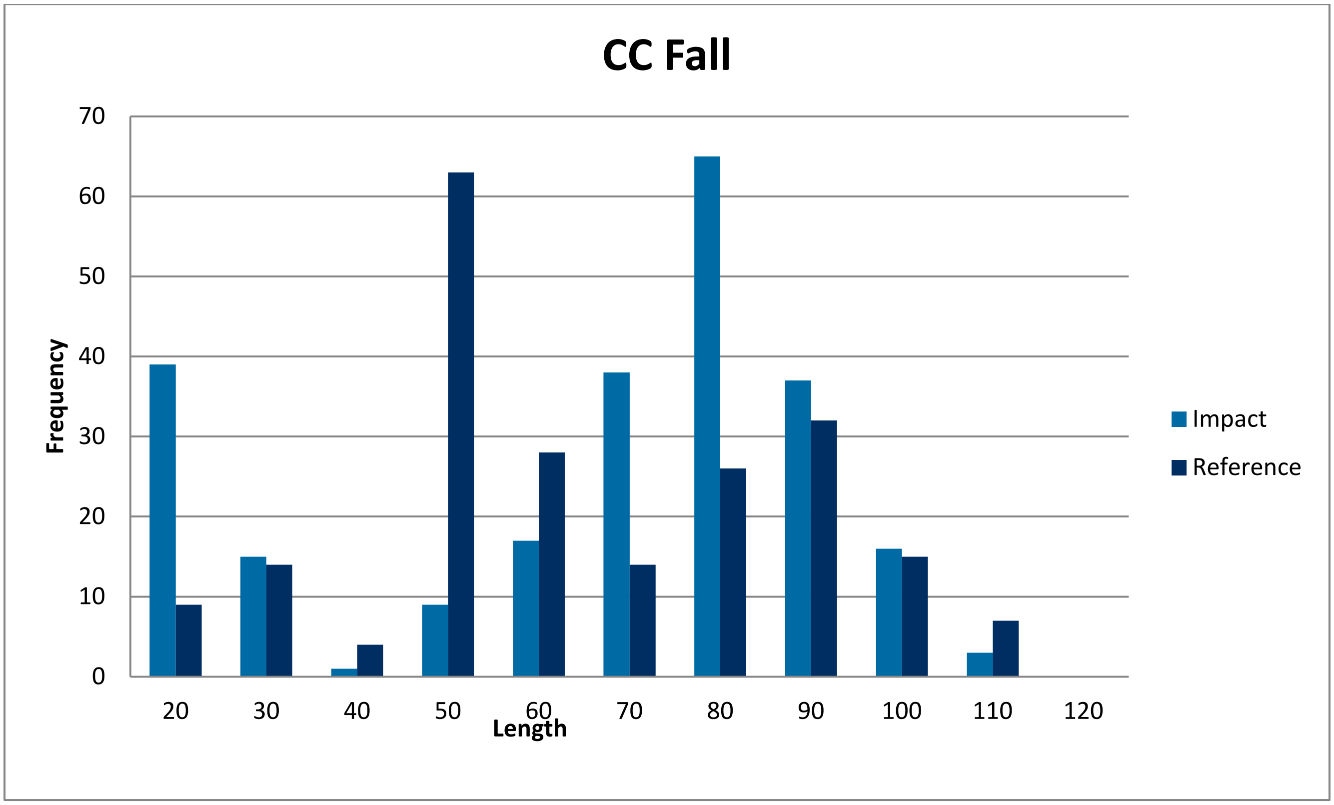


Figure 8-8: Lemon Creek Sculpin Length-Frequency Distribution – summer and fall 2014

There are no quantitative data on migration and dispersal on Shorthead Sculpin in nature[1]. Sculpins in western North America spawn in the spring. In experiments, newly hatched larvae averaged burrowed into the gravel substrate and after two weeks emerged metamorphosed at 10 mm in length (McPhail 2007). After the fry emerge they are thought to move to shallow water along stream edges moving laterally into deeper and faster water as they grow. In the Slocan River, fry averaged 25 mm to 35 mm by late August. Small juveniles averaged 45 mm by the next summer (1+) (COSEWIC 2010b). There are reports of sexually mature cottid species around 46 mm long in the Slocan River (three years old [2+]) (McPhail 2007). Literature indicates that the oldest Shorthead Sculpin in BC was 85 mm in length and in its seventh growing season (6+) (McPhail 2007).

Torrent sculpin reaches sexual maturity by age two, at approximately 57 mm (Brown 1971; Wydoski and Whitney 2003)[2]. Spawning generally occurs in April and May. Torrent sculpin fry may emerge from nests under rocks as early as August (Northcote 1954; Brown 1971) and are presumed to drift and disperse downstream (Sheldon 1968).

1 http://www.sararegistry.gc.ca/default.asp?lang=En&n=69D4B716-1#_Toc305137487
2 http://www.fisheriessociety.org/AFSmontana/SSCpages/Torrentsculpinstatus.htm

8.5.3.1.2 Evaluation of Sculpin Recovery

Sculpin were captured in all sample sites Lemon Creek. The initial sample set in July/August had a higher total abundance and a higher level of abundance variation among sites. Natural abundance variation is evident comparing the two mainstem habitat reference sites in the summer sample event, with over three times the number of sculpin sampled at site 9 as site 10. The September samples indicated an overall more uniform abundance among the lower sites, and a general increase in abundance in an upstream direction. Overall number of sculpin captured decreased between the summer and fall sample events, from a total of 547 to 459 in all sites respectively.

Historical stream inventory data indicate general fish distribution and relative abundance, with Torrent Sculpin comprising 42% of the total fish caught in the same reaches as considered in this study (Zimmer 1999). This is within the abundance range of the unidentified sculpin group (considered in the field to be either Slimy or Shorthead Sculpin), but far exceeds the relative abundance of confirmed Torrent Sculpin caught in 2014.

The overall endpoint objective was that fish abundance and community structure in Lemon Creek are similar to reference (non-impacted) sites. Thus habitat utilization downstream of the spill was compared to unimpacted reference sites upstream of 4.9 km of Lemon Creek. The impacted reach had similar relative abundance of sculpin as reference sites. As sculpin were the dominant species in each site, the decreasing CPUE downstream of site 6 indicates there may be a lower density of sculpin than exists upstream. However, based on the high numbers of sculpin fry (higher fry numbers in the impacted reach than reference), a length frequency distribution including multiple age classes, and the fact that sculpin do not range more than 200 m in their lifespan, it appears sculpin were recovering in 2014.

8.5.3.2 Rainbow Trout

A total of 273 Rainbow Trout were captured in Lemon Creek during the 2014 fish abundance and community recovery assessment program (all sites and methods combined). Species distribution extended through all sampled reaches. Past sampling of Lemon Creek indicated Rainbow Trout were the most abundant salmonid in the lower reaches (Addison et al. 1996; Zimmer 1999).

Average fork lengths of Rainbow Trout captured in summer and fall of 2014 ranged from 59 mm to 100 mm.

8.5.3.2.1 Biometric Parameters

Length-Frequency

All Rainbow Trout were measured for fork length. The length-frequency distribution is shown in Figure 8-9.

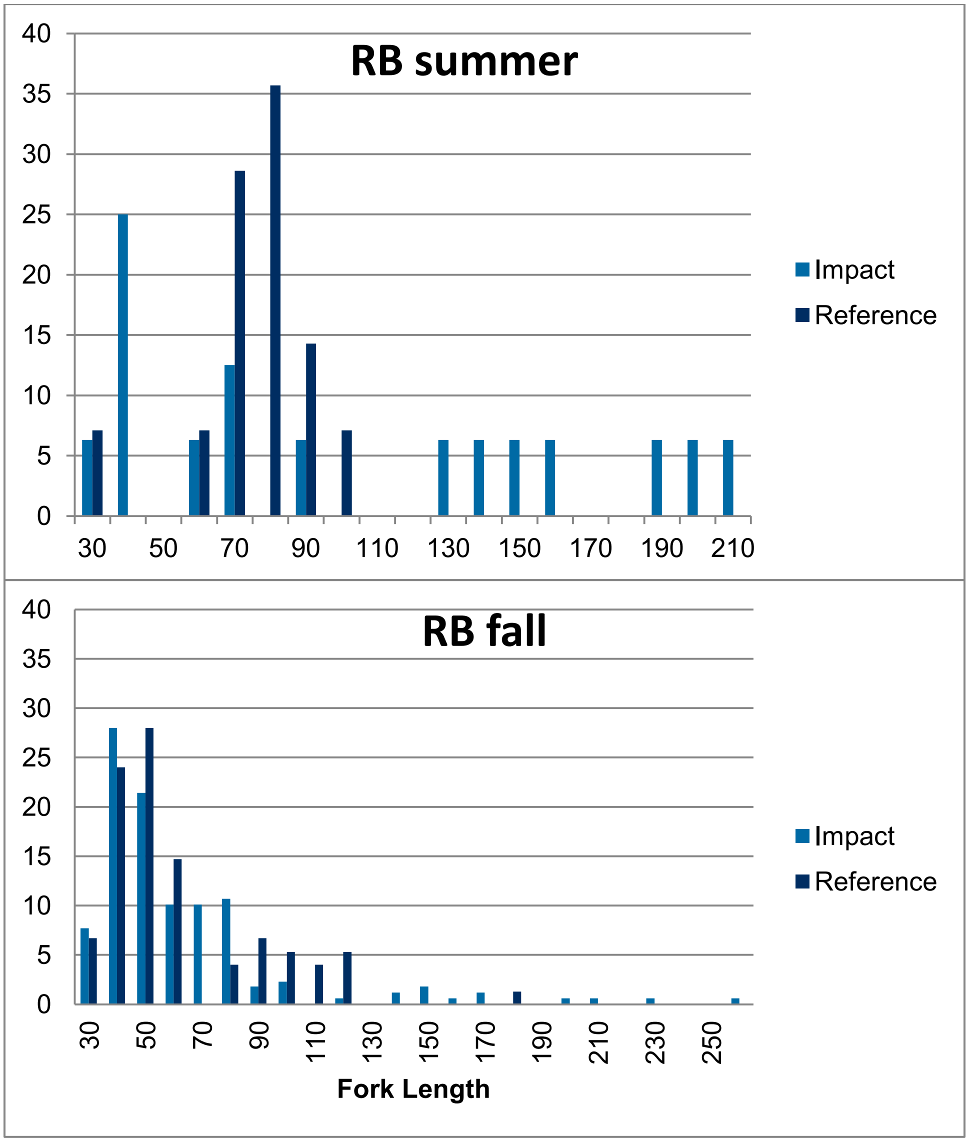


Figure 8-9: Lemon Creek Rainbow Trout Length-Frequency percentage Distribution – summer and fall 2014

The histograms indicate there may have been a YOY cohort in the fall that ranged from 25 mm to approximately 60 mm in the impact reach, and potentially a summer cohort of 60 mm to 100 mm fish in reference sites. However, based on data from McPhail (2007) suggests that fry can attain lengths of 100 mm to 120 mm at the end of their first summer after hatching in late spring or early summer, thus there may be overlapping size classes. The lengths range from YOY to mature adult fish in the impact site, while generally smaller juvenile fish occupied the reference sites.

8.5.3.2.2 Assessment of Rainbow Trout Recovery

The level of effects of the spill on Rainbow Trout in Lemon Creek are unknown, as no Rainbow Trout were salvaged from Lemon Creek itself in the emergency response, but may have comprised a portion of the fish recovered downstream in Slocan River. While no acute impacts to Rainbow Trout in Lemon Creek itself were documented during emergency response, Rainbow Trout was the third-most abundant deceased fish species collected in Slocan River after the spill incident (n=19).

Rainbow Trout were captured in all sites by electrofishing. Multiple age classes were observed with a large number of YOY. Presence of YOY suggests suitable rearing conditions or transient fish in September working their way through the system. Past sampling indicates similar size classes in 1998, when Zimmer (1999) caught Rainbow trout ranging in size from 40 mm to 215 mm. With 104 fish captured in all sampled sites of the drainage, Zimmer (1999) indicated Rainbow Trout were the most abundant species within the watershed. In the mainstem of Lemon Creek, Rainbow Trout accounted for 39% of the total catch. This historical relative abundance is similar to some of the impact sites fall relative abundance for Rainbow Trout, and exceeds the reference sites.

However, based on the high numbers of YOY in the impacted sites and a length frequency distribution including multiple age classes, it appears Rainbow Trout were re-colonizing in 2014.

8.5.3.3 Bull Trout

Bull Trout are a blue-listed (species of concern) fish species in BC. No Bull Trout mortalities were collected during seven days of post-spill salvages.

A total of 23 Bull Trout were captured in 2014; nine (9) in the summer and 14 in the fall. The distribution of juvenile Bull Trout was consistent with that of past years (i.e., increasing in abundance in an upstream direction). All Bull Trout captured were measured for length and weight. Measurements were indicative of fish in good condition and represented multiple age/size classes

Sampling in 2014 captured multiple age classes in preferred habitats. Furthermore, the capture of juveniles less than 60 mm in length indicates annual recruitment is occurring and recovery is progressing. Prior to conducting the 2013 bull trout redd surveys, Mirkwood Ecological Consultants observed eight mature bull trout staging in the Lemon pool directly south of the mouth of Lemon Creek (Corbett, pers. com). The 2013 redd survey identified only one redd in a tributary to Lemon Creek. These data suggest low recruitment of Bull Trout consistent with the low numbers of YOY caught in 2014.

With the low number of fish captured, a length-frequency histogram for the combined catch of all sites in each sample period was produced. With few individuals, cohorts may not be reliably assigned; however, there were two clusters of size classes (70 mm and 110 mm).

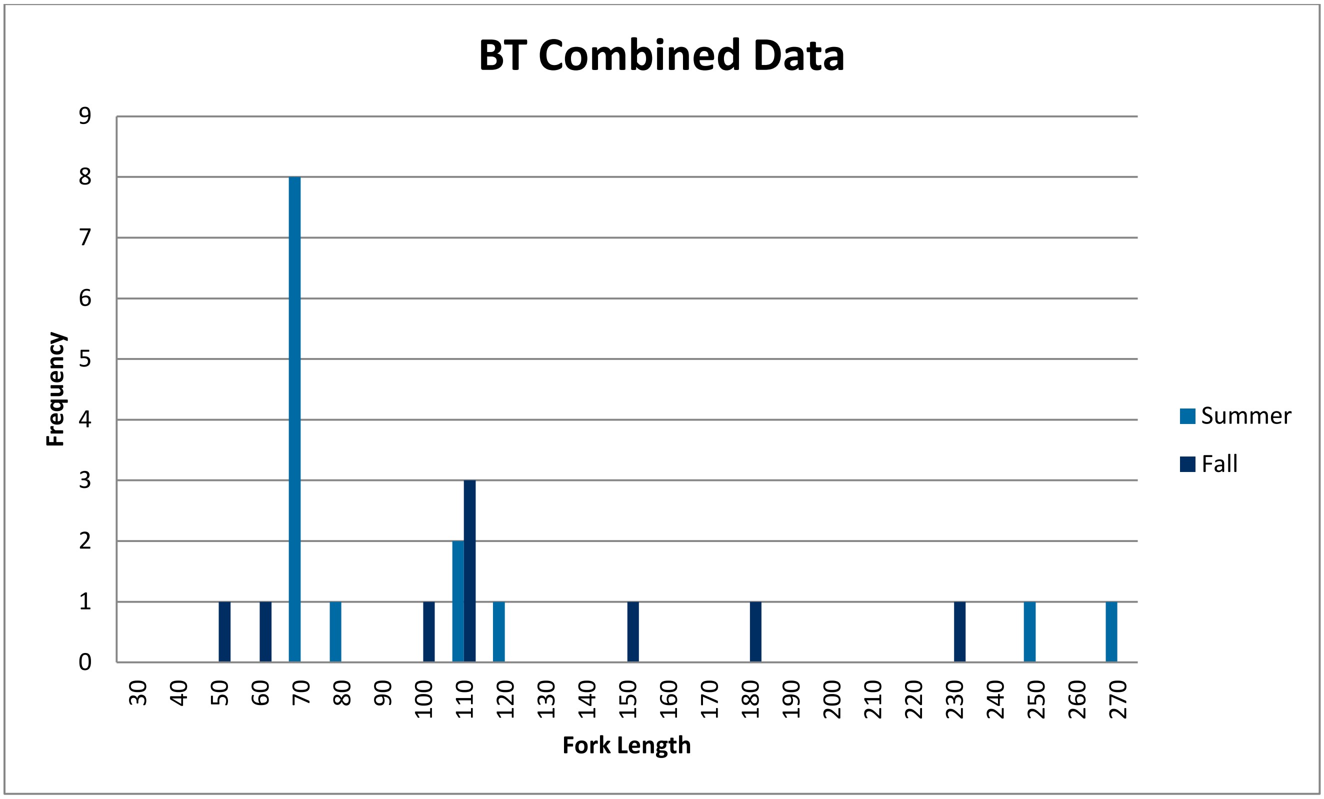


Figure 8-10: Lemon Creek Bull Trout Length-Frequency Distribution – summer and fall 2014

8.5.3.4 Mountain Whitefish

Zimmer (1999) caught a single juvenile Mountain Whitefish in the reach of Lemon Creek covered by this 2014 study. This represents a catch of one fish of 59 total for lower Lemon Creek.

Three Mountain Whitefish were caught in 2014, none of which were from reference sites. The three ranged in length from 75 mm to 90 mm, which could be from one cohort. With the limited data these results are not directly comparable; however, they represent a small portion of the total catch.

8.5.3.5 Eastern Brook Trout

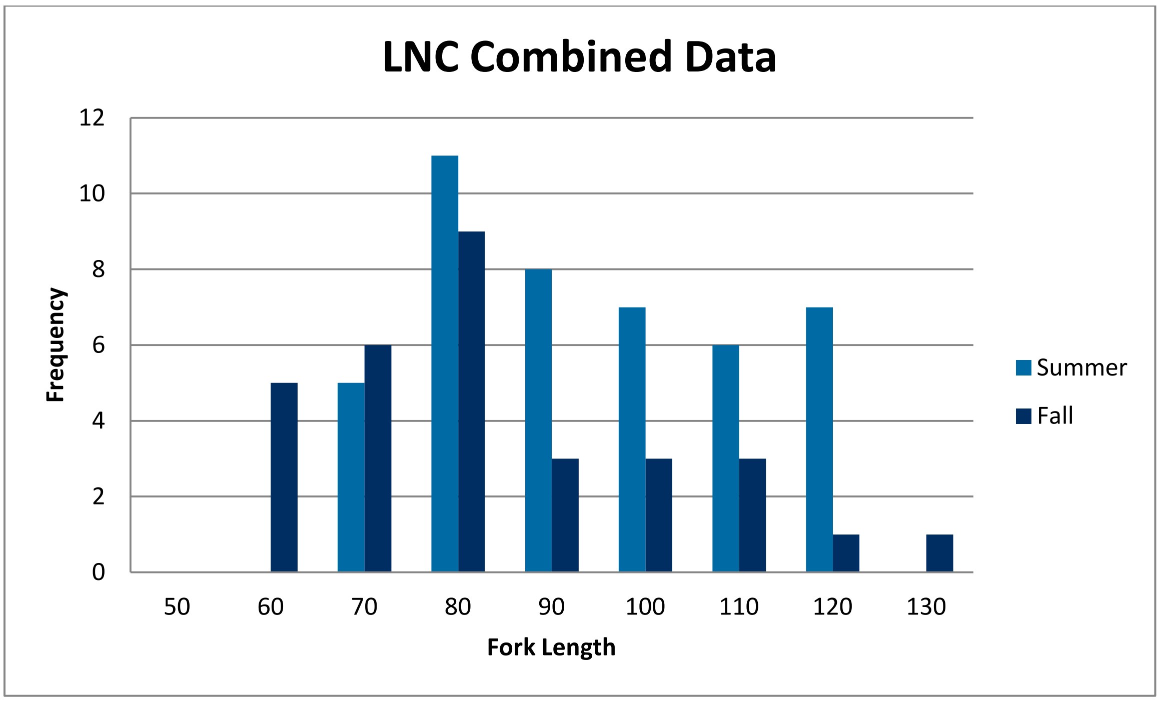
Eastern brook trout ranging in size between 37 mm and 270 mm were previously captured in Lemon Creek (Zimmer 1999).

This species was not encountered in 2014. It is a non-native fish and has not been considered further in this study.

8.5.3.6 Dace (Longnose and Umatilla)

Longnose Dace were moderately abundant. The length-frequency histogram would indicate the Longnose Dace population consists of adult or sub-adult fish.

Umatilla Dace were less abundant. The length-frequency histograms indicate that, being mid-summer spawners, the sampled Umatilla Dace were all at least 2 years old (1+), as they typically don't exceed 30 mm at the end of their first growing season. As adults they rarely have longer fork lengths than 120 mm (McPhail 2007).



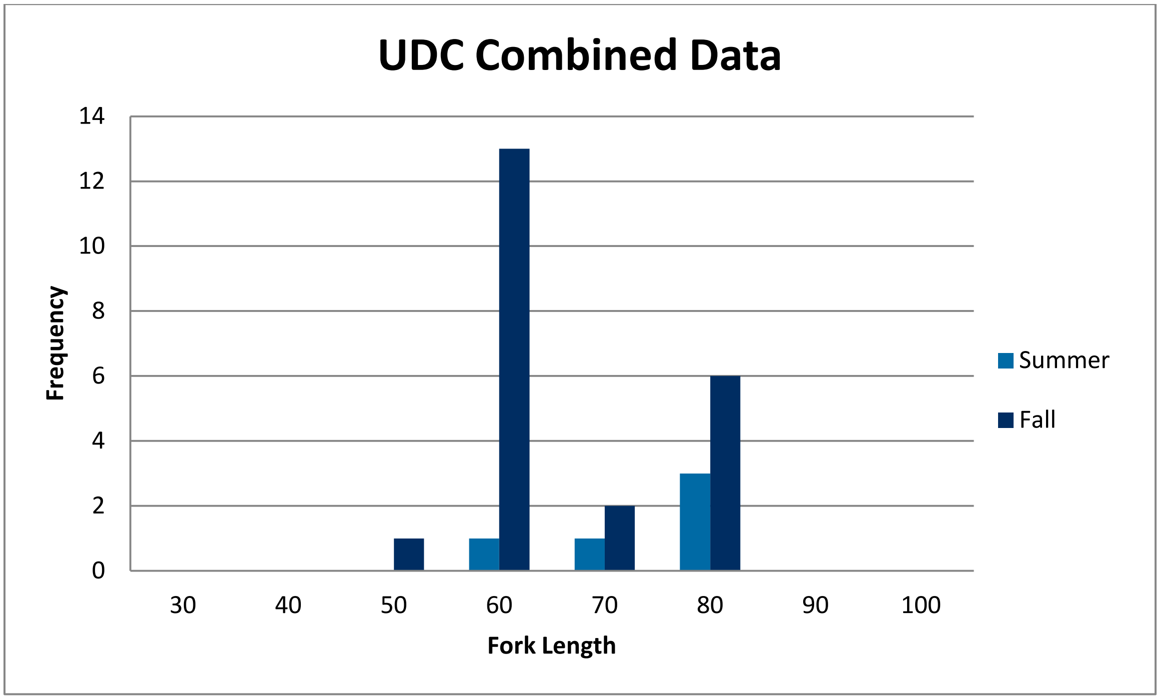


Figure 8-11: Lemon Creek Dace (Longnose and Umatilla) Length-Frequency Distribution – summer and fall 2014

Umatilla Dace and Longnose Dace are a benthic, riverine species that prefer silt free sections with large gravels to boulder-sized substrates where they can find shelter during the day (COSEWIC 2010c).

The Umatilla Dace likely moved into the Lemon Creek habitat from Slocan River, since they were only found in the lowest reach. Distribution of Longnose Dace extended from the Slocan River up to the furthest upstream impact site (Site 7). Catches of Longnose Dace consisted of mature adults, while no juveniles were captured. This would suggest that Lemon Creek provides marginal suitable spawning habitat and that spawning likely occurs in the warmer water of the Slocan River.

8.6 Discussion

Data analysis following fish sampling in Lemon Creek focused on key fisheries indicators (e.g., species-level, population-level, community-level) and detecting and identifying recovery process based on results from the assessment. Sampling was required to evaluate recovery progress towards the endpoint that fish abundance and community structure in Lemon Creek are similar to reference (non-impacted) sites. Sampling was initiated in late July 2014, one year after the fuel spill, following consultation with MoE and MFLNRO.

A total of 10 species of fish were found inhabiting Lemon Creek. Background information suggested that up to 12 species could be found in Lemon Creek. The species diversity trend observed in Lemon Creek in 2014 displayed increasing abundance in a down-gradient pattern from the spill site. The confined channel reaches upstream of the Highway 6 Bridge were found to contain fewer species. The unimpacted reference sites were inhabited by two to three species (Rainbow Trout, Bull Trout, and sculpin). The lower reach of Lemon Creek has slower flow velocities, a broader channel with floodplain features and limited off-channel habitat. Fish species from Slocan River or Lake are migrating into the lower part of Lemon Creek, some potentially transiently to forage. All sampled impact sites have at least similar or greater species diversity than the reference sites.

Fish distribution and relative abundance does not appear to show a change in community structure or species assemblage, except in consideration of unidentified sculpin. The historically documented species of sculpin that was in highest abundance in lower Lemon Creek was Torrent Sculpin. The documented relative abundance was in line with the currently documented unidentified sculpin, not with Torrent Sculpin abundance indicated by 2014 sampling. The unidentified sculpin were keyed to most likely being either Slimy Sculpin or Shorthead Sculpin, both of which are also documented as present in the system. There may be an error in interpretation or comparison of the data sets, or misidentification.

Fish density, as expressed as fish per area or as CPUE indicates a lower density of fish in sites downstream of site LC06M, and impact site less than 1 km downstream of the spill location. It is unclear whether this is a product of downstream sites being re-colonized, or whether it is a matter of habitat capability or preference. There is insufficient pre-impact data to suggest whether the lower sites will have a higher natural fish density over time.

The data also suggests that fish have successfully reproduced in the impacted reach since the fuel spill, and a range of size classes are rearing in the habitat. Sculpin are a good indicator of habitat conditions since they are not a migratory fish, and they live out their entire lives within a short distance of where they were hatched (up to a 200 m distance). Sculpin fry that were from spring 2014 spawning were abundant in the fall samples. Rainbow Trout and Bull Trout YOY were also prominent in the September impact site samples. These data indicate the impacted sites are re-colonizing.

The continued presence of at least two sculpin species and multiple age classes in the impacted section of Lemon Creek indicates reproduction and/ or colonization is occurring. Previous data suggested Torrent Sculpin were the dominant sculpin species in the lower section of Lemon Creek, while during 2014 surveys they were a minor component of the sculpin species present.

While densities appear to vary, this may be due in part to variations in habitat conditions. As there is limited historic data, it is not possible to determine with certainty at what levels populations would reach pre-spill natural abundance; however, results from 2014 surveys are a positive indication of recovery post-spill.

Bull Trout were confirmed to have spawned in upper Lemon Creek in 2013, based on the redd survey, and confirmed by YOY Bull Trout sampled in the fish community assessment. Previous inventory sampling indicated only low quantities of Bull Trout spawning, which appears to hold validity (Addison et. al. 1996) and supports the results summarized in the Bull Trout spawner assessment (Chapter 7 of this report).

8.7 Conclusion

Based on the results of the fish data, there has been re-colonization (thus signs of recovery) of most aspects of community structure in Lemon Creek one year after the spill. Lines of evidence from relative abundance, diversity, composition and age structure all indicate the fish have shown resilience and are re-colonizing. Furthermore, additional monitoring programs indicate suitable water quality, recovery of lower trophic producers (fish food) and continuation of critical life stages such as spawning.

Considering the endpoint stated in the BMP, the natural fish community was likely dissimilar to the reference sites in the lowest reach of Lemon Creek (i.e., higher diversity) prior to the spill, due to different habitat and influence of proximity to Slocan River and Slocan Lake. Thus a recovery of all 4.9 km of downstream affected channel to exactly match the species assemblage, diversity and density of the reference sites is likely a false assumption. When scaled back to account for the morphologically similar reach that ends at the Highway 6 crossing, recovery has progressed to levels that may be within levels of natural variation. This would be in line with the intent of the BMP endpoint.

9 BENTHIC INVERTEBRATE MONITORING PROGRAM

9.1 Introduction

Ecosystem resilience emphasizes two different aspects of stability: the capacity of an ecosystem to tolerate disturbances (sensitivity), and rebuild itself when necessary (recovery). Sensitivity quantifies the magnitude of disturbance that can be absorbed before a system changes its structure by changing the variables and processes that control behavior. Recovery refers to the rate at which a system returns to a single (or multiple) steady or cyclic state following a perturbation (Nelson 2014).

Benthic invertebrates are small animals that live on or in the bottom sediments of waterbodies and are an important source of food for fish. Benthic invertebrate communities represent an intermediate trophic level and are highly sensitive to a range of environmental factors. Macroinvertebrate communities integrate stresses and provide a “biological memory” of a particular environment. Short-term impacts to macroinvertebrates of limited duration (i.e., a pulse disturbance, for example a chemical spill), because of the rapid response of sensitive taxa, are dynamic (Barbour et al. 1999; Fritz & Dodds 2005) while long-term effects (i.e., a press disturbance) may be represented by a fixed invariable community. Community recovery from pulse disturbances is typically rapid (< 18 months) (Niemi et al. 1990) while press disturbances (wastewater or altered flows) are of a continuous or repetitive nature and can persist for several years, resulting in a stressor-adapted community (Nelson 2014). Recovery to a ‘normal state’ does not occur because environmental modifications persist.

Benthic invertebrates are commonly used to assess the health of aquatic ecosystems, and they are ideal candidates as they are closely associated with the stream bottom, relatively sedentary, and are sensitive to both short-term and long-term effects associated with changes in habitat, sediment, and water quality (Davis and Lathrop 1992). The abundance, distribution, and diversity of benthic invertebrates can provide valuable information with regards to aquatic ecosystem health over a spatial scale (e.g., from site-specific to a watershed scale). In addition to a spatial scale, benthic invertebrate communities can be used as a tool to help evaluate recovery from pulse disturbances (e.g., a chemical spill) (Nelson 2014).

A two-year benthic invertebrate monitoring program was conducted on Lemon Creek and Slocan River to assess the magnitude of impact to the invertebrate community that was exposed to spilled jet fuel, as well as assess the extent of recovery over this period of time.

9.2 Methods

The benthic invertebrate monitoring program was developed from both the *Canadian Aquatic Biomonitoring Network* (CABIN 2014) and *Guidelines for Sampling Benthic Invertebrates in British Columbia Streams* (Beatty et al. 2006).

CABIN is an aquatic biological monitoring network, managed by Environment Canada and based on the Reference Condition Approach (RCA) for assessing the health of freshwater ecosystems in Canada (CABIN 2014). CABIN allows benthic invertebrate assemblages from sampled sites to be compared to a database of CABIN-selected reference sites that measures the degree of impairment, or divergence, of the sample site invertebrate assemblages though a number of assessment metrics.

Beatty et al. (2006) provides provincial guidelines for sampling and analyzing benthic invertebrate data in BC streams. The document provides acceptable standardized methods aimed at enhancing the comparability and validity of benthic invertebrate monitoring data in BC, as well as analysis of results.

9.2.1 Site Selection

Historical benthic invertebrate information was reviewed in order to aid in the design of the Benthic Invertebrate Monitoring Program. The selection of sampling sites for the monitoring program incorporated historical sites where invertebrate data were previously collected, which provided 'background' information prior to the jet fuel spill and assisted in the temporal comparisons of results.

Several benthic invertebrate surveys have been conducted periodically in the Slocan River watershed and (to a lesser extent) Lemon Creek since the 1990s in an effort to evaluate aquatic health and the overall productivity of these systems. Numerous sampling sites were located throughout the Slocan River watershed, but a very limited number of sites were in the vicinity of the spill on Lemon Creek. These historical sites were considered during sample site selection of the monitoring program design phase and were evaluated based on applicability to this study program.

Four of the 16 sample sites were chosen based on available historic data with the expectation that pre-spill data could be obtained to provide comparisons with post-spill data; however, access to the data was difficult. Historical studies that have been collected are presented in Table 9-1. Unfortunately, data contained in these reports were relatively sparse and often from sites not located near sites sampled as part of the Benthic Invertebrate Monitoring Program conducted in 2013 and 2014. Graphs are presented in each of the reports, but metrics and indices used in the analyses were often only based on benthic invertebrates identified to the Order level. As such, a comparison between pre-spill and post-spill data was difficult given the limitations of what was presented in each study.

Table 9-1: Historical Benthic Invertebrate Studies Conducted in the Slocan River Watershed

Reference Document	Author	Site Name	Lowest Taxa Level	Metrics Analysed	Data Assessed as Part of 2013/2014 Monitoring Program
Slocan River Watershed 1998 Benthic Macroinvertebrate Assessment	Aquatic Resources Limited (2000a)	Airy Creek	Species	Functional group composition	Yes
		Bonanza Creek		Community composition	
		Lemon Creek		Organism count	
		Winlaw Creek		-	
1999 Slocan River Watershed: Benthic Macroinvertebrate Assessment	Aquatic Resources Limited (2000b)	Airy Creek	Species	Functional group composition	Yes
		Bonanza Creek		Community composition	
		Lemon Creek		Organism count	
		Winlaw Creek		% Abundance by taxa	
Section I Monitoring, Assessment and School Outreach Activities 2006-2007	Slocan River Streamkeepers (2006a)	Slocan Valhalla	Order	% abundance by taxa	No. Exposure site data not available.
		Little Slocan		Diversity and Evenness	
		South Slocan		% EPT, Total EPT	
		Winlaw Creek		Total Taxa	
		Carpenter Creek		-	
Monitoring, Assessment and School Outreach Activities 2005-2006	Slocan River Streamkeepers (2006b)	Slocan Valhalla	Order	% abundance by taxa	Yes
		South Slocan		EPT ratio	
		Winlaw Creek		Diversity and Evenness	
		Winlaw	Family	% abundance by taxa, EPT ratio, Simpsons diversity, Shannon-Wiener diversity	

Table 9-1 (Cont'd): Historical Benthic Invertebrate Studies Conducted in the Slocan River Watershed

Reference Document	Author	Site Name	Lowest Taxa Level	Metrics Analysed	Data Assessed as Part of 2013/2014 Monitoring Program
Slocan River Monitoring and Assessment 2007-2008	Slocan River Streamkeepers (2007)	South Slocan	Unknown	Unknown	No. Incomplete report. No data available.
		Slocan Valhalla			
		Carpenter Creek			
		Bonanza Creek			
Slocan River Benthic Invertebrate Assessment	Slocan River Streamkeepers (2008)	Slocan Park	Order	Abundance	No. Exposure site data not available.
Columbia Basin Watershed Network: Water Quality Monitoring Project	Kootenay River Network – BC (2008)	South Slocan Slocan Valhalla Bonanza Creek	Order	Community composition	No. Exposure site data not available.
				Functional group composition	
				Richness	
				Dominance	
				Evenness/diversity	
				Biotic indices	
				Karr BIBI metrics	

The optimal time to collect benthic invertebrates typically coincides with low flows associated with spring (prior to freshet) and late summer/fall (after freshet). It is during this time that the optimal peak for biomass and benthic community diversity occurs and water levels are low enough to allow for sampling (Beatty et al. 2006). As such, benthic invertebrate samples were collected over three separate periods:

- Fall 2013 (October 16-23);
- Spring 2014 (April 2-4); and
- Fall 2014 (October 21-24).

A total of 16 sites on Lemon Creek, the Slocan River, and the Little Slocan River were selected to be sampled during each of these three periods, and included collecting samples from sites downstream (exposure) and upstream (reference) of the spill location (Table 9-2; Figure 9-1).

Table 9-2: Lemon Creek and Slocan River Sample Site Summary1,2

Watercourse	Sample Site Name	Reference or Exposure Site	Distance from Spill Site	Historically Sampled
Lemon Creek	LCBI 05	Reference	-1.1 km	No
	LCBI 04	Reference	-0.3 km	No
	LCBI 03	Exposure	1.0 km	No
	LCBI 02	Exposure	1.5 km	No
	LCBI 01	Exposure	3.2 km	Yes
	LCBI 00	Exposure	3.8 km	No
Little Slocan River	LSBI 00	Reference	29.8 km[3]	Yes
Slocan River	SRBI 00	Reference	-10.2 km	Yes
	SRBI 01	Exposure	4.2 km	No
	SRBI 02	Exposure	5.2 km	No
	SRBI 07	Exposure	5.2 km	No
	SRBI 03	Exposure	5.8 km	No
	SRBI 04	Exposure	6.2 km	No
	SRBI 05	Exposure	9.0 km	No
	SRBI 06b	Exposure	20.3 km	No
	SRBI 06	Exposure	20.5 km	Yes

Note: [1] Sites are presented in a downstream direction.
[2] Negative distance values indicate sites there were upstream of the spill site
[3] Not located on the Slocan River.

The reference sites selected for Lemon Creek (LCBI04 and LCBI05) were located upstream of the spill site and in a relatively low-use watershed (commercial logging and associated road access). The sites were consistent with requirements for CABIN (CABIN 2014).

Although the side channels on the east side of the Slocan River located immediately downstream from the confluence with Lemon Creek were initially identified to establish benthic invertebrate monitoring sites, this area was ultimately discarded due to seasonally dry water conditions.

The Little Slocan River was selected as a reference site (LSBI00) due to its location on a separate watercourse that was not exposed to the jet fuel, and, as it was historically established by the Slocan

Valley Streamkeepers, data existed that could be used to compare to results from the Benthic Invertebrate Monitoring Program. October 2014 data from the Little Slocan River site (LSBI00), however, were suspect due to abnormally low abundance. Therefore, all data from this site (October 2013, April 2014, and October 2014) were not used to compare to results from the Slocan River exposure sites.

Choosing the location of a reference site on the Slocan River was difficult, as habitat conditions in the section upstream of the Lemon Creek confluence were not ideal (i.e., slow-moving water, very few riffle sections). The reference site (SRBI00) was eventually located at the same site that was historically established by the local Streamkeepers. However, after sampling SRBI00 in October 2013 and April 2014, it became apparent from results that the site did not meet CABIN site requirements (i.e., located in a riffle section of a watercourse). As such, this site was not considered further as a reference site and was not sampled in October 2014, and data from October 2013 and April 2014 were not used to compare to results from the Slocan River exposure sites.

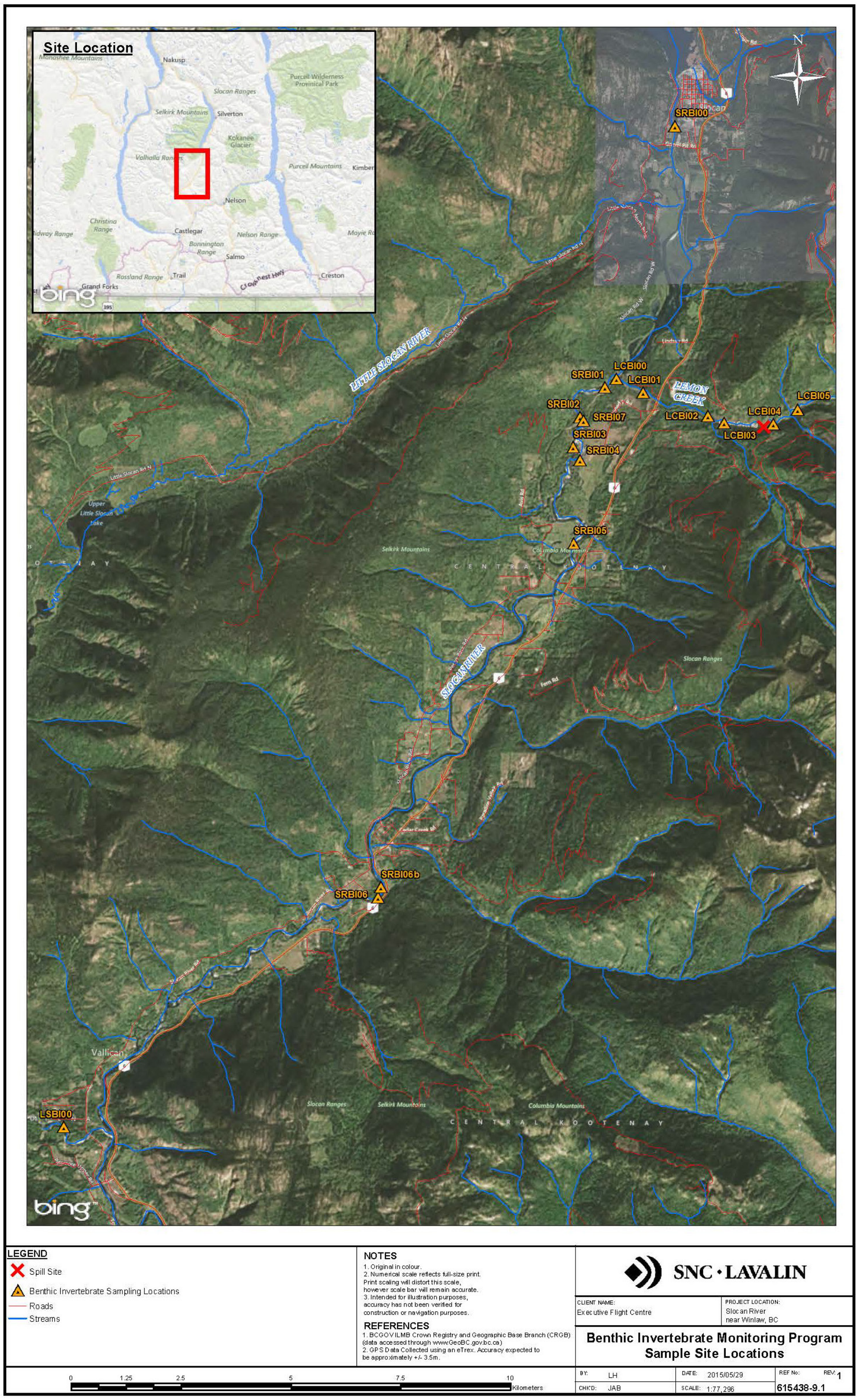


Figure 9-1: Lemon Creek Biological Monitoring Program Site Locations

Exposure site SRBI06, another historical site established by local Streamkeepers, also did not appear to conform to CABIN site requirements. Therefore, an additional exposure site (SRBI06b) was selected immediately upstream in a riffle section to compare results from SRBI06 to see if there was any difference in invertebrate assemblage between the two sites.

As data from the reference sites on Little Slocan River (LSBI00) and Slocan River (SRBI00) were suspect and could not be used to compare to Slocan River exposure site data, reference site data from the CABIN database were analyzed to determine whether they could be used as surrogate reference sites. However, a number of the CABIN reference site habitat characteristics (elevation, channel width, substrate composition, water conductivity, and water temperature) were different relative to the Slocan River exposure sites and were therefore not used for comparative purposes.

It should be noted that both Slocan River and Lemon Creek are located in a watershed with known historical and existing anthropogenic activity (e.g., agriculture/farming, cattle, residential properties, forestry), therefore may have been subjected to potential point- and non point-source pollution inputs unrelated to the spill incident. Generally speaking, biological systems are complex and impacts often result from indirect effects rather than direct toxicological causes (Kotta et al. 2008). Thus, all sites sampled were evaluated with this information in mind.

9.2.2 Sample Collection

Two sampling methods were used to collect benthic invertebrates from each of the 16 sites on Lemon Creek and Slocan River: a kick net and a Hess sampler.

9.2.2.1 Kick Net Sampling

Benthic invertebrates were collected at all 16 sites using a 400 µm kick net following CABIN field sampling protocols (CABIN 2014). Sites were sampled in an upstream direction (i.e., sample collection on Lemon Creek began at site LCBI00 at the confluence with the Slocan River and progressed upstream) to avoid influencing collected samples. All samples were collected in shallow riffle habitat (≤0.25 m deep) containing cobble/gravel substrate and a moderate water velocity. Due to the large wetted width and depth of both Lemon Creek and Slocan River, the margins of the stream were typically selected as sampling habitat.

The kick net was placed firmly on the substrate and sampling started at the downstream end of the defined area, progressing upstream. Dislodged invertebrates were captured by loosening substrates with a kicking motion while walking away from the net and moving upstream in a zigzag pattern. The substrate was disturbed to a depth of 5 to 10 cm, where possible. The travelling zig-zag pattern ensured that different microhabitats were sampled during the pass. The process was conducted once at each site over a set period of time (three minutes) to standardize effort.

The contents of the net were then washed into the kick net cod-end using a spray bottle, transferred to a 1L plastic bottle, and fixed in the field using 10% buffered formalin following sample handling and preservation procedures recommended by Beatty et al. (2006).

In an effort to maintain consistency between sites and minimize variability in sample abundance, the same biologist collected each benthic invertebrate kick net sample; however, a degree of variability in sample abundance may still exist due to other sample collection factors such as the intensity of substrate disturbance by the sampler, etc.

9.2.2.2 Hess Sampling

In addition to the CABIN kicknet samples, benthic invertebrates were also collected using a 500 µm mesh Hess sampler at site LCBI01 on Lemon Creek in order to compare results to data collected historically by Aquatic Resources Limited (ARL 2000a; 2000b).

The Hess sampler was placed on the streambed and pushed slightly into the substrate such that the screen was oriented into the current and the cod-end trailing downstream. All rocks within the sampler were turned over and rubbed to ensure that all organisms were dislodged. Once the larger substrate was discarded, the remaining gravel was stirred up to a depth of 5 to 10 cm. The contents of the net were washed into the cod-end using a spray bottle, transferred 1L plastic bottles, and preserved with 10% buffered formalin. Five individual replicates were collected within the site during the October 2013 sampling program; however the replicates were composited during the April 2014 program. The Hess sampler was not used during the October 2014 field program due to faulty equipment.

9.2.2.3 Habitat Parameters

As per CABIN sampling protocols (CABIN 2014), supporting environmental variables were also collected concurrently with benthic invertebrate sample collection. They included:

- Characterization of surrounding land uses (e.g., industrial, residential/urban, etc.);
- Reach data such as mesohabitat type (e.g., riffle), canopy coverage, and periphyton coverage;
- In situ water quality (dissolved oxygen, specific conductance, air and water temperature, pH, and turbidity);
- Physical characteristics such as channel and wetted width, bankfull depth, and slope;
- Flow velocity; and,
- Channel substrate data (i.e., size and degree of embeddedness of the substrate in the channel).

In situ water quality data were collected using a YSI Professional Plus multi-parameter water quality meter. Turbidity was measured with a Lamotte 2020we turbidimeter. Flow velocity measurements were recorded with a Swoffer model 2100.

General field observations documenting conditions along Lemon Creek and Slocan River as part of the Biological Monitoring Program were also made and are provided in Appendix I.

9.2.3 Data Compilation and Analysis

9.2.3.1 Laboratory Taxonomy and Enumeration

Collected samples were shipped to a North American Benthological Society-certified taxonomist, Ruxten Environmental, in Vancouver, BC for taxonomic identification and enumeration to the lowest practicable level (typically Family or Genus), following CABIN laboratory assessment guidelines (CABIN 2012). In some cases, invertebrates could only be identified to Class (e.g., Clitellata sp.) or Order (e.g., Plecoptera sp.) level, often due to damaged or immature organisms. Invertebrates were identified using standard taxonomic keys (e.g., Merritt et al. 2008).

All benthic invertebrate samples were sub-sampled by the taxonomist to 300 organisms. Samples with less than 300 organisms were processed whole (i.e., all of the benthic invertebrates in the entire sample were enumerated). Sub-sampling was conducted using a Marchant box, which consists of a box divided into 100 cells and into which the sample was divided evenly and organisms picked out randomly until 300 were counted. These raw data were then entered into the CABIN database, and, if the sample was sub-sampled, extrapolated to 100 cells to estimate total abundance. More details on lab analyses and methods are described in the CABIN manual (CABIN 2012).

All CABIN protocols for lab sample sorting and identification, internal auditing, and third party verification of 10% of the samples (CABIN 2012) were followed. Raw taxonomic data are provided in Appendix II.

9.2.3.2 Study Design

The Benthic Invertebrate Monitoring Program used a weight-of-evidence approach to assess for effects of the fuel spill on the invertebrate community as well as evaluate its recovery. For the purpose of this monitoring program, ‘recovery’ was defined as the impacted benthic invertebrate community returning to similar condition to that of reference sites and historical data (where applicable). The endpoints used to assess recovery included:

- Analysis of specific biometrics of the benthic invertebrate community, such as taxa abundance;

- A regression model which included Before/After-Control/Impact (BACI) and a Generalized Linear Mixed Model (GLMM) analyses;
- A non-parametric ordination (ANOSIM); and
- A Reference Condition Approach (RCA) analysis (CABIN Benthic Analysis of Sediment [BEAST] and River Invertebrate Prediction and Classification System [RIVPACS]);

9.2.3.2.1 Biometrics

Biometrics (i.e., effect endpoints) can be used to detect differences between reference and exposure site data (i.e., the presence or absence of an effect) (Lowell et al. 2002). With this in mind, the following analyses of key biometrics were performed in CABIN on the taxonomic data from the 16 sampled sites over the three sampling periods:

- **Percent Composition.** The abundance of each taxa group (e.g., Ephemeroptera, Diptera, Coleoptera) relative to the total abundance of the sample expressed as a percentage.
- **Total Taxa Abundance**. Total abundance data was pre-treated by converting it to the percent of total count for each respective sample, and then selecting the five most abundant families. Pre-treatment was done to reduce dimensionality and facilitate comparisons between samples. Given the semi-quantitative nature of the information, the percent abundance also provides a comparative measure less prone to bias (i.e., sampling error). Lastly, the pre-treatment standardized the data to facilitate appropriate comparisons.
- **EPT abundance.** The sum of Ephemeroptera, Plecoptera, and Trichoptera sp. (EPT) taxa present in a sample. EPT taxa are considered more pollution-sensitive relative to non-EPT taxa (e.g., Diptera, Coleoptera, Amphipoda, and Oligochaeta sp.), which are more pollution-tolerant (CABIN 2014). EPT data can provide insight into benthic invertebrate community health, as numbers typically decline with increasing watercourse or watershed disturbance. Low numbers of EPT taxa and high numbers of non-EPT taxa can indicate poor water and/or habitat quality.
- **Percentage of Oligochaete and Chironomid taxa.** The abundance of Oligochaetes and Chironomids relative to the total abundance of the sample. Provides an indication of the amount of pollution-tolerant taxa as compared to species that are more pollution-sensitive (i.e., EPT taxa) (USEPA 2009a,b; CABIN 2014).

All analyses were performed at the Family taxonomic level, given CABIN does not utilize higher level data (e.g., Class or Order) (CABIN 2014). As such, invertebrates from the 16 sampled sites that were only identified to Class or Order were excluded from the analyses. Results were compared:

1) Between exposure sites and between exposure and reference sites (biometric analyses, non-parametric multivariate invertebrate assemblage analysis);

2) Between exposure sites along a downstream gradient (gradient analysis) (Slocan River sites only); and
3) Between sampled sites and the CABIN-certified reference sites (BEAST model and RIVPACS analyses).

April 2014 data were determined to be not directly comparable to October 2013 and October 2014 data due to the time of the year (i.e., presence and abundance of invertebrate species can be different); therefore, the data were not used to assess whether endpoints (i.e., recovery to reference site levels) were achieved and assist in determining whether recovery was progressing over time, thus have not discussed in the results.

Hess sample results from site LCBI01 were analyzed using Family-level taxa data from all taxonomic levels. Historical data were also analyzed using Family-level data, and therefore, results may be different than what was presented in the reports. Results may have been influenced by the different mesh sizes used to collect the invertebrate samples (500 µm in 2013, 210 µm in 1998 and 1999).

9.2.3.2.2 Regression Models

Dr. Laurie Ainsworth (PhiStat Research and Consulting) generated the statistical models for both the Lemon Creek and Slocan River benthic invertebrate data, which included performing a GLMM and the Before-After/Control-Impact analyses (refer to Appendix III).

For Lemon Creek, GLMMs were fit to the benthic data using the *glmer* function from the *lme4* library (R version 3.2.5, R Core Team, 2016). In order to account for repeated sampling at each location, site was included as random effect. Two sets of mixed effects models were fit to assess the extent to which the Lemon Creek area is in recovery following the spill in 2013.

First, a BACI approach was used to group observations into exposure or control sites and compare the change from 2013 to 2014 in each group. If the system is recovering, a larger change is expected from 2013 to 2014 at the exposure sites. This effect was tested via the interaction between group and year.

Another indication of recovery can be obtained by considering the gradient of change in sample data collected at increasing distances from the spill. This was carried out for both Lemon Creek and Slocan River data. If the system is in recovery, the profile along the creek and/or river is expected to differ between 2014 and 2013. Thus, the interaction between distance and year was tested to determine if the gradient of change differed between the 2 years. Lemon Creek and Slocan River were assessed separately in order to avoid confounding differential flow regime effects. Distances along the Slocan River were spread over a larger area with one site at a large distance of 20.5 km. In order to ensure the results were not unduly influenced by this potential leverage point, log distance was also considered. For Slocan River, a sensitivity analysis was run using log(distance+20) in place of distance in the GLMM. This transformation pulled the large distance in closer to the other values and reduced its leverage. An alternative approach would be to run the analyses on the subset of data with distances less than 10 km.

No correction was made for multiple testing. Regression results are presented to 2 decimal places with p-values of 0.00 indicating p<0.005. Given that the data for several outcomes (EPT and total abundance) are over-dispersed and that there are a large number of tests carried out, p-values need to be interpreted with caution.

More details with respect to the methods applied for the regression models are presented in Appendix III.

9.2.3.2.3 Non-Parametric Ordination (ANOSIM)

A non-metric multidimensional scaling (NMDS) ordination was also used to examine for differences in benthic invertebrate family assemblages among Lemon Creek and Slocan River stations and between October 2013 and October 2014. Further, a one-way analysis of similarity (ANOSIM; PRIMER 6.0; Clarke and Gorley 2006) used the dissimilarity matrix underlying the NMDS ordination to statistically test for any differences observed between a priori groupings (e.g., Lemon Creek October 2013 versus Lemon Creek 2014). The Global R statistic from the ANOSIM reflects the observed differences between groups. For values of R around 0.4-0.5 or higher, dissimilarities between groups and separation on the ordination plot will be obvious, while for R values <0.25, groupings of meadows on the ordination will be almost indistinguishable (Clarke and Warwick 2001). The NMDS and ANSOIM were evaluated for benthic invertebrate assemblage differences using a Bray-Curtis similarity matrix calculated from square-root transformed abundance data. A hierarchical cluster analysis using complete linkages was also used to assess for group separation.

Observed differences identified in the NMDS and cluster analysis between October 2013 and October 2014 family assemblage composition was evaluated using similarity percentages (SIMPER in PRIMER). The SIMPER analysis examines the contribution of each invertebrate family to the average resemblances between sites. For Bray-Curtis similarities it determines the contributions to the average Bray-Curtis dissimilarity between the October 2013 and October 2014 sampling periods. SIMPER calculates a discrimination index which is the ratio of the average contribution of similarity between groups to the standard deviation of the similarity between groups; the higher the index value the more informative the species is for discriminating among groups. The analysis highlighted macroinvertebrate families that had a discrimination index value of at least 2.0.

9.2.3.2.4 Reference Condition Approach (RCA) Analysis (CABIN BEAST and RIVPACS)

The Reference Condition Approach (RCA) uses predictive models within the CABIN database to determine if biological and habitat data at sampled sites are similar to CABIN-selected reference sites, and if not, the degree to which they are impaired (CABIN 2014).

Using taxonomic data from the 16 sites sampled in October 2013 and October 2014, a BEAST analysis was performed in CABIN. The BEAST model assesses whether or not the sampled sites were in reference condition (i.e., were sampled site results similar to CABIN reference site results) and if not, the degree to which they were not in reference condition (i.e., how dissimilar or divergent were the sample site results from CABIN reference site results).

The first step of the analysis was to ensure that data from the 16 sample sites on Lemon Creek and Slocan River were correctly compared to the most similar group of CABIN reference sites in the CABIN prediction model (Columbia-Okanagan Preliminary March 2010). The degree of probability of a correct match was also determined through this process, which was accomplished by comparing habitat values (i.e., not taxa data) collected at the sampled sites to various groups of reference sites in the CABIN prediction model. The analysis, however, does not compare between sample sites and reference sites that were selected as part of the study design.

Once the most similar group of CABIN reference sites were selected, the BEAST model plots the sampled site and CABIN-selected reference site data and creates a confidence ellipse diagram that illustrates the degree to which the sampled site compares to the CABIN reference sites. Four ‘bands’ or ellipses, which are similar to confidence intervals around a mean, were generated:

- A test site that falls within the 90% confidence ellipse was designated 'Similar to Reference';
- A test site that falls within the 90% and 99% confidence ellipse was designated 'Mildly Divergent';
- A test site that falls within the 99% and 99.9% confidence ellipse was designated 'Divergent'; and
- A test site that falls outside of the 99.9% confidence ellipse was designated 'Highly Divergent'.

The assumption is that if the test site is not similar to the CABIN reference site to which it is predicted based on the habitat variables and benthic invertebrate data from the test site, then there is likely some anthropogenic stress exerted on the benthic community.

The RIVPACS model predicts (at a selected probability level of >70% taxon occurrence [i.e., the probability that at least 70% of the taxa at a test site are expected to be present]) the ratio of observed to expected taxa at each sampled site by using the BEAST model predictions and the probability of taxa occurrence at the CABIN-selected reference sites. The basis of the model is that if taxa that are typically present in unimpacted sites (i.e., expected) are not present (i.e., observed), there is likely some degree of impairment. Sites with ratios close to 1 are considered to be in good condition while sites with low ratios typically indicate impairment (CABIN 2014).

9.3 Results and Discussion

9.3.1 Lemon Creek

9.3.1.1 Variability in River Discharge

Knowledge of the influence of river discharge is one key to understanding the potential natural spatial and temporal variability in benthic invertebrate community structure observed at the sample sites. River discharge (m^3/s) is monitored at one station on Lemon Creek (08NJ160). Discharge graphs for 2013 and 2014 were generated from this station data (Figure 9-2 and Figure 9-3).

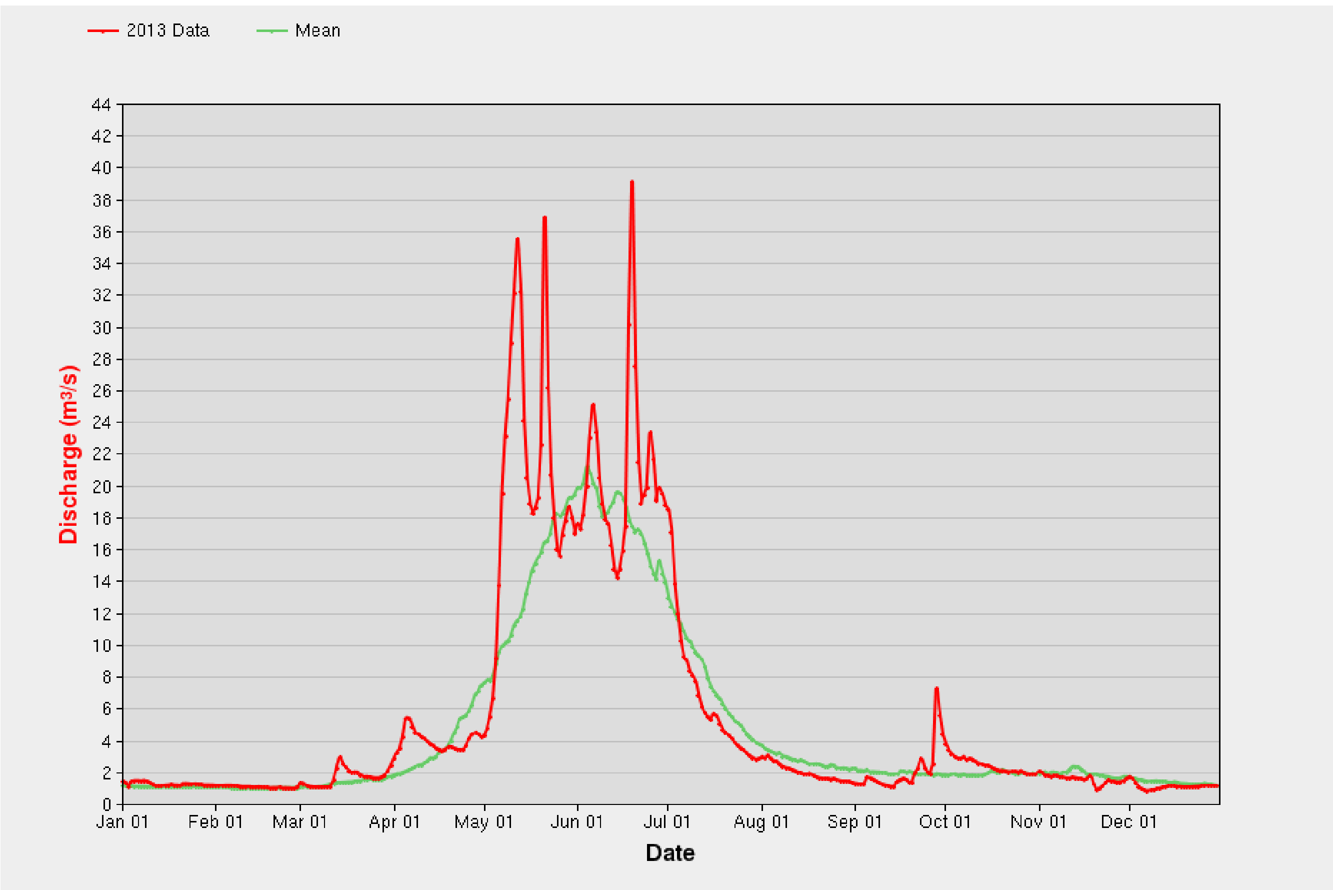


Figure 9-2: 2013 Lemon Creek Discharge (Environment Canada 2015)

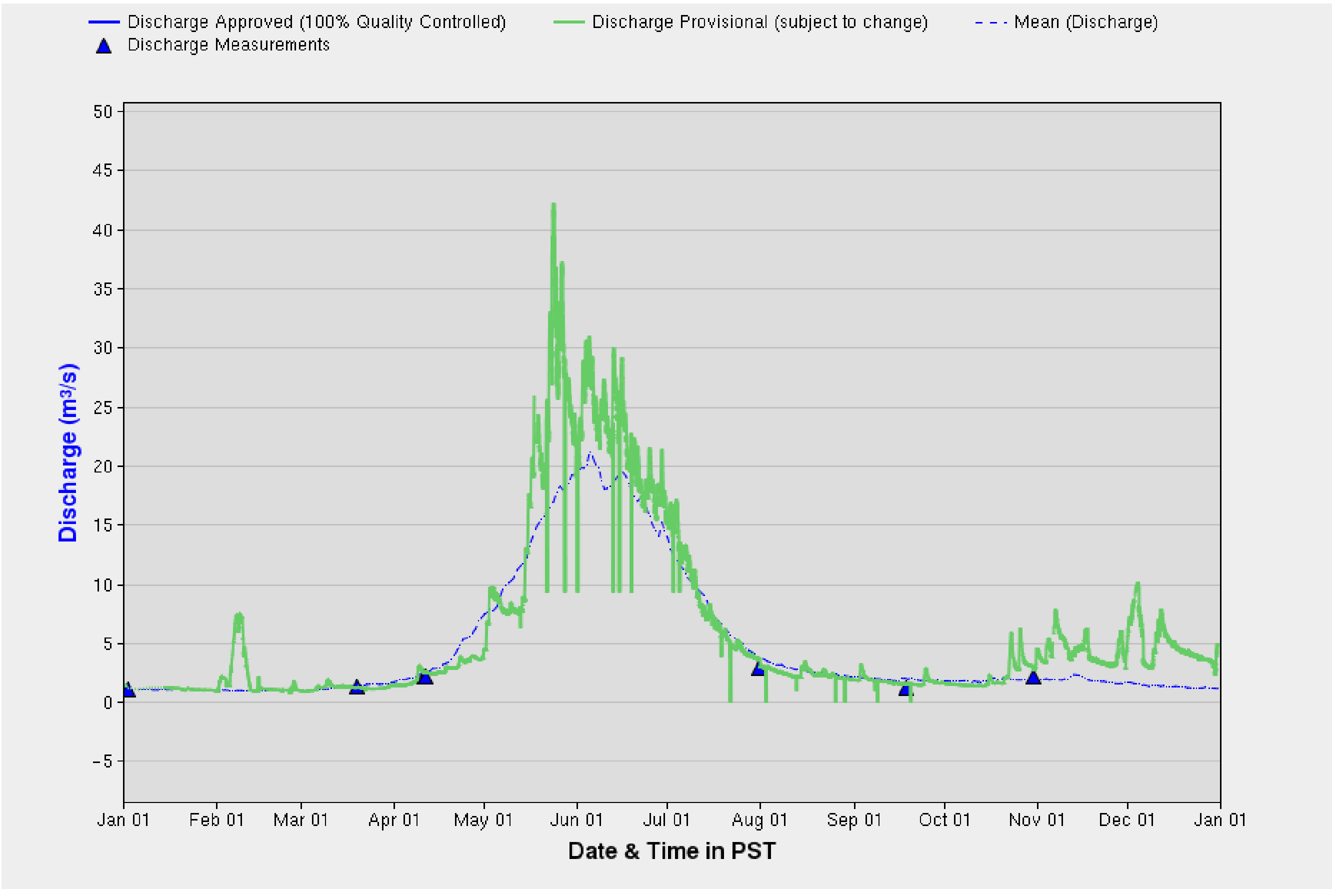


Figure 9-3: 2014 Lemon Creek Discharge (Environment Canada 2015)

While discharge at Lemon Creek was relatively high in late September 2013 (maximum of 7.25 m^3/sec), it decreased to between 2.02 and 2.41 m^3/sec in late October when the invertebrate samples were collected. Late October 2014 discharge (between 2.2 and 3.2 m^3/sec) was relatively similar to late October 2013 conditions; however, high flows were encountered prior to the last sample date. There is the possibility that the high flows in late September 2013 (and prior to the last sampling date in October 2014) may have altered habitat conditions thereby influencing the benthic invertebrate community (e.g., through scour or dislodging of invertebrates).

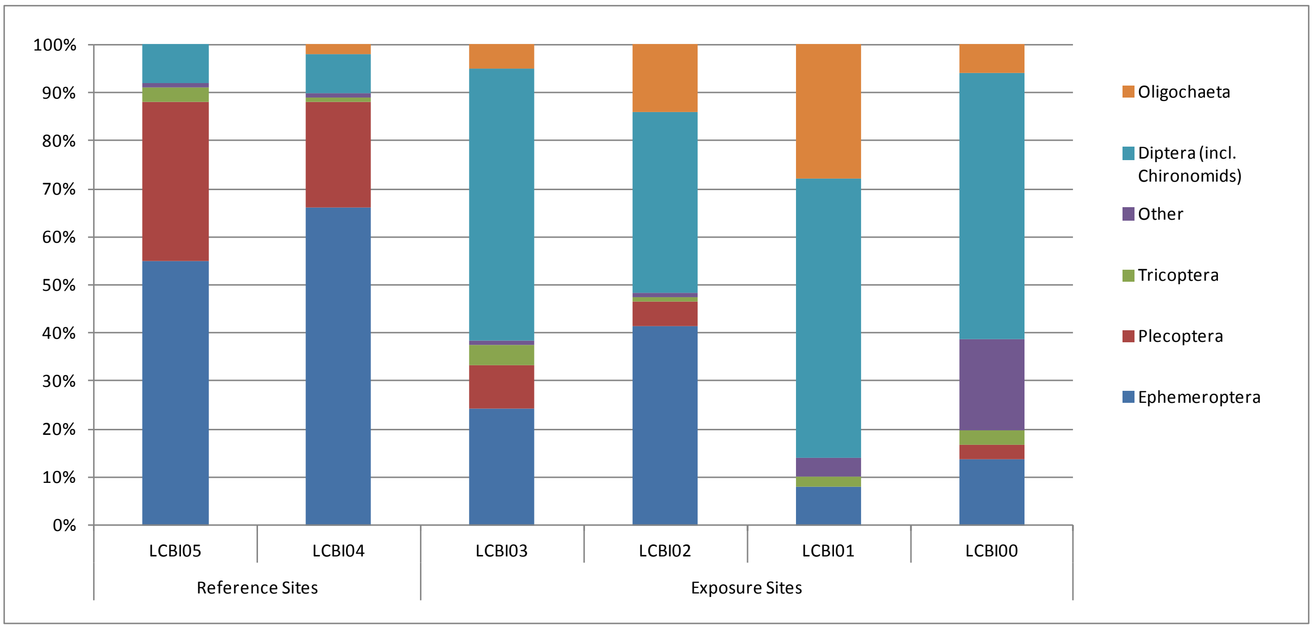
9.3.1.2 Biometrics

Six sites were sampled on Lemon Creek: four in the exposure area downstream of the spill site and two upstream of the spill site (reference area). Data from each of the 6 sites sampled in October 2013 and

October 2014 were analyzed using a number of biometrics to aid in interpreting potential effects on the benthic invertebrate community and assess the extent of recovery to reference site conditions.

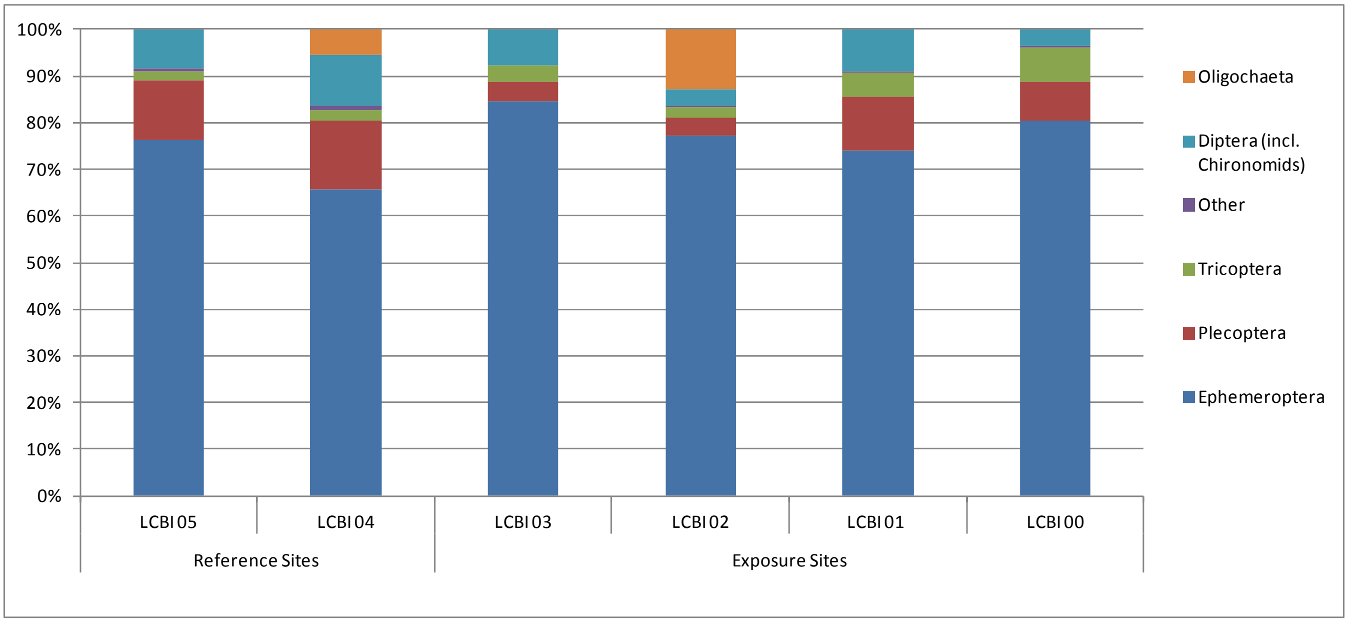
9.3.1.2.1 Taxa Family Percent Composition

The composition of each taxonomic group from the six sites sampled on Lemon Creek over the two sampling periods (October 2013 and October 2014) is presented in Figure 9-4 and Figure 9-5.



Notes: Sites are presented in a downstream direction.
Other = Coleoptera, Amphipoda, Trombidiformes

Figure 9-4: Lemon Creek Taxa Family Percent Composition – October 2013

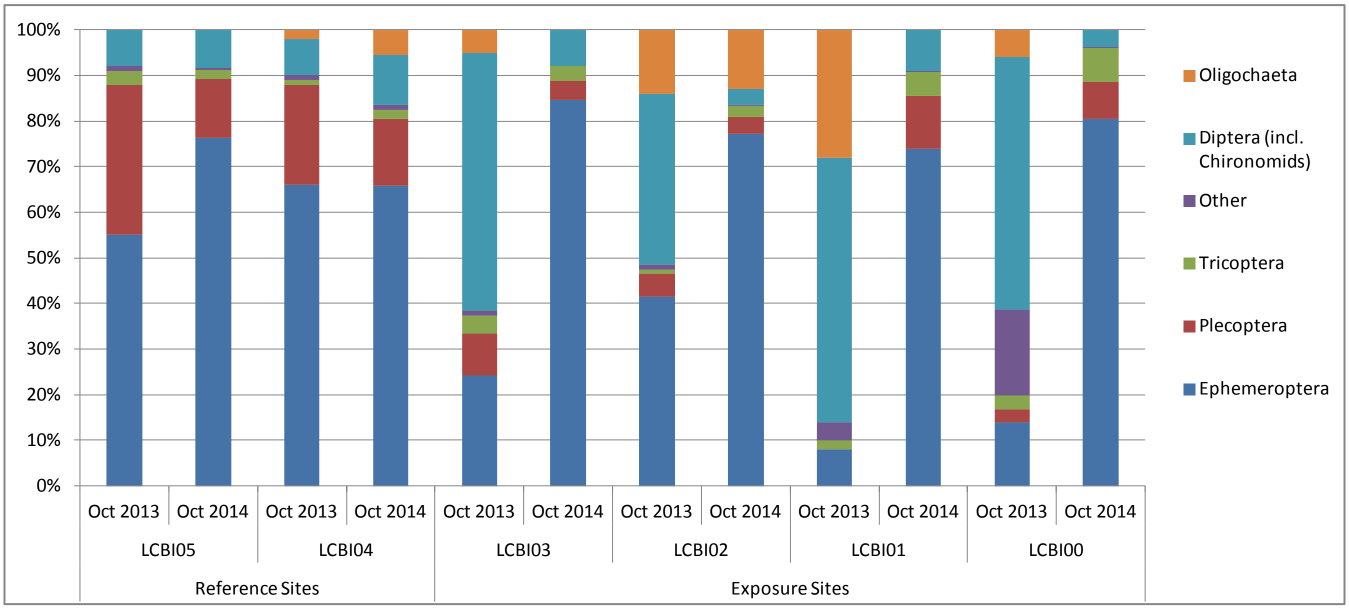


Notes: Sites are presented in a downstream direction.
Other = Coleoptera, Amphipoda, Trombidiformes

Figure 9-5: Lemon Creek Taxa Family Percent Composition – October 2014

Results from October 2013 indicate that samples from exposure sites (LCBI00, LCBI01, LCBI02, LCBI03) were dominated primarily by Diptera (which includes Chironomids), Oligochaeta, and Ephemeroptera. Coleopterans/Amphipods/Trombidiformes (represented as 'Other' in the figure) were also present in relatively high levels at exposure site LCBI00. Ephemeroptera and Plecoptera were the two dominant taxa present in the two Lemon Creek reference site (LCBI04, LCBI05) samples.

By October 2014, Ephemeropterans were the most dominant taxa present in both exposure and reference site samples, and, at the exposure sites, were present at levels that were considerably higher relative to October 2013. Plecoptera and Diptera, the second-most dominant taxa, were present in approximately equal percentages however, at much lower levels than Ephemeroptera taxa. Oligochaeta, Trichoptera and Coleoptera/Amphipoda/Trombidiformes taxa comprised only a small percentage of the total taxa present. Reference site taxa continued to be dominated by Ephemeropterans and Plecopterans. A comparison of species percent composition between October 2013 and October 2014 is presented in Figure 9-6.

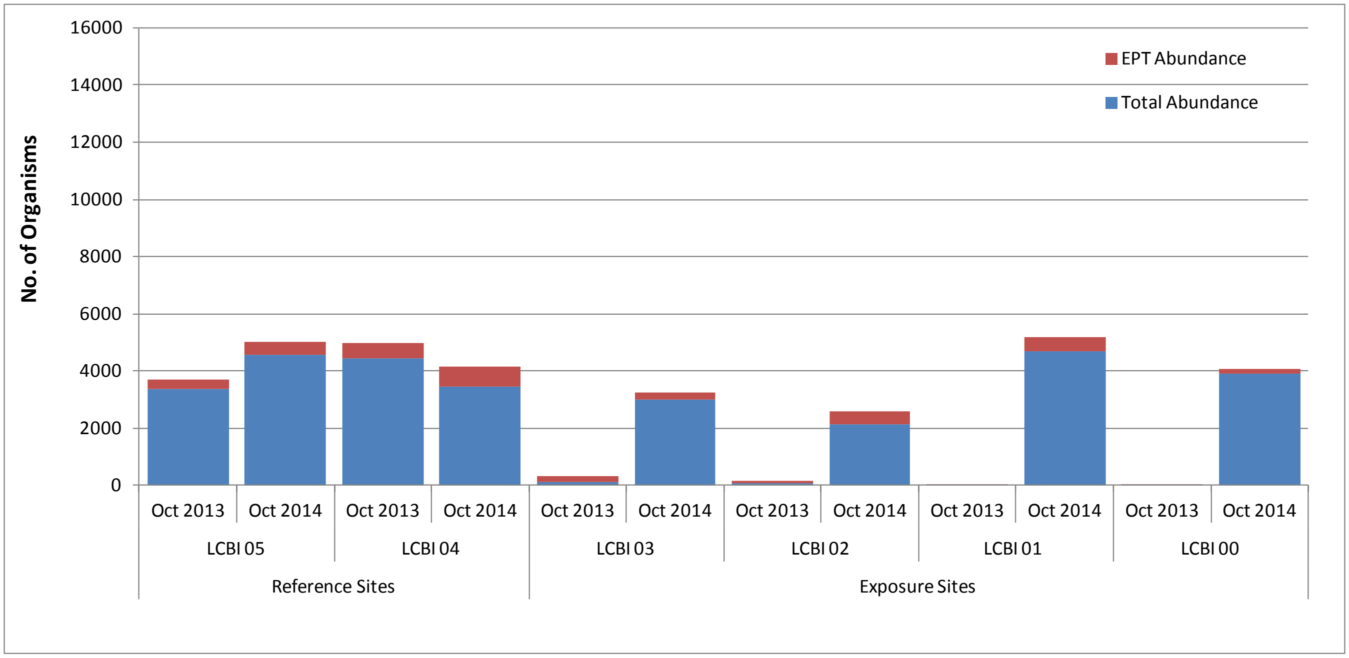


Notes: Sites are presented in a downstream direction.
Other = Coleoptera, Amphipoda, Trombidiformes

Figure 9-6: Lemon Creek Taxa Family Percent Composition – October 2013 and October 2014

9.3.1.2.2 Species Abundance

Total and EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa abundance results for the six sites sampled on Lemon Creek in October 2013 and October 2014 are summarized in Figure 9-7.



Sites presented in a downstream direction.

Figure 9-7: Lemon Creek Taxa Abundance Summary

Total taxa abundance at all sites (exposure and reference) ranged from 36 (LCBI00 – October 2013) to 5,167 (LCBI01 – October 2014) organisms, with EPT abundance ranging from 5 (LCBI01 – October 2013) to 4,683 (LCBI01 – October 2014) organisms.

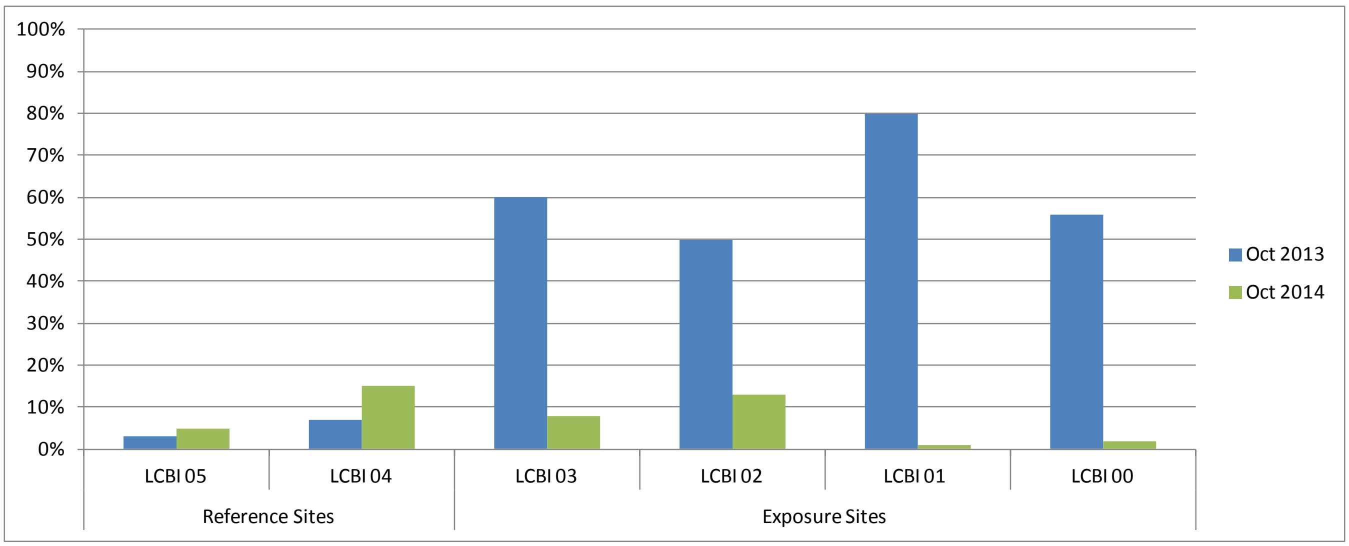
Both total and EPT species abundance at all four exposure sites on Lemon Creek (LCBI00, LCBI01, LCBI02, LCBI03) were extremely low in samples collected during the first sampling period (October 2013), approximately three months after the spill, relative to the two reference sites (LCBI04, LCBI05).

Total abundance results from Hess samples collected at exposure site LCBI01 in October 2013 (n=51) (not shown in figure) were considerably lower relative to samples collected by Aquatic Resources Limited in October 1998 (n=4,922) and September 1999 (n=1,198) (ARL 2000a,b). EPT taxa abundance in samples from October 2013 (n=6) were also substantially less than results from 1998 (n=4,068) and 1999 (n=245) (ARL 2000a,b). Hess samples were not collected from this site in October 2014. Given the considerably lower total and EPT abundance from October 2013 relative to historical levels, results indicate impairment of the benthic community at this site at that period; however, results may have been influenced by the different Hess mesh sizes used to collect the invertebrate samples (500 μm in 2013, 210 μm in 1998/1999).

By October 2014, total abundance results from all four exposure sites on Lemon Creek (mean of 3,770 organisms) had increased to levels comparable to the two reference sites (mean of 4,586 organisms). EPT abundance levels also increased and were also similar between exposure sites (mean of 3,436 organisms) and reference sites (mean of 4,000 organisms) by October 2014. Total and EPT abundance results from the two reference sites were relatively similar between October 2013 and October 2014 samples.

9.3.1.2.3 Oligochaete & Chironomid Percent Composition

The percentage of Oligochaetes and Chironomids from samples from the six sites sampled on Lemon Creek in October 2013 and October 2014 are summarized in Figure 9-8. These two taxonomic families are considered more pollution-tolerant relative to taxa that are more pollution-sensitive (e.g., EPT).



Sites presented in a downstream direction.

Figure 9-8: Lemon Creek Oligochaete and Chironomid Percent Composition Summary

The percentage of Oligochaetes and Chironomids at all sites (exposure and reference) ranged from 1% (LCBI01 – October 2014) to 80% (LCBI01 – October 2013). Results from October 2013 indicated that the composition of all four exposure site samples had high percentages of Oligochaetes and Chironomids (mean of 59%) relative to the two reference sites (mean of 6%).

The percentage of Oligochaetes and Chironomids in Hess samples collected at exposure site LCBI01 in October 2013 (76%) (not shown in figure) were considerably higher relative to samples collected by Aquatic Resources Limited in October 1998 (14%), but were comparable to levels in September 1999 (76%) (ARL 2000a,b). Hess samples were not collected from this site in October 2014. Although the considerably higher percentage of Oligochaetes and Chironomids from October 2013 relative to 1998 levels suggests impairment of the benthic community at this site at that period; results from 1999 suggest that there may be a degree of natural variability. Results may have been influenced by the different Hess mesh sizes used to collect the invertebrate samples (500 µm in 2013, 210 µm in 1998/1999).

However, by October 2014, levels at the exposure sites were considerably lower (mean of 5%), and were similar to levels exhibited at the reference sites (mean of 10%). Results also correspond to the high percentage of pollution-sensitive taxa (EPT) (mean of 91%) that was exhibited by exposure site samples from October 2014 (Figure 9-17). Results for the two reference sites (LCBI04, LCBI05) were relatively similar between October 2013 and October 2014, increasing slightly at both reference sites over this period.

9.3.1.3 Non-Parametric Ordination (ANOSIM)

A hierarchical cluster analysis and non metric multi dimensional scaling (NMDS) ordination was conducted on Lemon Creek (Figure 9-9 and Figure 9-10) data sampled in October 2013 and October 2014. From the examination of the NMDS ordination, cluster diagrams, and the ANOSIM result, the four Lemon Creek exposure sites (LC0-LC4) in 2013 are significantly dissimilar from the two Lemon Creek reference sites sampled in 2013 but are similar to the two reference sites sampled in October 2014 (ANOSIM R=0.43, p=0.004).

Figure 9-9: Lemon Creek Bray-Curtis Dissimilarity NMDS Ordination Plot

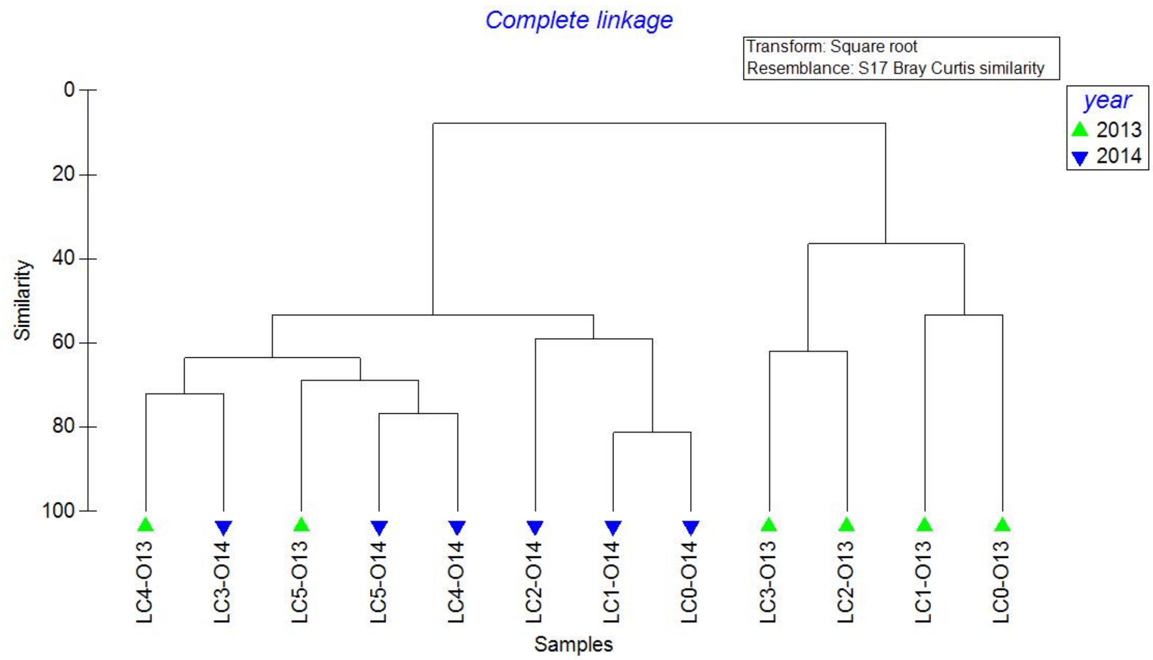


Figure 9-10: Lemon Creek Bray-Curtis Dissimilarity Dendrogram

Invertebrate family assemblages at the four Lemon Creek exposure sites in October 2013 (Group A) were compared to the two Lemon Creek reference sites from October 2013 and all six sites sampled in October 2014 (Group B) in a similarity percentage composition analysis (Table 9-3). Four families with a dissimilarity standard deviation greater than two (2) accounted for approximately 52% of the differences immediately after the event (October 2013) and one year later (October 2014). Families Baetidae, Heptageniidae, Nemouridae and Ephemerellidae were responsible for most of the separation between October 2013 and October 2014. However, several other families contributed to the separation, with an additional nine families exceeding the discrimination index value of 1. The results indicate that the majority of invertebrate families at the four Lemon Creek exposure sites downstream of the spill site were initially impacted.

Table 9-3: Lemon Creek Taxa Group Similarity Percentages

Species	Group A Average Abundance	Group B Average Abundance	Dissimilarity Average	Dissimilarity Standard Deviation	Percent Contribution	Cumulative Percent
Baetidae	42.16	4.18	17.86	3.41	22.04	22.04
Heptageniidae	28.18	1.68	12.33	4.82	15.21	37.25
Nemouridae	17.71	0.91	7.51	2.58	9.27	46.52

Table 9-3 (Cont'd): Lemon Creek Taxa Group Similarity Percentages

Species	Group A Average Abundance	Group B Average Abundance	Dissimilarity Average	Dissimilarity Standard Deviation	Percent Contribution	Cumulative Percent
Ephemerellidae	10.27	0.25	4.59	3.11	5.66	52.19
Leptophlebiidae	8.90	0.85	3.88	1.42	4.79	56.97
Taeniopterygidae	8.61	0.79	3.62	1.07	4.47	61.44
Empididae	7.15	0.00	3.34	1.26	4.13	65.57
Chironomidae	12.11	7.42	3.08	1.52	3.80	69.36
Enchytraeidae	5.51	1.79	2.84	0.92	3.51	72.87
Hydropsychidae	6.35	1.00	2.64	0.99	3.26	76.13
Rhyacophilidae	6.33	1.00	2.59	1.69	3.20	79.33
Ameletidae	6.04	1.80	2.56	1.35	3.16	82.49
Perlodidae	4.71	0.61	2.11	1.29	2.60	85.09
Chloroperlidae	5.17	0.96	2.06	1.60	2.55	87.63
Tipulidae	3.48	0.50	1.49	1.26	1.83	89.47
Psychodidae	3.09	0.25	1.36	0.87	1.67	91.14

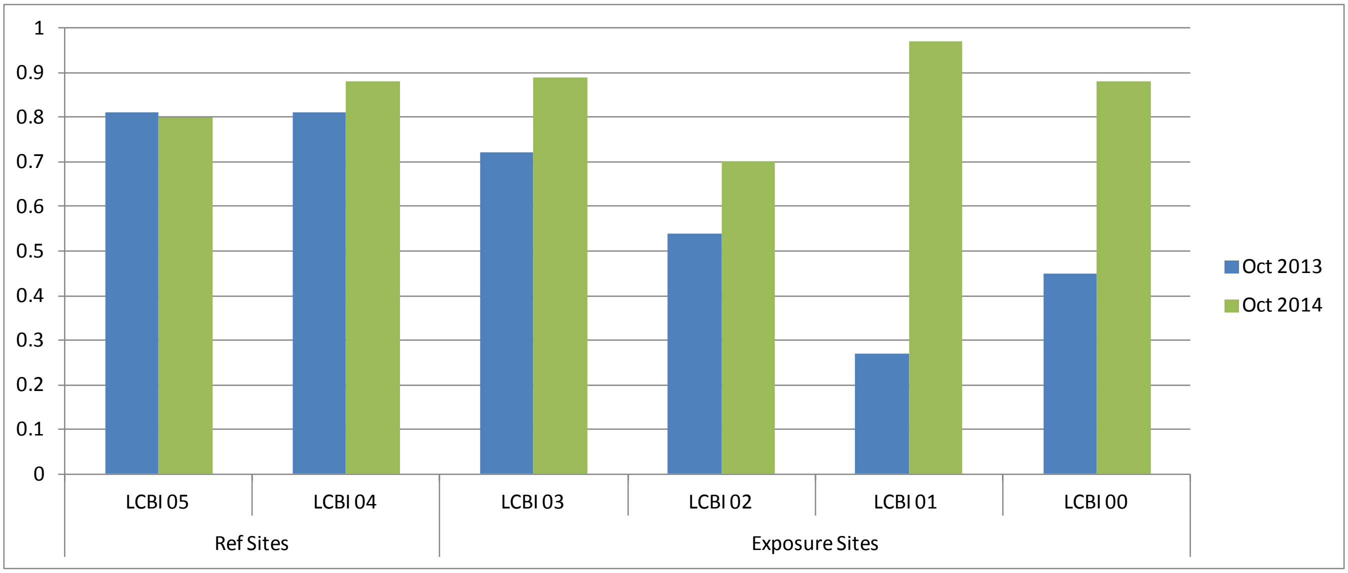
Notes: Average dissimilarity = 0.83

9.3.1.4 Reference Condition Approach

9.3.1.4.1 RIVPACS

The RIVPACS model predicts (at a selected probability level of >70%) the ratio of observed to expected taxa at each test (exposure) site by using the BEAST model predictions and the probability of taxa occurrence at the CABIN-selected reference sites. The basis of the model is that if taxa that are typically present in unimpacted sites (i.e., expected) are not present (i.e., observed) there is likely some degree of impairment. Sites with ratios close to 1 are considered to be in good condition while sites with low ratios typically indicate impairment.

RIVPACS model results for the six sites sampled on Lemon Creek in October 2013 and October 2014 are summarized in Figure 9-11.



Sites presented in a downstream direction.

Figure 9-11: Lemon Creek RIVPACS Summary

RIVPACS results at all sites (exposure and reference) varied over the two sampling periods, ranging from 0.27 (LCBI01 – October 2013) to 0.97 (LCBI01 – October 2014). Results from October 2013 indicated a relatively low ratio of observed to expected taxa at the four exposure sites (mean of 0.50) relative to levels at the two reference sites (mean of 0.81). RIVPACS results from Hess samples for exposure site LCBI01 were not provided in the ARL reports (2000a,b) and were not calculated from the provided raw data.

RIVPACS results increased considerably at the four exposure sites by October 2014, with a mean percentage of 0.86, which was similar to the mean percentage exhibited at the two reference sites (0.84). RIVPACS results for the two reference sites (LCBI04, LCBI05) were consistent between October 2013 and October 2014.

9.3.1.4.2 BEAST Model Probability of Impairment

Samples from the 6 sites on Lemon Creek were tested for the degree of impairment using the BEAST model in CABIN. April 2014 results were not analyzed using the BEAST model, as this model was designed in CABIN for analysis of benthic invertebrates collected only in the summer/fall period.

The BEAST analysis first evaluated the group of CABIN reference sites (using the Columbia-Okanagan Preliminary March 2010 model) that most closely matched the habitat/environmental values of the six (6) sampled sites on Lemon Creek established during the project study design. Probabilities of how closely these habitat values matched the CABIN group of reference sites are presented in Table 9-4.

Table 9-4: CABIN BEAST Reference Group Selection Probability1,2

Watershed	Site	October 2013	October 2014
Lemon Creek	LCBI 05 – Ref	62.4%	75.8%
	LCBI 04 – Ref	60.6%	77.4%
	LCBI 03 – Exp	62.4%	75.9%
	LCBI 02 – Exp	56.4%	78.8%
	LCBI 01 – Exp	62.4%	78.9%
	LCBI 00 – Exp	54.6%	76.5%
Average	-	**59.8%**	**77.2%**

Note: [1] Sites are presented in a downstream direction.

[2] Based on the CABIN Columbia-Okanagan Preliminary March 2010 model.

In October 2013, the group selection probabilities for Lemon Creek averaged 59.8%. In October 2014, the average group selection probability increased by approximately 30% to 77.2%. The low group selection probability observed in 2013 may be a result of the large discharge event observed at the end of September 2013 (refer to Figure 9-2). The large difference in group selection probability between 2013 and 2014 may confound the interpretation of BEAST results because of the CABIN assumption that the variability of the benthic invertebrate community is based on a wide range of environmentally similar reference sites. That is, the reference sites are selected based on non-biological measures, and if the measures are subjected to largely modified water quality, discharge or temperature then reference assemblages may be affected.

After the appropriate group of CABIN reference sites was selected, taxonomic data from each of the six (6) sites were evaluated against these reference sites to determine the degree of impairment and divergence from reference condition. Figures in Appendix IV summarize the ordination results from the two sampling periods and illustrate the level of divergence calculated for each site on Lemon Creek by plotting the taxonomic results in an ellipse, relative to the group of assigned CABIN reference sites. Each band of the ellipse represents the 'distance' the transect site was from the reference sites and thus the degree of impairment. Table 9-5 summarizes the BEAST ordination results for the Lemon Creek reference and exposure sites.

Table 9-5: Lemon Creek CABIN BEAST Ordination Results

Site	October 2013	October 2014
LCBI 05 – Ref	MD	MD
LCBI 04 – Ref	MD	MD
LCBI 03 – Exp	MD	MD

Table 9-5 (Cont'd): Lemon Creek CABIN BEAST Ordination Results

Site	October 2013	October 2014
LCBI 02 – Exp	MD	MD
LCBI 01 – Exp	HD	MD
LCBI 00 – Exp	HD	MD

Notes: Sites are presented in a downstream direction.
HD=highly divergent, MD=mildly divergent.

Results from BEAST assessment indicate that the two sites (LCBI02 and LCBI03) immediately downstream of the spill (1.0 km to 1.5 km) were considered mildly divergent in October 2013, while two sites (LCBI00 and LCBI01) further downstream (3.2 km to 3.8 km) were highly divergent. It is unclear why sites closest to the spill were only mildly divergent from reference condition, as results from the biometric and statistical analyses clearly indicate impairment at these sites in October 2013. However, the key results of the BEAST assessment were that the upstream reference sites were mildly divergent in both October 2013 and October 2014 and thus are generally considered representative of reference conditions in Lemon Creek, and that the two downstream sites that were highly divergent in October 2013 'recovered' by October 2014. Based on these results, the benthic invertebrate assemblage at all of the Lemon Creek exposure sites by October 2014 was representative of assemblages expected at the CABIN-selected reference sites.

9.3.1.5 Regression Models

The BACI and gradient analyses for total and EPT abundance, percent of oligochaete-chironomid, and percent EPT individuals in Lemon Creek exposure stations initially indicated reduced invertebrate-based properties in 2013; however, the invertebrate data indicated recovery to reference station conditions in 2014. The BACI analysis indicated that reference sites in Lemon Creek had relatively stable values while abundance and percent EPT individuals increased from 2013 to 2014, and the percent of oligochate-chironomid decreased from 2013 to 2014. Similarly, the distance analysis indicates relatively stable counts along the Lemon Creek stream gradient in 2014 compared to 2013 (see Appendix III for detailed results). Further exploratory modeling indicated that it is expected that the GLMM results would remain significant after further adjustments for over-dispersion.

9.3.2 Slocan River

9.3.2.1 Variability in River Discharge

Knowledge of the influence of Slocan River discharge is one key to understanding the potential natural spatial and temporal variability in benthic invertebrate community structure observed at the sample sites.

River discharge (m^3/s) is monitored at one station on the Slocan River (08NJ103). Discharge graphs for 2013 and 2014 were generated from this data for the Slocan River (Figure 9-12 and Figure 9-13).

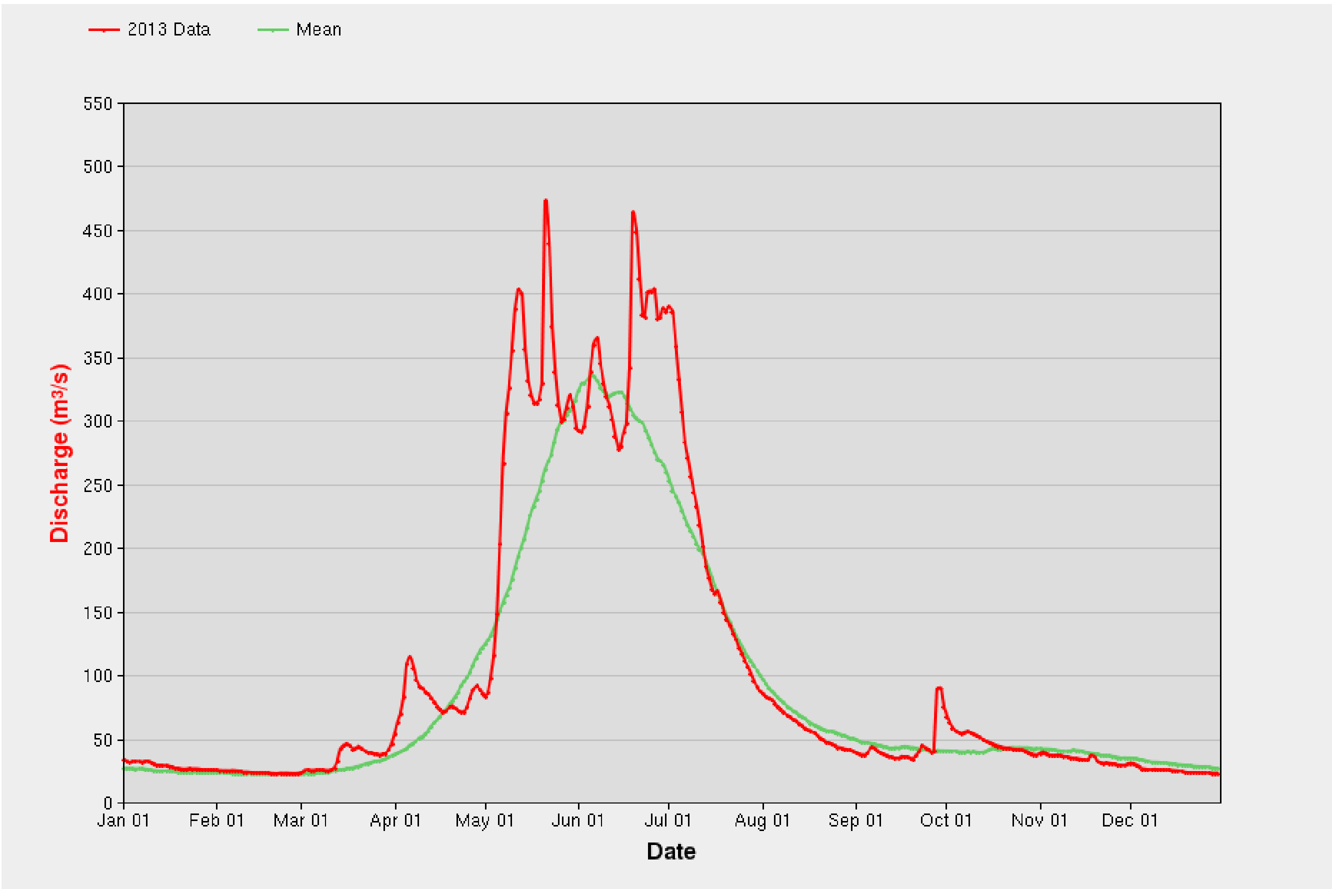


Figure 9-12: 2013 Slocan River (at Crescent Valley) Discharge (Environment Canada 2015)

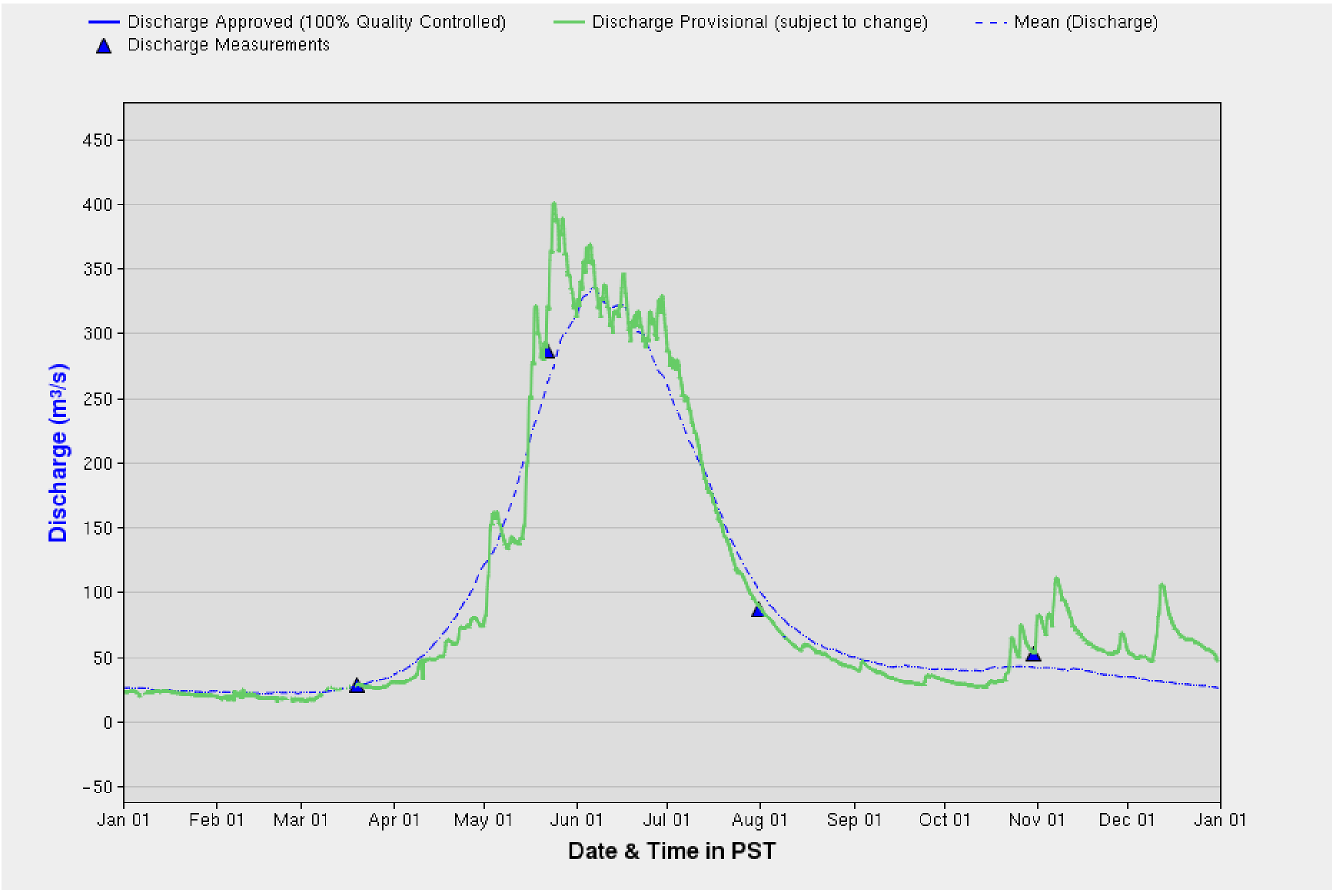


Figure 9-13: 2014 Slocan River (at Crescent Valley) Discharge (Environment Canada 2015)

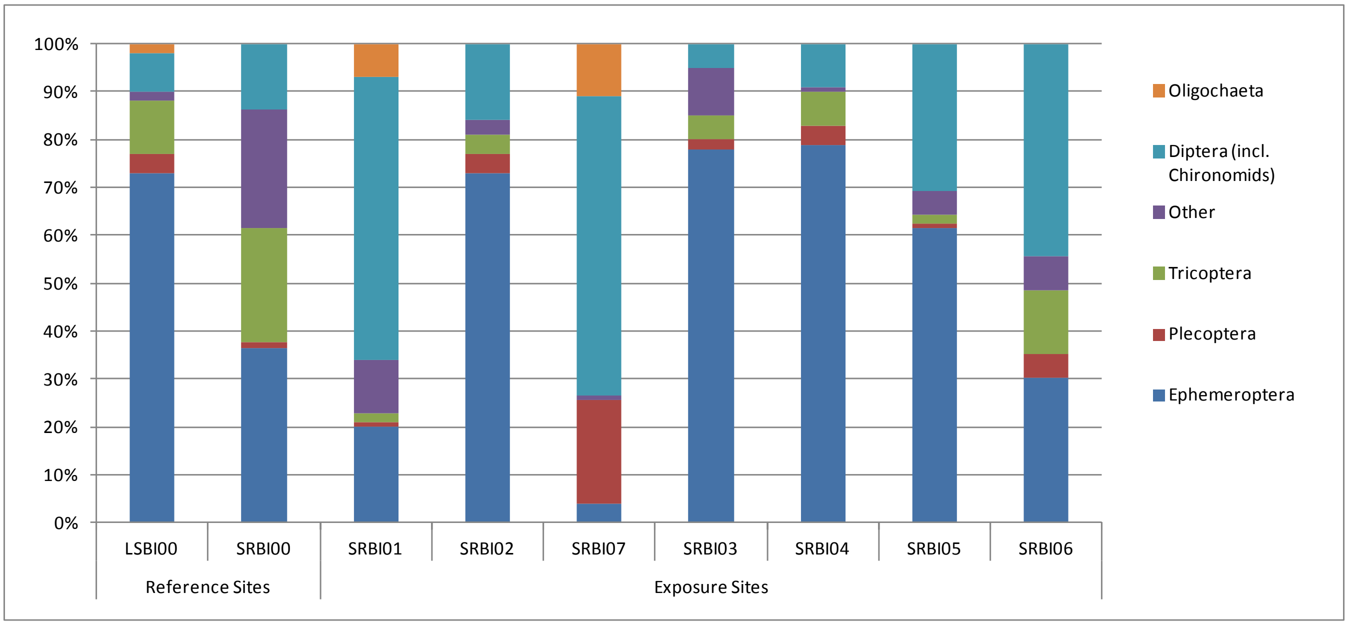
The late October 2013 and 2014 discharge in Slocan River was similar to Lemon Creek. There is the possibility that the high flows in late September 2013 (and prior to the last sampling date in October 2014) may have altered habitat conditions thereby influencing the benthic invertebrate community (e.g., through scour or dislodging of invertebrates).

9.3.2.2 Biometrics

Ten sites were sampled on Slocan River: eight in the exposure area downstream of the confluence with Lemon Creek, one upstream of the confluence (reference area), and one on Little Slocan River (reference area). Data from each of the 10 sites sampled in October 2013 and October 2014 were analyzed using a number of biometrics to aid in interpreting potential effects on the benthic invertebrate community and assess the extent of recovery to reference site conditions.

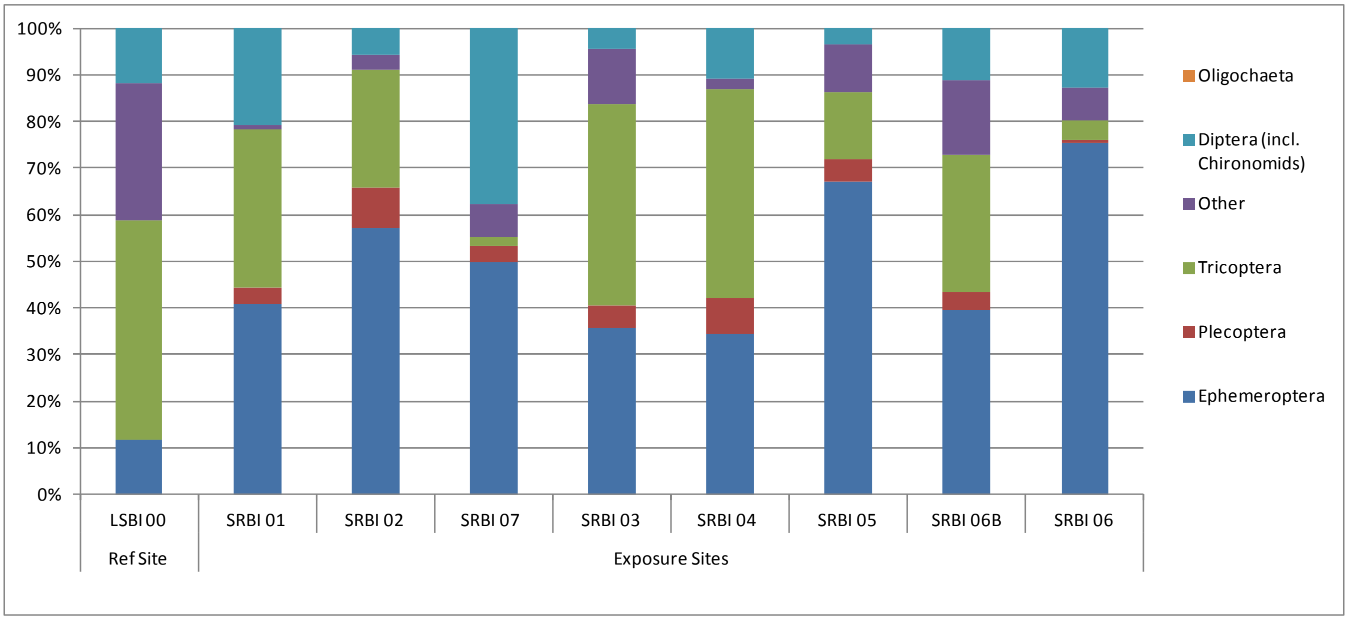
9.3.2.2.1 Taxa Family Percent Composition

The composition of each taxonomic group from the ten sites sampled on October 2013 and October 2014 is presented in Figure 9-14 and Figure 9-15.



Notes: Exposure sites are presented in a downstream direction.
Other = Coleoptera, Amphipoda, Trombidiformes

Figure 9-14: Slocan River Taxa Family Percent Composition – October 2013



Notes: Exposure sites are presented in a downstream direction.
Other = Coleoptera, Amphipoda, Trombidiformes

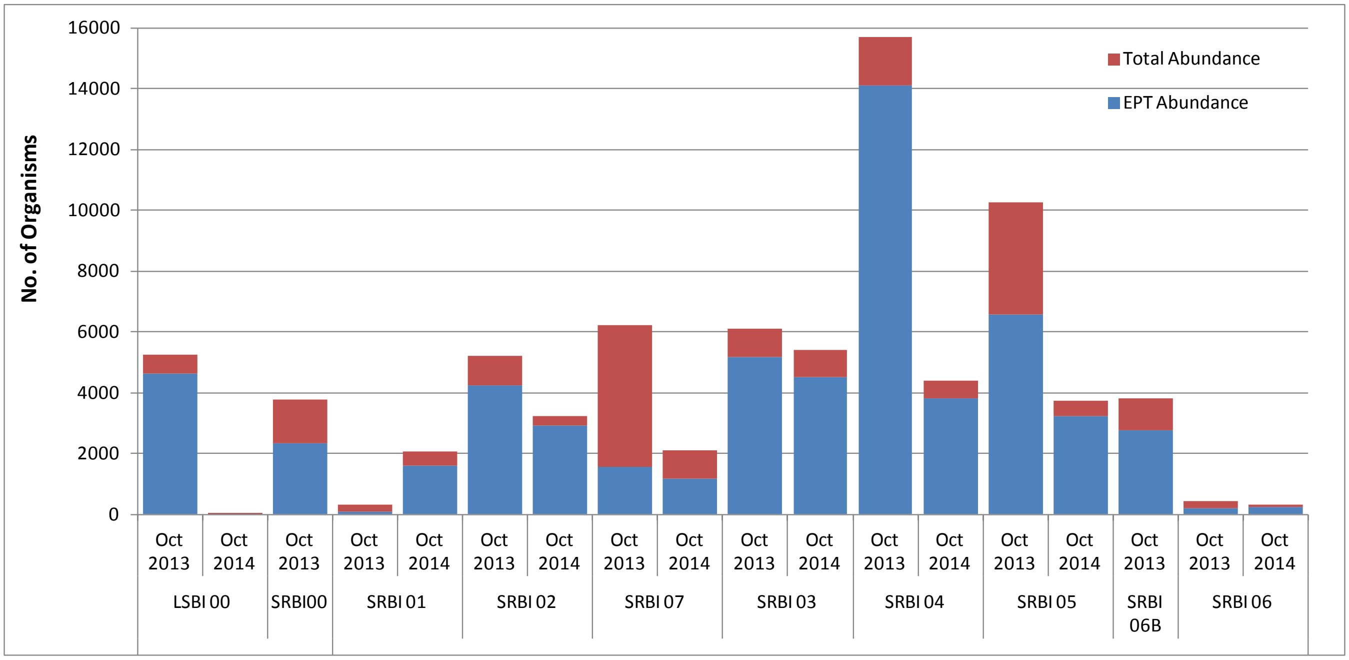
Figure 9-15: Slocan River Taxa Family Percent Composition – October 2014

Results from October 2013 indicated that samples from exposure sites (SRBI01, SRBI02, SRBI03, SRBI04, SRBI05, SRBI06, SRBI06b, SRBI07) were dominated primarily by Ephemeroptera and Diptera (which includes Chironomids) taxa. Trichoptera, Oligochaeta, and Coleoptera/Amphipoda/Trombidiformes (represented at 'Other' in the figure) taxa were also present but comprised a much lower percentage of the samples. Although Plecoptera taxa were present in relatively high levels at exposure site SRBI07, their presence at other sites was minimal. Ephemeroptera, Trichoptera, and Coleoptera/Amphipoda/Trombidiformes were the dominant taxa present in the two Slocan River reference site (LSBI00, SRBI00) samples, followed by Diptera taxa.

Ephemeroptera taxa continued to be the most dominant taxa present in exposure site samples by October 2014, along with Trichoptera, which increased relative to October 2013. Dipterans, however, decreased considerably over this period. Coleoptera/Amphipoda/Trombidiformes and Diptera taxa were the next most-dominant taxa. Plecoptera taxa levels continued to be low at all sites and no Oligochaeta taxa were recorded. The two reference sites continued to be dominated by Ephemeroptera and Trichoptera taxa.

9.3.2.2.2 Species Abundance

Total and EPT species abundance results for the ten sampled sites on Slocan River in October 2013 and October 2014 are summarized in Figure 9-16.



Exposure sites presented in a downstream direction.

Figure 9-16: Slocan River Taxa Abundance Summary

Total species abundance at all sites (exposure and reference) ranged from 17 (LSBI00 – October 2014) to 15,700 (SRBI04 – October 2013) organisms, with EPT abundance ranging from 10 (LSBI00 – October 2014) to 14,100 (SRBI04 – October 2013) organisms.

Total and EPT species abundance results from Slocan River samples were highly variable between sites and dates. With the exception of total and EPT abundance at exposure site SRBI01 and EPT abundance at exposure site SRBI06, abundance levels at all exposure sites on the Slocan River decreased from October 2013 to October 2014.

The high abundance in samples from exposure sites SRBI04 and SRBI05 in October 2013, which were dominated by Ephemeroptera taxa, were likely a result of samples being collected during the mayfly hatch.

Exposure site SRBI06 was the only site where results were consistently low over the two sampling periods. Historical total abundance results from October 2005 (n=335; Slocan River Streamkeepers 2006b), which were collected using a kicknet similar to 2013/2014, were similar to results from October 2013 (n=452) and October 2014 (n=318), suggesting that abundance levels at this site may be naturally low. Data could not be compared to 2003 or 2004 Streamkeepers results due to a different sampling method (i.e., Hess sampler). Although it is not known why abundance levels were low at this site, habitat conditions affecting abundance may be a factor, as the site, established by the Slocan Valley Streamkeepers, likely did not meet CABIN standards (i.e., site was not located in a riffle section of a watercourse) (CABIN 2014). Additionally, results from exposure site SRBI06b, located approximately 250 m upstream of site SRBI06, and situated in a riffle section, were considerably higher, also suggesting that habitat conditions may have been responsible for the consistently low abundance results at site SRBI06.

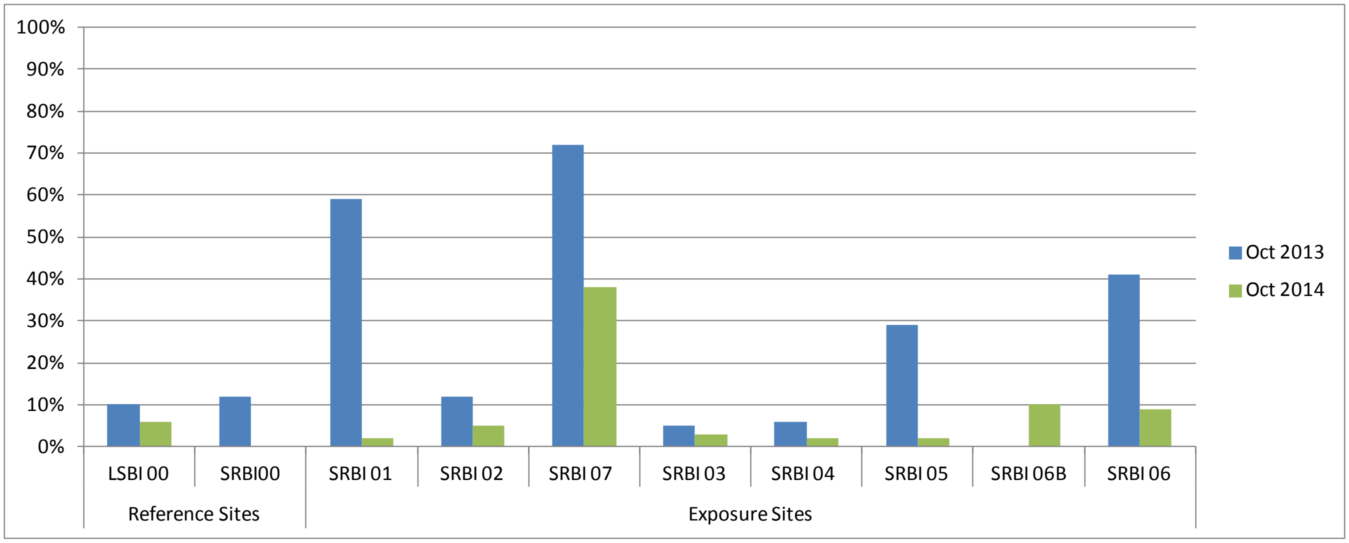
Reference site LSBI00, a historical Streamkeepers sample site, exhibited a decrease in total and EPT abundance between October 2013 and October 2014, with exceptionally low abundance in October 2014 (n=17). It is unknown why abundance was so low during this period. Sampling was discontinued at reference site SRBI00, another historical Streamkeepers sample site, as results from October 2013 and April 2014 (see also the BEAST model analysis section 9.3.4) indicated that this site did not conform to CABIN standards, as it was not located in a riffle area.

As results from the two reference sites were suspect, a gradient analysis approach was conducted. Results, however, were inconclusive, as there was no clear increase or decrease in October 2013 or October 2014 total or EPT species abundance in a downstream direction from the Lemon Creek confluence.

It is unknown why species abundance decreased at the majority of Slocan River exposure sites between October 2013 and October 2014; however, these declines may be due to natural variability, potentially due to changes in habitat conditions over time.

9.3.2.2.3 Oligochaete & Chironomid Percent Composition

The percentage of Oligochaete and Chironomid taxa in each sample from all ten sites on Slocan River was calculated to provide an understanding of the presence and abundance of these pollution-tolerant taxa; results are summarized in Figure 9-17.



Exposure sites presented in a downstream direction.

Figure 9-17: Slocan River Oligochaete and Chironomid Percent Composition Summary

The percentage of Oligochaetes and Chironomids at all sites (exposure and reference) were highly variable, ranging from 2% (SRBI01 – October 2014; SRBI04 – October 2014; SRBI05 – October 2014) to 72% (SRBI07 – October 2013). However, levels at all exposure sites on the Slocan River decreased from October 2013 to October 2014. The high levels at exposure site SRBI07 may have been related to the abundance of algae observed at that site, as Oligochaete and Chironomid densities can increase with increasing eutrophic conditions and nutrient enrichment (Adamus and Brandt 1990; Burton and Pitt 2001). Although the percentage of Oligochaete and Chironomid taxa also decreased at reference site LSBI00, the extremely low October 2014 abundance levels (n=17) were suspect; therefore this site not used for comparison purposes.

Historical Oligochaete and Chironomid results at exposure site SRBI06 in October 2005 could not be calculated, as invertebrate data were not available in the report appendix; however, report figures suggest a percent abundance of Dipterans, the Order to which Chironomids belong, of approximately 70% (Slocan River Streamkeepers 2006b). This result was higher than levels in October 2013 (41%) and October 2014 (9%), illustrating the variability in Oligochaete and Chironomids numbers. Results from 2013 and 2014 could not be compared to 2003 or 2004 Streamkeepers results due to different sampling methods (Hess vs. CABIN kicknet).

As results from the two reference sites (LSBI00 and SRBI00) were suspect, exposure site data could not be used to compare against these sites to assess for potential impacts from the spill. Therefore, a gradient analysis approach was conducted. Results, however, were inconclusive, as there was no clear increase or decrease between October 2013 and October 2014 Oligochaete and Chironomid levels in a downstream direction from the Lemon Creek confluence. Although a decrease in overall Oligochaete and Chironomid levels was observed between October 2013 (mean of 22%) and October 2014 (mean of 6%), it is not known whether this was due to natural variation or a result of increasing benthic invertebrate community health.

9.3.2.3 Non-Parametric Ordination (ANOSIM)

A hierarchical cluster analysis and non metric multi dimensional scaling (NMDS) ordination was conducted on Slocan River (Figure 9-18, Figure 9-19) data sampled in October 2013 and October 2014. From an examination of the NMDS ordination, cluster diagrams, and the ANOSIM result, the Slocan River sites do not clearly cluster into 2013 (impact) and 2014 (recovery). For example, although the Slocan River sites exhibited a statistically significant dissimilarity between sites (ANOSIM R=0.138, p=0.039), the ANOSIM R-value is close to zero and therefore invertebrate community separation is not considered 'real'; this is supported by the lack of clear separation between SR13 and SR14 sites in the ordination plot and classification diagram (Figure 9-18 and 9-19).

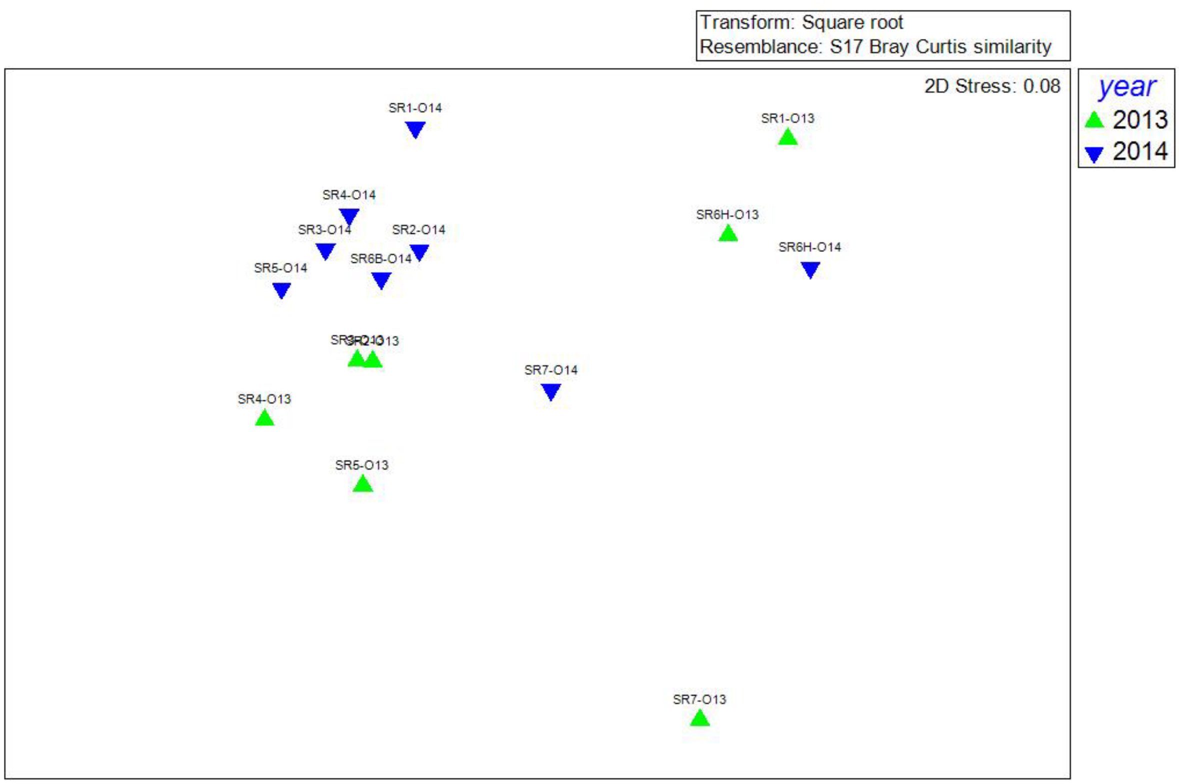


Figure 9-18: Slocan River Bray-Curtis Dissimilarity NMDS Ordination Plot

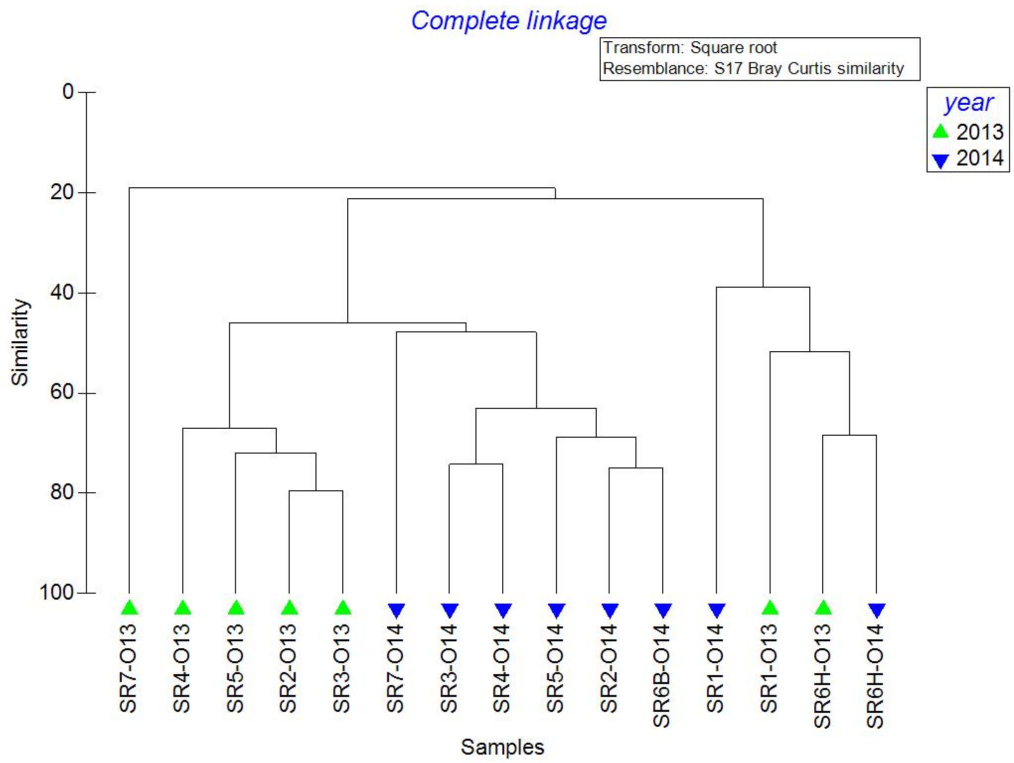
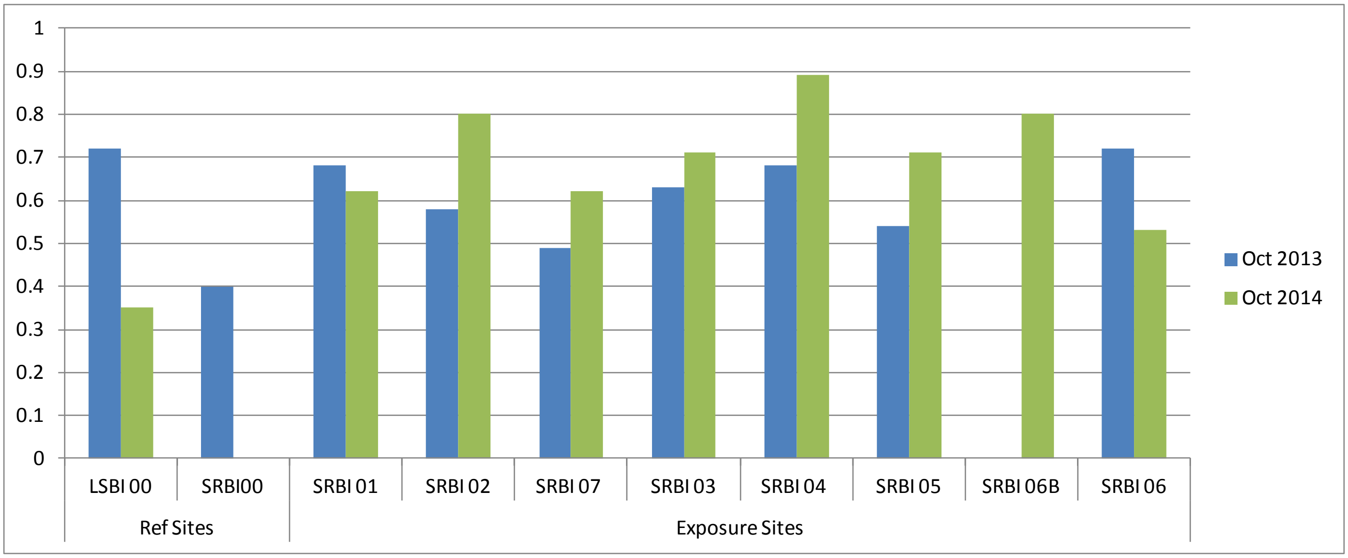


Figure 9-19: Slocan River Bray-Curtis Dissimilarity Dendrogram

9.3.2.4 Reference Condition Approach

9.3.2.4.1 RIVPACS

RIVPACS model results for the 10 sites sampled on Slocan River in October 2013 and October 2014 are summarized in Figure 9-20.



Sites presented in a downstream direction.

Figure 9-20: Slocan River RIVPACS Summary

RIVPACS results from all sites (exposure and reference) over the two sampling periods were highly variable, ranging from 0.35 (LSBI00 – October 2014) to 0.89 (SRBI04 – October 2014).

With the exception of exposure sites SRBI01 and SRBI06, the ratio of observed to expected taxa at all exposure sites on the Slocan River increased from October 2013 to October 2014. The ratio also decreased at reference site LSBI00. As this site exhibited a low October 2014 abundance levels (n=17), it was excluded for comparison purposes.

No historical RIVPACS results from exposure site SRBI06 were available from the Slocan Valley Streamkeepers report (2006b), and as no raw data were provided in the report, could not be calculated. As results from the two reference sites (LSBI00 and SRBI00) were suspect, exposure site data could not be used to compare against these sites to assess for potential impacts from the spill.

9.3.2.4.2 BEAST Model Probability of Impairment

Samples from the ten sites on Slocan River were tested for the degree of impairment using the BEAST model in CABIN. April 2014 results were not analyzed using the BEAST model, as this model was designed in CABIN for analysis of benthic invertebrates collected only in the summer/fall period.

The BEAST analysis first evaluated the group of CABIN reference sites (using the Columbia-Okanagan Preliminary March 2010 model) that most closely matched the habitat/environmental values of the ten sampled sites on Slocan River established during the project study design. Probabilities of how closely these habitat values matched the CABIN group of reference sites are presented in Table 9-6.

Table 9-6: CABIN BEAST Reference Group Selection Probability1,2

Watershed	Site	October 2013	October 2014
Slocan River	LSBI 00 – Ref	55.3%	75.1%
	SRBI 00 – Ref	48.8%	-
	SRBI 01 – Exp	48.5%	73.8%
	SRBI 02 – Exp	50.3%	72.7%
	SRBI 07 – Exp	49.6%	71.8%
	SRBI 03 – Exp	54.9%	71.7%
	SRBI 04 – Exp	48.2%	69.0%
	SRBI 05 – Exp	57.0%	74.3%
	SRBI 06b – Exp	-	73.1%
	SRBI 06 – Exp	57.7%	75.4%
Average	**-**	**52.3%**	**73.0%**

Note: [1] Sites are presented in a downstream direction.
[2] Based on the CABIN Columbia-Okanagan Preliminary March 2010 model.

In October 2013, the group selection probabilities for Slocan River averaged 52.3%. In October 2014, the average group selection probability increased dramatically (by ~40%) to 73.0%. The low group selection probability observed in 2013 may be a result of the large discharge event observed at the end of September 2013 (refer to Figure 9-4). The large difference in group selection probability between 2013 and 2014 may confound the interpretation of BEAST results because of the CABIN assumption that the variability of the benthic invertebrate community is based on a wide range of environmentally similar reference sites. That is, the reference sites are selected based on non-biological measures, and if the measures are subjected to largely modified water quality, discharge or temperature then reference assemblages may be affected.

After the appropriate group of CABIN reference sites was selected, taxonomic data from each of the ten sites were evaluated against these reference sites to determine the degree of impairment and divergence from reference condition. Figures in Appendix IV summarize the ordination results from the two sampling periods and illustrate the level of divergence of each site on Slocan River by plotting the taxonomic results in an ellipse, relative to the group of assigned CABIN reference sites. Each band of the ellipse represents the 'distance' the transect site was from the reference sites and thus the degree of impairment. Figures 14 (LSBI00-Ref-Oct 2014), 15 (SRBI00-Ref-Oct 2013), 22 (SRBI04-Exp-Oct 2013), and 29 (SRBI07-Exp-Oct 2013), however, were so highly divergent from reference that the ellipse, normally visible, was represented by a green dot. Table 9-7 summarizes the BEAST ordination results for the Slocan River reference and exposure sites.

Table 9-7: Slocan River CABIN BEAST Ordination Results

Site	October 2013	October 2014
LSBI 00 – Ref	MD	HD
SRBI 00 – Ref	HD	n/s
SRBI 01 – Exp	MD	MD
SRBI 02 – Exp	MD	MD
SRBI 07 – Exp	HD	D
SRBI 03 – Exp	MD	HD
SRBI 04 – Exp	HD	MD
SRBI 05 – Exp	D	MD
SRBI 06b – Exp	n/s	MD
SRBI 06 – Exp	MD	MD

Notes: exposure sites are presented in a downstream direction.
n/s=not sampled, HD=highly divergent, D=divergent, MD=mildly divergent.

The BEAST assessment results for the Slocan River sites were highly variable in October 2013. With the exception of two exposure sites (SRBI07, SRBI04) which were classified as highly divergent from reference, and one exposure site (SRBI05), which was divergent from reference, the remaining exposure sites were mildly divergent from reference, suggesting little to no difference from CABIN reference site invertebrate assemblages. By October 2014, exposure site SRBI07 had improved to divergent and SRBI05 had improved to mildly divergent; however, SRBI03 declined from mildly divergent to highly divergent.

The classification of exposure sites SRBI04 (highly divergent) and SRBI05 (divergent) in October 2013 was likely due to the very high abundances (n=15,700 and n=10,267, respectively) recorded at the site, the majority of which were mayflies, suggesting that the samples were collected during the mayfly hatch and not a result of direct impact from the fuel spill.

Abundant algae were observed at exposure site SRBI07 in both October 2013 and April 2014, and to a lesser extent, October 2014. The presence of these algae may have been a result of nutrient enrichment from surrounding local residences and slower water velocities, as the site was located in a side channel of the Slocan River. The classification of exposure site SRBI07 as highly divergent in October 2013 was likely the result of the high abundance of Oligochaetes and Chironomids (72% of the sample in October 2013 and 82% of the sample in April 2014), and may have been due to the abundance of algae observed at the site, and whose densities can increase with increasing eutrophic conditions and nutrient enrichment (Adamus and Brandt 1990; Burton and Pitt 2001), rather than an impact from the jet fuel.

The reason for the classification of exposure site SRBI03 as highly divergent from reference in October 2014 was less clear. Biometric and statistical analyses of data from the site during that period did not indicate anything out of the ordinary; however it may have been related to a lack of certain invertebrate species at the site.

Reference site SRBI00 was classified as highly divergent in both October 2013 and April 2014 (not shown). As such, sampling at this site was not sampled in October 2014. Although it is not known why this site was highly divergent, habitat conditions may be a factor, as the site, established by the Slocan Valley Streamkeepers, likely did not meet CABIN standards (i.e., site was not located in a riffle section of a watercourse) (CABIN 2014). Reference site LSBI00 also declined in condition, changing from mildly divergent to highly divergent from October 2013 to October 2014. This change is likely a result of very low species abundance recorded in October 2014 (n=17), relative to October 2013 (n=5,250); however, cause is unknown.

9.3.2.5 Regression Models

The BACI and gradient results for the Slocan River invertebrate data (Appendix III) were less clear than results from Lemon Creek for several reasons. First, as invertebrate data from the two reference sites on the Slocan River system were suspect, a BACI analysis could not be completed. Second, there was little evidence in the gradient analysis for a noticeable impairment to invertebrate-based properties in 2013, and hence it was not clear if recovery occurred in 2014. Rather, the data collected in 2013 and 2014 most likely represent natural variability in the stream invertebrate community properties rather than a direct effect from the jet fuel spill.

9.4 Conclusions

Benthic invertebrates were monitored during three sampling periods: October 2013, April 2014, and October 2014. Although, the April 2014 data were not directly comparable to October 2013 and October 2014 data due to seasonal variation in sampling, raw data is suggested that benthic invertebrate recruitment was evident.

9.4.1 Lemon Creek

9.4.1.1 Biometrics

9.4.1.1.1 Taxa Abundance

Table 9-8 summarizes the relative changes in total and EPT taxa abundance observed between October 2013 and October 2014 for sites on Lemon Creek.

Table 9-8: Trends in Lemon Creek Taxa Abundance - October 2013 to October 2014

Watershed	Site	Total Species Abundance	EPT Species Abundance
Lemon Creek	LCBI 05 – Ref	+	+
	LCBI 04 – Ref	-	-
	LCBI 03 – Exp	+	+
	LCBI 02 – Exp	+	+
	LCBI 01 – Exp	+	+
	LCBI 00 – Exp	+	+

Note: sites are presented in a downstream direction.
n/a=not applicable, '+'=increase, '-'=decrease

Results indicate that total and EPT abundance in samples collected from the four exposure sites on Lemon Creek were similar to levels exhibited at the two reference sites by October 2014. Overall, total and EPT taxa abundance results from the four exposure sites in Lemon Creek suggest a recovery of the invertebrate community to reference site levels.

9.4.1.1.2 Percentage of Oligochaetes and Chironomids

Although comparisons to historical data suggest a degree of natural variability in the levels of Oligochaete and Chironomid species, overall results from Lemon Creek clearly indicate that levels of pollution-tolerant Oligochaete and Chironomid taxa at exposure sites were initially high after the spill in October 2013, but had decreased by October 2014 to levels exhibited at the reference sites. Together with an increase in species abundance, the decline in pollution-tolerant invertebrate species at Lemon Creek exposure sites suggests a recovery of the benthic invertebrate community to reference site levels by October 2014.

9.4.1.2 Non-Parametric Ordination (ANOSIM)

Non-parametric statistical analysis of Lemon Creek exposure site Bray-Curtis results without the CABIN-selected reference site data indicated the dissimilarity of the October 2013 exposure sites from both the October 2013 and 2014 reference sites as well as the October 2014 exposure sites. As such, based on the results from the statistical analysis of the Bray-Curtis dissimilarity index, the four Lemon Creek exposure sites, although initially dissimilar relative to the two reference sites, appear to be similar to reference sites by October 2014.

9.4.1.3 Reference Condition Approach (RCA)

9.4.1.3.1 RIVPACS

Results from Lemon Creek indicated that the ratio of observed to expected taxa at exposure sites increased by October 2014 and were similar to ratios exhibited by the reference sites. Combined with species abundance and the percent Oligochaete and Chironomid results, the increase in the RIVPACS ratio suggested that the benthic invertebrate community at exposure sites on Lemon Creek are in good condition as of October 2014 and indicates a recovery to reference site levels.

9.4.1.3.2 BEAST

Overall, BEAST model results for Lemon Creek indicated that all exposure sites were classified as mildly divergent by October 2014, and that benthic invertebrate assemblage of the exposure sites in October 2014 was representative of assemblages expected at CABIN-selected reference sites.

9.4.1.4 Regression Models

The BACI and gradient analyses for total and EPT abundance, percent of oligochaete-chironomid, and percent EPT individuals in Lemon Creek exposure stations initially indicated reduced invertebrate-based properties in 2013; however, the invertebrate data clearly displayed evidence of recovery to reference station conditions by October 2014.

9.4.1.5 Summary

Table 9-9 summarizes the results of the various analyses performed on the Lemon Creek benthic invertebrate data.

Table 9-9: Summary of Weight of Evidence Analyses – Lemon Creek

Endpoint	Component	Year	Conclusion
Biometrics	Total and EPT Abundance	2013	Impact
		2014	Evidence of recovery to reference site levels
	% Oligochaetes and Chironomids	2013	High abundance
		2014	Decline in abundance to reference site levels

Table 9-9 (Cont'd): Summary of Weight of Evidence Analyses – Lemon Creek

Endpoint	Component	Year	Conclusion
Non-Parametric Ordination (ANOSIM)	Bray-Curtis	2013	Impact
		2014	Evidence of recovery to reference site condition
RCA	RIVPACS	2013	Impact
		2014	Evidence of recovery to reference site condition
	BEAST	2013	Some exposure sites highly divergent from reference condition
		2014	All exposure site divergence similar to reference site divergence
Regression Models	BACI AND GLMM	2013	Impact
		2014	Evidence of recovery to reference site condition

9.4.2 Slocan River

9.4.2.1 Biometrics

9.4.2.1.1 Taxa Abundance

Table 9-10 summarizes the relative changes in total and EPT taxa abundance observed between October 2013 and October 2014 for sites on Slocan River.

Table 9-10: Trends in Slocan River Taxa Abundance - October 2013 to October 2014

Watershed	Site	Total Species Abundance	EPT Species Abundance
Slocan River	LSBI 00 – Ref	-	-
	SRBI 00 – Ref	n/a	n/a
	SRBI 01 – Exp	+	+
	SRBI 02 – Exp	-	-
	SRBI 07 – Exp	-	-
	SRBI 03 – Exp	-	-
	SRBI 04 – Exp	-	-
	SRBI 05 – Exp	-	-
	SRBI 06b – Exp	n/a	n/a
	SRBI 06 – Exp	-	+

Note: sites are presented in a downstream direction.
n/a=not applicable, '+'=increase, '-'=decrease

Total and EPT abundance declined at the majority of sites on the Slocan River from October 2013 to October 2014. However, total abundance in 2013 consisted mainly (mean of 67%) of two families: Mayflies (family Ephemerellidae) and Chironomids (family Chironomidae). By October 2014, the abundance of these two families only accounted for an average of 21% of the total invertebrate abundance. This suggests that the decline in abundance at Slocan River sites from 2013 to 2014 was due to changes in the two families, one a pollution-tolerant family (Chironomids) and the other (Ephemerellidae – a mayfly) that likely had a large emergence at the time of sampling in October 2013. More importantly, the gradient analysis on total and EPT abundances did not indicate a significant increase in these biometrics in a downstream direction, as would be expected if sites were impacted by the spill. Overall, results from the Slocan River sites indicate that invertebrate assemblages in October 2014 were not dominated by few families relative to 2013. However, whether this was due to natural environmental variability or from the fuel spill is unknown.

9.4.2.1.2 Percentage of Oligochaetes and Chironomids

The percentage of Oligochaetes and Chironomids decreased over time at all sites on the Slocan River. However, as indicated by historical data from exposure site SRBI06, which exhibited high (70%) levels, there may be large shifts in the abundance of these populations, suggesting natural environmental variability not related to anthropomorphic influences (i.e., the fuel spill). Overall, conclusions as to whether Oligochaetes and Chironomids in the Slocan River exposures sites were affected by the spill or whether composition changes were due to natural environmental variability could not be made.

9.4.2.2 Non-Parametric Ordination (ANOSIM)

Statistical analysis of the Slocan River dissimilarity results indicated a significant difference in invertebrate assemblages between the exposure site SRBI07 (October 2013) and the remaining Slocan River sites, as well as between exposure sites SRBI01 (October 2014), SRBI07 (October 2014) and SRBI06 (October 2013 and October 2014) and the remaining Slocan River sites. However, as reference site data were suspect and not utilized, whether these differences in invertebrate assemblages were likely the result of natural variability or from the fuel spill could not be inferred.

9.4.2.3 Reference Condition Approach (RCA)

9.4.2.3.1 RIVPACS

Although no clear increasing trend in RIVPACS ratio at the Slocan River exposure sites in a downstream direction from the Lemon Creek confluence was observed, the ratio did increase over time at the majority of sites. However, whether this was related to natural environmental variability or to anthropomorphic influences is unknown. As such, indications as to whether the Slocan River exposures sites were impacted by the spill to begin with could not be inferred.

9.4.2.3.2 BEAST

BEAST model results for exposure sites on the Slocan River indicated some sites were divergent or highly divergent from reference condition by October 2014. However, the reasons for these classifications were likely a result of specific habitat conditions (e.g., very low or high invertebrate abundances, potential enrichment), and likely not related to direct impacts from the fuel spill.

9.4.2.4 Regression Models

The BACI and gradient results for the Slocan River invertebrate data were less clear than results from Lemon Creek and suggest that the data collected in 2013 and 2014 most likely represented natural variability in the stream invertebrate community structure rather than a direct effect from the jet fuel spill.

9.4.2.5 Summary

Table 9-11 summarizes the results of the various analyses performed on the Slocan River benthic invertebrate data.

Table 9-11: Summary of Weight of Evidence Analyses – Slocan River

Endpoint	Component	Year	Conclusion
Biometrics	Total and EPT Abundance	2013	Inconclusive – no evidence of impact
		2014	Inconclusive
	% Oligochaetes and Chironomids	2013	Inconclusive – no evidence of impact
		2014	Inconclusive
Non-Parametric Ordination (ANOSIM)	Bray-Curtis	2013	Inconclusive – no evidence of impact
		2014	Inconclusive
RCA	BEAST	2013	Inconclusive – no evidence of impact
		2014	Inconclusive
	RIVPACS	2013	Inconclusive – no evidence of impact
		2014	Inconclusive
Regression Models	BACI AND GLMM	2013	Inconclusive – no evidence of impact
		2014	Inconclusive

10 CONCLUSIONS

The fish community structure of select off-channel habitats were similar in terms of species composition, species dominance, and species richness and displayed an increasing trend in relative abundance between 2013 and 2014. Even though an increase in abundance was observed, it is difficult to ascertain whether the increase in abundance is related to initial declines in fish numbers as a result of the spill or simply natural variability. In our opinion, we believe the latter is a more likely scenario. Based on the results from the 2013/2014 mark-recapture program, we believe that the modified endpoints have been achieved.

Rainbow Trout population data collected in 2013 and 2014 displayed a decreasing trend that was similar to that observed since 2010. Data observed post-spill suggests population levels still remain within the natural variation exhibited in the population prior to the spill. Given the consistent trends in the Rainbow Trout population since 2006, post-spill data suggest that the observed decrease is likely attributed to natural variability in the species and are not indicative of an effect to the population as a result of the spill. In our opinion the population of Rainbow Trout in the Slocan River system appear to be stable, and believe this endpoint has been achieved.

Based on the Bull Trout redd surveys conducted in 2013 and 2014, data indicate that successful Bull Trout spawning has occurred in upper Lemon Creek and tributaries post spill. Redds, juvenile and adult Bull Trout have been documented in 2014, providing evidence that Bull Trout migration through the exposure area to upstream spawning habitat is not being impeded. Given the recent surveys, the lack of suitable spawning habitat observed in the upper reaches of the Lemon Creek watershed is likely the limiting factor to the spawning success of the Bull Trout.

Based on the results of fish data analysis, there has been recovery of community structure in Lemon Creek over one year after the spill event. Lines of evidence from relative abundance, diversity, composition and age structure all indicate the fish are recovering and is further supported from the results of other monitoring programs (i.e., suitable water quality, abundance of invertebrates (fish food) and continuation of critical life stages such as spawning).

The fish community in Lemon Creek was likely dissimilar to select reference sites in the lowest reach of Lemon Creek (i.e., higher diversity) prior to the spill due to different habitat and influence of proximity to Slocan River and Slocan Lake. Thus, a recovery of all 4.9 km of downstream impacted channel to exactly match the species assemblage, diversity and density of the reference sites is likely a false assumption. When scaled back to account for the morphologically similar reaches that end at the Highway 6 crossing, our data suggest that recovery has progressed to levels that may be within levels of natural variation. This would be in line with the intent of the BMP endpoint.

Results from the benthic invertebrate monitoring program indicated that while the invertebrate assemblage in Lemon Creek was initially impacted by the spill, recovery is evident, as indicated by the results from the applied weight of evidence approach (ANOSIM, regression models [BACI and GLMM], and RCA [RIVPACS and BEAST]). In summary, it appears that while the jet fuel spill initially impacted the benthic invertebrate community at sites downstream of the spill location in Lemon Creek, they have since recovered to reference site levels. These findings fall in line with results presented in the scientific literature from other similar incidents of jet fuel and recovery of aquatic endpoints (e.g., Guiney et al. 1987).We believe that the endpoint has been met for Lemon Creek.

Results from the Slocan River data were less clear. Evaluation of benthic invertebrate data did not suggest any clear indication that sample sites had been exposed to jet fuel. Based on the weight-of-evidence, results suggest that there was no obvious impact on the benthic community structure at exposure sites in Slocan River in October 2013 or October 2014 and that results most likely represented natural variability in the stream invertebrate community structure rather than a direct effect from the jet fuel spill.

Combined, the findings from the fish and benthic invertebrate monitoring programs suggest that the Lemon Creek and Slocan River aquatic ecosystems are displaying resilience in the wake of a moderately acute effect and evidence of recovery since the incident. The nature of the impact and the resiliency and recovery shown in the benthic invertebrate results is not unexpected given our understanding of the environmental fate and transport of the spilled product. It is our opinion that the findings from each of the biological monitoring programs have achieved the anticipated (modified) endpoints.

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APPENDIX I

General Field Observations

Field Crew: JB / JC / MS Site Code: LCBI00-1MP

Sampling Date: (DD/MM/YYYY) 16/10/2013

☐ **Occupational Health & Safety: Site Inspection Sheet completed**

PRIMARY SITE DATA

CABIN Study Name: Lemon Creek Local Basin Name: Slocan R

River/Stream Name: Lemon Creek Stream Order: (map scale 1:50,000) ____________

Select one: ☑ Test Site ☐ Potential Reference Site

Geographical Description/Notes:

- No algae observed in channel
- Hydrocarbon odour + sheen observed

Surrounding Land Use: (check those present) Information Source: ____________

☑ Forest ☐ Field/Pasture ☐ Agriculture ☑ Residential/Urban

☐ Logging ☐ Mining ☐ Commercial/Industrial ☐ Other ____________

Dominant Surrounding Land Use: (check one) Information Source: ____________

☑ Forest ☐ Field/Pasture ☐ Agriculture ☐ Residential/Urban

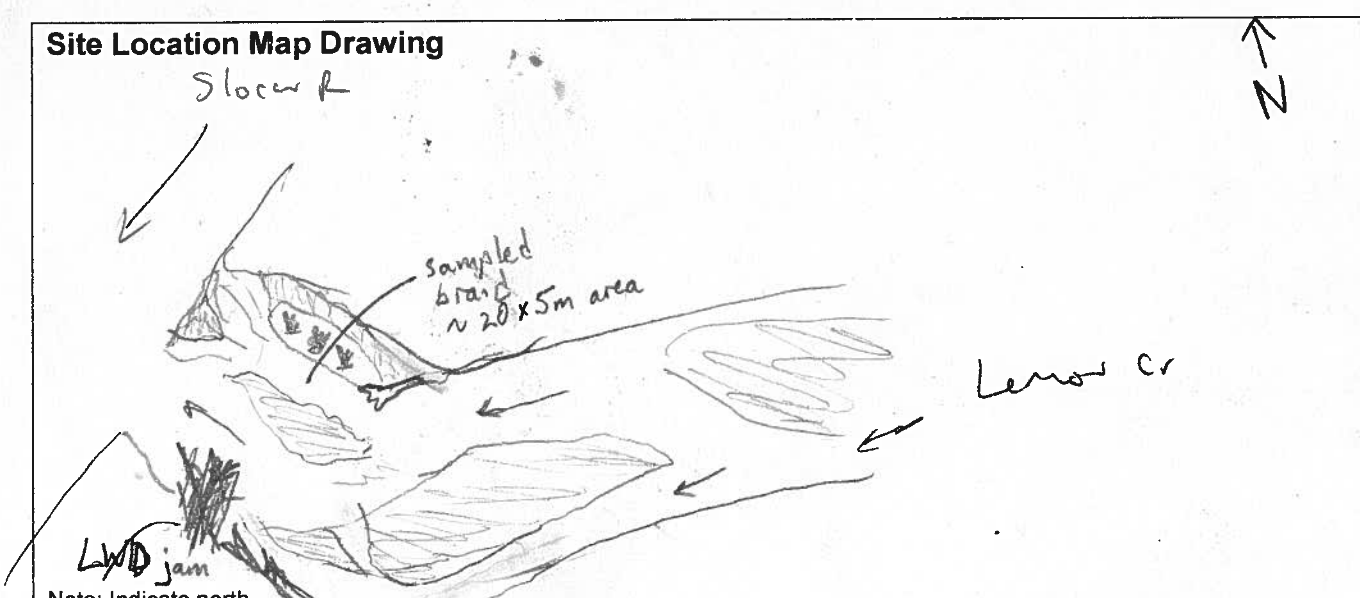
☐ Logging ☐ Mining ☐ Commercial/Industrial ☐ Other ____________

Location Data

Latitude: 49°42'23.4" N Longitude: - 117°29'32.8" W (DMS or DD)

Elevation: 539 (fasl *or* masl) GPS Datum: ☑ GRS80 (NAD83 WGS84) ☐ Other: ____________

Site Location Map Drawing



Note: Indicate north

Field Crew: JB JL MS Site Code: LCB102 IMP

Sampling Date: (DD/MM/YYYY) 16/10/2013

☐ **Occupational Health & Safety: Site Inspection Sheet completed**

PRIMARY SITE DATA

CABIN Study Name: Lemon Creek Local Basin Name: Slocan

River/Stream Name: Lemon Creek Stream Order: (map scale 1:50,000) ______

Select one: ☒ Test Site ☐ Potential Reference Site

Geographical Description/Notes:

- hydrocarbon sheen observed
- abundant green filamentous algae in thalweg. None along margins

Surrounding Land Use: (check those present) Information Source: ______

☒ Forest ☐ Field/Pasture ☐ Agriculture ☐ Residential/Urban

☐ Logging ☐ Mining ☐ Commercial/Industrial ☐ Other ______

Dominant Surrounding Land Use: (check one) Information Source: ______

☒ Forest ☐ Field/Pasture ☐ Agriculture ☐ Residential/Urban

☐ Logging ☐ Mining ☐ Commercial/Industrial ☐ Other ______

Location Data

Latitude: 49 41 56 8 N Longitude: - 117 27 49 3 W (DMS or DD)

Elevation: 607 (fasl or masl) GPS Datum: ☐ GRS80 (NAD83/WGS84) ☐ Other: ______

Site Location Map Drawing

Note: Indicate north

10°C

CABIN

Field Crew: SB JC MS　　Site Code: LCB103-IMP

Sampling Date: (DD/MM/YYYY) 17/10/2013

☐ **Occupational Health & Safety: Site Inspection Sheet completed**

PRIMARY SITE DATA

CABIN Study Name: Lemon Cr　　Local Basin Name: Slocan

River/Stream Name: Lemon Cr　　Stream Order: (map scale 1:50,000) ______

Select one: ☒ Test Site ☐ Potential Reference Site

Geographical Description/Notes:

- Hydrocarbon sheen + odour noted when substrate disturbed
- Abundant dark green, filamentous algae in channel thalweg

Surrounding Land Use: (check those present)　　Information Source: ______

☒ Forest ☐ Field/Pasture ☐ Agriculture ☐ Residential/Urban

☐ Logging ☐ Mining ☐ Commercial/Industrial ☐ Other ______

Dominant Surrounding Land Use: (check one)　　Information Source: ______

☒ Forest ☐ Field/Pasture ☐ Agriculture ☐ Residential/Urban

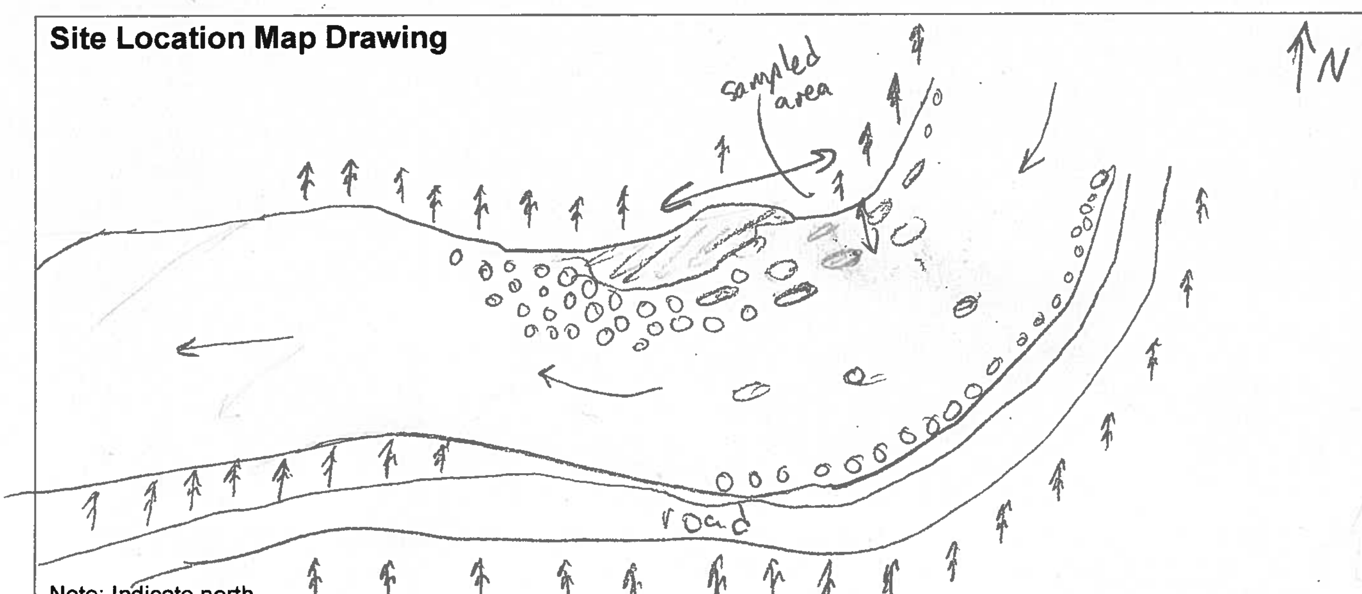
☐ Logging ☐ Mining ☐ Commercial/Industrial ☐ Other ______

Location Data

Latitude: 49° 41' 51.5" N　Longitude: - 117° 27' 30.9" W (DMS or DD)

Elevation: 596 (fasl or masl)　GPS Datum: ☒ GRS80 (NAD83/WGS84) ☐ Other: ______

Site Location Map Drawing



Note: Indicate north

Scope - Lemon Creek SW sampling

ID	Time	pH	Cond	ORP	Temp	NTU	DO
SW13-300	11:53	7.68	34	249.4	5.13	0.7	11.73
SW13-01	12:30	7.87	35	236.8	5.44	0.4	11.63
SW13-353	13:00	7.84	35	230.4	5.60	0.1	11.67
SW13-305	13:30	7.83	35	227.2	5.48	0.3	11.60
SW13-351	14:12	7.83	36	230.4	5.81	7.2	11.63
SW13-352	14:48	7.92	37	227.0	6.03	0.4	11.33
SW13-05	CRUSSECS — NO ACCESS						
SW13-23	15:34	7.88	36	236.0	6.32	0.8	11.[illegible]
SW13-03	16:20	8.00	37	225.8	6.39	1.9	11.[illegible]

8:30-11:40 label bottles, buy ice, drive to Lemon creek, access SW13-300. HASP

SW13-300 Background sample
- sediment sample collected 0.3m below surface in back eddy

SED13-300 SAND (f-c), some gravel (f), yellow/br. loose, wet, trace organics (rootlets)

SW13-01 Accident Site

SAND (f-c), some organics (moss), brown, loose, wet
- taken at water level
- no odour

SW13-353 - no odour, no sheen
SED13-353 - sediment collected 0.4 cm below surface (rocks + moss above)

- SAND (f-c), trace gravel (f-sa) br, loose, wet

SW14-DUPA-LC - (DUP) on #353

13:30

SW13-305

SED13-305 - SAND (f-c), trace gravel (f, sa), grey/br loose, wet
- sample taken ~ 50m upstream
- 0.3 m below water level

14:05

SW13-351 - slight odour
- log jam d/s from sample point

SED13-351 - SAND (f-c), brown, loose, wet, trace organics (0.3m b water level)

- moss on rocks at water level, mod Hydrocarbon odour

SED13-351-02 - Sample of moss on rocks. + sediment
ORGANICS, some sand (f-c), dk br, loose, wet
- ODOUR

SW/SED13-352 (14:46) - no obvious ambient odour
- odour on moss on rocks
- sediment sample collected @ 0.3 m b water level.

SW/SED13-23 - no obvious ambient odour
slight odour on rocks on moss
- braid u/stream of sample location - flowing
- sample taken as well (as per instructions by Trevor + Dan
- Sample at site limited - some moss in sample
~ 50m upstream in braided channel - Sediment present
SED13-23-02 taken

LOG SED13-23
SAND (f-c) & ORGANICS (moss), brown, loose, wet - limited sample size

SED13-23-02
SAND (f-m), brown, loose, wet with organics (moss + wood debris)
- taken at water level - see photo

SW/SED13-03 - Confluence

- Ambient odour of HC
- slight sheen on water (where eddy circles on surface
- log jam & debris at sample location

SAND (f-m), some organics, brown, loose, wet.

615438 CMS K4052

Scope: Sampling @ Russells well
2 channels that feed well
1° - 1 from across road and upslope
2° - 1 from dyke to east @ high water
- conductivity tests

- Memo from Rob - well good candidate for trackin of fuel movement - 1

Qu
- Took ht @ closest point in creek
- almost identical elevation - late Sept

- SLE - Aug - diff 0.45 m elevation

- Russell happy - thinks water from alternative sources

- SW present now => dries up

High level = 1.6

Elevation of well
- taken on N edge (tape in " not cm)
TOC to water = 46" (lower lip)
TOC to water = 47" 1/4 (upper lip)
Casing Ht = 8" 1/4 (upper lip)

- Russel believes 1.6 - HWC (a)dders More, product mobilize - impact 3° input (from Creek to his well (input behind dyke)
- one day - green impact 3°

- Hit 1m => really bad odour & visible sheen
- last week (hit 1m)
- Next morning - gone

Qu * Why were we not here last week?

Qu - representative of sediment sample concerned => as stirring up

Qu - doesn't believe his well is representative

- Says Kick sample - porewater / sediment sample.

* he wants field comments included *

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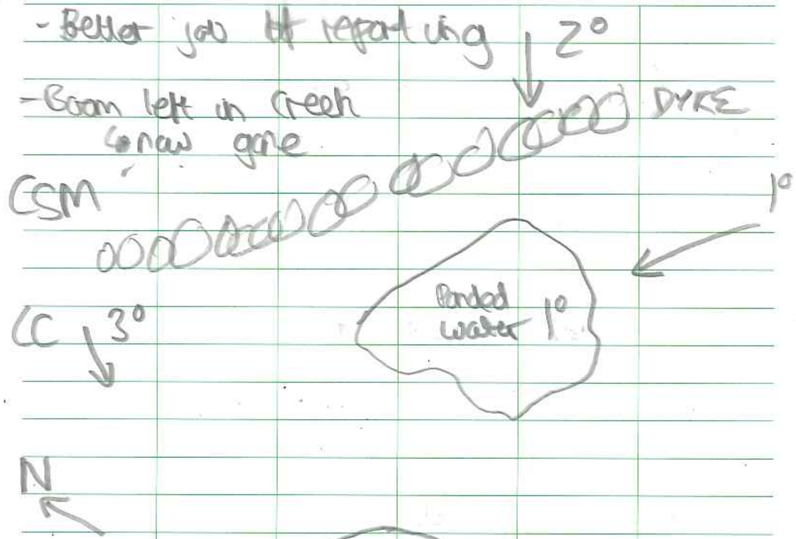
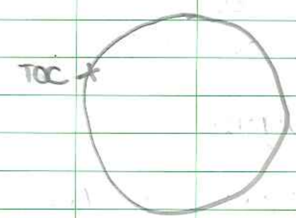
- Better job of reporting

- Boom left in creek (snow gone)





Elevation - Ponded water → TOC

- Rough sighting 3.5" ½

ID	Time	pH	Cond	ORP	Temp	NTU	DO
DW13-01	9:50	7.87	112	205.2	9.17	0.4	8.36
SW13-05	10:04	9.72	34	114	4.86	0.6	11.83
SW14-01	11:09	7.95	34	286.2	5.11	0.1	11.80

pH ? - lab analysis & check
- Bump test

10:26
SW14-01
- sampling in side channel
Thurs - 15 cm water
Russel - impacted sediment
→ - & ↑ turbulance may impact side channel
- stream keepers have sampled
- during spill in August

Sediment in side channel
- Odour in sediment

- top of side channel - water care
Russel observed product seeping out of sand
- stated product in gravel

SW14-01 taken 20 m from waterfall

- GPS # 001
- low energy back water

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SED14-01 - Taken at water level by SW14-01,
SAND (f-m), some silt, Gr,
loose, wet - HC odour
some organics

SED14-02 Taken at 0.2m below water surface
by SW14-01
SAND (f-m), brown, loose,
wet, trace organics - no odour observed

SED14-03 - Taken at 0.2m below water
surface d/stream of
log jam in side channel
- no odour observed

- water level dropping 140521

SE SAND (f-m) brown, loose,
wet, trace organics

SED14-04 SAND (f-c), yellow/Gr,
loose, wet slight odour
no sheen

- sample collected @ 0.75 cm
below existing water level
→ where Russel indicated
that last Thurs 'picked up
sediment + rainbow sheen
on water'

GPS #002
~ 40m d/stream from -01

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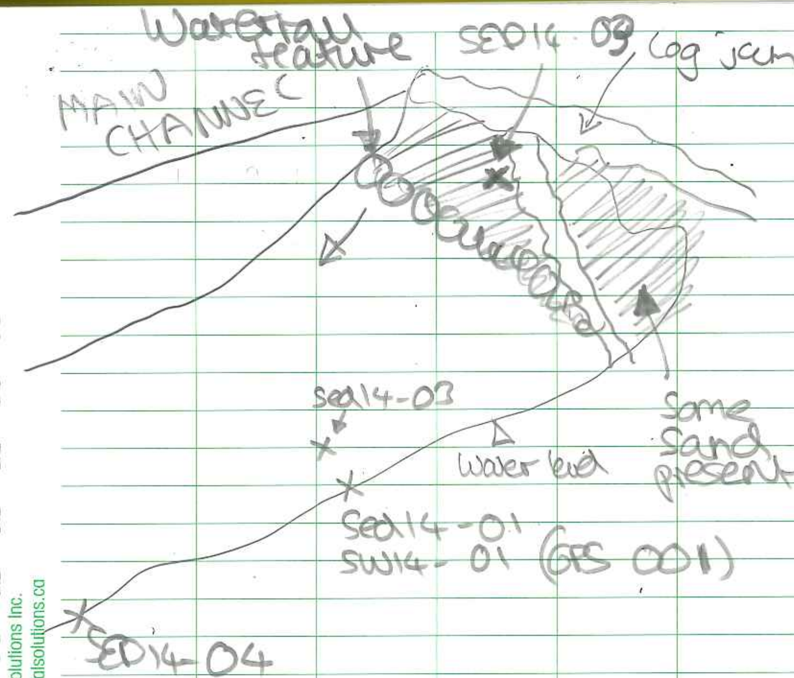

- Waterfall feature ~0.5m

15:00 Back at office
Ship samples

140522 CMS 615438

Scope: SW, PW & sed sampling
- Rafting

8:15 - Met craig at junction
- Drive to Man Amie
- Prep + H&S + truck drop

10:50 - launch

11:00 - SW13-A
- no ambient odour, no sheen
- no sediment at sample location
- sediment sample taken on the back channel
- SW13-A collected in area of lower flow
- water level in grass

SED13-A - SAND (f-m), grey / Gr, loose wet, trace organics & black flecs
- slight odour in sediment
- emulsified scum? / foam
- no ambient odour

- disturbed water in both locations - no sheen BUT foam, emulsified scum
- Kevin assessed area yesterday & noted ambient odour in side channel - not today

ID	pH	Cond	NTU	ORP	DO	Temp	time
SW13-A	7.75	57	0.4	189.9	10.85	8.70	11:00
SW13-SK	7.73	98	0.2	273.5	11.04	10.63	12:00
SW13-06	7.59	95	1.3	205.4	11.03	10.40	13:15
SW13-113	7.26	96	2.1	240.4	10.57	11.36	15:27

SW13-SK - accessed from South
- walk in
- photos of walk in
- no sheen or odour

1201 YSI screen appears 'burnt'

SED13-SK - SILT trace sand (f), dk brown, loose, wet
- taken at water line

- both samples collected in side channel above log jams (upstream of log jam)

- Could not access far side channel

* slight odour d/stream of SED13-SK in next main side channel

13:00
SW13-06

- SW13-06-01
- SW13-06-02 (1.0m b water level)
- SED13-06
  SILT, some organics, dk gr, loose, wet (organics are grass & rootlets)

- No ambient odour
- No odour in SW / SED
- No sheen
- No foam / scum.

SW13-113 / PW13-113 / SED13-113

3:37 - No ambient odour
no odour in sediment
no sheen

(PW) v. slow recharge @ end of HC sampling

6:00 - back in Nelson
6:30 - Truck empty + return

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APPENDIX II

Benthic Invertebrate Raw Data

Extrapolated Data - October 2013

	Extrapolated Data																			
Site:	SRBI 03 IMP	SRBI 04 IMB	SRBI 07 IMP	LCBI 05 REF	LCBI 03 IMP	SRBI 02-IMP	LSBI 00 REF	LCBI 04 REF	LCBI 01 IMP Hess #4	SRBI 05 IMP	SRBI 01 IMP	LCB 101 IMP Hess#3	SRBI 00 REF	SRBI 06 IMP	LCBI 01 IMP Hess#2	LCBI 01 IMP	LCBI 01 IMP Hess#1	LCBI 02 IMP	LCBI 01 IMP Hess#5	LCBI 00 IMP
Sampling Date:	23-Oct-13	23-Oct-13	23-Oct-13	17-Oct-13	17-Oct-13	21-Oct-13	17-Oct-13	17-Oct-13	18-Oct-13	18-Oct-13	16-Oct-13	18-Oct-13	22-Oct-13	21-Oct-13	18-Oct-13	18-Oct-13	18-Oct-13	16-Oct-13	18-Oct-13	16-Oct-13
# of Cells sorted (out of 100)	5.00	2.00	5.00	8.00	100.00	6.00	6.00	7.00	100.00	3.00	100.00	100.00	8.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Phylum: Arthropoda																				
Subphylum: Hexapoda																				
Class: Insecta																				
Order: Ephemeroptera		0	0	13	1	0	33	0	0	100	0	0	0	0	0	0	0	2	0	1
Family: Ameletidae		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ameletus sp.		0	0	88	3	0	17	0	0	0	2	0	0	4	0	1	0	20	0	0
Family: Baetidae	560	600	0	625	43	250	1417	1814	0	67	28	0	0	1	0	1	0	20	0	0
Accentrella sp.	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Baetis sp.	0	0	0	0	12	0	33	43	0	33	0	0	0	0	0	2	0	11	0	4
Family: Ephemerellidae	0	0	0	138	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Serratella sp.	3660	9300	140	0	0	3300	1783	214	0	5100	29	2	1313	69	0	0	0	0	0	0
Drunella sp.	80	0	0	125	0	17	0	57	0	0	0	0	13	17	0	0	0	0	0	0
Family: Heptageniidae	20	450	40	900	15	67	367	971	0	167	0	0	0	5	0	0	1	5	0	0
Cynigmula sp.	0	0	0	63	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Epeorus sp.	140	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Ironodes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Rhithrogena sp.	0	0	0	38	0	0	50	29	0	100	0	0	0	0	0	0	0	0	0	0
Family: Leptophlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paraleptophlebia sp.	300	2100	40	75	4	183	150	157	0	867	2	0	50	40	0	0	0	2	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Order: Plecoptera	0	50	0	125	9	0	17	71	0	0	0	0	0	0	0	2	0	5	0	0
Family: Chloroperlidae	0	50	0	38	8	0	17	29	1	0	0	0	0	3	0	0	0	0	0	1
Sweltsa sp.	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Leuctridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perlomyia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Nemouridae	0	0	1340	13	4	0	17	657	0	0	0	0	0	0	0	0	0	1	0	0
Zapada sp.	0	0	0	350	1	0	83	343	0	0	0	0	0	0	0	0	0	1	0	0
Visoka sp.	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Family: Peltoperlidae	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Perlidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
calineuria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Perlodidae	100	500	0	75	0	200	117	29	2	67	2	0	0	0	0	0	0	6	0	0
Skwala sp.	40	0	0	0	0	0	0	0	0	0	0	0	50	21	0	0	0	0	0	0
Family: Taeniopterygidae	0	0	20	725	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Order: Trichoptera	0	0	0	38	2	17	67	14	0	0	0	0	0	0	0	3	0	1	0	0
Family: Brachycentridae	0	0	0	0	0	0	0	0	0	67	0	0	0	20	0	0	0	0	0	0
Brachycentrus sp.	0	0	0	0	0	0	0	0	0	0	0	0	188	0	0	0	0	0	0	0
Micrasema sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Glossosomatidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glossosoma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Empididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Hydropsychidae	0	350	0	0	4	0	50	0	0	0	0	0	0	0	0	0	0	1	0	0
Arctopsyche sp.	0	0	0	0	0	0	17	14	0	0	0	0	0	0	0	0	0	0	0	0
Cheumatopsyche sp.	0	0	0	0	0	0	0	0	0	0	0	0	175	0	0	0	0	0	0	0
Parapsyche sp.	0	750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydropsyche sp.	220	0	0	0	0	183	167	0	0	67	2	0	113	10	0	0	0	0	0	1
Family: Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydroptila sp.	0	0	0	0	0	33	0	0	0	33	0	0	0	5	0	0	0	0	0	0
Family: Leptoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceraclea sp.	0	0	0	0	0	0	0	0	0	0	0	0	388	0	0	0	0	0	0	0
Family: Lepidostomatidae	0	0	0	0	0	0	0	29	0	0	0	0	0	3	0	0	0	0	0	0
Lepidostoma sp.	0	0	0	0	0	17	350	0	0	0	0	0	38	0	0	0	0	0	0	0
Family: Rhyacophilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhyacophila sp.	60	0	0	100	9	0	0	29	0	0	6	0	0	21	0	1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Order: Diptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Ceratopogonidae	0	0	80	13	3	0	0	14	0	0	1	1	0	0	0	3	0	2	0	0
Family: Chironomidae	280	850	3780	113	172	617	383	257	11	3000	176	4	463	183	2	26	0	52	2	18
Family: Empididae	0	0	0	0	0	0	0	0	0	0	0	0	38	16	0	0	0	0	0	0
Chelifera/ Metachela	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Family: Psychodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pericoma sp.	0	0	0	113	0	0	0	57	0	0	0	0	0	0	1	0	0	0	0	1
Family: Simuliidae	20	500	0	0	1	167	17	0	0	33	14	0	0	0	0	0	0	0	0	0
Family: Tipulidae		0	40	38	1	0	0	0	0	33	0	0	13	2	0	0	0	0	0	1
Hexatoma sp.		0	0	0	0	0	0	14	0	0	0	1	0	0	0	0	0	0	0	0
Pedicia sp.		0	0	13	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Dicronata sp		0	0	0	0	33	0	43	0	167	4	0	0	0	0	0	0	0	0	0

Site:	SRBI 03 IMP	SRBI 04 IMB	SRBI 07 IMP	LCBI 05 REF	LCBI 03 IMP	SRBI 02-IMP	LSBI 00 REF	LCBI 04 REF	LCBI 01 IMP Hess #4	SRBI 05 IMP	SRBI 01 IMP	LCB 101 IMP Hess#3	SRBI 00 REF	SRBI 06 IMP	LCBI 01 IMP Hess#2	LCBI 01 IMP	LCBI 01 IMP Hess#1	LCBI 02 IMP	LCBI 01 IMP Hess#5	LCBI 00 IMP
Sampling Date:	23-Oct-13	23-Oct-13	23-Oct-13	17-Oct-13	17-Oct-13	21-Oct-13	17-Oct-13	17-Oct-13	18-Oct-13	18-Oct-13	16-Oct-13	18-Oct-13	22-Oct-13	21-Oct-13	18-Oct-13	18-Oct-13	18-Oct-13	16-Oct-13	18-Oct-13	16-Oct-13
# of Cells sorted (out of 100)	5.00	2.00	5.00	8.00	100.00	6.00	6.00	7.00	100.00	3.00	100.00	100.00	8.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Order: Coleoptera		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Elmidae	480	150	0	0	1	150	50	29	0	367	32	0	275	24	0	0	0	0	0	2
lara sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	1
narpus sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Optioservus sp.		0	0	0	0	0	0	0	0	0	0	0	638	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Gammaridae		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gammorus sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrachnida	160	50	40	50	2	17	50	0	2	100	6	0	13	7	0	1	0	0	0	4
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Class: CLITELLATA		0	160	13	0	0	0	0	1	0	0	1	0	3	1	6	2	1	1	3
Order: Haplotaxida		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Enchytraeidae		50	0	0	2	0	17	114	2	0	8	0	0	1	5	1	0	11	2	2
Family: Naididae		0	700	0	14	0	100	0	7	0	17	1	0	0	1	13	1	10	1	0
Totals:	6120	15750	6380	3900	327	5250	5367	5071	26	10367	340	10	3763	455	10	61	4	156	7	40

Extrapolated Data - October 2014

	Extrapolated														
Site:	SRBI 03	SRBI 04	SRBI 07	LCBI 05	LCBI 03	SRBI 02	LCBI 00	LCBI 04	SRBI 05	SRBI 01	SRBI 06A	SRBI 06B	LCBI 01	LCBI 02	LSBI 00
Sampling Date:	21-Oct-14	21-Oct-14	21-Oct-14	23-Oct-14	23-Oct-14	Oct 21,2014	22-Oct-14	23-Oct-14	21-Oct-14	22-Oct-14	22-Oct-14	22-Oct-14	22-Oct-14	23-Oct-14	22-Oct-14
# of Cells sorted (out of 100)	7	8	17	7	9	11	8	7	10	16	100	9	6	12	100
Phylum: Arthropoda															
Subphylum: Hexapoda															
Class: Insecta															
Order: Ephemeroptera															
Family: Ameletidae															
Ameletus sp.		13	12	114		9	25	214			4			75	
Family: Baetidae															
Accentrella sp.															
Baetis sp.	100	113		3114	1578	373	2500	1357	240	450		456	2517	1342	1
Family: Ephemerellidae					44			14						8	
Drunella sp.	171	100	371	14	11	91	13	29	60	31	17	44	83	25	
Ephemerlla sp.															
Serratella sp.	1471	1038	241	43	11	1155	75		1550	325	122	622	33	17	1
Family: Heptageniidae	14	25	29	343	400	64	438	514	290	31	15	178	850	292	
Cynigmula sp.															
Epeorus sp.				14	400		225	429				11	300	192	
Ironodes sp.															
Rhithrogena sp.				43		9		43					17	17	
Family: Leptophlebiidae															
Paraleptophlebia sp.	171	238	406	129	311	136		143	380	6	82	189	17	25	
Order: Plecoptera		63			78			114	50				17		
Family: Capniidae															
Family: Chloroperlidae	29		47	14	11				80			22	33		
Sweltsa sp.		50		57		82		86					17		
Family: Leuctridae															
Perlomyia sp.															
Family: Nemouridae				14										17	
Nemoura sp.															
Visoka sp.														17	
Zapada sp.		13		471	67		150	300					500	42	
Family: Peltoperlidae															
Family: Perlidae		13						71	40			11	17		
Calineuria sp.									10						
Claassenia sp.		150										22			
Doroneuria sp.															
Hesperoperla sp.		75				9	13					11			
Family: Perlodidae	186	25	24		44	36	75			44	2	67		8	
Skwala sp.	43					155	13			31		11	17		
Perlinodes sp.							13								
Isoperla sp.															
Family: Pteronarcyidae															
Pteronarcys sp.	14	13										11			
Pteronarcella sp.									60						
Family: Taeniopterygidae				86	11		75	157					17	17	

Site:	SRBI 03	SRBI 04	SRBI 07	LCBI 05	LCBI 03	SRBI 02	LCBI 00	LCBI 04	SRBI 05	SRBI 01	SRBI 06A	SRBI 06B	LCBI 01	LCBI 02	LSBI 00
Sampling Date:	21-Oct-14	21-Oct-14	21-Oct-14	23-Oct-14	23-Oct-14	Oct 21,2014	22-Oct-14	23-Oct-14	21-Oct-14	22-Oct-14	22-Oct-14	22-Oct-14	22-Oct-14	23-Oct-14	22-Oct-14
# of Cells sorted (out of 100)	7	8	17	7	9	11	8	7	10	16	100	9	6	12	100
Doddsia sp.															
Order: Trichoptera												22			
Family: Brachycentridae															
Brachycentrus sp.															
Micrasema sp.												122			
Family: Glossosomatidae															
Glossosoma sp.	43	88						14	70			11	17		
Family: Hydropsychidae			6				13				3				
Arctopsyche sp.				14	11			14					17		
Cheumatopsyche sp.															
Hydropsyche sp.	2186	1763			11	591	263		200	681		733	217	8	
Parapsyche sp.															
Family: Hydroptilidae															
Hydroptila sp.	14											22			5
Stactobiella sp.			24												
Family: Leptoceridae															
Ceraclea sp.															
Family: Lepidostomatidae															
Lepidostoma sp.		50				182			260		8	156			
Family: Limnephilidae												11		50	
Ecclisomyia sp.															
Family: Rhyacophilidae															
Rhyacophila sp.	86	75	12	86	89	45	25	57	10	19	2	56	17		3
Order: Diptera															
Family: Ceratopogonidae									20						
Family: Chironomidae	143	88	800	257	244	173	63	386	80	44	30	367	67	8	1
Family: Empididae	29			114	11		75	43			9		367	67	
Chelifera/ Metachela				14					30		1	11			
Roederiodes sp.															
Hemerodromia sp.															
Chelitera sp.															
Family: Psychodidae															
Pericoma sp.								14						8	
Family: Simuliidae	57	363				9	13	14		388		44	17		
Family: Tanyderidae															
Protanyderus sp.	14														1
Family: Tipulidae															
Antocha sp.															
Hexatoma sp.		25													
Pedicia sp.															
Dicronata sp				29									17	8	
Order: Coleoptera															
Family: Elmidae			35			82				6					
lara sp.															
narpus sp.															
Optioservus sp.															

Site:	SRBI 03	SRBI 04	SRBI 07	LCBI 05	LCBI 03	SRBI 02	LCBI 00	LCBI 04	SRBI 05	SRBI 01	SRBI 06A	SRBI 06B	LCBI 01	LCBI 02	LSBI 00
Sampling Date:	21-Oct-14	21-Oct-14	21-Oct-14	23-Oct-14	23-Oct-14	Oct 21,2014	22-Oct-14	23-Oct-14	21-Oct-14	22-Oct-14	22-Oct-14	22-Oct-14	22-Oct-14	23-Oct-14	22-Oct-14
# of Cells sorted (out of 100)	7	8	17	7	9	11	8	7	10	16	100	9	6	12	100
Zaitzevia sp.	614	50							380		14	456			5
Family: Haliplidae															
Brychius sp.															
Amphipoda															
Family: Gammaridae															
Gammorus sp.															
Cl. ARACHNIDA															
Hydrachnida	14	38	82	29		18	13	43		6	9	111	17		
Cl. CLITELLATA															
Order: Haplotaxida															
Family: Enchytraeidae								229						333	
Family: Naididae															
Hirudinidae	14	13	35							6		44		8	
Totals:	5414	4475	2124	5000	3333	3218	4075	4286	3810	2069	318	3822	5183	2583	17

APPENDIX III

Benthic Invertebrate Regression Model Analysis Summary

Lemon Creek Analysis - DRAFT

1 Data Overview

Table 1 lists the input data while Table 2 and 3 provide the Lemon Creek and Slocan River mean values for control and exposure sites in 2013 and 2014. Figure 1 shows each Lemon Creek outcomes in 2013 and 2014 with control data in green and exposure data in blue. Figures 2 and 3 show the outcomes by distance for Lemon Creek and Slocan River respectively. In order to focus in on the majority of Slocan River sites, an additional set of plots (Figure 4) are provided which restrict the x axis to distances between 3 and 10 km.

Table 1: Raw Data

Location	Site	Year	EPT Abund	Tot Abund	EPT Rich	Tot Rich	% EPT ind	% Oligo Chiro	Distance
Slocan River	SRBI06	2013	219	452	12	18	0.49	0.41	20.50
Slocan River	SRBI05	2013	6567	10267	8	13	0.64	0.29	9.00
Slocan River	SRBI04	2013	14100	15700	7	12	0.90	0.06	6.20
Slocan River	SRBI03	2013	5180	6120	7	11	0.85	0.05	5.80
Slocan River	SRBI07	2013	1580	6220	5	10	0.25	0.72	5.20
Slocan River	SRBI02	2013	4250	5234	8	13	0.81	0.12	5.20
Slocan River	SRBI01	2013	78	340	8	17	0.23	0.59	4.20
Lemon Creek	LCBI00	2013	7	36	4	10	0.19	0.56	3.80
Lemon Creek	LCBI01	2013	5	50	3	9	0.10	0.80	3.20
Lemon Creek	LCBI02	2013	70	147	7	12	0.48	0.50	1.50
Lemon Creek	LCBI03	2013	119	315	10	18	0.38	0.60	1.00
Lemon Creek	LCBI04	2013	4443	4986	10	16	0.89	0.07	-0.30
Lemon Creek	LCBI05	2013	3375	3713	10	15	0.91	0.03	-1.10
Slocan River	SRBI06	2014	255	318	8	12	0.80	0.09	20.50
Slocan River	SRBI05	2014	3250	3760	11	15	0.86	0.02	9.00
Slocan River	SRBI04	2014	3838	4413	14	20	0.87	0.02	6.20
Slocan River	SRBI03	2014	4529	5414	11	18	0.84	0.03	5.80
Slocan River	SRBI07	2014	1171	2124	9	13	0.55	0.38	5.20
Slocan River	SRBI02	2014	2936	3218	11	15	0.91	0.05	5.20
Slocan River	SRBI01	2014	1619	2069	7	12	0.78	0.02	4.20
Lemon Creek	LCBI00	2014	3913	4075	10	14	0.96	0.02	3.80
Lemon Creek	LCBI01	2014	4683	5167	12	17	0.91	0.01	3.20
Lemon Creek	LCBI02	2014	2150	2583	10	16	0.83	0.13	1.50
Lemon Creek	LCBI03	2014	3000	3256	10	12	0.92	0.08	1.00
Lemon Creek	LCBI04	2014	3443	4171	12	18	0.83	0.15	-0.30
Lemon Creek	LCBI05	2014	4557	5000	10	14	0.91	0.05	-1.10

Table 2: Mean Values for Lemon Creek Control and Exposure Sites in 2013 and 2014. Harmonic Mean used for Abundance and Richness

Exposure	Year	EPT Abund	EPT Rich	Tot Abund	Tot Rich	Percent Oligo-Chiro	Percent Indiv
0	2013	3872.35	10.00	4302.68	15.49	0.05	0.90
1	2013	23.24	5.38	95.55	11.81	0.61	0.29
0	2014	3961.03	10.95	4566.73	15.87	0.10	0.87
1	2014	3297.22	10.47	3647.91	14.62	0.06	0.90

Table 3: Mean Values for Slocan River Exposure Sites in 2013 and 2014. Harmonic Mean used for Abundance and Richness

Exposure	Year	EPT Abund	EPT Rich	Tot Abund	Tot Rich	Percent Oligo-Chiro	Percent Indiv
1	2013	1772.73	7.63	3369.92	13.16	0.32	0.60
1	2014	1870.74	9.91	2356.88	14.75	0.09	0.80

2 Regression Models

Generalized linear mixed models (GLMMs) are a flexible class of regression models which encompass models for both normally distributed data and count or proportion data. They are termed mixed models as they include both fixed effects and random effects which can accommodate correlated data that may arise, for example, from repeated sampling. See Jiang (2007), Pinheiro and Bates (2000) or Stroup (2012) for a detailed discussions of GLMMs. Here GLMMs were fit to the benthic data using the glmer function from the lme4 library (R version 3.2.5, R Core Team, 2016). In order to account for repeated sampling at each location, site was included as random effect. Two sets of fixed effects models were fit to assess the extent to which the Lemon Creek area is in recovery following the environmental contamination in 2013.

First, a BACI approach was used to group observations into exposure or control and compare the change from 2013 to 2014 in each group. If the system is recovering, a larger change is expected from 2013 to 2014 at the exposure sites. This effect was tested via the interaction between group and year.

Another indication of recovery can be obtained by considering the gradient of change in sample data collected at increasing distances from the spill. This was carried out for both Lemon Creek and Slocan River data. If the system is in recovery, the profile along the creek and/or river is expected to differ between 2014 and 2013. Thus, the interaction between distance and year was tested to determine if the gradient of change differed between the 2 years. Lemon Creek and Slocan River were assessed separately in order to avoid confounding differential flow regime effects. Distances along the Slocan River were spread over a larger area with one sites at large distance of 20.5 km. In order to ensure the results were not unduly influenced by this potential leverage points, log distance was also considered. For Slocan River, a sensitivity analysis was run using log(distance+20) in place of distance in the GLMM. This transformation pulled the large distance in closer to the other values and reduced it's leverage. An alternative approach would be to run the analyses on the subset of data with distances less than 10 km.

As noted above, GLMMs can use one of several distributions. Abundance and richness counts were modelled using a Poisson distribution with a log link while the percent Oligo-Chiro and percent EPT individuals were modelled using a binomial distribution with a logit link function. Rather than model percent, the Oligo-Chiro and EPT individual counts were input directly along with the non-Oligo-Chiro and non-EPT individual counts respectively. This method accounts for the total number of organisms available for estimating each percentage.

The problem of over-dispersion often arises when modelling count data. Unlike the normal distribution, which allows the mean and variance to be estimated separately, standard count distributions, such as the Poisson and binomial, impose a link between the mean and variance parameters. When the variance exceeds that imposed by the model, the data are considered over-dispersed. The problem is that over-dispersion can lead to biased p-values. Apparent over-dispersion can be addressed by including appropriate covariates in the model. However, here the data for several outcomes remain over-dispersed even after accounting for available covariates. Alternative distributions, such as the negative binomial distribution, are commonly used to address over-dispersion in generalized linear models (GLMs). Although such alternative models are not available for GLMMs in the lme4 library through the glmer function, alternatives methods could be explored to address over-dispersion and obtain more accurate p-values.

No correction was been made for multiple testing. Regression results are presented to 2 decimal places with p-values of 0.00 indicating $p<0.005$. Given that the data for several outcomes (EPT and total abundance) are over-dispersed and that there are a large number of tests carried out, p-values need to be interpreted with caution.

2.1 Reverse BACI Analysis

Statistical results for each outcome are presented in tables below. The predicted values are superimposed on the raw data plots in Figure 1. Predicted values from the BACI model are indicated using colored lines (green for control; blue for exposure). Since site is included as a random effect, each site has a unique intercept (mean value). For plotting purposes, the random effect for LCBI03 was used to obtain predicted values for exposure and control in 2013 and 2014. Due to the inclusion of a random site effect, the overall level of the predicted values differ for each site but the pattern remains the same across all sites.

Table 4: BACI Results for EPT Abundance

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	8.27	0.16	51.38	0.00
Exposure	-4.39	0.21	-20.99	0.00
year.fac2014	0.02	0.02	1.45	0.15
Exposure:year.fac2014	4.20	0.07	57.72	0.00

Table 5: Anova Results for BACI on EPT Abundance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ept.abund.baci.lc.drop	4.00	11395.38	11397.32	-5693.69	11387.38			
fit.ept.abund.baci.lc	5.00	740.71	743.14	-365.36	730.71	10656.67	1.00	0.00

Table 6: BACI Results for EPT Richness

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.30	0.22	10.30	0.00
Exposure	-0.51	0.30	-1.69	0.09
year.fac2014	0.10	0.31	0.31	0.76
Exposure:year.fac2014	0.46	0.40	1.16	0.25

Table 7: Anova Results for BACI on EPT Richness

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ept.rich.baci.lc.drop	4.00	62.61	64.55	-27.31	54.61			
fit.ept.rich.baci.lc	5.00	63.27	65.69	-26.63	53.27	1.34	1.00	0.25

Table 8: BACI Results for Total Abundance

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	8.38	0.14	61.81	0.00
Exposure	-3.48	0.17	-20.35	0.00
year.fac2014	0.05	0.01	3.53	0.00
Exposure:year.fac2014	3.26	0.05	70.93	0.00

Table 9: Anova Results for BACI on Total Abundance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.tot.abund.baci.lc.drop	4.00	10862.77	10864.71	-5427.38	10854.77			
fit.tot.abund.baci.lc	5.00	900.83	903.26	-445.42	890.83	9963.94	1.00	0.00

Table 10: BACI Results for Total Richness

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.74	0.18	15.26	0.00
Exposure	-0.24	0.23	-1.03	0.31
year.fac2014	0.03	0.25	0.13	0.90
Exposure:year.fac2014	0.15	0.32	0.48	0.63

Table 11: Anova Results for BACI on Total Richness

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.tot.rich.baci.lc.drop	4.00	67.35	69.29	-29.68	59.35			
fit.tot.rich.baci.lc	5.00	69.12	71.54	-29.56	59.12	0.24	1.00	0.63

Table 12: BACI Results for Percent Oligo-Chiro

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-3.03	0.56	-5.44	0.00
Exposure	2.88	0.69	4.18	0.00
year.fac2014	0.71	0.06	11.85	0.00
Exposure:year.fac2014	-3.68	0.12	-31.35	0.00

Table 13: Anova Results for BACI on Percent Oligo-Chiro

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.oligo.baci.lc.drop	4.00	1234.38	1236.32	-613.19	1226.38			
fit.oligo.baci.lc	5.00	249.78	252.21	-119.89	239.78	986.60	1.00	0.00

Table 14: BACI Results for Percent EPT Individuals

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.25	0.31	7.32	0.00
Exposure	-2.71	0.39	-7.00	0.00
year.fac2014	-0.33	0.05	-6.79	0.00
Exposure:year.fac2014	3.15	0.11	28.74	0.00

Table 15: Anova Results for BACI on Percent EPT Individuals

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ind.baci.lc.drop	4.00	1088.36	1090.30	-540.18	1080.36			
fit.ind.baci.lc	5.00	239.07	241.49	-114.53	229.07	851.29	1.00	0.00

Table 16: Predicted Values using Random Site Effect for LCBI03

Exposure	Year	EPT Abund	EPT Rich	Tot Abund	Tot Rich	Perc Oligo-Chiro	Perc EPT ind
0.00	2013	3630.39	10.00	4084.01	15.50	0.08	0.91
1.00	2013	44.97	6.00	125.27	12.25	0.61	0.40
0.00	2014	3714.90	11.00	4305.60	16.00	0.15	0.88
1.00	2014	3075.46	10.50	3447.44	14.75	0.07	0.92

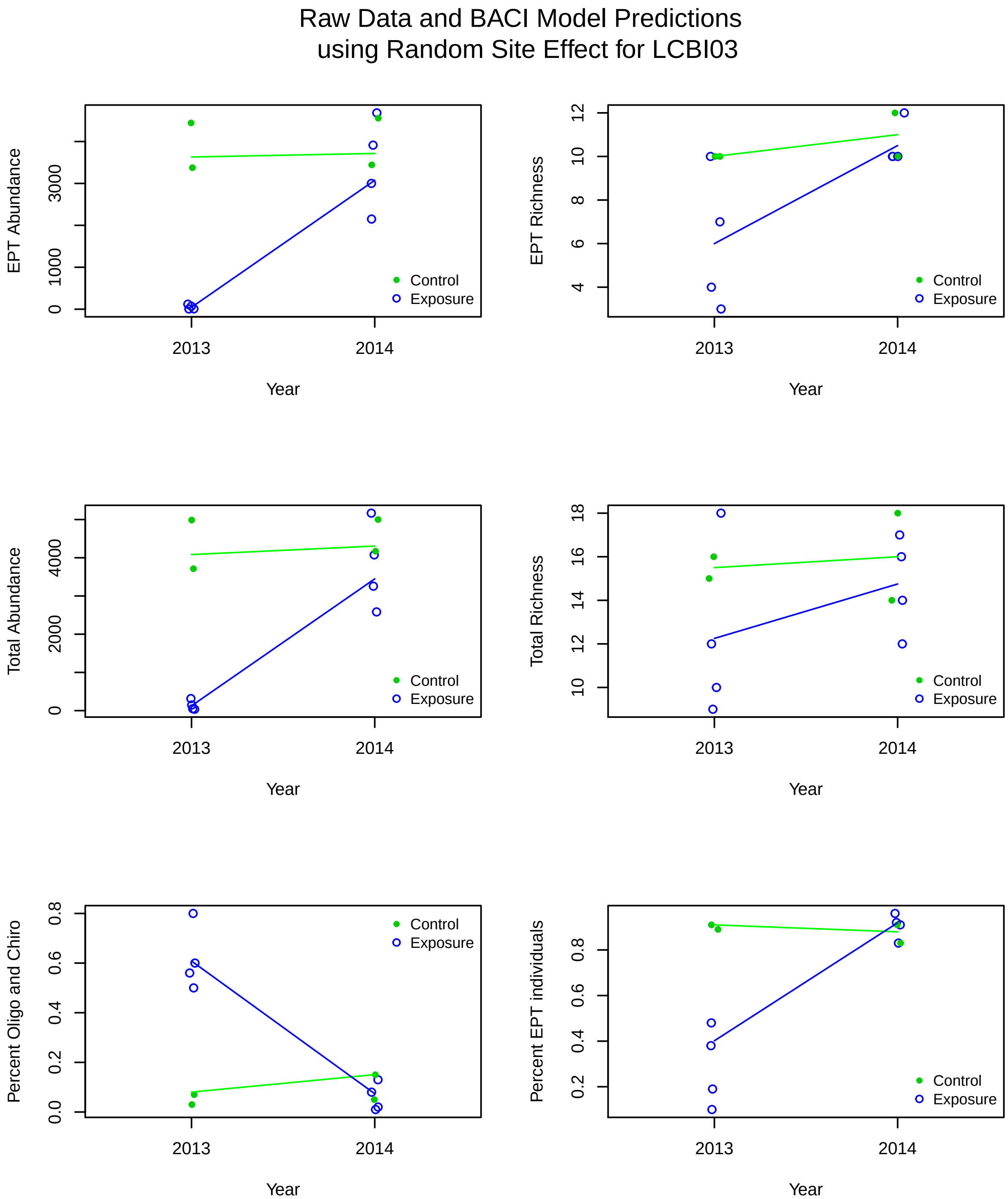

Figure 1: Raw Data and Predictions based on BACI Analysis

2.2 Analysis using Distance

Distance analyses were carried out separately for Lemon Creek and Slocan River data. Statistical analysis results are presented in tables below. The predicted values from the GLMM models are superimposed on the raw data plots in Figures 2 and 3. As for the BACI analysis, one representative site was chosen for the purpose of plotting predicted values. For Lemon Creek, LCBI03 was used; for Slocan River, SRBI03 was used.

Table 17: Lemon Creek Distance Results for EPT Abundance

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	7.26	0.16	45.47	0.00
Distance	-1.03	0.07	-13.91	0.00
year.fac2014	0.88	0.02	53.26	0.00
Distance:year.fac2014	1.04	0.02	63.01	0.00

Table 18: Anova Results for Lemon Creek EPT Abundance by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ept.abund.dist.lc.drop	4.00	11401.97	11403.91	-5696.98	11393.97			
fit.ept.abund.dist.lc	5.00	2621.93	2624.35	-1305.96	2611.93	8782.04	1.00	0.00

Table 19: Lemon Creek Distance Results for EPT Richness

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.22	0.16	13.50	0.00
Distance	-0.22	0.09	-2.39	0.02
year.fac2014	0.15	0.23	0.65	0.52
Distance:year.fac2014	0.22	0.12	1.90	0.06

Table 20: Anova Results for Lemon Creek EPT Richness by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ept.rich.dist.lc.drop	4.00	61.73	63.67	-26.87	53.73			
fit.ept.rich.dist.lc	5.00	60.05	62.48	-25.03	50.05	3.68	1.00	0.06

Table 21: Lemon Creek Distance Results for Total Abundance

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	7.47	0.15	49.92	0.00
Distance	-0.92	0.07	-13.31	0.00
year.fac2014	0.79	0.01	54.73	0.00
Distance:year.fac2014	0.92	0.01	67.23	0.00

Table 22: Anova Results for Lemon Creek Total Abundance by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.tot.abund.dist.lc.drop	4.00	10870.38	10872.32	-5431.19	10862.38			
fit.tot.abund.dist.lc	5.00	2112.91	2115.34	-1051.46	2102.91	8759.47	1.00	0.00

Table 23: Lemon Creek Distance Results for Total Richness

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.72	0.13	20.92	0.00
Distance	-0.11	0.07	-1.69	0.09
year.fac2014	-0.00	0.19	-0.01	0.99
Distance:year.fac2014	0.11	0.09	1.24	0.21

Table 24: Anova Results for Lemon Creek Total Richness by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.tot.rich.dist.lc.drop	4.00	66.93	68.87	-29.46	58.93			
fit.tot.rich.dist.lc	5.00	67.38	69.81	-28.69	57.38	1.55	1.00	0.21

Table 25: Lemon Creek Distance Results for Percent Oligo-Chiro

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-2.12	0.34	-6.29	0.00
Distance	1.06	0.16	6.61	0.00
year.fac2014	-0.19	0.05	-3.56	0.00
Distance:year.fac2014	-1.50	0.05	-28.63	0.00

Table 26: Anova Results for Lemon Creek Percent Oligo-Chiro by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.olig.dist.lc.drop	4.00	1232.51	1234.45	-612.26	1224.51			
fit.olig.dist.lc	5.00	347.24	349.66	-168.62	337.24	887.28	1.00	0.00

Table 27: Lemon Creek Distance Results for Percent EPT Individuals

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.48	0.19	7.80	0.00
Distance	-0.91	0.10	-9.44	0.00
year.fac2014	0.48	0.04	10.80	0.00
Distance:year.fac2014	1.08	0.05	23.18	0.00

Table 28: Anova Results for Lemon Creek Percent EPT Individuals by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ind.dist.lc.drop	4.00	1087.56	1089.50	-539.78	1079.56			
fit.ind.dist.lc	5.00	469.36	471.78	-229.68	459.36	620.21	1.00	0.00

Table 29: Predicted Values using Random Site Effect for LCBI03

Distance	Year	EPT Abund	EPT Rich	Perc Oligo-Chiro	Perc EPT ind
-1.10	2013	3453.62	11.67	0.06	0.92
-0.30	2013	1520.20	9.79	0.13	0.85
1.00	2013	400.68	7.37	0.37	0.64
1.50	2013	239.92	6.61	0.49	0.53
3.20	2013	41.95	4.56	0.85	0.20
3.80	2013	22.67	4.00	0.92	0.12
-1.10	2014	2654.05	10.61	0.21	0.86
-0.30	2014	2679.29	10.63	0.16	0.87
1.00	2014	2720.83	10.66	0.10	0.90
1.50	2014	2736.97	10.67	0.08	0.90
3.20	2014	2792.59	10.71	0.04	0.93
3.80	2014	2812.48	10.72	0.03	0.93

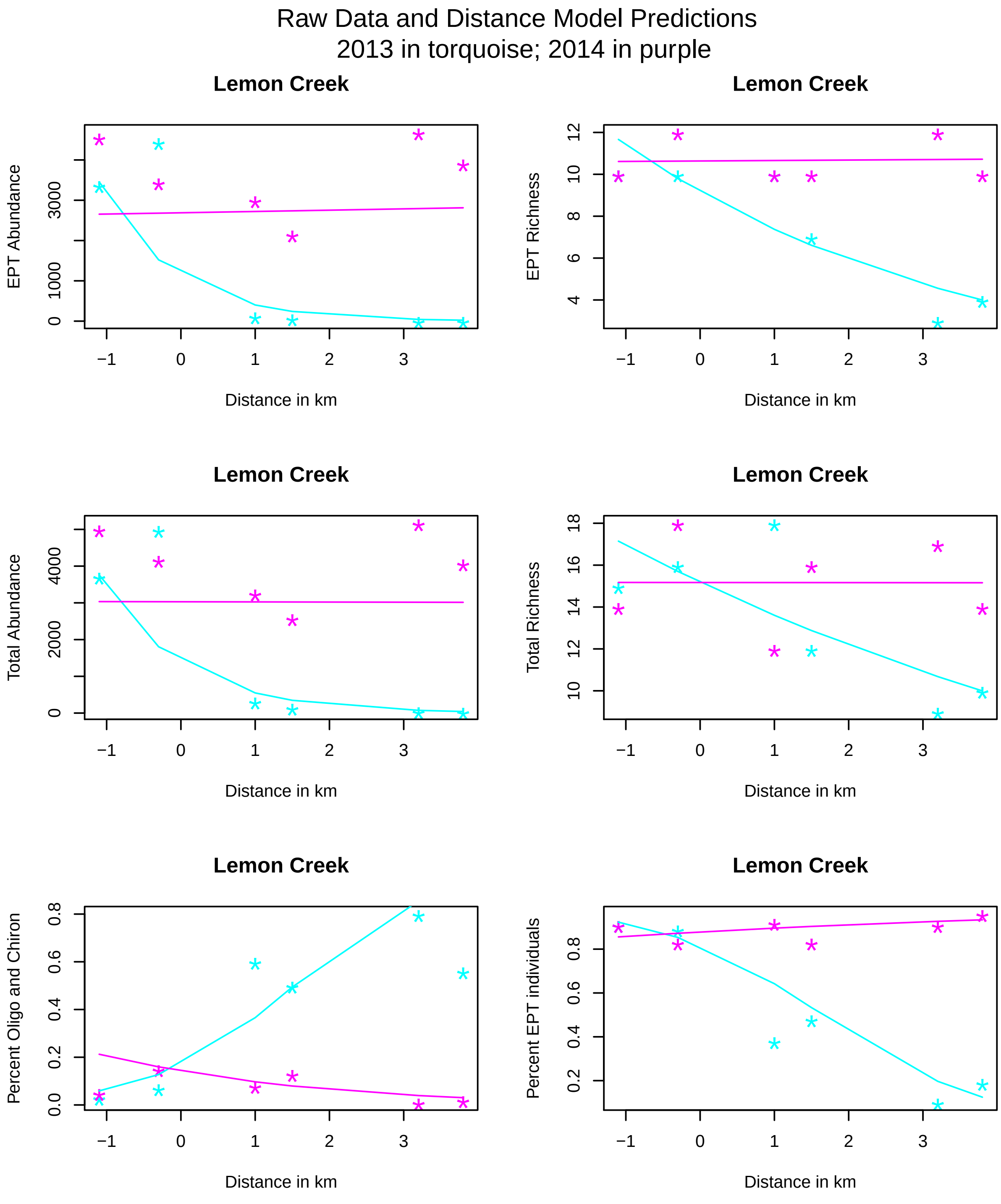

Figure 2: Lemon Creek Plots by Distance. Negative distances represent locations upstream of the spill.

Table 30: Slocan River Distance Results for EPT Abundance

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	8.95	0.62	14.43	0.00
Distance	-0.12	0.06	-1.93	0.05
year.fac2014	-0.19	0.04	-5.21	0.00
Distance:year.fac2014	-0.06	0.01	-11.80	0.00

Table 31: Anova Results for Slocan River EPT Abundance by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ept.abund.dist.sr.drop	4.00	5427.37	5429.92	-2709.68	5419.37			
fit.ept.abund.dist.sr	5.00	5279.12	5282.31	-2634.56	5269.12	150.25	1.00	0.00

Table 32: Slocan River Distance Results for EPT Richness

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.76	0.24	7.27	0.00
Distance	0.03	0.02	1.58	0.11
year.fac2014	0.64	0.33	1.98	0.05
Distance:year.fac2014	-0.05	0.03	-1.44	0.15

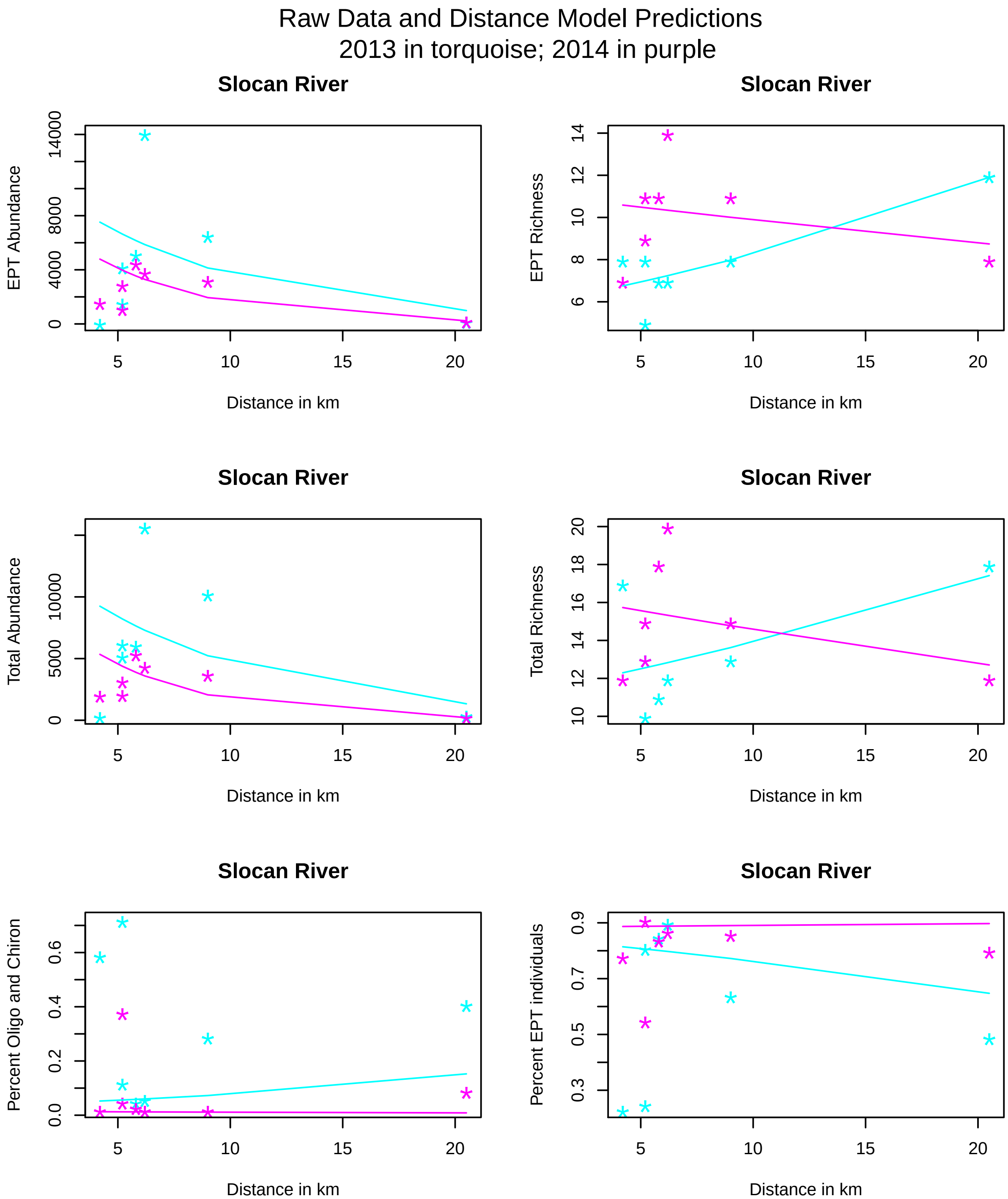

Figure 3: Slocan River Plots by Distance

Table 33: Anova Results for Slocan River EPT Richness by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ept.rich.dist.sr.drop	4.00	70.35	72.91	-31.18	62.35			
fit.ept.rich.dist.sr	5.00	70.27	73.47	-30.13	60.27	2.08	1.00	0.15

Table 34: Slocan River Distance Results for Total Abundance

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	9.34	0.54	17.41	0.00
Distance	-0.12	0.06	-2.13	0.03
year.fac2014	-0.21	0.03	-6.89	0.00
Distance:year.fac2014	-0.08	0.00	-17.22	0.00

Table 35: Anova Results for Slocan River Total Abundance by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.tot.abund.dist.sr.drop	4.00	5851.41	5853.97	-2921.71	5843.41			
fit.tot.abund.dist.sr	5.00	5521.42	5524.62	-2755.71	5511.42	331.99	1.00	0.00

Table 36: Slocan River Distance Results for Total Richness

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.42	0.19	13.05	0.00
Distance	0.02	0.02	1.20	0.23
year.fac2014	0.39	0.26	1.52	0.13
Distance:year.fac2014	-0.03	0.03	-1.30	0.19

Table 37: Anova Results for Slocan River Total Richness by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.tot.rich.dist.sr.drop	4.00	78.19	80.75	-35.10	70.19			
fit.tot.rich.dist.sr	5.00	78.48	81.68	-34.24	68.48	1.71	1.00	0.19

Table 38: Slocan River Distance Results for Percent Oligo-Chiro

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.82	0.83	-2.19	0.03
Distance	0.07	0.09	0.84	0.40
year.fac2014	-1.04	0.10	-9.93	0.00
Distance:year.fac2014	-0.10	0.02	-6.24	0.00

Table 39: Anova Results for Slocan River Percent Oligo-Chiro by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.olig.dist.sr.drop	4.00	792.90	795.45	-392.45	784.90			
fit.olig.dist.sr	5.00	747.41	750.61	-368.71	737.41	47.49	1.00	0.00

Table 40: Slocan River Distance Results for Percent EPT Individuals

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.13	0.61	1.86	0.06
Distance	-0.05	0.06	-0.84	0.40
year.fac2014	0.33	0.07	4.82	0.00
Distance:year.fac2014	0.06	0.01	6.26	0.00

Table 41: Anova Results for Slocan River Percent EPT Individuals by Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ind.dist.sr.drop	4.00	1192.39	1194.94	-592.19	1184.39			
fit.ind.dist.sr	5.00	1153.31	1156.50	-571.65	1143.31	41.08	1.00	0.00

Table 42: Predicted Values using Random Site Effect for SRBI03

Distance	Year	EPT Abund	EPT Rich	Perc Oligo-Chiro	Perc EPT ind
4.20	2013	7522.84	6.75	0.05	0.81
5.20	2013	6641.07	6.99	0.06	0.81
5.80	2013	6162.42	7.14	0.06	0.80
6.20	2013	5862.65	7.24	0.06	0.80
9.00	2013	4135.15	7.98	0.07	0.77
20.50	2013	985.91	11.90	0.15	0.65
4.20	2014	4788.81	10.59	0.01	0.89
5.20	2014	3968.89	10.46	0.01	0.89
5.80	2014	3545.96	10.39	0.01	0.89
6.20	2014	3289.36	10.34	0.01	0.89
9.00	2014	1944.23	10.01	0.01	0.89
20.50	2014	224.30	8.74	0.01	0.90

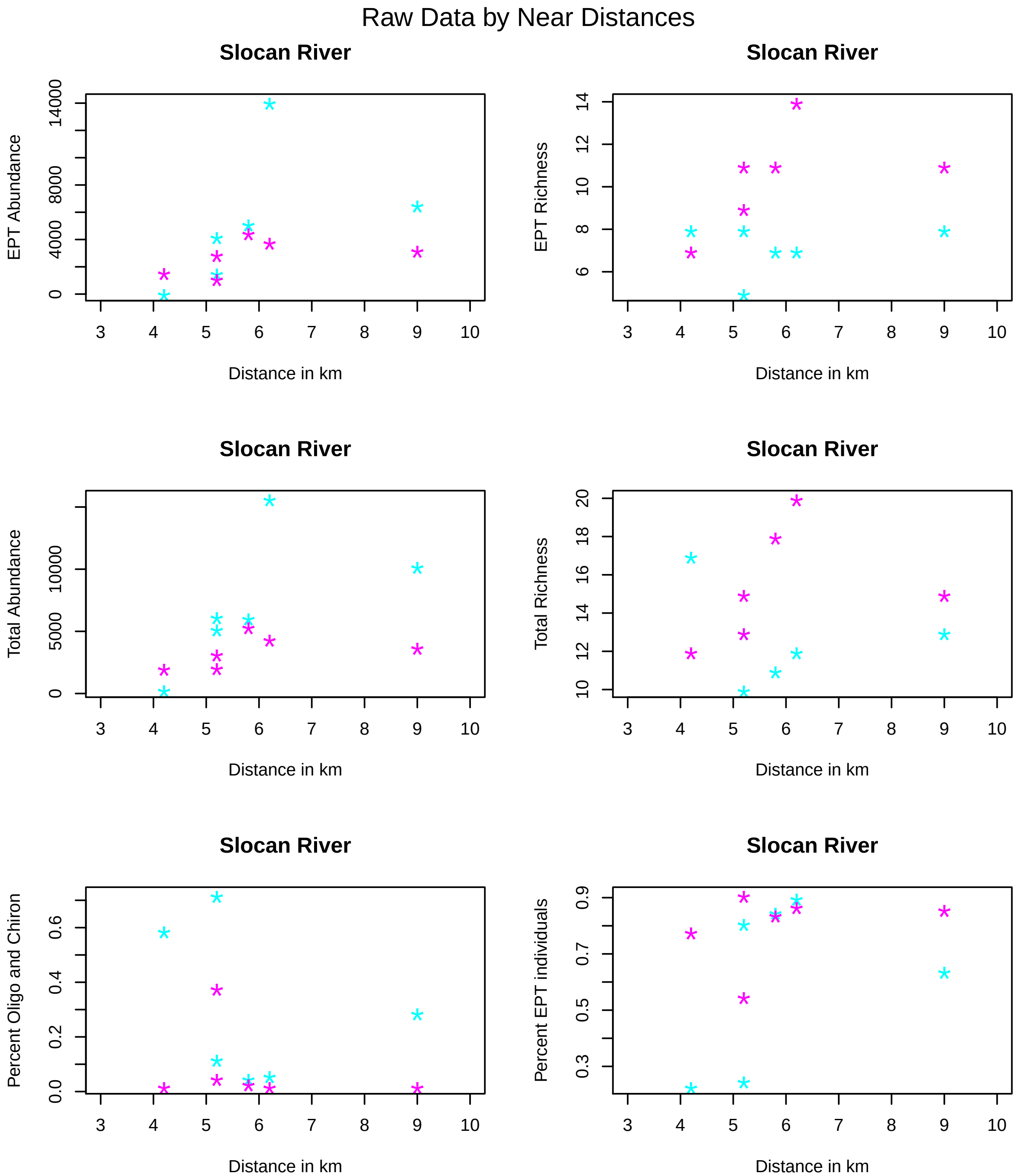

Figure 4: Focused Slocan River Plots by Distance

2.3 Sensitivity Analysis

Table 43: Slocan River log Distance Results for EPT Abundance

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	20.07	7.23	2.77	0.01
log.dist	-3.65	2.18	-1.68	0.09
year.fac2014	7.16	0.52	13.85	0.00
log.dist:year.fac2014	-2.37	0.16	-15.00	0.00

Table 44: Anova Results for Slocan River EPT Abundance by log Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ept.abund.dist.sr.drop.sens	4.00	5427.88	5430.44	-2709.94	5419.88			
fit.ept.abund.dist.sr.sens	5.00	5187.15	5190.35	-2588.58	5177.15	242.73	1.00	0.00

Table 45: Slocan River log Distance Results for EPT Richness

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.64	2.39	-0.69	0.49
log.dist	1.11	0.71	1.56	0.12
year.fac2014	5.03	3.45	1.46	0.15
log.dist:year.fac2014	-1.44	1.04	-1.39	0.17

Table 46: Anova Results for Slocan River EPT Richness by log Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ept.rich.dist.sr.drop.sens	4.00	70.30	72.86	-31.15	62.30			
fit.ept.rich.dist.sr.sens	5.00	70.37	73.56	-30.18	60.37	1.93	1.00	0.16

Table 47: Slocan River log Distance Results for Total Abundance

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	20.06	6.43	3.12	0.00
log.dist	-3.52	1.94	-1.82	0.07
year.fac2014	8.32	0.44	18.76	0.00
log.dist:year.fac2014	-2.76	0.14	-20.40	0.00

Table 48: Anova Results for Slocan River Total Abundance by log Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.tot.abund.dist.sr.drop.sens	4.00	5852.03	5854.59	-2922.02	5844.03			
fit.tot.abund.dist.sr.sens	5.00	5393.65	5396.85	-2691.83	5383.65	460.38	1.00	0.00

Table 49: Slocan River log Distance Results for Total Richness

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.40	1.92	0.21	0.84
log.dist	0.66	0.57	1.15	0.25
year.fac2014	3.58	2.82	1.27	0.20
log.dist:year.fac2014	-1.04	0.85	-1.23	0.22

Table 50: Anova Results for Slocan River Total Richness by log Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.tot.rich.dist.sr.drop.sens	4.00	78.19	80.75	-35.10	70.19			
fit.tot.rich.dist.sr.sens	5.00	78.66	81.86	-34.33	68.66	1.53	1.00	0.22

Table 51: Slocan River log Distance Results for Percent Oligo-Chiro

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-8.68	9.21	-0.94	0.35
log.dist	2.24	2.77	0.81	0.42
year.fac2014	8.42	1.50	5.61	0.00
log.dist:year.fac2014	-3.08	0.46	-6.71	0.00

Table 52: Anova Results for Slocan River Percent Oligo-Chiro by log Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.olig.dist.sr.drop.sens	4.00	792.94	795.50	-392.47	784.94			
fit.olig.dist.sr.sens	5.00	741.44	744.63	-365.72	731.44	53.50	1.00	0.00

Table 53: Slocan River log Distance Results for Percent EPT Individuals

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	5.88	6.81	0.86	0.39
log.dist	-1.56	2.05	-0.76	0.45
year.fac2014	-4.87	0.94	-5.18	0.00
log.dist:year.fac2014	1.71	0.29	5.97	0.00

Table 54: Anova Results for Slocan River Percent EPT Individuals by log Distance

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
fit.ind.dist.sr.drop.sens	4.00	1192.43	1194.99	-592.21	1184.43			
fit.ind.dist.sr.sens	5.00	1157.52	1160.72	-573.76	1147.52	36.91	1.00	0.00

3 Discussion

The results of both the BACI and distance analyses for abundance, percent Oligo-Chiro and percent EPT individuals in Lemon Creek indicate system recovery. The BACI analysis indicates that control sites had relatively stable values while abundance and percent EPT individuals increased from 2013 to 2014 and percent Oligo-Chiro decreased from 2013 to 2014. Similarly, the distance analysis indicates relatively stable counts along the gradient in 2014 as compared to 2013. As noted above, there are concerns regarding the accuracy of the p-values due to over-dispersion and multiple testing. However, further exploratory modelling (not presented here) using linear mixed effects models (LMEs), with adjustments for heterogeneity of variance, showed significant BACI interaction effects for abundance, percent Oligo-Chiro and percent EPT. This it is expected that the GLMM results would remain significant after further adjustment for over-dispersion. On the other hand, the richness data did not show a significant change.

The results for Slocan River are less clear. No BACI analyses were carried out for Slocan River as there were no appropriate control data available. For the distance analysis, there was one distant site at 20.5 km which was a potential leverage point. Therefore, a sensitivity analysis was carried out by deforming the distances into a more uniform distribution to determine the extent to which the results were driven by this single distant site. A comparison of results suggests the distant point at 20.5 km influences the Slocan River results. It may be useful to carry out subset analyses to assess effects within the smaller range of 10 km.

4 References

- Jiang, J. (2007). Linear and Generalized Linear Mixed Models and Their Applications, Springer, New York.
- Pinheiro, J. C. and Bates, D. M. (2000). Mixed-effects models in S and S-PLUS, Springer, New York.
- R: A Language and Environment for Statistical Computing, R Core Team, R Foundation for Statistical Computing, Vienna, Austria, 2016, http://www.R-project.org.

- Stroup, W.W. (2012). Generalized Linear Mixed Models, CRC Press, Boca Raton.

APPENDIX IV

Benthic Invertebrate CABIN BEAST Ordination Plots

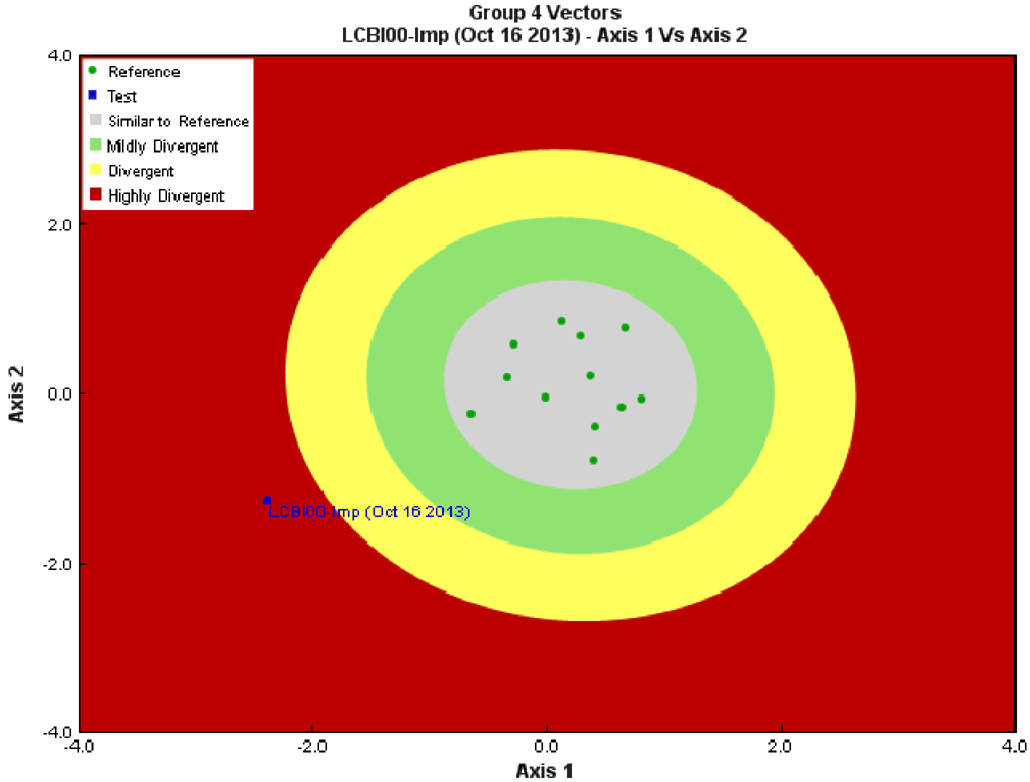

Figure 1: LCBI00-exposure, October 2013

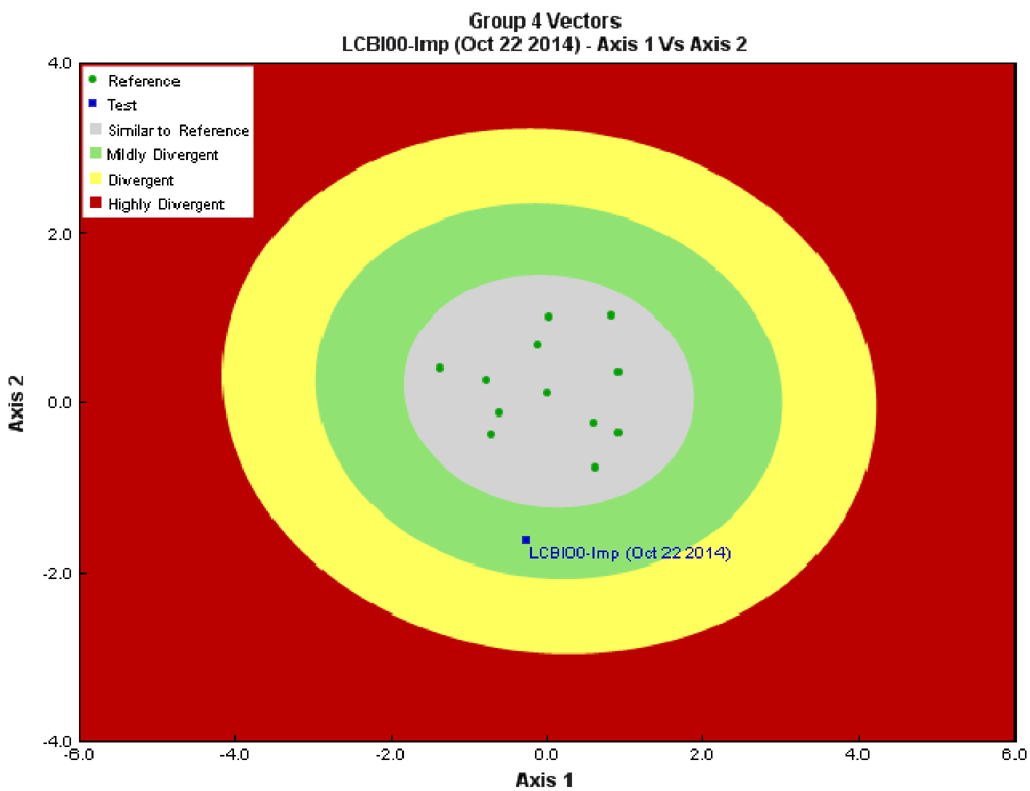

Figure 2: LCBI00-exposure, October 2014

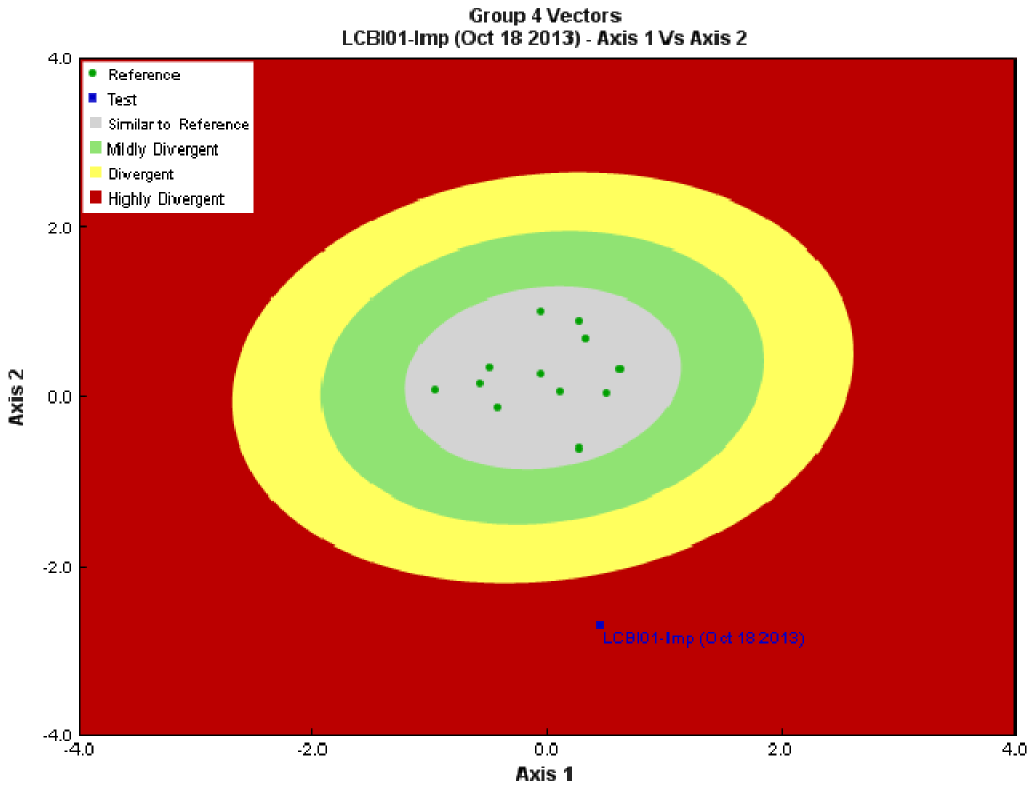

Figure 3: LCBI01-exposure, October 2013

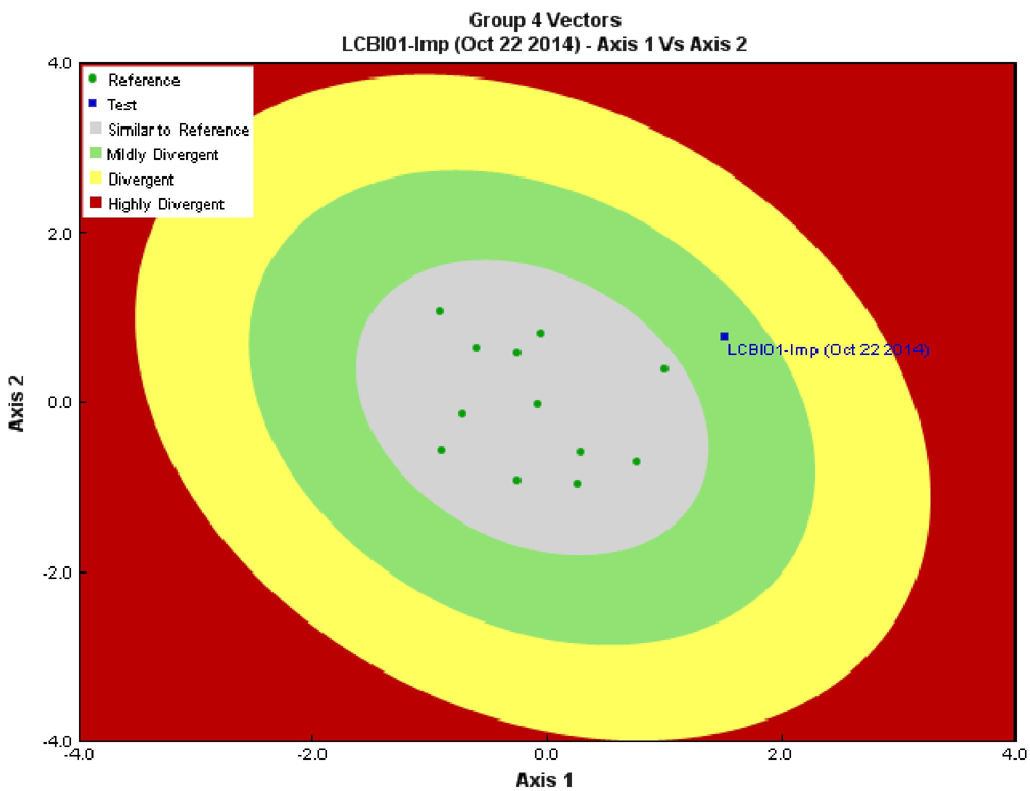

Figure 4: LCBI01-exposure, October 2014

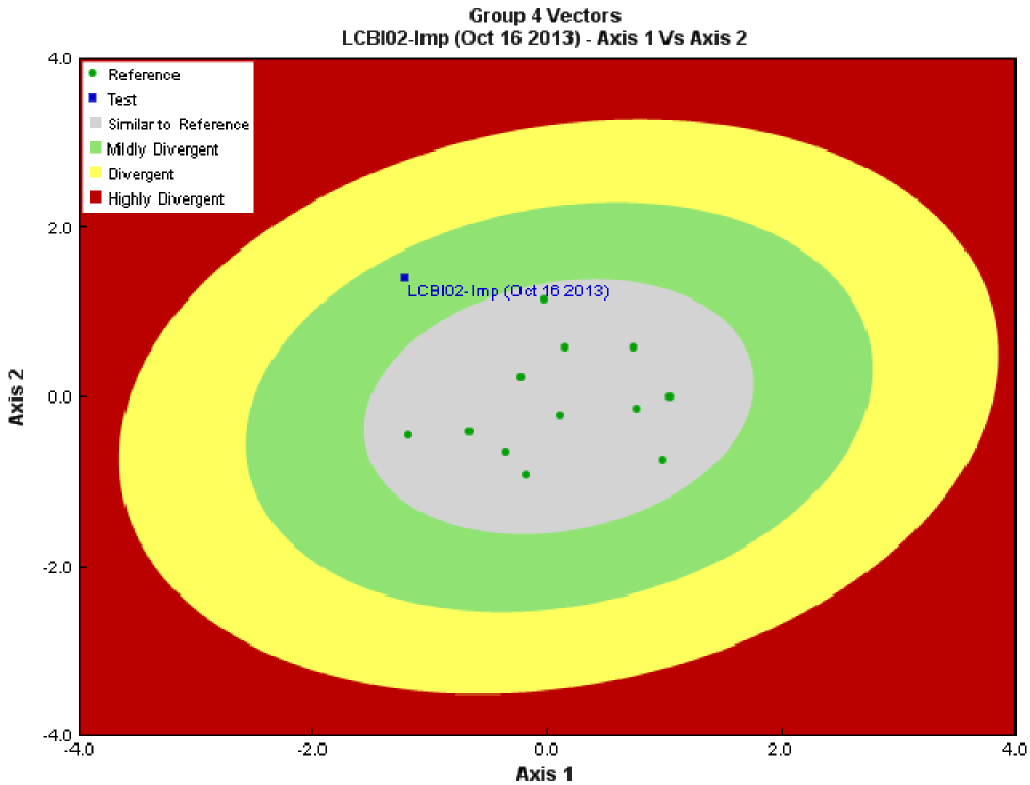

Figure 5: LCBI02-exposure, October 2013

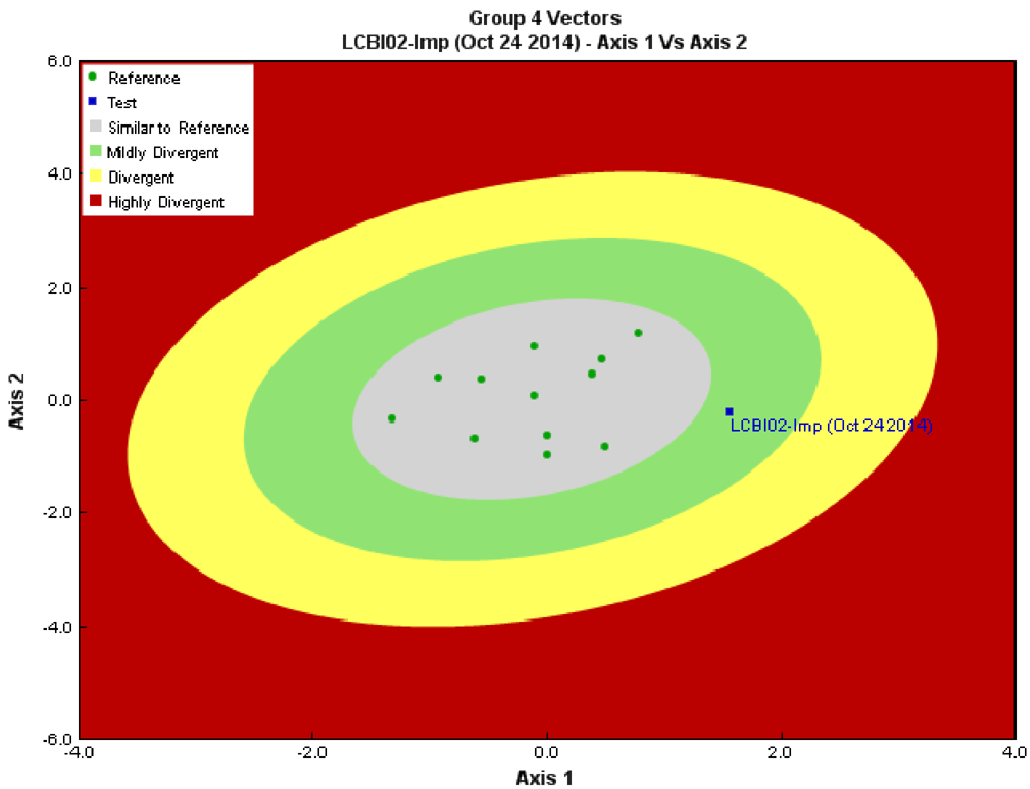

Figure 6: LCBI02-exposure, October 2014

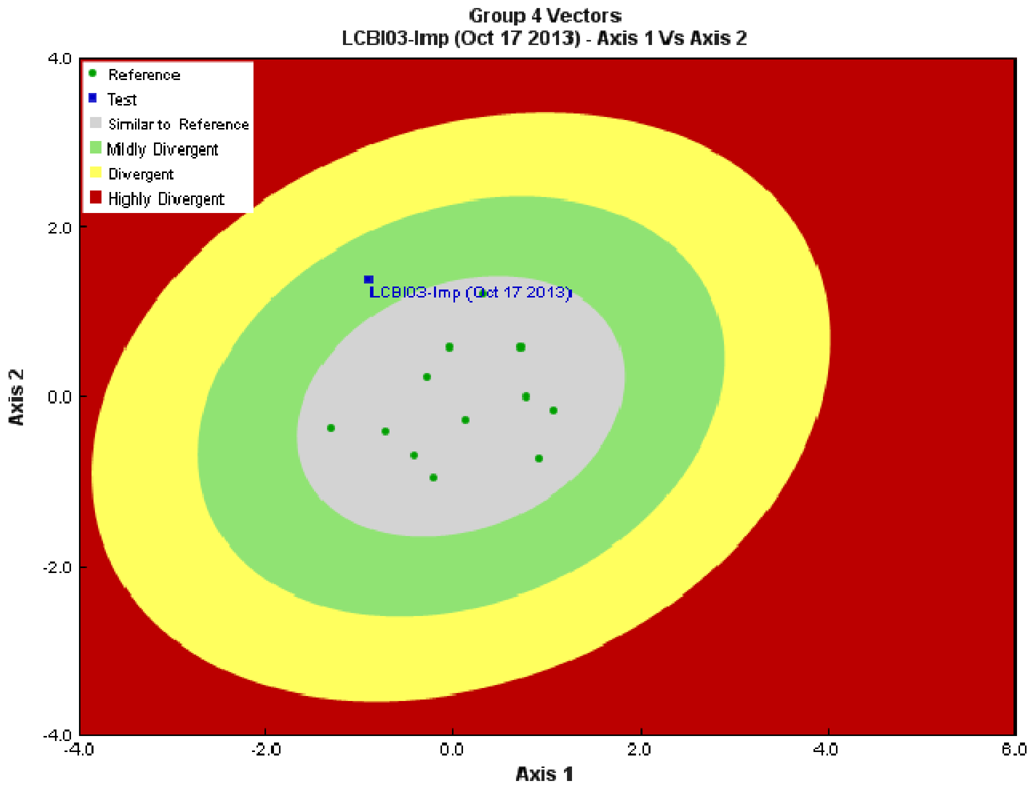

Figure 7: LCBI03-exposure, October 2013

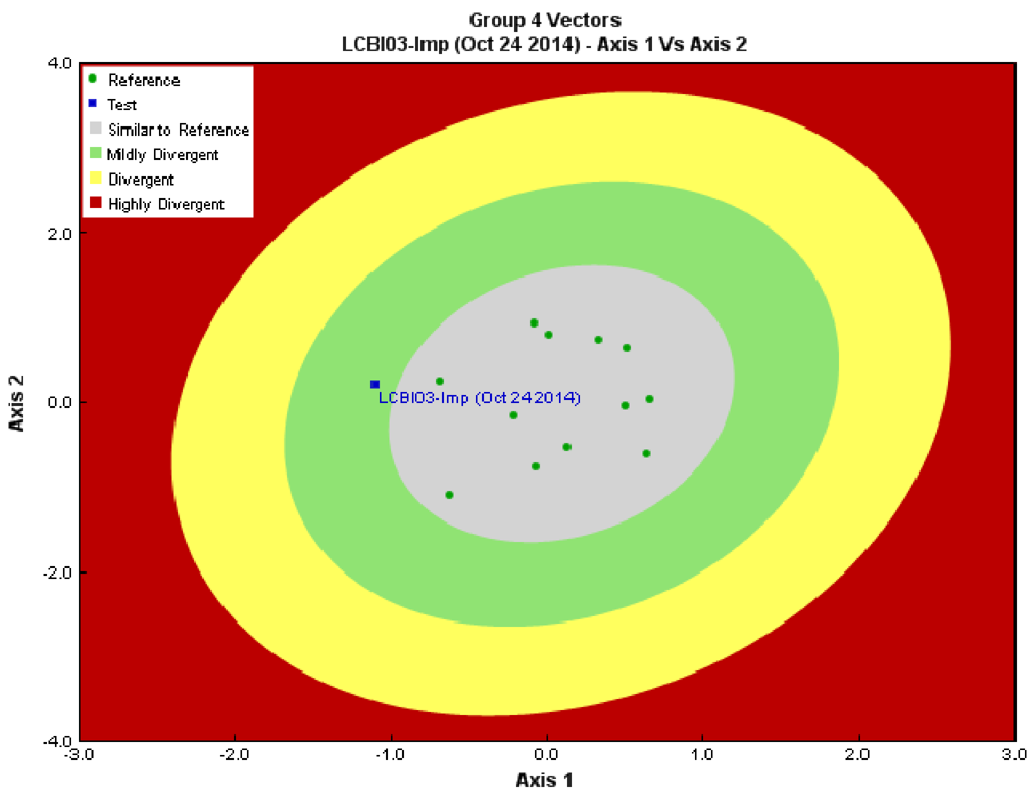

Figure 8: LCBI03-exposure, October 2014

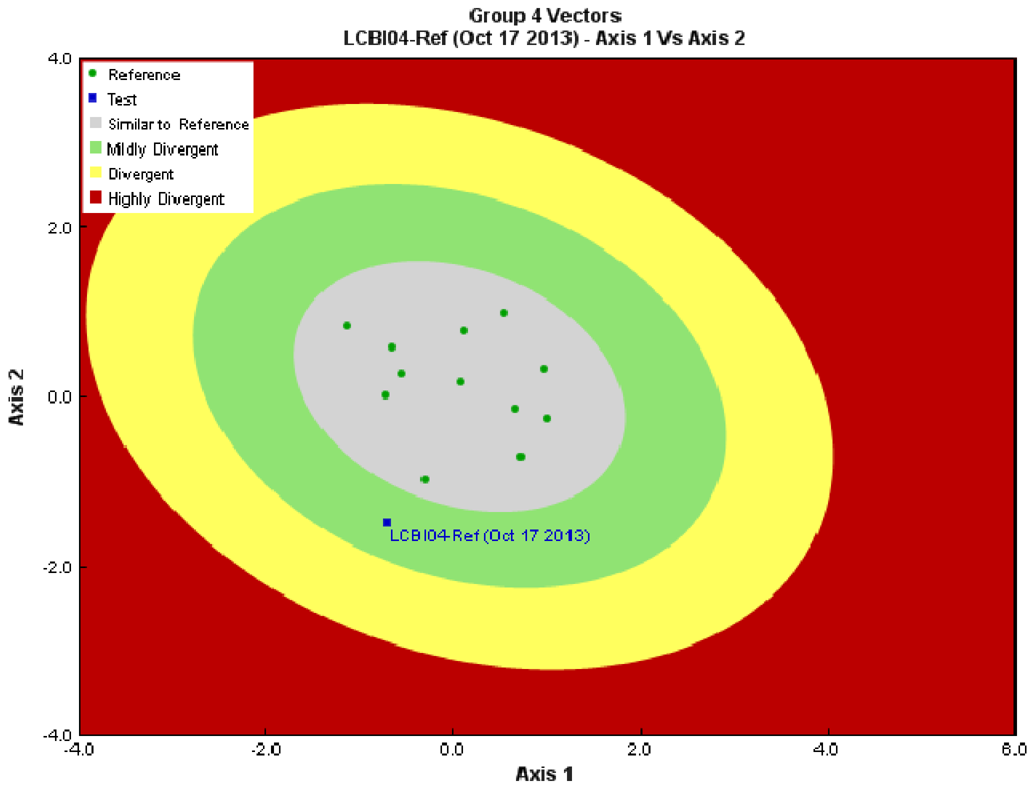

Figure 9: LCBI04-reference, October 2013

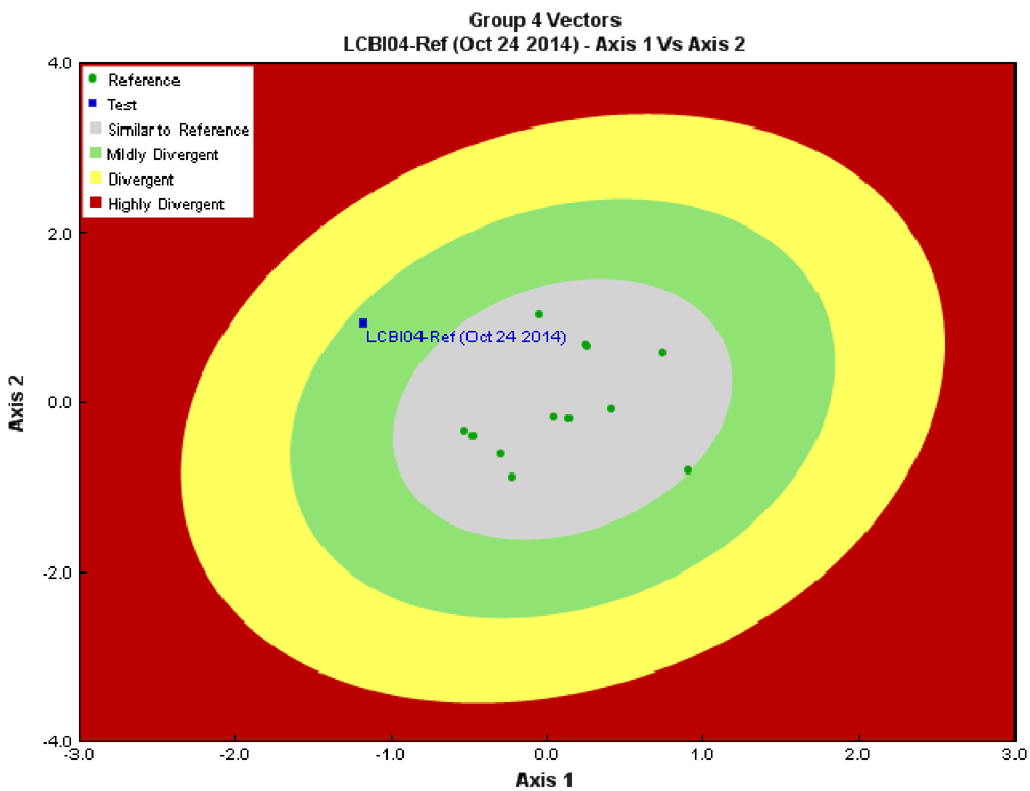

Figure 10: LCBI04-reference, October 2014

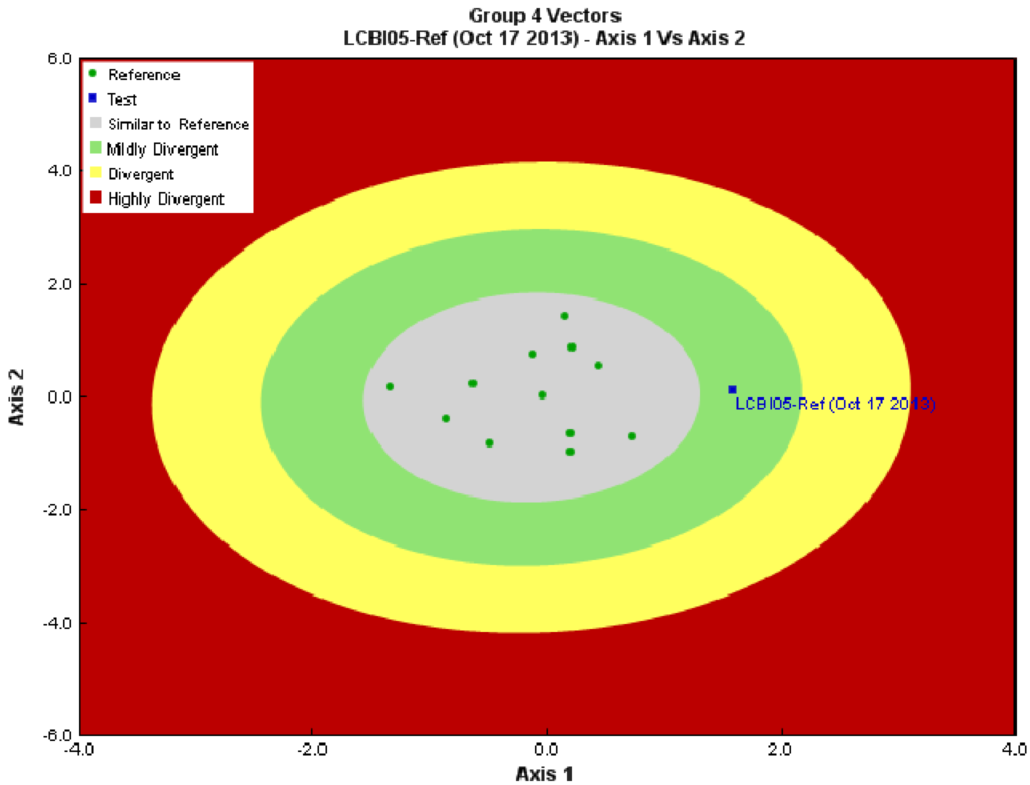

Figure 11: LCBI05-reference, October 2013

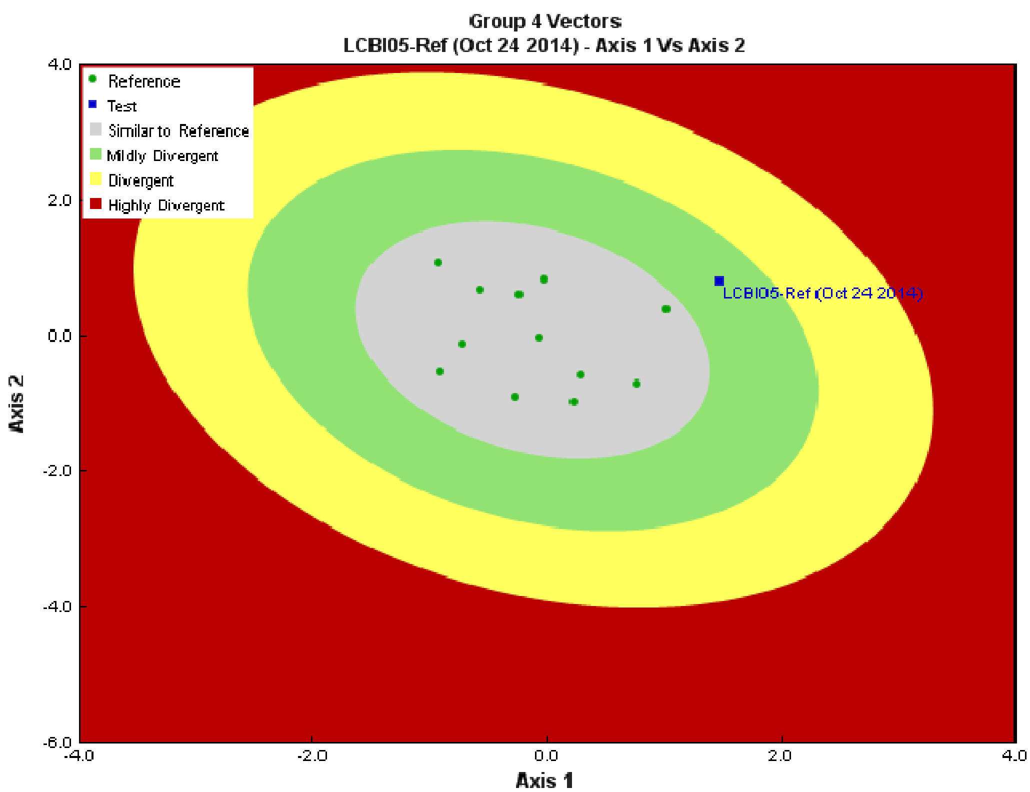

Figure 12: LCBI05-reference, October 2014

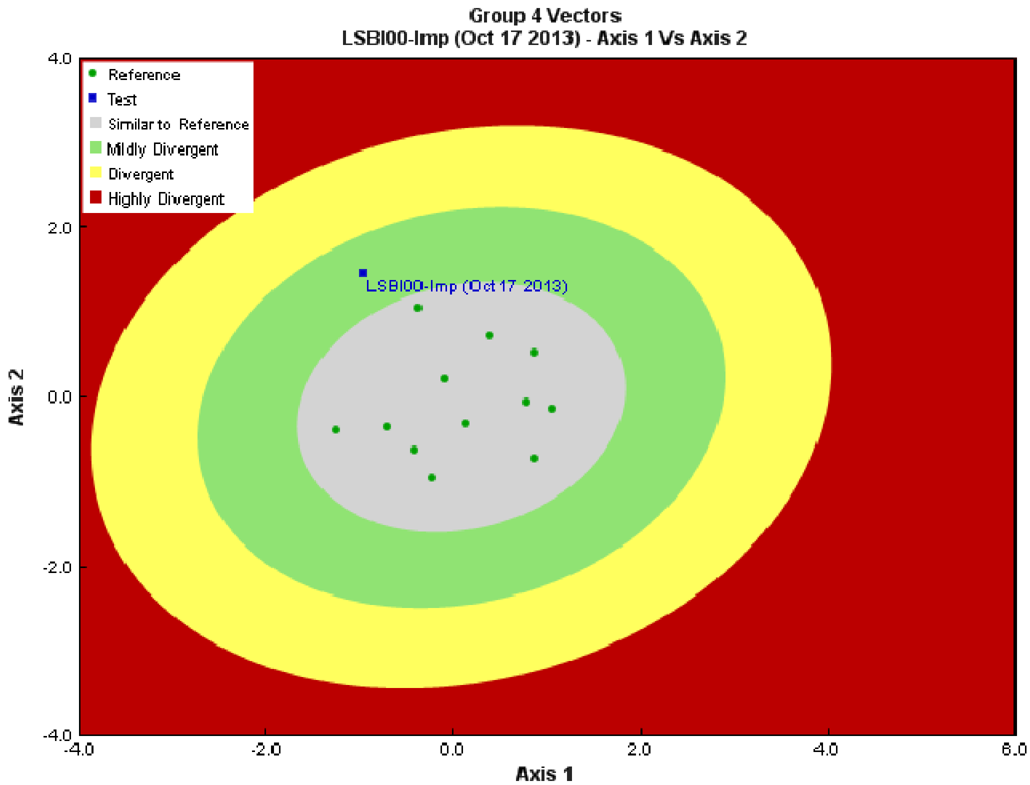

Figure 13: LSBI00-reference, October 2013

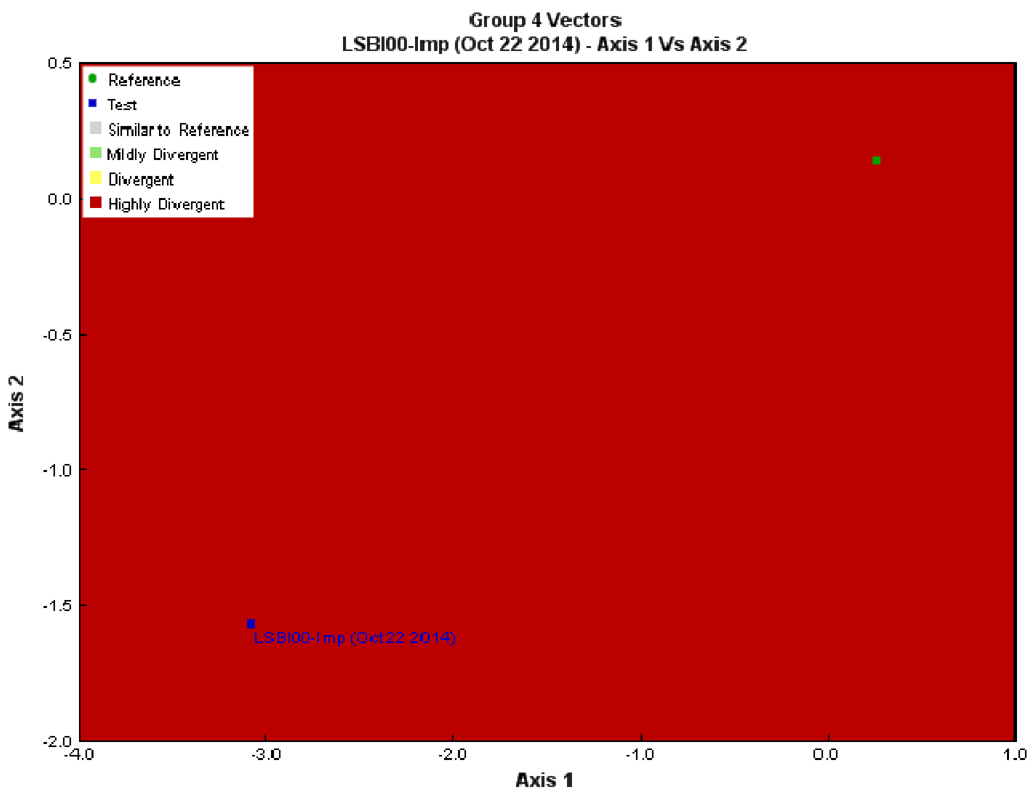

Figure 14: LSBI00-reference, October 2014

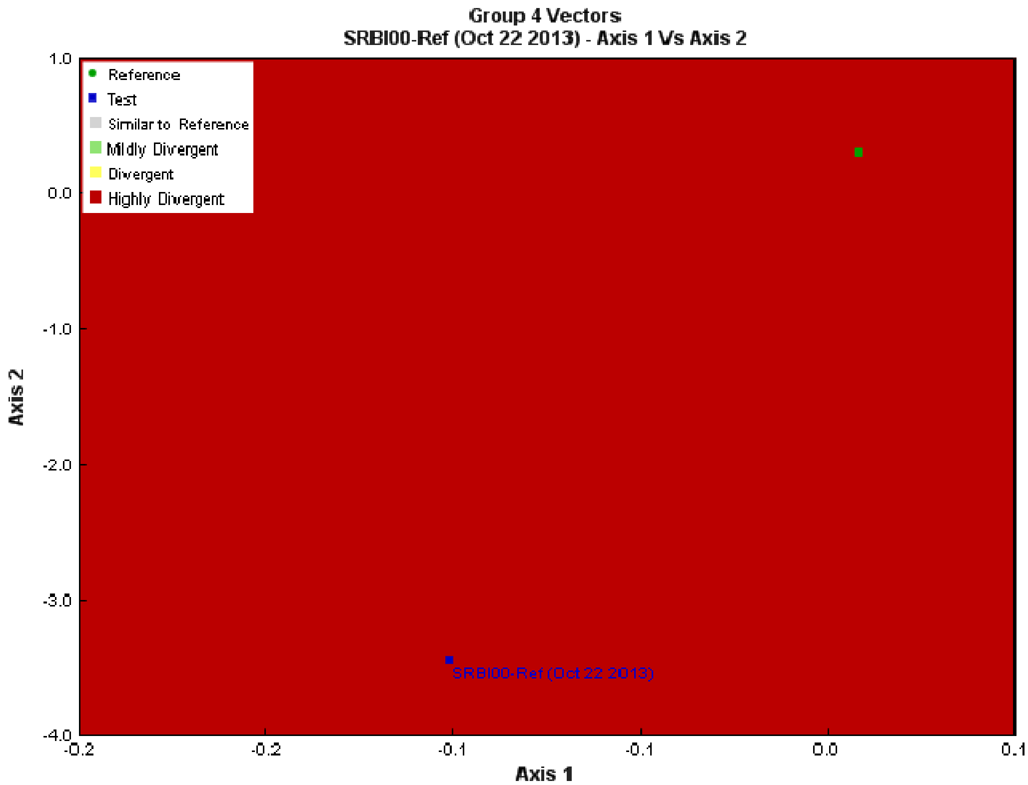

Figure 15: SRBI00-reference, October 2013

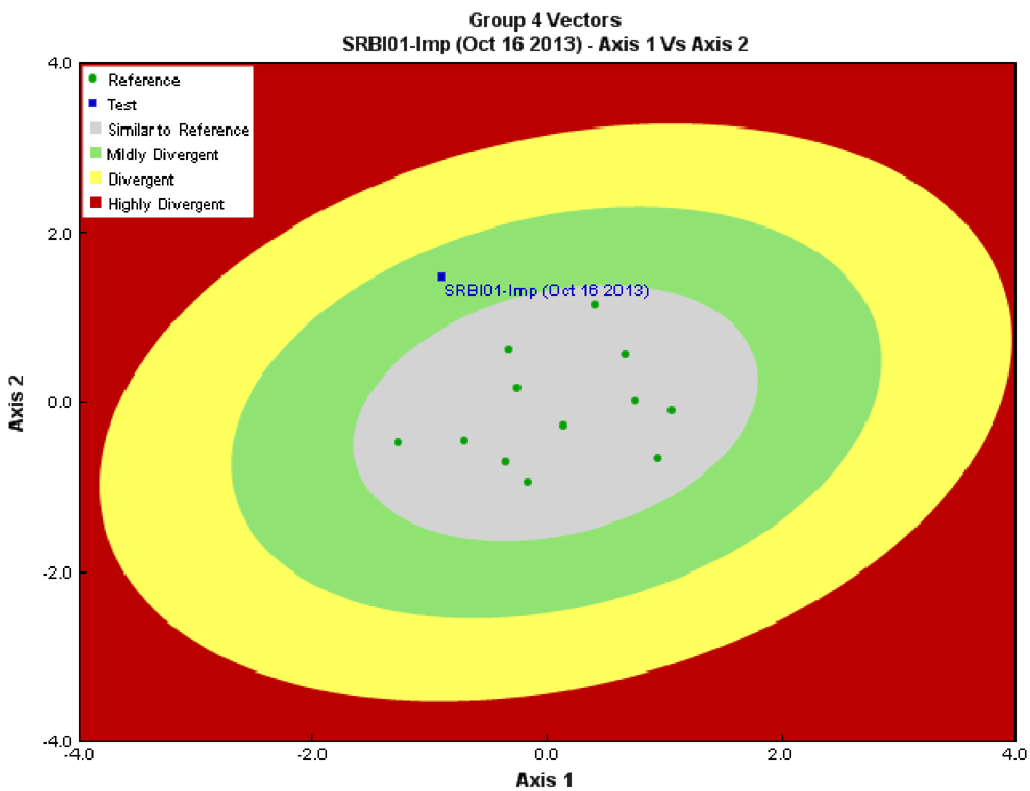

Figure 16: SRBI01-exposure, October 2013

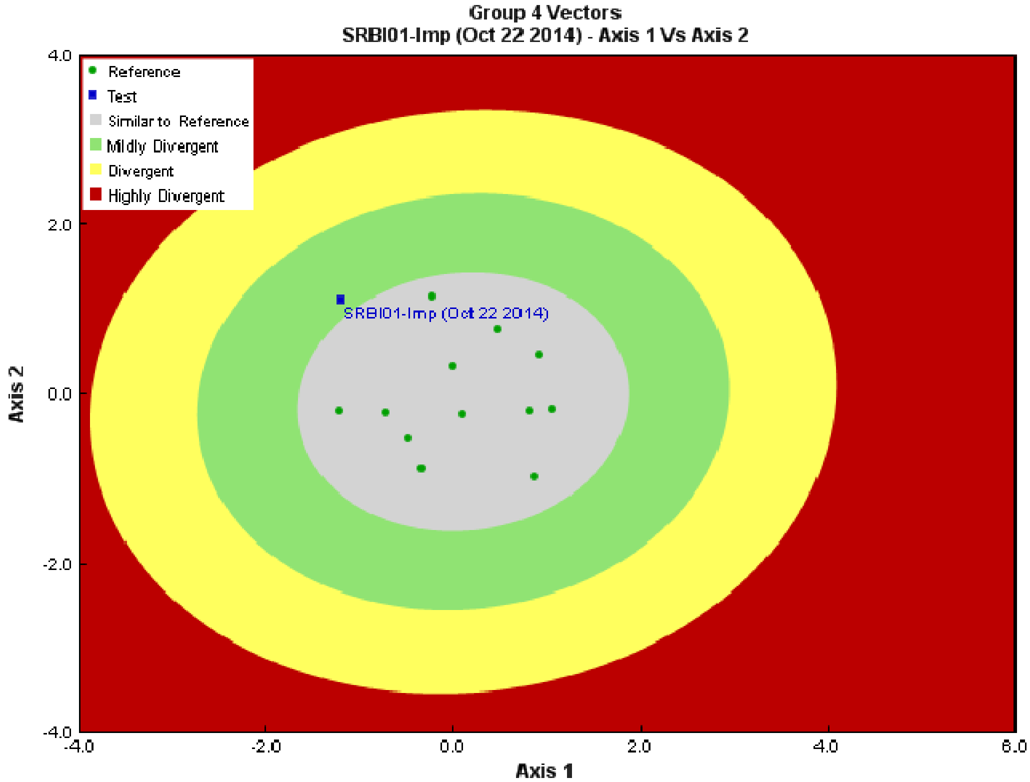

Figure 17: SRBI01-exposure,October 2014

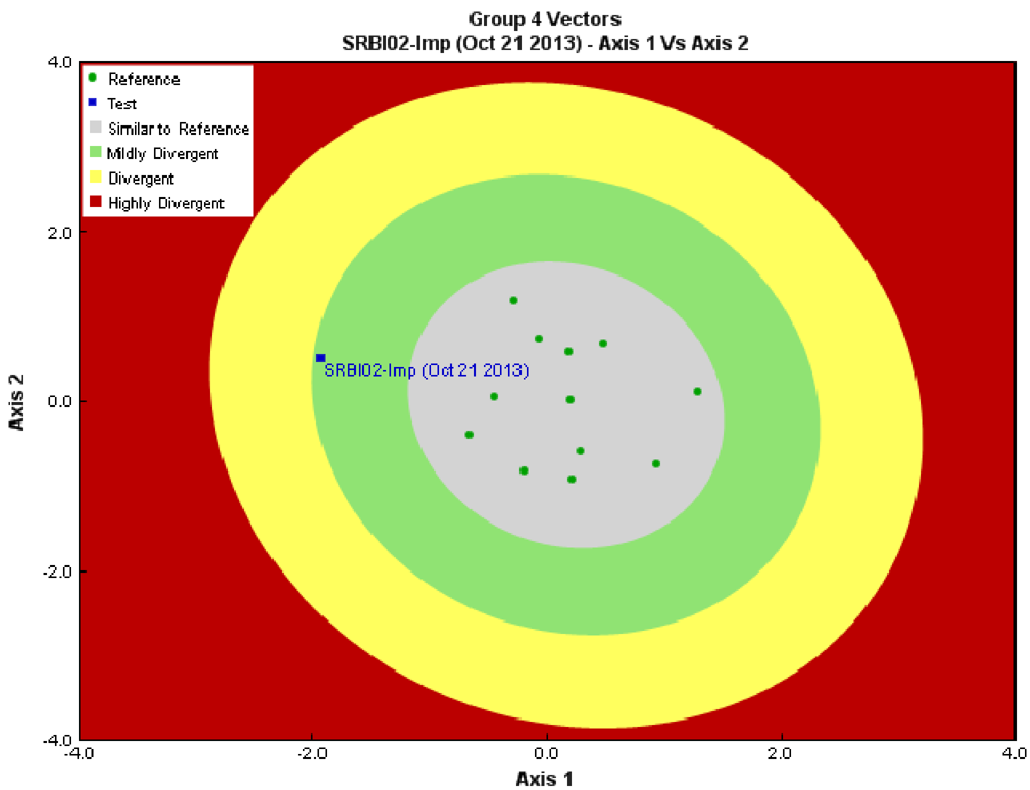

Figure 18: SRBI02-exposure,October 2013

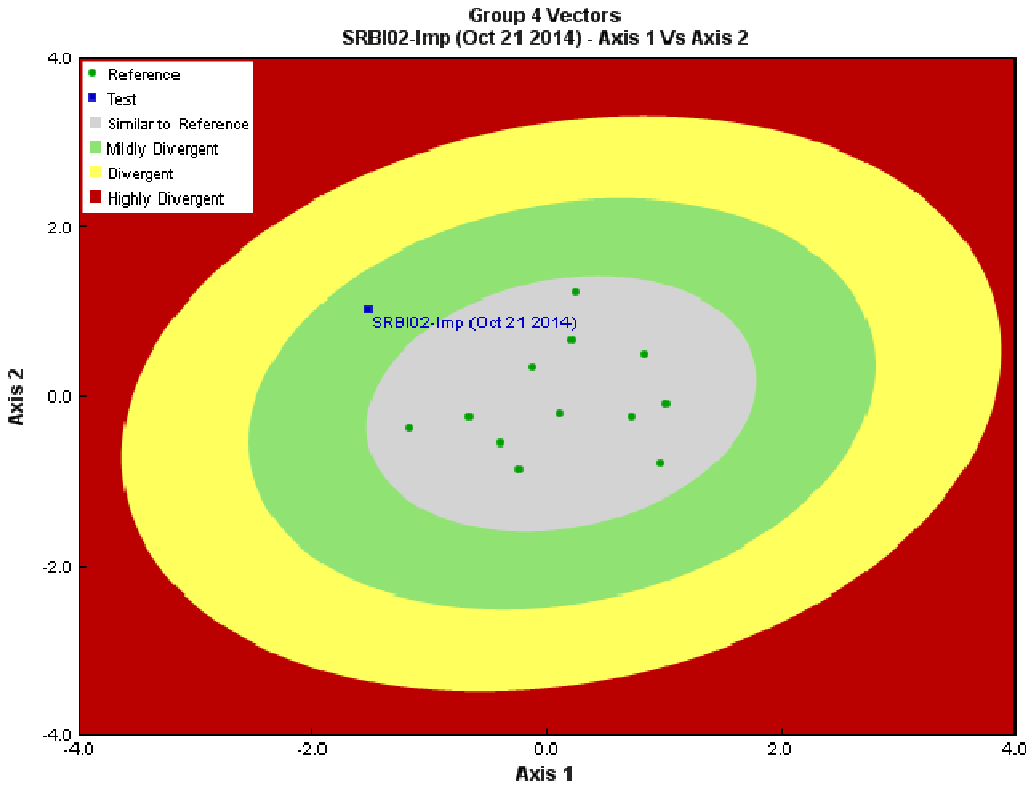

Figure 19: SRBI02-exposure, October 2014

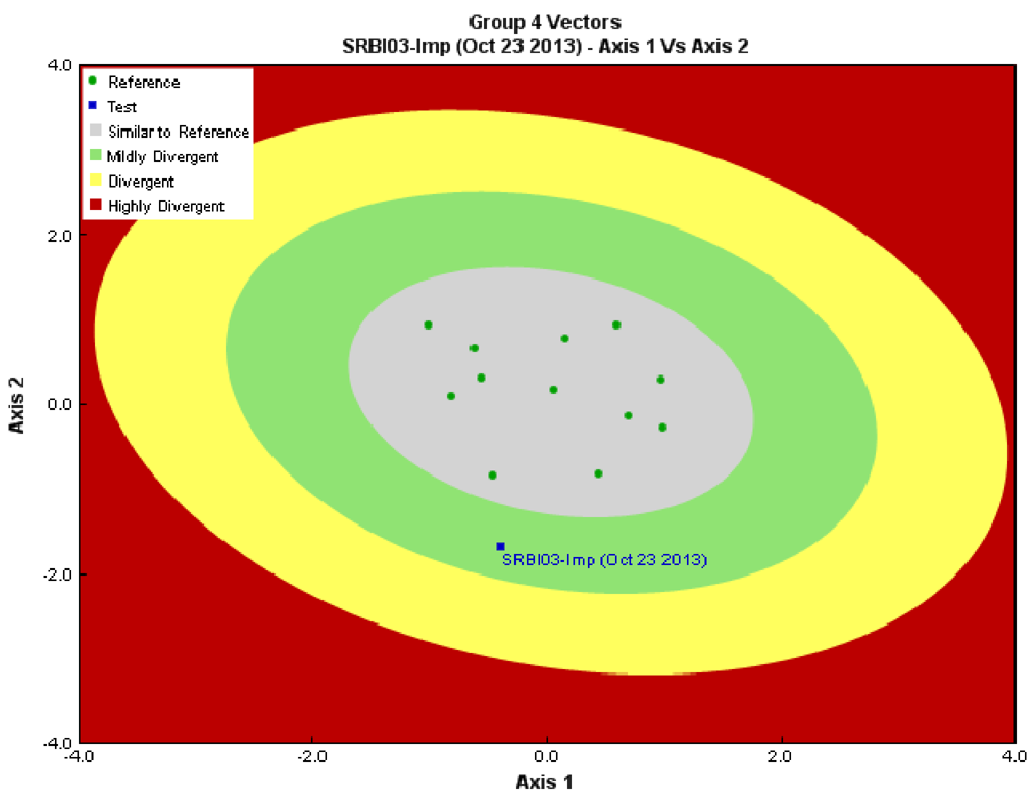

Figure 20: SRBI03-exposure, October 2013

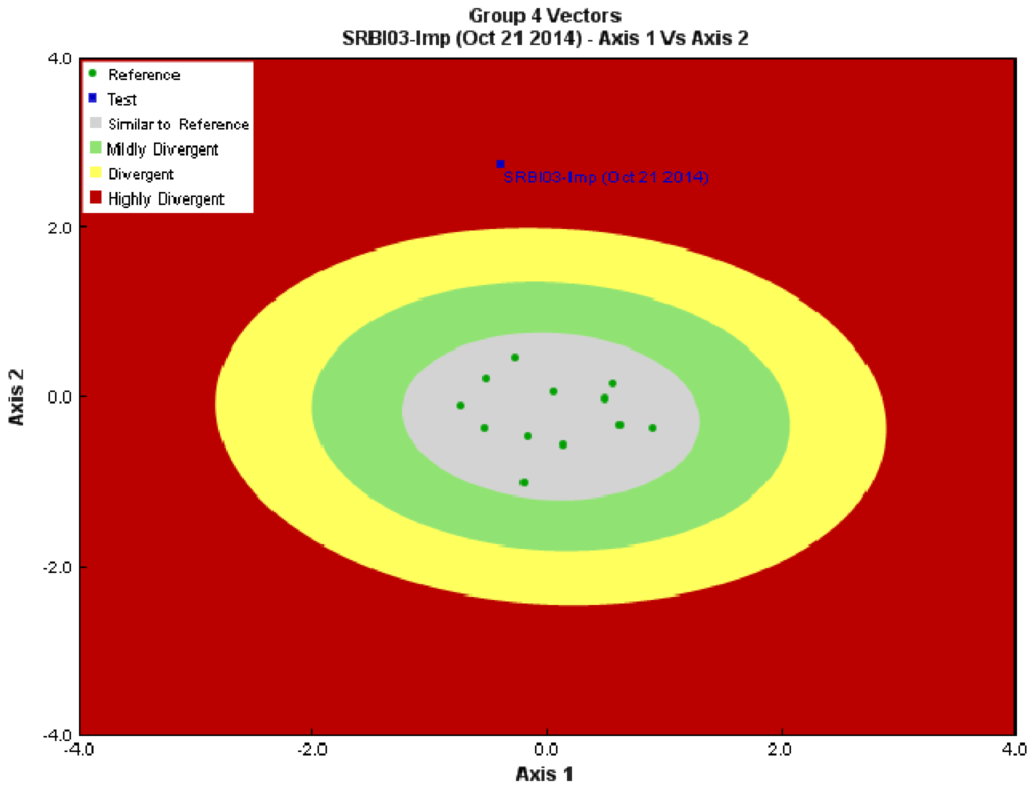

Figure 21: SRBI03-exposure, October 2014

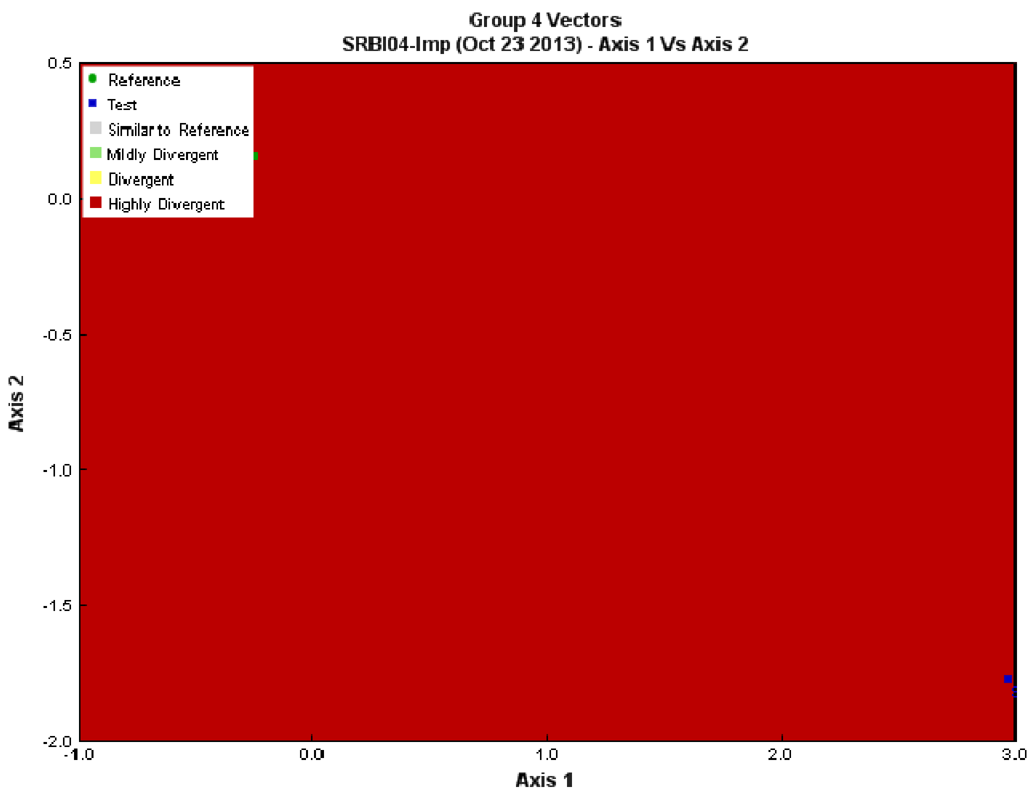

Figure 22: SRBI04-exposure, October 2013

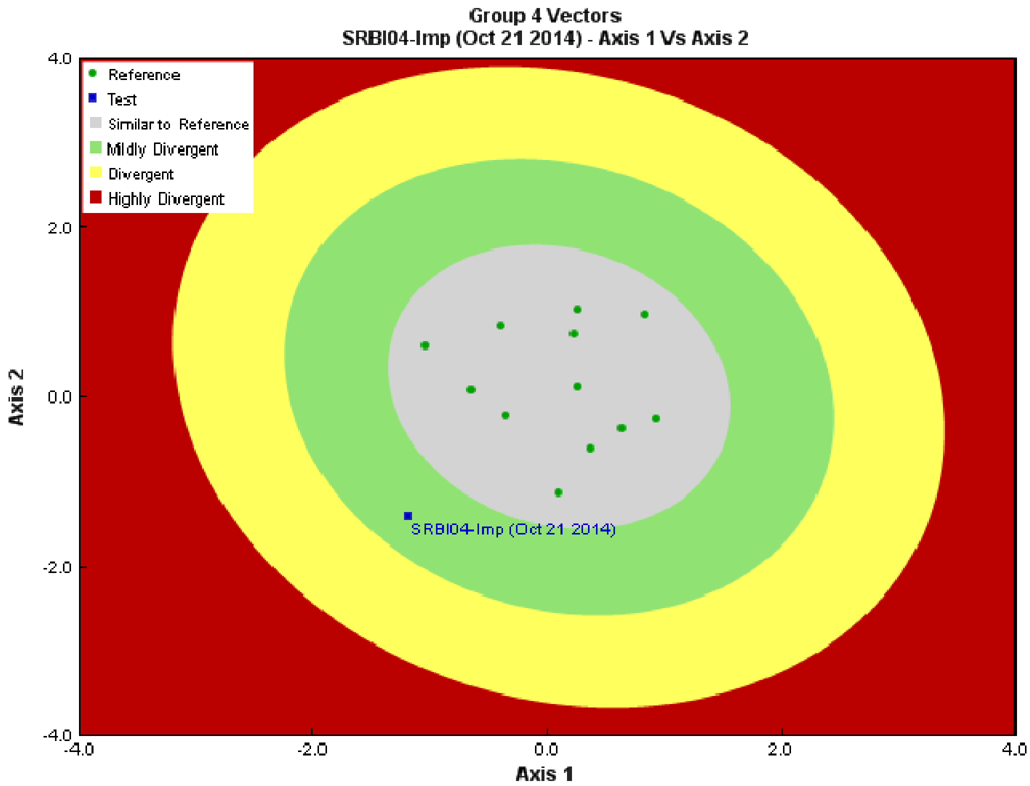

Figure 23: SRBI04-exposure, October 2014

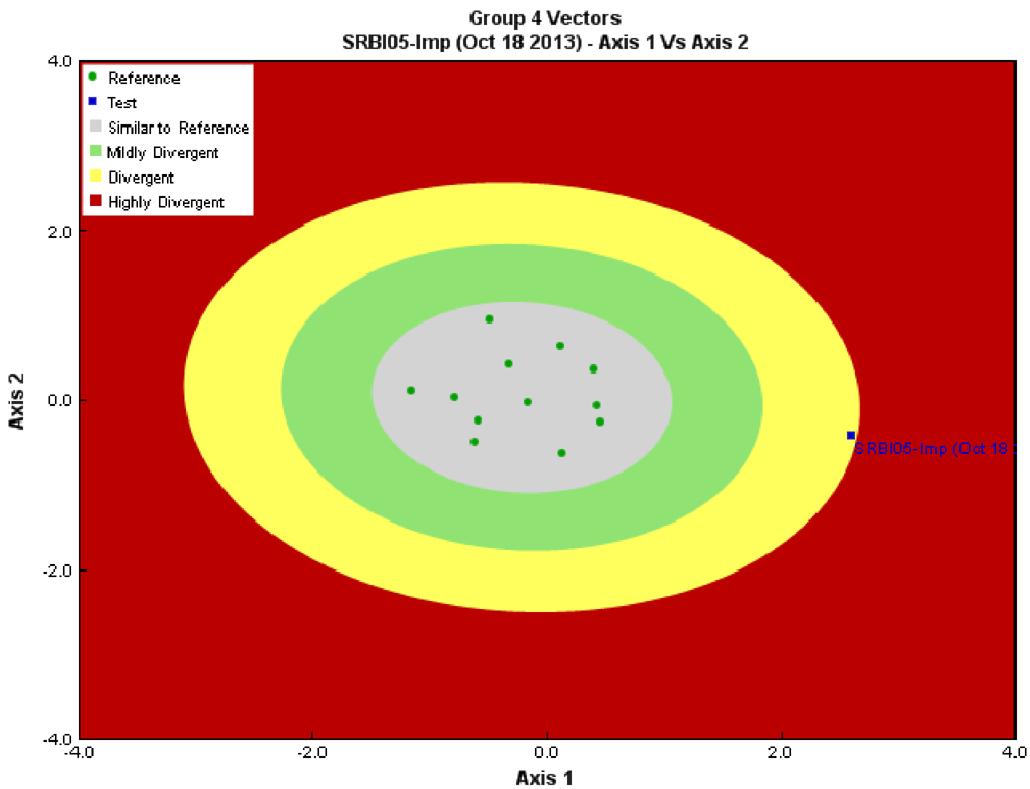

Figure 24: SRBI05-exposure, October 2013

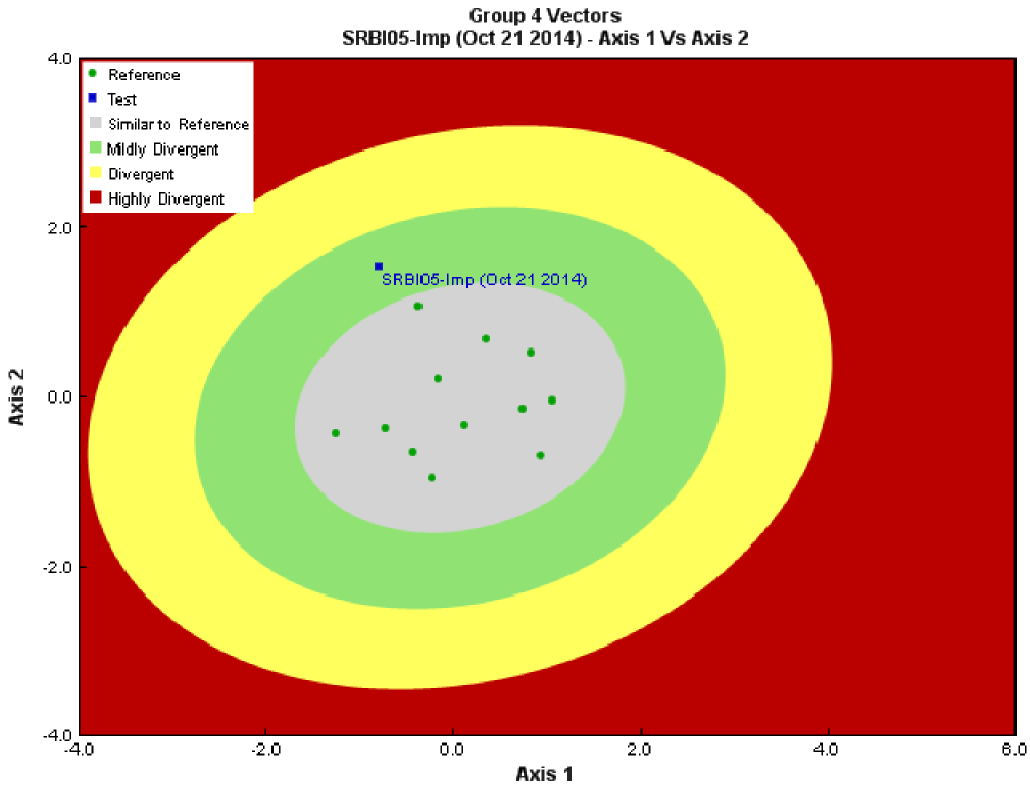

Figure 25: SRBI05-exposure, October 2014

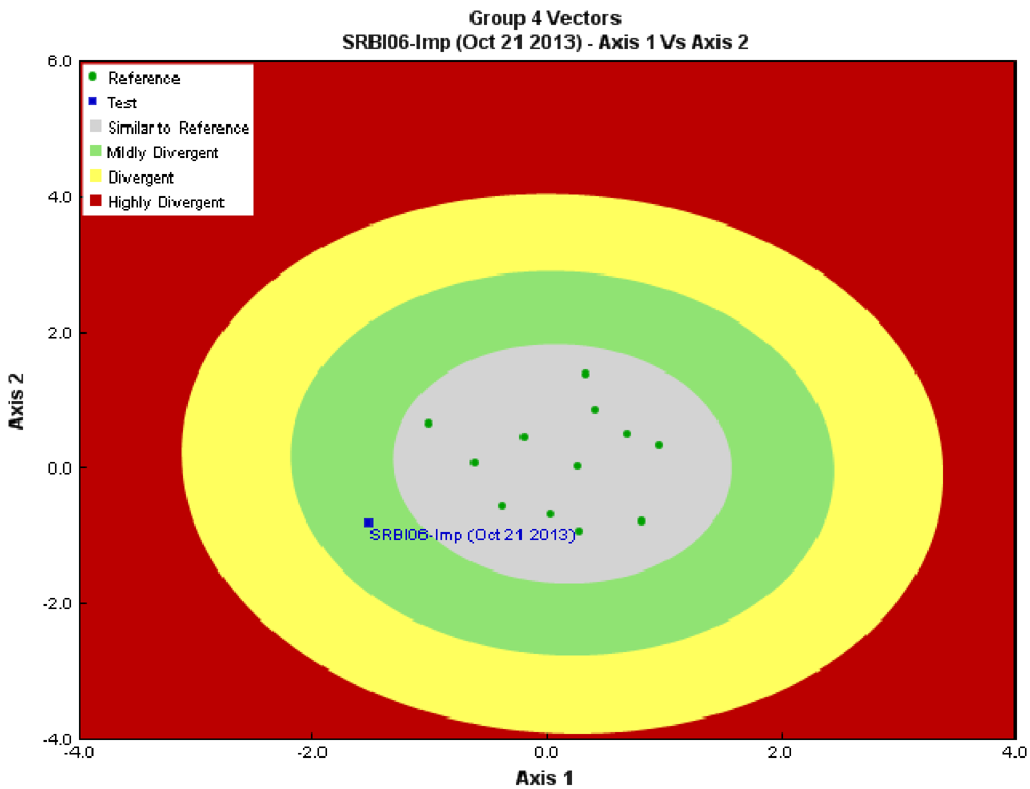

Figure 26: SRBI06-exposure, October 2013

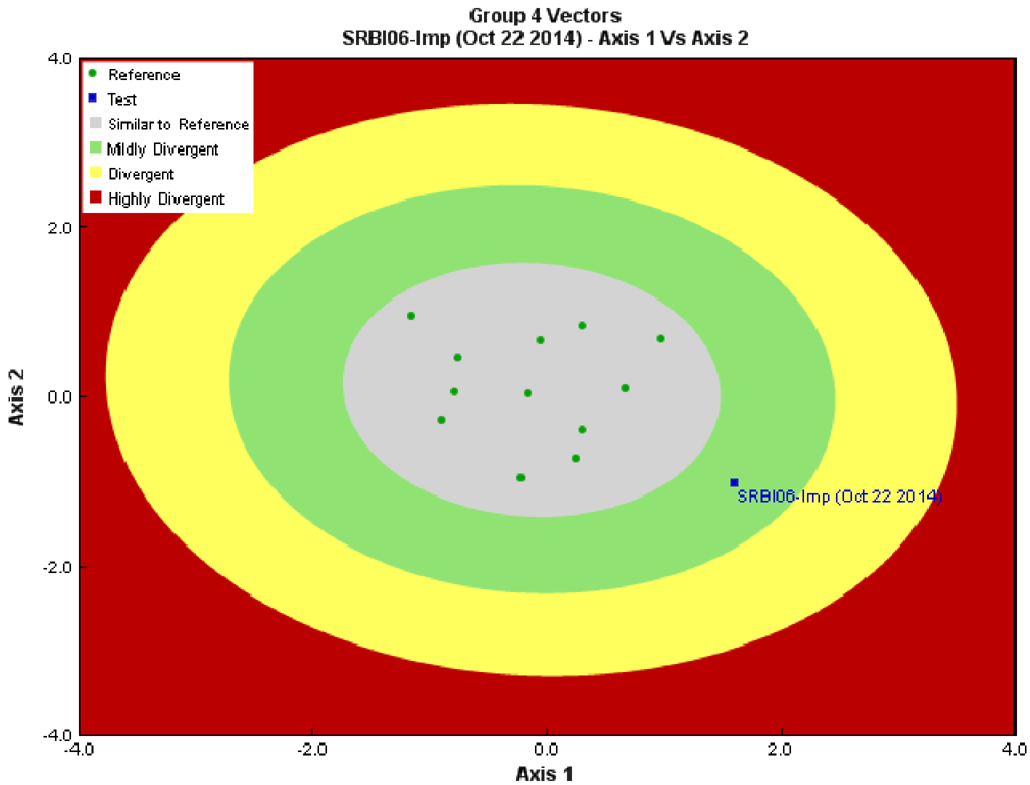

Figure 27: SRBI06-exposure, October 2014

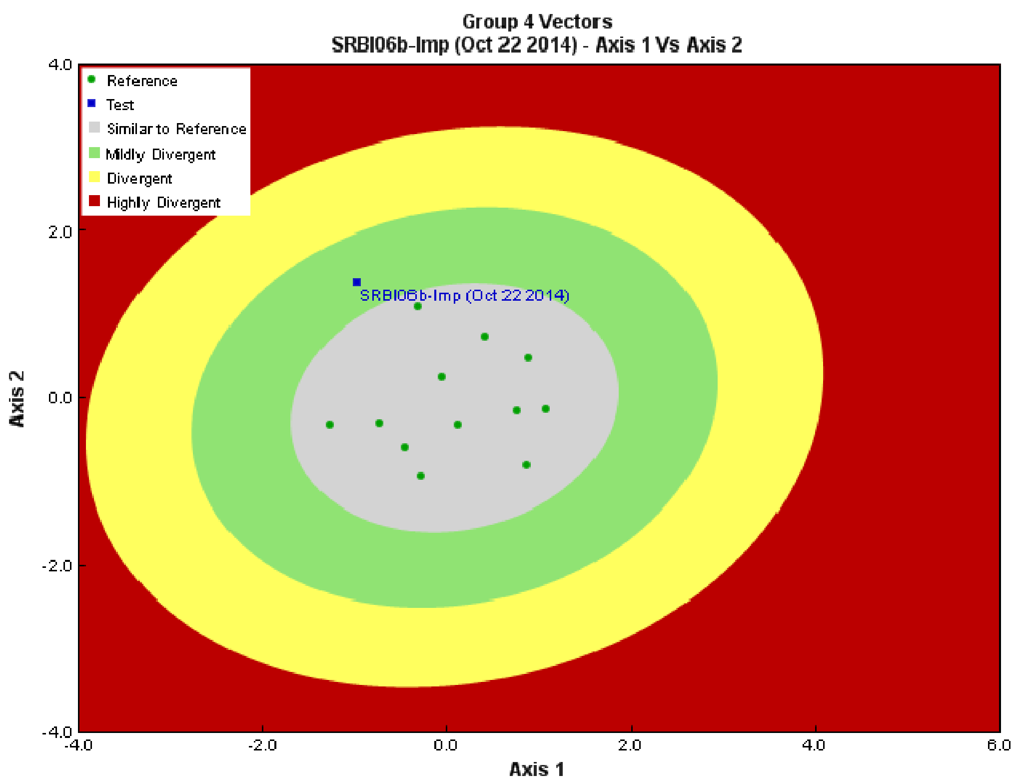

Figure 28: SRBI06b-exposure, October 2014

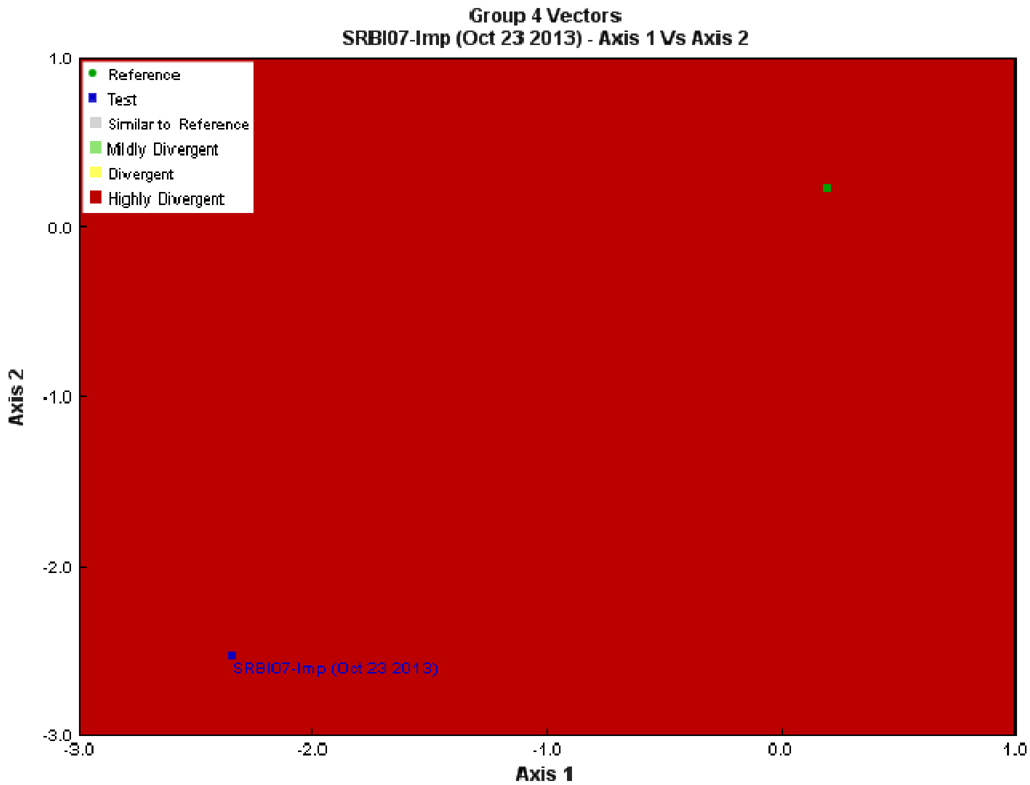

Figure 29: SRBI07-exposure, October 2013

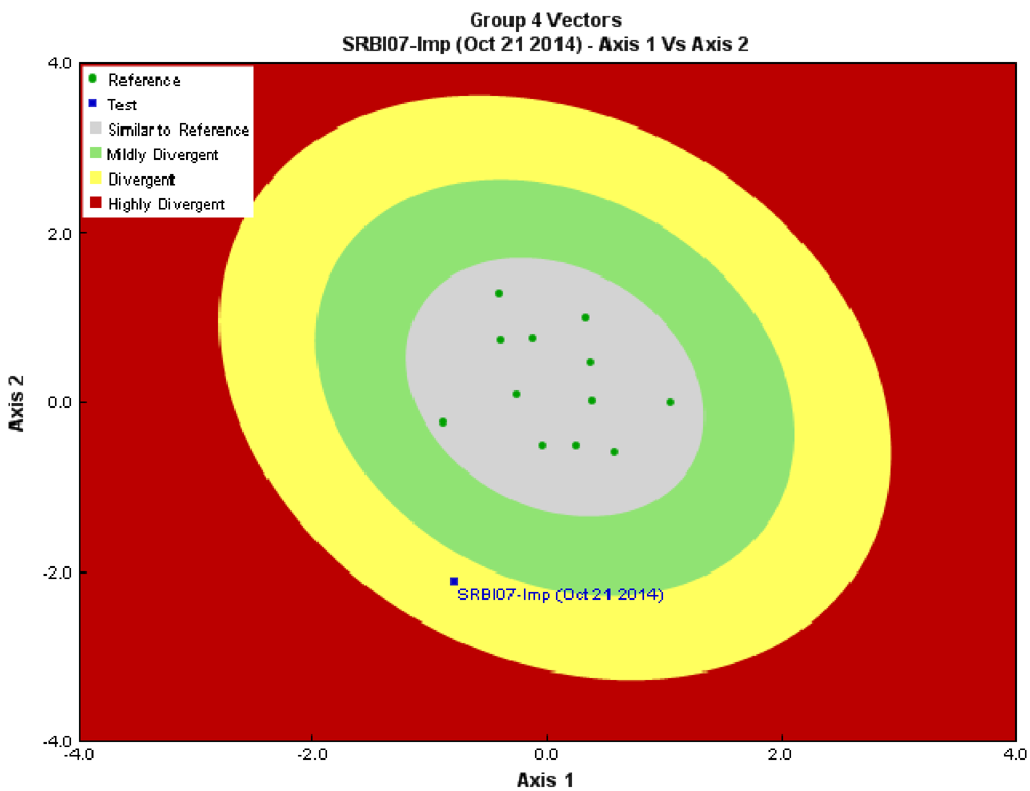

Figure 30: SRBI07-exposure, October 2014

APPENDIX V

Ministry of Environment Comments on Final Report

BRITISH
COLUMBIA

July 20, 2016

File: 32936-20/037/Lemon Creek

Dean Buckland, President
Executive Flight Centre
200, 680 Palmer Road
NE Calgary AB T6E 7R3

Dear Dean Buckland:

RE: *Lemon Creek Spill: Biological Monitoring Program – Final Report (April 29, 2016)*

The Ministry of Environment (MoE) and the Ministry of Forests, Lands and Natural Resource Operations (FLNRO) have reviewed the *Lemon Creek Spill: Biological Monitoring Program – Final Report (April 29, 2016)* prepared by SNC-Lavalin Inc. Sections 5 – 8, on fisheries-related components, were reviewed by Jeff Burrows (FLNRO). Section 9, on benthic invertebrate monitoring, was reviewed by Carrie Morita (MoE). Statistical components were reviewed by Dr. Carl Schwarz from Simon Fraser University and his comments are attached in Appendix 1.

MoE and FLNRO are generally satisfied with the revisions. FLNRO key concerns, as outlined in the March 12, 2016 email from Jeff Burrows, have been addressed. MoE would like to see two outstanding items, noted below, addressed. Please include this letter, as submitted, as an addendum to the report along with responses to the outstanding items (i.e. single pdf). MoE has made a commitment to share documentation related to the Lemon Creek spill with the public. MoE would like to request permission to publish the final report and addendum (i.e. single pdf) to its website (http://www2.gov.bc.ca/gov/content/environment/air-land-water/spills-environmental-emergencies/spill-incidents/past-spill-incidents/lemon-creek). Please also post the final report with the addendum to the Executive Flight Centre's Lemon Creek Response website (http://www.lemoncreekresponse.ca/index.php?pid=2).

MoE would like the following outstanding items addressed:

1) As per the memo submitted to MoE (July 22, 2014), SNC-Lavalin committed to "observe and document the conditions along Lemon Creek and Slocan River as part of the ongoing Biological EMP". These field observations remain outstanding in the revised report. Please include the field observations in the addendum.

...2

2) Figures 21, 22, 23, 33, 43 are not clear as probability ellipses are not visible. Please provide legible figures and interpretation of the information displayed.

When the final report and addendum are received by MoE, the work related to the environmental monitoring following the spill will be considered complete.

If you have any questions, please do not hesitate to contact me.

Sincerely,

Carrie Morita, M.R.M., R.P.Bio.
EIA Biologist

cc: Jeff Burrows, Senior Fisheries Biologist, FLNRO, Nelson
Robyn Roome, Director of Monitoring, Assessment and Stewardship, MoE, Nelson

Attachment: Appendix 1 – Email from Carl Schwarz (SFU) to Carrie Morita (MoE)

Appendix 1: Email of May 22, 2016 from Carl Schwarz (SFU) to Carrie Morita (MoE)

From: Carl Schwarz [mailto:cschwarzstatsfuca@gmail.com]
Sent: Sunday, May 22, 2016 3:39 PM
To: Morita, Carrie ENV:EX
Subject: Re: further review required - revised Lemon Creek report

Hi Carrie -- I read over the report and am generally satisfied with the revisions. The BACI analyses and Regression analysis are mostly well done -- I don't think their conclusions will change much if they redid the analyses according to my suggestions...

---------- Lemon Creek Comments ---------------------

p.8 Fish Tissue ..."PAH levels are similar ..." Is there any formal analysis? Where are the graphs?

"PAH levels found in Mountain WhiteFish tissue.... similar to implied reference sites"....

Section 5.
p.9 "Pop estimates of RT ... are stable over temporal and spatial scales".
Not clear what is meant by spatial scales? Do you mean density is similar everywhere?

p.20 Used a pie chart to compare the proportions between the two years.
There are formal statistical procedures to compare proportions (chi-square tests) and if you are going to use a pie chart, make the pie circular and not oval. No useful information presented in Figure 5.5 compared to the table of percentages.
Rather than a pie chart, present segmented bar charts similar to Figure 9-4/9-5 etc.

p.21 Y axes here should be % to account for different number of fish captured.

p.22 Ditto comments. Don't report species proportions to any decimal places, i.e. report to integer values only.

p.29 Figure 5.12/5.13/5.14 should have Y axis as % rather than numbers to account for different sample sizes in the two years.

p.31 Table 5.9 SE (and not SD) should be reported when comparing means. A formal t-test could be used here, but given the high variation, likely not necessary. It would be easier to compare the mean if the SE were given.

p.31 Table 5.10. Not clear what the +/- refer to? SE or 95% confidence interval?
You are comparing population numbers, but perhaps the area of the sites differ? Table 5.10 is like comparing Vancouver to New Denver. Yes, the population size of Vancouver is larger than New Denver, but the area of Vancouver is also much larger than New Denver. You need to convert the population number to a density estimate to provide more meaningful comparisons.

p.33 Discussion of population numbers should be recast interns of density (e.g. per river km) to account for different areas sampled using electrofishing?

p.34 Ditto to p.33 for discussion of population estimates.

p.38 Leave a blank for 2012 in Figure 6-2/ 6-3/ 6-4 to avoid distortion as noted on bottom of page 38.

p.66 Figure 8-9. Y axis should be % not frequency to deal with different sample sizes.

p.68 Figure 8-10. Fix the X axis.

p.79 "... this data was considered suspect" - need more details.
"LSBI00 site was excluded because of abnormally low abundance Oct 2014.

p 79 – the reference site on the Slocan River and Little Slocan River were dropped from the analyses
The reasons given are a bit sparse and could use more explanation, but if the sites do have the problems cited, then there would be a good reason to exclude it.

p. 82 – some different analyses and biometrics from the draft report were employed
The newer methods are sensible and are reasonably well done. I would have modeled abundance and richness directly using normal theory methods and using log() and % OC and %EPT using the logia-transform rather than the glmer() model done by the authors. I don't think the conclusions will change but it removes on level of problem (the over dispersion mentioned).

Refer to Barton (2011) The Arcsine is asinine, Ecology 92, 3-10. Similarly, Gary White has several paper that shows modeling log(counts) using normal theory models works pretty well. In both cases you don't need to worry about over dispersion.

The analysis of # species could be slightly problematic as there is no distinction between, for example, 1000/1 individuals of 2 species and 500/500 individuals of 2 species - both have "number of taxa=2". The authors tired to get at this problem by decomposing the analysis into several lower levels such as total abundance, EPT abundance, and Oliogo/Chiron % abundance which is often done. You might be able to delve deeper into the data using the diversity profiles that I mentioned in my previous review, but the proposed measures may be "good enough"

p.83. Excluding April 2014 data seems sensible if there is no other April data available from previous years.

p.84 BACI / Regression analyses generally ok, but see comments below on Appendix II

p. 84 – "no correction was made for multiple testing"
This actually "helps you" as they didn't try and downgrade "positive results" as artifacts of the testing. The problem of multiple-testing is that if you don't correct for multiple testing, you get too many false positives. So some of the results with p-values < .05 may be "false positives" but they didn't try and remove these by essentially reducing the significant p-value to .01 (from .05).

Appendix II. p.1. Table 2. "Harmonic mean". This seems like an odd choice. Do you mean geometric mean, i.e. abundance data analyzed on the log() scale? For example, the EPT Richness for exposed areas in Lemon Creek (Table 2), give a value of
5.38=exp(mean(log(4)+log(3)+log(7)+log(10))

Appendix II. p.1, Table 3. Ditto.

Appendix II. p.2/3 I would have modeled abundance and richness directly using log() and % OC and %EPT using the logit-transform using normal theory methods. Refer to
Barton (2011) The Arcsine is asinine, Ecology 92, 3-10. Similarly, Gary White has several paper that shows modeling log(counts) using normal theory models works pretty well. In both cases you don't need to worry about over dispersion as noted on page 3.

Appendix II. p.3. "Reverse BACI Analysis"? What does the "Reverse" refer to?

Appendix II. p.3. If you use the regular mixed linear models on log(Abundance) or logit(abundance) directly, you get the mean (over all sites) directly and don't have to pick "one" station for plotting.

Appendix II. p.4. Tables 5, 7, 9, 11, 13, 15 etc are redundant as they just give you the result from the last line of the table immediately above it.

Appendix II. p.5. Table 16. See comments 2 above.

Appendix II, p.7/8. Again, every second table is redundant.

SNC-Lavalin Inc.
8648 Commerce Court
Burnaby, British Columbia, Canada, V5A 4N6
604.515.5151 604.515.5150

August 11, 2016 Project: 615438

Executive Flight Centre
200, 680 Palmer Road
NE Calgary, AB T6E 7R3

ATTENTION: Dean Buckland, President

REFERENCE: Responses to MoE Comments Regarding Review of *Lemon Creek Spill: Environmental Monitoring Plan Final Report*

As requested by Ministry of Environment (MoE), SNC-Lavalin Inc. (SNC-Lavalin) has prepared this letter to address comments received by MoE on July 20, 2016 as it relates to the *Lemon Creek Spill: Environmental Monitoring Plan Final Report,* dated April 29, 2016. Our responses pertain specifically to the two comments received from MoE.

RESPONSE TO COMMENTS PROVIDED BY MINISTRY OF ENVIRONMENT

The format of responses follows the same outline as that provided by MoE and each bullet point under each section heading is addressed in the same order as in the response letter.

1) As per the memo submitted to MoE (July 22, 2014), SNC-Lavalin committed to "observe and document the conditions along Lemon Creek and Slocan River as part of the ongoing Biological EMP". These field observations remain outstanding in the revised report. Please include the field observations in the addendum.

- **Notes regarding observations made in the field have been included in the Final report and referenced as Appendix I. Field notes were only applicable to the water quality and benthic invertebrate programs.**

2) Figures 21, 22, 23, 33, 43 [in Appendix IV] are not clear as probability ellipses are not visible. Please provide legible figures and interpretation of the information displayed.

- **Text has been added to Section 9.3.2.4.2 that describes why the figures in question are different from the other figures in Appendix IV. The figures have now also been renumbered and Figure 23 was removed from the appendix as April 2014 data were not used in the CABIN analyses.**

CLOSURE

We trust this meets your current requirements. Should you have any further questions, please feel free to contact one of the undersigned.

Jason Baird, B.Sc., B.Tech., R.P.Bio.
Aquatic Biologist
Environment & Geoscience
Infrastructure
SNC-Lavalin Inc.

Cory Bettles, M.Sc., R.P.Bio., CFP
Principal Fisheries Biologist
Pisces Scientific Group

JB
P:\LOB\EIAM-BC\CURRENT PROJECTS\EXECUTIVE FLIGHT CENTRE\615438 (EMP)\REPORTING\MOE COMMENTS\SNC RESPONSE TO MOE COMMENTS\FINAL REPORT\L1218CBA_SNC RESPONSE TO MOE COMMENTS ON FINAL EMP.DOCX
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