1999 Slocan River Watershed: Benthic Macroinvertebrate Assessment.

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EXECUTIVE SUMMARY

During our 1999 quantitative benthic macroinvertebrate monitoring program, four indicator streams (Airy, Bonanza, Lemon and Winlaw Creeks) were sampled . Samples from these creeks were sorted and processed, and any macroinvertebrates found were identified to taxa (usually family). The resulting data were examined to assess environmental impacts using a variety of indicators (metrics). Possible impacts from sediment contamination were also reviewed.

In addition, levels of trace metals and total phosphorus in the indicator streams were monitored in 1999 using a stratified random sampling design, and these levels were compared with B.C. provincial criteria. Levels of other forms of phosphorus and nitrogen were measured during the fall low-flow period to assess possible nutrient limitation at this time.

Finally, data collected by the Slocan Valley Water Quantity and Quality Monitoring Program were reviewed to assess potential influences of specific parameters (e.g., water quantity, sediment type, conductivity, temperature) on benthic macroinvertebrate communities.

The greatest abundances of macroinvertebrates were observed in Winlaw Creek. Winlaw, Airy and Lemon Creeks had the most diverse feeding group assemblages, and Winlaw and Airy Creeks supported the greatest diversity of benthic macroinvertebrate taxa.

Habitat stability ratios in Winlaw, Lemon and Airy Creeks exceeded 0.5, which indicated that substrate stability was a limiting factor for their macroinvertebrate communities. In contrast, stable substrates were not found to limit macroinvertebrate communities in Bonanza Creek.

In 1999, scrapers were more common than collector-filterers in Bonanza, Winlaw and Airy Creeks, while the opposite was true in Lemon Creek.

Airy Creek had a high ratio of predators to total functional feeding groups, indicating that there was a sufficient prey base to support a large predator population. This was not the case in Winlaw, Lemon and Bonanza Creeks, which had low ratios of predators to total functional feeding groups.

A high percentage of EPT (Ephemeroptera Plecoptera Trichoptera) organisms in all of the sampled streams indicated that the community has not been impacted by high levels of deposited sediment. However, background literature suggests that macroinvertebrate abundance could potentially be influenced by low levels of deposited sediment, especially if sediments move along the bottom and scour invertebrates.

In the surveyed streams, most trace metals measured were present at levels below the threshold values established by BC Ministry of Environment, Lands and Parks (MELP) and Health and Welfare Canada. Dissolved aluminum levels were not measured during 1999. However, total aluminum levels – although consistently higher in spring than in fall on most creeks – were sufficiently low to suggest that

dissolved aluminum dose not present a drinking water concern, nor is it likely to affect macroinvertebrates.

Copper levels measured during the present study were well below B.C. Water Quality Criteria for raw drinking water. However, copper levels exceeded fresh water/aquatic life criteria at certain times. Mean total copper level exceeded the 30-day average criterion in Winlaw, Elliot, Jerome and Bonanza Creeks during the 1999 spring freshet, and in Elliot and Bonanza Creeks during the fall low-flow period. Maximum copper levels exceeded the threshold considered acceptable for waters which support aquatic life on one occasion during spring freshet on Bonanza Creek. However, these levels of copper were still well below some of the published thresholds values for impairment of aquatic life.

Future monitoring of trace metals and nutrients in the study creeks should be based on assessment of duplicate samples from each sampling location. As well, pH and water hardness measurements should be made when water samples are collected for trace metal monitoring. We recommend that future substrate measurements are carried out using a McNeil sampler in order to better characterize substrate composition and presence of deposited sediment. Periphyton sampling should also be carried out in order to better characterize macroinvertebrate food availability.

Future assessments of benthic macroinvertebrates should be aided by the establishment of region-wide control or reference streams. Interpretation of macroinvertebrate data could also be improved if multivariate techniques were used to examine impacts of water quality, sediment levels and other habitat measures on macroinvertebrate community data. Finally, long term monitoring in these creeks is essential to the assessment of the effects of forest practices and other impacts on macroinvertebrates.

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1. INTRODUCTION

The Slocan River Watershed Benthic Macroinvertebrate Monitoring Project (SRWBMMP) is a joint effort by the Winlaw Watershed Commitee and the Ministry of Environment, Lands and Parks (MELP). The project is a component of two larger projects, namely the Slocan Valley Water Quality and Quantity Monitoring Program (SVWQQMP) and the FRBC Water Resource Inventory Program.

The SVWQQMP was initiated because of concerns over recent increases in erosion and sedimentation in the Slocan River and its tributaries. The overall objectives of the program are to:

- obtain baseline data on water quantity, temperature and quality and biological indicators of selected creeks in the Slocan Valley drainage for the purpose of characterizing current conditions;
- develop streamflow measurement techniques and community knowledge of creeks and watershed field conditions;
- establish a working relation between government, community and the forest licensee as a basis for forest management;
- conduct strategic level watershed assessments in order to: develop site-specific water quality objectives; assess forestry activities; and evaluate the Forest Practices Code.

The main goal of our 1999 work was to collect, analyze and interpret macroinvertebrate sampling data from indicator streams in the Slocan River Watershed. Specific objectives of the study were to:

- Carry out quantitative monitoring of the benthic macroinvertebrate community from four indicator streams in the Slocan River Watershed.
- Analyze benthic invertebrate data for potential impacts from forest activities, sediment and other water quality variables.
- Recommend research and further monitoring programs that may be necessary to support the Slocan River Watershed program.

Monitoring of macroinvertebrates in the Slocan watershed was initiated in 1997 with a program that included qualitative monitoring (using unreplicated sampling) of Five Mile, Airy, Bartlett, Bonanza, Cadden, Duhamel, Elliot, Harris, Hasty, Jerome, Lemon, McFayden and Winlaw Creeks. In this study, several 'metrics' (ARC 1998) were used to qualitatively relate macroinvertebrate communities to stream condition. However, *quantitative* data on macroinvertebrate populations of these streams was not collected. As a result, in 1998 a quantitative sampling program was initiated on four indicator streams (Airy, Bonanza, Lemon and Winlaw Creeks) to establish a database for use in examining long-term trends in benthic macroinvertebrate abundance.

In 1999, quantitative monitoring of macroinvertebrates was continued using similar methods to those employed in 1998. Macroinvertebrates collected from the four creeks were sorted, processed and identified to taxonomic group (usually family or order). The resulting data were examined for impacts to a variety of indicators or 'biometrics' using methods developed by the US EPA as outlined in their web site (Barbour *et al.* 1997) and described in Plafkin *et al.* (1989). Quantitative data collected in 1999 were compared to those collected in 1998.

In 1999, in addition to collecting macroinvertebrates we also measured levels of trace metals and total phosphorus in the four indicator streams using a stratified sampling program. Observed levels were compared to B.C. provincial criteria. Other forms of nitrogen and phosphorus were also measured during the fall low-flow period, in order to assess possible nutrient limitation during this period. This assessment also included evaluations three small streams (Jerome, Mcfayden and Elliot Creeks) that were not sampled for macroinvertebrates.

1.1 Macroinvertebrate as Indicators of Stream Health

Freshwater macroinvertebrates are an essential part of the aquatic food web, providing an important food resource for fish and other vertebrate species. Cconsequently, they have been extensively used as indicators of stream health (Barbour *et al.* 1997).

Typically, there are two distinct pathways for food acquisition in a stream: *autotrophic* (based on sunlight and algae/plant production) and *heterotrophic* (based on leaf litter that falls into the stream from riparian areas). Macroinvertebrates can be differentiated groups that correspond to these pathways, according to their mode of food acquisition (Table 5, Figure 1).

Certain groups of macroinvertebrate taxa are more sensitive to environmental disturbances (e.g., changes in sediment inputs, nutrient abundance, pollution, *etc.*) than others, and consequently are not found under impacted conditions. Conversely, other groups are highly tolerant of impacts and thrive in impacted streams. Thus, the types of organisms that are present in a stream can serve as an indicator of stream condition.

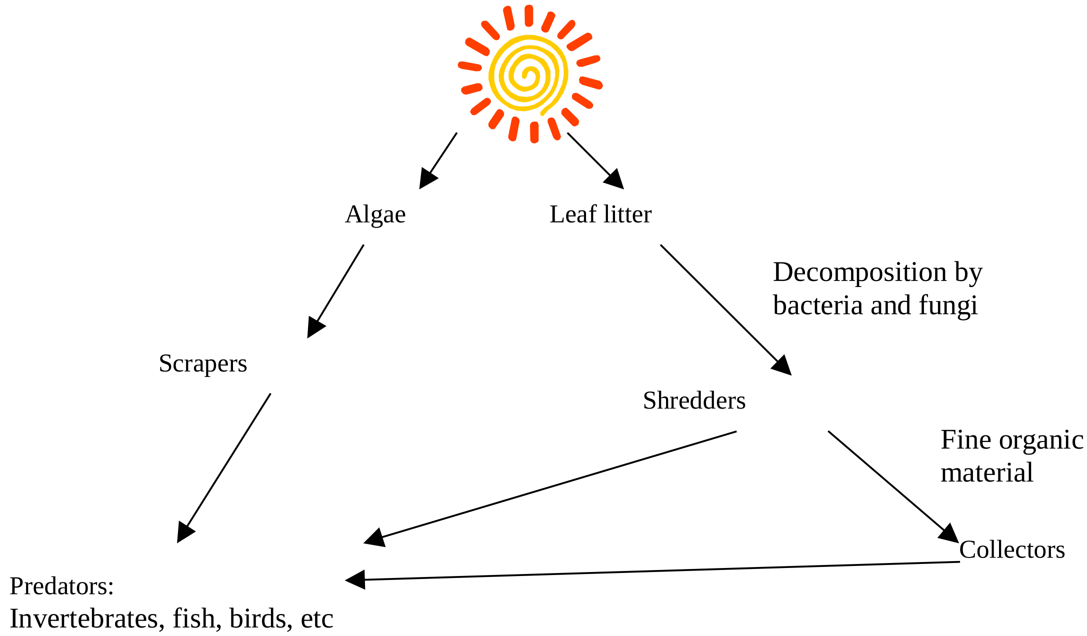

Figure 1. Food web for functional feeding groups

2. METHODS

2.1 Characteristics of Indicator Creeks and Sampled Sites

Bonanza, Lemon, Winlaw and Airy Creeks were monitored for macroinvertebrates, periphyton and water quality in 1999. These streams were selected because they are large streams with high fisheries values (

Table 2), and are also sources of domestic water for a number of local residents. Macroinvertebrates were sampled from water quantity monitoring stations (Table 1) described in Yeow and Yeow (1999). Characteristics of these creeks (Table 3) are discussed below.

Elliot, Jerome and MacFayden Creeks were sampled solely for trace metals and nutrients. These streams are sources of drinking water for streamside residents.

Table 1. Locations of macroinvertebrate, and water quantity and quality monitoring sites

Creek	Closest Town/Village	Parameters Assessed in Present Study	Latitude (N)	Longitude (W)
Bonanza	Hills	Macroinvertebrates, periphyton, trace metals, nutrients	50°06’36”.36	117°28’50”.30
Lemon	Slocan	Macroinvertebrates, periphyton, trace metals, nutrients	49°42’12”.65	117°29’03”.28
Winlaw	Winlaw	Macroinvertebrates, periphyton, trace metals, nutrients	49°36’10”.10	117°32’38”.45
Elliot	Passmore	Macroinvertebrates, periphyton, trace metals, nutrients	49°33’31”.07	117°42’28”.21
Airy	Appledale	Trace metals, nutrients	50°06’42”00	117°29’31”.00
Jerome	Appledale	Trace metals, nutrients	49°39’35”.00	117°32’10”.00
McFayden	Vallican	Trace metals, nutrients	49°34’14”.00	117°39’22”.00

Bonanza Creek mainstem is 13.8 km long and flows southeast from Summitt Lake into the north end of Slocan Lake. The creek’s mouth is located 7.5 km north of Roseberry, 2 km south of Hills along Highway 6. A weir at the Summit Lake outflow provides minor flow control to Bonanza Creek. There is a small marsh downstream of the outflow area, after which the stream becomes more channelized and has a higher gradient. Macroinvertebrates were sampled in this middle of the stream, approximately 3.5 km upstream from the mouth. The stream channel becomes considerably more marsh-like and less channelized below the sampled area, as it nears Slocan Lake (KFC 1997). Bonanza Creek is an important spawning area for kokanee and rainbow trout.

Lemon Creek is a fifth-order stream 26 km long with a gradient that ranges from 2-6%. The creek is fed by approximately 380 km of tributary streams, its main tributaries being South Lemon, Chapleau, Holmsen, Monument, Crusader and Nilsik Creeks. Lemon Creek flows into the Slocan River 7 km downstream of Slocan Lake, at a point where the river’s floodplain is quite wide. However, not far downstream from the Lemon Creek mouth, the Slocan River becomes much more confined and fast-flowing. The lower reaches of Lemon Creek therefore support an unusually diverse fish assemblage composed of fast and slow-species (Zimmer 1999). Macroinvertebrate sampling in Lemon Creek was done at a site was located approximately 800 m from the creek’s mouth.

Winlaw Creek flows west from Mount Eccles into the Slocan River, with a watershed covering 47.5 km^2. It is primarily a low elevation system, as most of the watershed’s area falls below the 1800 m contour (Apex 1998). The community of Winlaw is located on the alluvial fan near the creek’s mouth, and a total of fifty-five water licenses have been registered on the creek (Apex 1998). Winlaw Creek provides important spawning habitat for rainbow trout and bull trout (AEC 1997). The macroinvertebrate sampling station was located approximately 700 m upstream from the creek's mouth.

Airy Creek is a third-order stream with a total stream length of 147.8 km and an watershed covering 56.9 km^2 (DBL 1995). Its major tributaries are Tindale and Camp 5 Creeks. Airy Creek's gradient ranges from 3-25%, and a with a population of rainbow trout inhabits the lower (i.e., low-gradient) reaches. There are eleven domestic water licenses on Airy Creek (DBL 1995). The Airy Creek macroinvertebrate monitoring station was situated approximately 500 m from the creek mouth.

Table 2. Presence of fish species in the four indicator creeks selected for macroinvertebrate monitoring[1]

Species		**CreekName**			
		Bonanza[1]	**Lemon[2]**	**Winlaw[3]**	**Airy[4]**
Rainbow trout	*Oncorhyncus mykiss*	X	X	X	X
Kokanee	*Oncorhyncus nerka*	X	X		
Westslope cutthroat trout	*Oncorhyncus clarki lewisi*		X		
Bull trout	*Salvelinus confluentus*		X	X	
Eastern brooktrout	*Salvelinus fontinalis*		X		
Mountain whitefish	*Prosopium williamsoni*		X		
Prickly sculpin	*Cottus asper*	X			
Mottled sculpin	*Cottus bairdi*	X		X	
Shorthead sculpin	*Cottus confusus*		X		
Slimy sculpin	*Cottus cognatus*		X		
Torrent sculpin	*Cottus rhotheus*		X		
Peamouth chub	*Mylocheilos caurinus*			X	

[1] KFC (1997) [2] Zimmer (1999), [2,4]Addison (1996), [1,2,3,4] Anon. (1997), [2]Wildstone (1995)

Table 3. Characteristics of creeks sampled for macroinvertebrates and/or water quality[1]

Measure	Bonanza Ck.	Lemon Ck.	Winlaw Ck.	Airy Ck.	Jerome Ck.	McFayden Ck.	Elliot Ck.
Area (km^2)	Not available	58.0	40.7	58.0	2.9	5.0	2.0
Aspect	South	West	West	North	SE	SE	SW
Maximum. Elevation (m)	2200	2200	1700	2600	1800	2100	1750
Gradient %	3.0	2.0	2.5	2.0	15+	15+	15+
Stream type	Riffle-Pool	Cascade-Pool	Riffle-Pool	Riffle-Pool	Step-Pool	Step-Pool	Step-Pool
Min.-Max. flows ($m^3 \cdot sec^{-1}$) 1997	0.6-16.7	1.14-39.0	0.1-14.9	0.15-19.8	0.004-0.357	0.008-1.2	0.003-0.131
Min.-Max. flows ($m^3 \cdot sec^{-1}$) 1998	0.7-8.0	1.12-26.3	0.9-5.5	0.09-13.3	0.009-0.18	0.002-0.737	0.001-0.089
Min.-Max. flows ($m^3 \cdot sec^{-1}$) 1999	0.9-11.9	0.9-44.9	0.02-9.1	0.22-25.4	0.007-0.262	0.009-1.2	n/a-0.10
Max. Total suspended sediment concentration, TSS ($mg \cdot l^{-1}$) 1997	54.3	266.0	168.0	177.0	46.3	63.8	28.8
Max. TSS ($mg \cdot l^{-1}$) 1998	120.0	213.0	34.5	13.8	15.0	6.3	7.0
Max. TSS ($mg \cdot l^{-1}$) 1999	125	174	284	102	43.5	34	52.2
Min.-Max. conductivity ($\mu S \cdot cm^{-1}$) 1997	111.0-157.0	Not available	47.3-132.0	10.3-40.3	79.3-181	31.7-126	85.4-202
Min.-Max. conductivity ($\mu S \cdot cm^{-1}$) 1998	122.0-158.0	Not available	49.4-143.0	10.4-37.9	87.3-172	36.6-123	97.2-213
Min.-Max. conductivity ($\mu S \cdot cm^{-1}$) 1999	110-160	28-92.9	40.8-127	8.3-66.2	85.4-178	28.2-122	85.3-208

[1] Data from Yeow and Yeow 1997, 1998 and 1999

2.2 Field and Laboratory Methods

2.2.1 *Water Quality Parameters*

Methodologies used for measuring water quality and quantity in the study creeks and other Slocan Valley tributaries have been summarized in a series of reports produced by Passmore Laboratory Ltd and the Slocan Valley Watershed Alliance (Yeow and Yeow, 1995, 1997, 1998, 1999, 2000).

In general, local residents collected data on temperature, weather, took water samples and monitored water levels throughout the study. In addition, volunteers conducted *in situ* field tests to determine acidity, alkalinity, hardness, pH and oxygen using a Model AL-36B Hach *Water Ecology Kit* in 1994 and 1995. Laboratory testing of water samples for turbidity, suspended sediment, conductivity, total and fecal coliform has been carried out at Passmore Laboratory Ltd since 1994, and is on-going (see Yeow and Yeow, 1995, for laboratory methods).

In the present study, analyses of samples for metals and total phosphorus were carried out for five dates stratified over high and low flows on Jerome, Elliot, McFayden, Bonanza, Winlaw and Airy Creeks.

In Lemon Creek, total phosphorus was monitored once during spring freshet and once during the low flow period, and metals were measured once during the spring freshet.

Nitrate, nitrite, total Kjeldahl nitrogen and ammonia nitrogen samples were collected once during the low flow period on each of Bonanza, Airy, Lemon, and Winlaw Creeks. For more details on the sampling schedule see Yeow and Yeow (2000). ASL analytical Laboratory Ltd. in Vancouver, B.C. performed these laboratory analyses using procedures adapted from APHA (1998). These data were evaluated and compared to B.C. MELP water quality guidelines (MELP 1999).

pH was not monitored during the water sampling for trace metals in 1999, and pH data collected from 1994–1995 were used to estimate present conditions. Hardness was calculated for each creek using average levels of total calcium and total magnesium in 1999. Average data were ompared with criteria established by the provincial government (MELP 1999). Because Lemon Creek metals were only analyzed once in 1999, 1994/95 data were used in all Lemon Creek calculations.

2.2.2 *Periphyton*

Periphyton samples were collected at the same times and locations as benthic invertebrate samples (i.e., Sept. 16-20, 1999 on Airy, Bonanza, Winlaw and Lemon Creeks. At each site, five replicate cobbles were selected from the stream bottom. Flat stones fully covered with water and from similar depths and light exposure were chosen to minimize environmental variation. Periphyton was scraped from a known area using a dental brush and a rubber ring (inside area = 8.55 cm^2). All periphyton was rinsed from the pipette and the brush. The algal densities appeared to be low and, as a result, five scrapes of each cobble were combined in one sample bottle. The bottles were wrapped in foil and put in a cooler on ice to prevent further growth of algae. Samples were kept in the freezer until processing by the laboratory. After thawing, each sample was filtered with a hand held Sartorius pump onto a 0.45 μm Millipore filter paper to retain the algae. After filtration, the filter paper was folded and placed inside a larger Whatman filter paper labeled with the sampling site, date, time, area scraped and replicate number. The processed samples were refrozen until shipment to the laboratory.

2.2.3 *Macroinvertebrate Habitat Data*

Habitat data were collected in the field at each macroinvertebrate sampling site at the time of sample collection. Standard methods were followed according to RIC (1998), Hayslip (1993), and Kappesser (1993).

Each site length was measured using a 30 m Eslon tape. Channel and wetted widths were also taken at each site, measuring bankfull (flood stage) width of the stream channel and wetted width portion, respectively. Stream gradient was measured at each site using a Suunto clinometer and staff gauge. Stream stage of the current discharge, recorded as a percentage of bankfull, was visually estimated. Air and water temperature was recorded and water clarity (turbidity) was visually estimated. These methods followed RIC (1998).

Types and amounts of in-channel cover were visually estimated as a percentage of total available cover over the site. Abundance and distribution of functional large woody debris and types of instream vegetation were also recorded. The bank shape, type and stage of the riparian vegetation, and texture of the dominant material of the channel bank were also identified. Visual assessments of dominant and sub-dominant bed material were conducted. Disturbance indicators, channel pattern, types of channel bars, and presence and frequency of islands were also visually estimated. The linkage between the hillslope and the channel, known as coupling, and the confinement of lateral channel movement by the valley walls was also recorded. The above methods followed RIC (1998).

A boulder, leaf pack, and large and small woody debris count was conducted within the sampling site. Water velocity, depth of water, and distance of benthic invertebrate sampling sites from the left bank were also recorded.

Particle size distribution of the stream bed was determined by the sampling procedure known as the Wolman pebble count (Kappesser 1993). A transect was begun at a randomly selected point within the sampling site, at one of the bankfull elevations. Walking heel to toe, one step was taken across the channel in the direction of the opposite bank. Picking up the first particle touched by the tip of an index finger at the toe of the wader, the intermediate diameter of the particle was measured with a metric ruler. Embedded particles, or those too large to be moved, were measured in place. Very large particles were counted as the same particle as many times as a toe encountered it. The samples were then tallied by the Udden-Wentworth size class as less than 2 mm, 2-4 mm, 4-8 mm, 8-16 mm, 16-32 mm, 32-64 mm, 128-256 mm, 256-512 mm and 512-1024 mm. After counts and tallies were complete, the cumulative percent finer was then calculated for each size class, and the data were plotted by size class and frequency.

2.2.4 *Benthic Macroinvertebrates*

Benthic invertebrates sample collection was coordinated by Darcie Quamme (ARL) and Jennifer Yeow (Passmore Labs) during September 16-20, 1999. Other individuals who aided in sample collection (including habitat and periphyton data) included Peter Wood, Leslie Mayfield, Rita Corcoran, and Aram Yeow.

A Hess sampler (mesh size 210 μm, area 0.0642 m^2) was used to sample riffle habitat in each stream. Five replicate sites were chosen at each stream in riffles with adequate flow and gravel/cobble substrate. The sampler was placed on the stream bed and larger rocks were brushed and removed from the sampler first. Remaining gravels were then disturbed by hand to a depth of 5 –10 cm. The substratum was disturbed by hand for one minute. All organisms were rinsed from the net into a sampling jar. All samples were preserved in 70% ethanol.

Macroinvertebrates were washed and decanted from sediments, detritus and preservative. Preservative was removed using a screen of mesh 100 μm. Benthos was sorted using a dissecting microscope (10× magnification) and macroinvertebrates were removed from detritus and sediment. Individuals were identified to the genus level wherever possible, and to lower levels depending on the size and quality of the specimen. All macroinvertebrate groups were removed and delivered to Danusia Dolecki for taxonomic identification in Vancouver. Identified taxa were preserved in 70% ethyl alcohol in glass vials. Vial lids were air-tight fit and appropriately labeled.

Methods were consistent and comparable to previous work carried out on these streams (ARC 1998, ARL 1999) and where possible similar keys were used to identify macroinvertebrates.

Quality assurance checks were done of 10% of the samples ensuring that sorters were checked. Darcie Quamme co-ordinated sample tracking. A record of the location of each sample was kept on file at all times.

It was necessary to subsample most samples because time required to count the whole sample was prohibitive (Merritt and Cummins 1984). Subsampling was performed using a sample splitter. At least 100 individuals (±10%) were randomly removed and counted (Merritt and Cummins 1984).

2.3 Analysis and Interpretation of Macroinvertebrate Data

Benthic macroinvertebrate sampling data were analyzed using a variety of biometrics designed to assess the state of the macroinvertebrate community (Table 4). Macroinvertebrate abundance, taxonomic richness (i.e., number of taxa) and composition, tolerance, trophic and habitat stability metrics were assessed for each site. These metrics were then rated on a scale ranging from not impacted, slightly impacted, and moderately impacted to severely impacted.

Streams with good habitat and high water quality should have a diverse group of macroinvertebrates. Indicators of stream condition include the number of taxa, the number of EPT taxa at a site, and the ratio of EPT (Ephemeroptera Plecoptera Trichoptera) to total taxa. Epemeroptera are commonly known as mayflies, Plecotera as stoneflies, and Trichoptera as caddisflies. These groups are good indicators of increasing water quality and are important fish food items. In our analyses, the number of taxa per sample was calculated by counting the number of genera identified in a sample. However, if there was no identification to genus then highest resolvable taxonomic unit was included in the count (usually family or order).

Table 4. Metrics used in analysis of benthic invertebrates.

Metric	Measure	Indicator	Assessment/Rating
Abundance/ density	Production	Indicator of stream health, production of food for other organisms such as fish	Quantitative assessment allows comparison from year to year and between sites
Total number of taxa	Taxonomic richness	Indicates health of the community, reflects increasing water quality, habitat diversity and suitability	No impact- >26 taxa present Slight impact - 19-26 taxa Moderate impact- 11-18 taxa Severe impact- <11 taxa
Number of EPT taxa	Taxonomic richness	Number of sensitive taxa (including mayflies (E), stoneflies (P) and caddisflies (T)), indicators of high water quality	No impact- >10 taxa present Slight impact - 6-10 taxa Moderate impact- 2-5 taxa Severe impact- <1 taxa
EPT/total taxa	Taxonomic richness	Ratio of sensitive taxa (including mayflies (E), stoneflies (P) and caddisflies (T)) to total number of taxa	No impact- >40% Slight impact - 30-39% Moderate impact- 20-29% Severe impact- <20%
% Dominant taxon	Compositio n	Indicates community balance, a community with only a few taxa indicates community stress	No impact- <20% Slight impact - 20-29% Moderate impact- 30-39% Severe impact- >40%
Hilsenhoff biotic index	Tolerance	Pollution tolerance, mainly organics	No impact- 0-3.5 Slight impact - 3.5-5.5 Moderate impact- 5.5-7.5 Severe impact- 7.5-10
EPT/(EPT+ chironomid) ratio	Tolerance	Measure of community balance, good biotic condition is reflected in communities with even distribution of all four groups	No impact- >75% Slight impact - 50-75% Moderate impact- 25-50% Severe impact- <25%
No. taxa by functional feeding group (FFG), and Percent functional feeding group	Trophic (feeding) status	Indicator of community food base, reflects the type of impact detected (Functional feeding groups include: predators, collector-gatherers collector-filterers, scrapers, shredders, parasites)	Descriptive assessment based on number of taxa in each group and relative proportions
Scraper/(Scraper+Collect or-Filterer)	Dominant food resources	Indicates the condition of the periphyton community, availability of fine particulate organic matter and availability of attachment sites for filtering	Ratios of greater than 0.5 indicate that periphyton is the dominant food resource and ratios of less than 0.5 indicate that organic materials are the dominant resources available for macroinvertebrates
(Scraper + Collector-Filterer) /(Shredders + Collector-Gatherers)	Habitat Stability	Assessment of available surfaces for stable attachment and substrate stability	Ratios of greater than 0.5-0.6 indicate that stable substrates are not limiting, ratios of less than 0.5-0.6 indicate stable substrates are limiting

[1]from Plafkin *et al*. 1989, Barbour *et al.* 1997 and Merrit *et al.* 1996

Streams impacted by disturbance are sometimes dominated by a few types of organisms that can tolerate disturbed conditions. The percent dominance by abundance of each taxonomic group indicates community balance.

Hilsenhoff's Biotic Index assesses community tolerance to organic pollution. Certain species of macroinvertebrates thrive in a polluted environment while other species tend to drop out. Thus, tolerance values can be assigned to individual taxa ranging from 0 (intolerant) to 11 (tolerant). A higher tolerance value indicates tolerance to higher levels of organic pollution including sediment loading and lower oxygen levels within the substrates. Tolerance values for this analysis were taken from Barbour *et al.* 1997 for Idaho and the Mid-Atlantic Coast.

Hilsenhoff's Biotic Index was calculated as follows:

$$HBI = (\sum n_i a_i) / N$$

n_i = the number of macroinvertebrates in each taxonomic group
a_i = the pollution tolerance score for that taxonomic group
N = the total number of organisms in the sample

The EPT/(EPT + Chironomidae) ratio is a measure of the balance of a macroinvertebrate community. In a healthy stream there will be a high proportion of EPT organisms, but at some sites where, for instance, there may be high levels of deposited sediment or contaminants, there will often be an increasing proportion of chironomids (midge larvae).

An analysis of macroinvertebrate functional feeding groups provides important information on the links between food resources and various components of the food web. In the present study, basic trophic metrics (e.g. number of taxa by functional feeding group, percent functional feeding group and the ratio of scrapers to scrapers plus collector-filterers, see Table 5) were used to assess feeding status and the dominant food resources (Plafkin *et al.* 1989). Individual taxa were assigned a trophic feeding status based on Merritt and Cummins (1996) and assignments developed for Idaho and Mid-Atlantic Coast (Barbour *et al.* 1997).

Table 5. Stream invertebrate functional feeding groups and associated food resources.[1]

Functional Feeding Group	Food Resource
Shredders	Either live aquatic macrophyte tissue or plant and leaf litter
Scrapers	Periphyton (algae, fungi etc..) and associated material from substrate surfaces
Filtering or Gathering Collectors	Fine particulate organic matter
Parasites	Invertebrate and vertebrate hosts
Plant Piercers	Plant fluids from macroalgae and vascular hydrophytes
Predators	Live prey (typically other macroinvertebrates)

[1]Based on descriptions in Merritt *et al.* 1996

A ratio of habitat stability (Table 4) was used to assess available surfaces for stable attachment and substrate stability (Merritt *et al.* 1996). If stable substrates are not limiting, this ratio should be greater than 0.5. The ratio of scrapers to scrapers plus collector-filterers was used to assess of the condition of the periphyton community, and availability of fine particulate organic matter and availability of attachment sites for filtering (Plafkin *et al.*1989). Ratios of greater than 0.5 indicate that periphyton is the dominant food resource and ratios of less than 0.5 indicate that organic materials are the dominant resources available for macroinvertebrates.

3. RESULTS AND DISCUSSION

3.1 Water Quality Parameters

3.1.1 *Trace Metals*

Most trace metals were below the criteria set by the MELP and Health and Welfare Canada with the exception of Total copper and possibly aluminum levels at certain time periods on some of the creeks (MELP 1999). Trip blanks were also evaluated and contamination problems were found to be negligible.

Water quality criteria for dissolved aluminum is typically calculated based on corresponding pH for the same time period. However, pH was not measured in any of the streams in 1999. Thus, data on pH was based on measurements made in 1994-96. All pH measurements taken from 1994-96 for all creeks were 6.5 or greater.

Dissolved aluminum was not monitored during the present study and thus could not be directly compared to criteria. However, maximum Total aluminum levels were compared to and exceeded the criteria for fresh water/aquatic life (0.1 mg/l dissolved aluminum) in Airy, McFayden, Winlaw, Jerome and Bonanza Creek during spring freshet. In addition, maximum Total aluminum levels exceeded the criteria for drinking water (0.2 mg/l dissolved aluminum) during freshet in Airy, McFayden, Winlaw and Bonanza Creek.

The 30-day average Total aluminum levels exceeded criteria for aquatic life (0.5 mg/l dissolved aluminum) on all creeks sampled except Elliot Creek (Appendix A) during the 1999 spring freshet. In contrast, the 30-day average aluminum levels were below criteria in all creeks except Elliot Creek during autumn low flow periods (Appendix B). Total aluminum levels include an unavailable fraction of aluminum that is bound up or sorbed to organics and suspended sediments. Thus, actual dissolved aluminum levels found in this study are likely much lower that Total aluminum values and may not exceed criteria that is based on dissolved aluminum.

Aluminum is not considered to be a serious risk to public health. It is rapidly absorbed to sediments and organic material and precipitated from solution (Cavanagh et al 1998). Much research has been done on increased aluminum levels that accompany acidification of inland waters (Hall et al. 1985). Generally, aluminum toxicity has been found to be related to aluminum speciation, pH and the organic content of the water (Burton and Alan 1986). Aluminum is more toxic to aquatic macroinvertebrates in its monomeric form as compared to polymeric or when bound to dissolved organics. Aluminum also appears to be less toxic to some macroinvertebrates when the organic content of the water is increased (Burton and Alan 1986). Burton and Alan (1986) found that additions of 0.25 mg/l aluminum (at pH 5) caused no increased mortality for Genus Nemoura, Physella, Pycnopsyche, Lepidostoma or Asellus. In our study, none of the 30-day averaged Total aluminum levels in study streams exceeded 0.25 mg/l except for Bonanza Creek in the spring. However as discussed above, the dissolved fraction of aluminum for Bonanza Creek was not assessed.

Water quality criteria for dissolved copper is typically calculated based on corresponding water hardness for the same time period. Hardness values were typically lower during spring freshet compared to fall low flows, and fresh water/aquatic life criteria changed according to changes in hardness (Appendix A/B). Mean hardness values for the creeks during low flow were 64.6 mg/l) for Bonanza, 6.94 mg/l for Airy, 51.5 mg/l for Winlaw, 41.8 mg/l for McFayden, 93.8 mg/l for Elliot, 75.0 mg/l for Jerome, and 62.9 mg/l (94/95 data) for Lemon. Mean hardness values for the creeks during spring freshet were 56.5 mg/l) for Bonanza, 4.11 mg/l for Airy, 23.2 mg/l for Winlaw, 15.9 mg/l for McFayden, 71.5 mg/l for Elliot, 39.5 mg/l for Jerome, and 62.9 mg/l (94/95 data) for Lemon.

Total copper levels observed during the present study were well below B.C. Water Quality Criteria for raw drinking water (5.0 mg/l). In addition, Total copper levels exceeded fresh water/aquatic life criteria at certain time periods (Appendix A/B).

Mean Total copper exceeded the 30-day average criteria on Winlaw, Elliot, Jerome and Bonanza Creeks during the 1999 low flow and on Elliot and Bonanza Creeks during spring freshet. Lemon Creek could not be assessed as to exceedance of the 30-day average criteria because only one sample was collected in 1999. Maximum Total copper levels exceeded aquatic life criteria once during spring freshet on Bonanza Creek.

Copper is acutely toxic to aquatic life at low concentrations and is highly modified by water hardness (Cavanagh et al. 1998). A literature review of work based on short term exposure to copper levels showed that lethal or other endpoints ranged from 0.015 to 3.0 mg/l for fish and aquatic invertebrates (McKee and Wolf 1963). Artificial stream studies have shown that copper levels of 0.0084 - 0.0267 mg/l (water hardness, 77.3 – 78.0 mg/l) can impair clam tissue and shell grown in Asiatic clams, Corbicula fluminea (30-d LC50 was 0.019 mg/l). Newly hatched amphipods were shown to grow to adult stage only in copper concentrations less than 0.004 mg/l copper (water hardness 38 – 55 mg/l) (Arthur and Leonard 1970).

An isolated exceedence in drinking water criteria (0.05 mg/l) occurred with manganese on June 17 in Bonanza Creek, but all other samples taken over the 5 week sampling period remained below criteria. No other systematic trends were observed in the 1999 monitoring regime.

The origins of trace metals to the study creeks are thought to be largely due to natural processes. However, water quality may also potentially be affected by historical or current forest practices. There are other no other anthropogenic inputs of trace metals to these systems upstream of water collection sites

3.1.2 *Nutrients*

Our initial assessment of total phosphorus levels suggests that phosphorus may limit production during the spring high flow periods in Jerome, Elliot, McFayden, Winlaw and Airy Creeks, and during autumn low flow periods on all creeks, as levels were generally below 0.01 mg/l (Bothwell 1989) (n=5 during spring and fall stratified sampling for all creeks except Lemon Creek where n=1). Highest phosphorus levels were seen on Bonanza Creek during spring freshet (see Appendix C), with average phosphorus levels of 0.05 mg/L (n=5). Total phosphorus on Lemon Creek was 0.011 mg/l during spring sampling (on 99/06/22).

Nutrient-limitation (low levels of nutrients) may result in low productivity of the study streams and low abundances of macroinvertebrates. This is likely a natural phenomena exacerbated by the historical loss of nutrients associated with the decline of ocean-going salmon stocks to the Slocan River tributaries. 1996 data from Bonanza Creek show an increase in total phosphorus levels (from 0.005 mg/l to 0.049 mg/l in 1996) that coincides with the kokanee spawning period and die-off in mid to late October.

Nitrogen is unlikely to limit productivity in Bonanza and Winlaw Creeks, however it may limit productivity in Airy and Lemon Creeks. Perrin (1989) showed that algal biomass is potentially limiting at nitrogen levels less than 0.02 mg/l. Total nitrogen levels were greater than 0.02 mg/l on Bonanza and Winlaw Creeks and less that 0.02 mg/l on Airy and Lemon Creeks (Appendix C). However, this assessment of nitrogen-limitation is based only one grab sample collected in late September at all creeks. Nitrogen was not monitored on Jerome, McFayden or Elliot Creeks.

Ammonia, Kjeldahl nitrogen, nitrate and nitrite levels in Bonanza Creek during low flow were 0.02 mg/L, 0.11 mg/L, 0.574 mg/L and 0.004 mg/L, respectively (Appendix C). Winlaw ammonia and Kjeldahl nitrogen levels were both below detection (0.02 mg/L and 0.05 mg/L, respectively). The nitrate level was 0.156 mg/L in Winlaw Creek while nitrite was 0.001 mg/L. Lemon Creek ammonia and Kjeldahl nitrogen levels were below detection (0.02 mg/L and 0.05 mg/L, respectively). Nitrate levels were 0.005 mg/L in Lemon Creek, while the nitrite levels was 0.001 mg/L. Ammonia and Kjeldahl nitrogen levels were below detection in Airy Creek, and nitrate and nitrite levels were 0.005 mg/L and 0.001 mg/L, respectively.

According to Ptolemy *et al.* (1991), typical BC streams have nitrate nitrogen levels ranging between 0.004 mg/L and 0.454 mg/L, with a median value of 0.037 mg/L, while typical Kootenay region streams have median nitrate nitrogen levels of 0.085 mg/L. Thus, nitrate levels in Bonanza and Winlaw Creeks were seven and two times higher than typical Kootenay streams at low flow, respectively. Nitrate nitrogen levels in Lemon and Airy Creeks were 17 times lower than the typical Kootenay Region median nitrate levels.

3.2 Periphyton

The results of the periphyton biomass analyses show that periphyton levels were relatively low at the time of sampling (Appendix D). The presence of chlorophyll α was detected in all replicates for each stream sampled. Average levels were 0.09, 0.46, 0.29, and 0.11 ug/cm^2 for Airy, Bonanza, Lemon and Winlaw Creeks, respectively. Visual observations of periphyton at the time of sampling confirm the laboratory results. There was no substantial periphyton mat or filamentous algae at any of the sampled sites.

Low observed levels of periphyton could be due to a variety of contributing factors including: lateness of sampling date, nutrient limitation, canopy shading, high flows and sloughing of the periphyton mat. Water quality data collected in 1999 indicates that all these streams are phosphorus-limited and Airy and Lemon Creeks are likely nitrogen-limited during the summer months. Nutrient limitation could be a contributing factor.

Also, these streams are high gradient with high flows) and unstable substrates. High flows and the lack of stable substrates can cause sloughing of the periphyton mat and lower algal biomass. Finally, low light levels can also contribute to low periphyton production. Crown closure was high on Winlaw Creek (41-70%) and Airy Creek (71-90%) at the time of periphyton sampling, but was relatively low on Bonanza (21-40%) and Lemon Creeks (1-20%). Thus, shading of the stream may be a contributing factor in Airy and Winlaw Creeks but is less likely to a factor in Bonanza and Lemon Creeks.

3.3. Benthic Invertebrates

3.3.1. Habitat Data

Habitat data is summarized in Appendix E and Wolman Pebble Count data is summarized in Appendix F.

BONANZA CREEK

Air and water temperatures on Bonanza Creek were 14.0 °C and 13.0 °C, respectively, at the time of habitat data collection. The staff gauge reading was 0.435 m. Bankfull width was approximately 9 meters, and wetted width was approximately 7 m.

Stream gradient at the sampling site was approximately 4.0%, and the water was slightly turbid at the time of sampling. Overhanging vegetation made up the majority of the in-channel cover, with moderate amounts of boulders and undercuts and trace amounts of small and large woody debris and deep pools making up the remainder of the cover. Crown closure was moderate, averaging between 21% and 40%. The left bank was u-shaped and vegetated by a young mixed forest of conifers and deciduous trees, while the right bank was sloping, and vegetated by a similar stand of vegetation as the left bank. Dominant and subdominant bed material consisted of cobbles and gravels, respectively. No disturbance indicators were observed, and the morphology of the stream was considered a cascade-pool. Channel pattern can be described as straight, and no bars or channels were present. Lateral channel movement is considered confined and the linkage between the hillslope and the channel is considered de-coupled.

Supplemental habitat data revealed that the average water depth and velocity of benthic invertebrate sampling sites was 0.288 m and 0.476 m/s. The average distance of the macroinvertebrate sampling sites from the left bank (looking upstream) was 4.28 m. There was a few (number not recorded) pieces of functional large woody debris (LWD) at the sampling site, and these were evenly distributed. The number of leaf packs and boulders were not recorded at this sampling site.

The Wolman Pebble Count revealed that Bonanza Creek riffles consisted predominantly of sand, small and large cobbles (21%, 23% and 30%) (see Figure

2 and Appendix F). The majority of the remaining pebbles consisted of small boulders (11%), and coarse to very coarse gravel (14%).

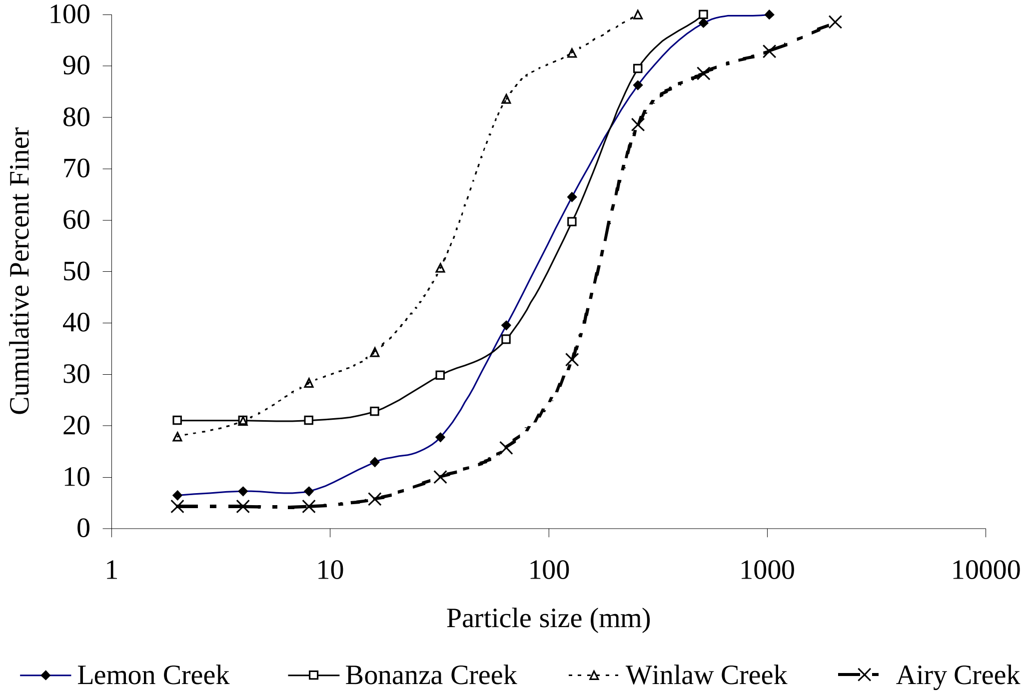

Figure 2. Particle size distribution of streams

LEMON CREEK

At the time of sampling, air temperature was 18.0 °C on Lemon Creek, while water temperature was 10.8 °C. A gauge reading was not recorded on Lemon Creek at the time of sampling. Bankfull width was between 19 and 28 m, and wetted width was not measured.

Stream gradient was approximately 11.0 %, and dominant and sub-dominant bed material consisted of cobbles and boulders, respectively. The amount and type of in-channel cover was not estimated on Lemon Creek. Crown closure was low, averaging between 1% and 20%. The left and right banks were sloping, and vegetated by a mature forest of mixed conifers and deciduous trees. No disturbance indicators were present. Channel pattern can be described as straight, with un-confined lateral channel movement and de-coupling between the hillslope and the channel. Occasional islands were present and instream vegetation consisted of vascular plants

Supplemental habitat data revealed that the average water depth was 0.198 m and the average water velocity was 0.28 m/s. The average sampling distance from the right bank (looking upstream) was 9.8 m. Functional large woody debris was abundant, and clumped together. The number of leaf packs and boulders were not recorded at this sampling site.

Results from the Wolman Pebble Count revealed that Lemon Creek riffles consisted of approximately 40% sands and gravels (7% sand and 33% medium to coarse gravels), and 47% small and large cobbles. The remainder of the particle sizes (13%) were in the form of small and medium boulders (see Figure 2, Appendix F)

WINLAW CREEK

Air and water temperatures on Winlaw Creek were 14.0 °C and 9.0 °C, respectively, at the time of sampling. The gauge reading was 0.238 m, the bankfull width was between 8 and 23.5 m, and wetted width was not recorded.

The Winlaw Creek macroinvertebrate sampling site was approximately 10 m in length. Small and large woody debris made up the majority of in-channel cover, with trace amounts of boulders and overhanging vegetation making up the remainder. Crown closure was high, averaging between 41% and 70%. The left and right banks were finely textured and vegetated by a young forest of mixed conifers and deciduous trees. Dominant and subdominant bed material consisted of cobbles and gravels, respectively. Stream morphology was not recorded.

Supplemental habitat data revealed that the average water depth was 0.142 m, the average water velocity was 0.466 m/s and the average distance of the sampling site from the right bank (looking upstream) was 4.12 m. There were four pieces of functional large woody debris (LWD) and 3 small woody debris items located within the sampling site. There were 2 leaf packs located within the riffles of the sampling site.

The bottom substrate of Winlaw Creek was considered optimal, with less than 10% fines deposited mostly on the edge of the channel. The ‘embeddedness’ of Winlaw Creek riffles was also considered optimal, with gravel, cobble and boulder particles between 0-25% surrounded by fine sediment. Over 90% of the streambank surfaces are covered by vegetation, thus offering optimal bank vegetation protection. There was no evidence of erosion or bank failure on the lower banks, and the zone of influence was considered optimal, as human activities have not seemed to have impacted this zone at all.

The Wolman Pebble Count revealed that Winlaw Creek riffles consisted predominantly of coarse and very coarse gravels (50%), while small to large cobbles made up 16% of the particle size distribution and sand composed 18% of the sample (See Figure 2, Appendix F).

AIRY CREEK

Air temperature was 15.0 °C on Airy Creek at the time of sampling, while water temperature was 9.0 °C. The staff gauge reading was 0.235 m and the bankfull width ranged between 8 and 24 m up and downstream from the sampling sites. Wetted width was not recorded on Airy Creek.

Stream gradient was 5.0%, and the stream was at a low flow stage. Boulders and undercut banks made up the majority of in-channel cover, with trace amounts of small and large woody debris and deep pools making up the remainder of the cover. Crown closure was high, averaging between 71% and 90%. No other cover or morphology parameters were recorded on the Airy Creek site card.

Supplemental habitat data revealed that the average water depth was 0.264 m and the average water velocity was 0.157 m/s. The average distance of the sampling sites from the left bank (looking upstream) was 6.06 m. The amount and distribution of leaf packs, boulders, functional and non-functional large and small woody debris was not recorded at the sampling site. The bottom substrate of Airy Creek was considered sub-optimal, with between 10 and 20% fines. The embeddedness of Airy Creek riffles was considered optimal, with gravel, cobble and boulder particles between 0-25% surrounded by fine sediment. No other parameters were recorded on Airy Creek.

The results of the Wolman Pebble Count revealed that Airy Creek riffles consisted predominantly of large cobbles (46%), while small to very large boulders made up 22% of the particle size distribution, and small cobbles made up 17% of the stream bed. (see Figure 2, Appendix F). Sand grains and medium to very coarse gravel made up the remainder of the composition.

3.3.2. Evaluation of Biometrics

Abundance data from October 1999 sampling suggests that there was a high variability among replicates within a stream. This is typical of macroinvertebrate samples, and reflects the inherent 'patchiness' of invertebrate communities. In addition, comparisons between 1999 and 1998 suggest high year-to-year variation in invertebrate abundance.

Table 6. Results of impact ratings/assessments for various biometrics

Metric	Creek			
	Airy	Bonanza	Lemon	Winlaw
Mean count (± std. deviation)	173 ± 157	112 ± 81	248 ± 310	453 ± 344
Mean density per m^2 (± std. deviation)	2,701 ± 2,444	1,741 ± 1,264	3,857 ± 4,825	7,053 ± 5,358
Total number of taxa	Slight impact	Moderate impact	Slight impact	Slight impact
Number of EPT taxa	Slight impact	Slight impact	Slight impact	No impact
EPT/total taxa	No impact	Slight impact	Slight impact	No impact
% Dominant taxon	Slight impact	Moderate impact	Moderate impact	No impact
Hilsenhoff biotic index	Slight impact	Moderate impact	Slight impact	Slight impact
EPT/(EPT+ chironomid) ratio	Slight impact	Slight impact	Moderate impact	Slight impact
No. taxa by functional feeding group (FFG), and Percent functional feeding group	See Below			
Scraper/(Scraper+Collector-Filterer)	Dominant food source is algae	Dominant food source is algae	Dominant food source is organic material	Dominant food source is algae
(Scraper + Collector-Filterer) /(Shredders + Collector-Gatherers)	Stable substrates not limiting	Stable substrates limiting	Stable substrates not limiting	Stable substrates not limiting

Highest abundances of macroinvertebrates occurred in Winlaw Creek, with an average of 453 invertebrates/replicate and an average density of 7,053 invertebrates/m^2 (see Appendix I and **Table 6**). These results were substantially lower than results obtained in 1998, where the average abundance was 1,032 invertebrates/replicate and an average density of 14,907 invertebrates/m^2. Lemon Creek had an average abundance of 248 invertebrates/replicate (3,857 invertebrates/m^2), compared to 1,105 invertebrates/replicate (12,280 invertebrates/m^2) in 1998. Airy and Bonanza Creek had lower abundances. Airy Creek averaged 173 invertebrates/replicate (2,701 invertebrates/m^2), compared to 678 invertebrates/replicate (7,536 invertebrates/m^2) in 1998, and Bonanza Creek averaged 112 invertebrates/replicate (1741 invertebrates/m^2), compared to 203 invertebrates/replicate (2,252 invertebrates/m^2) in 1998. The systematic trends in abundance, however, correlated with 1998 data.

Functional feeding analyses indicate that Bonanza Creek has the least diverse assemblage of feeding groups, mainly due to the high percentage (76%) of collector-gatherers (Figure 2, Appendix G). Winlaw, Airy and Lemon Creeks had a diverse assemblage of functional feeding groups. Numerically, thirteen percent of the macroinvertebrates from Winlaw Creek were comprised of shredders. Shredders comprised only six percent of macroinvertebrates in Bonanza, eight percent in Airy Creek and four percent in Lemon Creek. Lemon Creek had a higher percentage of collector-filterers (35%) compared to Airy (21%), Winlaw (18%) and Bonanza (3%) Creeks. Bonanza Creek had the highest percent abundance of collector-gatherers (76%), while Airy, Winlaw, and Lemon Creeks had percent abundances of 30%, 34% and 38% collector-gatherers, respectively. Winlaw Creek had the highest percentage of scrapers (23%) while Airy, Lemon and Bonanza had lower percentages (23%, 16%, and 7%, respectively). Airy Creek had a high ratio of predators to total functional feeding groups (18%), indicating that there was a sufficient prey base to support a predator population (Merritt *et al*. 1996). Winlaw, Lemon and Bonanza Creeks had low ratios of predators to total functional feeding groups (8%, 6% and 3%, respectively), indicating there may not be a sufficient prey base to support a predator population.

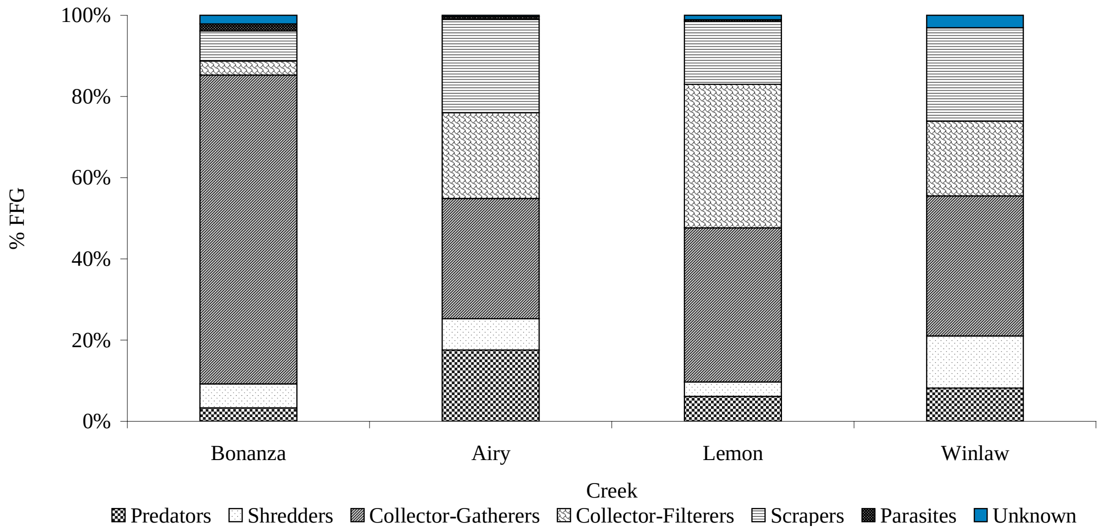

Figure 3. Percent abundance by functional feeding group for Slocan Watershed creeks

The ratio of scrapers to scrapers plus collector-filterers was 0.5 or greater (0.68) for Bonanza Creek (Appendix G). This indicates that scrapers predominate over collector-filterers in Bonanza Creek. Typically, scrapers increase with higher biomass of diatoms and decrease as filamentous algae and aquatic mosses increase (Plaftkin *et al.* 1989). Scrapers in Bonanza Creek may be able to take advantage of an increase in nutrients that likely occurs as kokanee spawn and die-off. Winlaw and Airy Creeks had a ratio of 0.55 and 0.51, respectively. Lemon Creek had a ratio of scrapers to scrapers plus collector-filterers of 0.39, indicating that the macroinvertebrates were dependent on organic materials as their food base. However, filter feeders such as simuliids were extremely low in abundance and mollusks were absent from all creeks.

Airy, Lemon and Winlaw Creeks had a habitat stability ratio of greater than 0.5-0.6 indicating that stable substrates were available for scrapers and collector-filterers in these creeks (**Table 6**). However, in Bonanza Creek collector-gatherers predominated resulting in habitat stability ratios of less than 0.5-0.6 (0.14). This suggests that stable substrates may have been limiting in this stream.

Initial assessment of the taxonomic richness suggests that Winlaw Creek has the highest number of taxa (24) in comparison to Bonanza (18), Airy (21) and Lemon

Creeks (19) (Figure 3). However, taxa counts in Airy, Lemon and Winlaw Creeks all resulted in a slight impact rating for this particular biometric, and a moderated impact rating for Bonanza Creek. The ratio of the number of EPT/total taxa indicated “no impact” for Winlaw Creek, but “slightly impacted” for Airy, Lemon and Bonanza Creeks. EPT organisms comprised 44% of the organisms found in Airy Creek and 35% in Bonanza, 38% in Lemon and 49% in Winlaw Creeks . The ratio of EPT/(EPT + Chironomids) for Winlaw, Bonanza and Airy Creeks indicated that they may be slightly impacted by the abundance of chironomids within the system, while Lemon Creek may be moderately impacted (Table 6). The percent total chironomids for each creek was also calculated. Lemon Creek contained the highest percentage of chironomids, with an average of 55% chironomids/replicate. Airy, Winlaw and Bonanza Creeks averaged 28%, 25%, and 21% chironomids, respectively.

The macroinvertebrate community found within Airy, Lemon and Winlaw Creeks had relatively low tolerances to pollution (from organic enrichment), resulting in Hilsenhoff Biotic Index ratings between 3.5 and 5.5, and resulting in slightly impacted assessments (Appendix H). Bonanza Creek was assigned a moderate impact rating due to a much higher HBI rating.

Table 7. Dominant families and other groups found in each creek

Creek	Dominant Families	Other Groups
Airy	Baetidae, Heptageniidae, Ephemerellidae, Chironomidae, Capniidae, Nemouridae, Chloroperlidae, Taeniopterigidae, Glossosomatidae, Enchytraeidae, and Torrenticolidae	other Diptera, Hydracarina, Ostracoda, and Coleoptera
Lemon	Baetidae, Chironomidae, Phychodidae, Ephemerellidae, Heptageniidae, Enchytraeidae, and Leuctridae	other Diptera, Coleoptera, Annelida, Harpactoida, Hemiptera, and Hydracarina
Bonanza	Chironomidae, Baetidae, Ephemerellidae, Heptageniidae, Glossosomatidae, Enchytraeidae, and Naididae	other Diptera, Coleoptera, Annelida, Harpactoida, Hydrozoa, and Ostracoda
Winlaw	Ceratopogonidae, Elmidae, Chironomidae, Psychodidae, Tipulidae, Baetidae, Ephemerellidae, Heptageniidae, Capniidae, Chloroperlidae, Leuctridae, Torrenticolidae, Silphonuridae, Nemouridae, Taeniopterigidae, Enchytraeidae, and Glossosomatidae	included other Diptera, Coleoptera, Harpactoida, and Ostracoda

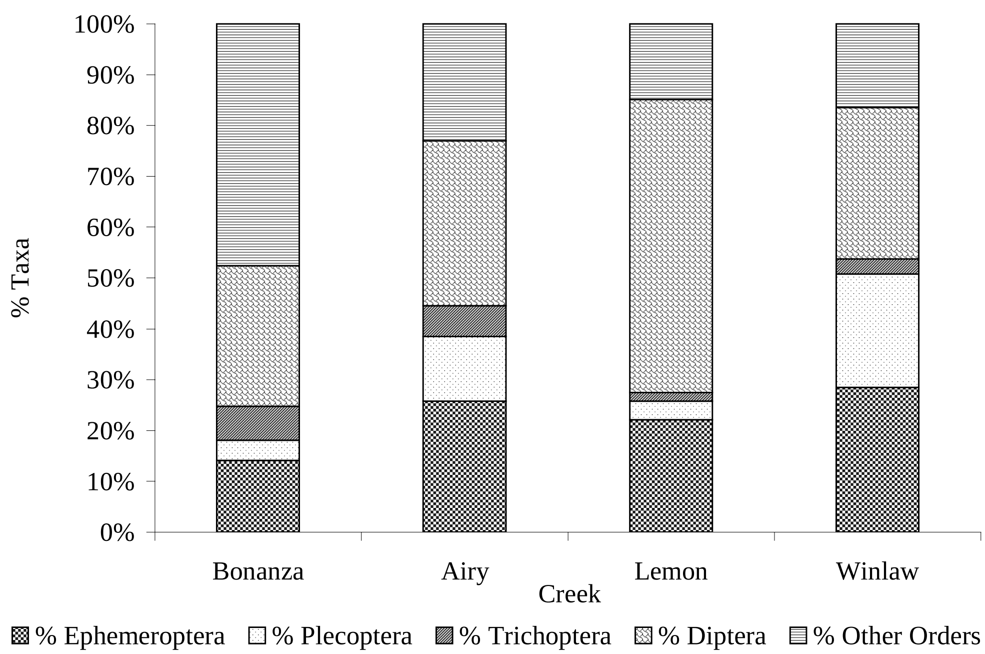

Figure 4. Percent abundance of macroinvertebrates by taxa for Slocan Valley creeks

3.3.3. *Potential Influence of Other Parameters Monitored by the Slocan Valley Water Quantity and Quality Monitoring Program on the Macroinvertebrate Community*

The Slocan Valley Water Quantity and Quality Monitoring Program was initiated in May 1994 and has been intensively monitoring sediment, conductivity, temperature and water quantity on a number of creeks in the Slocan Valley since August 1996. These evaluations have included data collected from the macroinvertebrate sampling sites on Bonanza, Lemon, Winlaw and Airy Creeks. These parameters were evaluated as to their potential effects on the macroinvertebrate community. The data for 1999 is summarized in Yeow and Yeow (2000).

WATER QUANTITY

Generally, Lemon Creek has been observed to have the highest annual peak flows, which ranged from 26.3-44.9 m3/sec over the duration of the study (1997-1999). Annual peak flows in Airy Creek were also fairly high, ranging from 13.3-25.4 m^3/sec (from 1997-99). Annual peak discharges in Bonanza (ranged from 8.0-16.7 m^3/sec) and Winlaw Creeks (5.5-14.9 m^3/sec) were lower than Lemon and Airy Creeks over this three year period).

The flow regimes observed in the study streams (detailed in Yeow and Yeow, 2000) affect macroinvertebrates and macroinvertebrate habitat in a number of ways including: direct effects on macroinvertebrate drift; characteristics of bottom substrate; amount of channel under water; food availability; suspended sediment; and water quality. Increased current or discharge leads to increased drift (downstream transport of aquatic organisms in the current) especially during spring run-off. Increased drift during high flows is due to increased scouring and higher shear stresses (Brittain and Eikland 1988). However, rapid recolonization is also commonly observed.

The hydrological regime of a stream has a direct effect on particle size, composition and relative stability of the bottom substrate (Minshall 1984). Descriptions of substrate composition (Wolman Pebble count) are summarized under Section 3.3.1 for each sampling site. The effects of deposited sediment are discussed below. However, particle size analyses and detailed assessments of the relative stability of the bottom substrate have not been carried out at macroinvertebrate sampling sites.

In addition, discharge levels can also influence levels of suspended sediment, water chemistry, the amount of channel under water, and food availability (Minshall 1984). The effects of suspended sediment on macroinvertebrates is discussed below. Water chemistry data (trace metals and ions) are summarized under Section 110and is stratified by high and low flows. Trends in conductivity for Slocan Valley streams are detailed in Yeow and Yeow (2000) and evaluated below. The total amount of macroinvertebrate habitat (or channel under water) has not been deemed a high assessment priority to date. However, wet width data is available for a range in flows but has not been summarized with respect to macroinvertebrate habitat. In addition, food availability in relation to flow is dicussed in Section 3.2 for periphyton (photosynthetic food pathways) and Section 3.3.1 for organic materials (food available to detrivores).

SEDIMENT

It was difficult to assess the effects of suspended sediment on the macroinvertebrate community because there is little published literature concerning the impacts of suspended sediment on macroinvertebrates. The little that does exist suggests that low to moderate levels of suspended sediment do not appear to have a significant impact on macroinvertebrate abundance (Waters 1995).

However, elevated suspended sediment levels can have negative impacts on filter-feeders (Waters 1995). Low abundances of simuliids (black flies) and sphaeriid clams were observed in all the study streams from 1997-99. There may be a possible link between levels of suspended sediment or some other factor such as habitat type or lack of fine organic material and the low abundance of these organisms. Other potential impacts of suspended sediment to macroinvertebrates include: increased invertebrate drift and the effect of redeposited suspended sediment at high levels downstream.

Potential impacts at low levels of deposited sediment include decreased biomass and abundances of macroinvertebrates due to in-filling of substrates and a reduction in the interstitial habitat. These effects at low levels of deposited sediment may be subtle, with possibly no change in community type or taxonomic richness. Low to moderate levels of sediment may have higher impacts in streams if sediments move along the bottom and scour macroinvertebrates (Culp *et al.* 1985). These types of effects are difficult to measure in the field and may require rigorous experimental design. However, recent research suggests that metrics including: EPT taxa richness; % Orthocladiinae; and % Chironominae may be appropriate metrics to assess the effects of low to moderate levels of deposited sediment on macroinvertebrate communities colonizing natural substratum (Angradi 1999).

At higher levels of deposited sediment community structure and species diversity may be altered with a possible increase in total abundance. At high levels of deposited sediment, cobbles become embedded with fine sediment and typically the community changes from one with a high percentage of EPT organisms to one dominated by oligochaetes and burrowing chironomids (Waters 1995).

Samples collected in 1997-1999 from Airy, Bonanza and Winlaw Creeks, typically, had a healthy population of EPT taxa with ratings of slight to no impacts. This indicates that in general these communities are likely not impacted by high levels of deposited sediment. Lemon Creek had a higher percentage of chironomids than the other streams resulting in a rating of moderate impact for the

EPT/EPT+chironomid ratio. It is possible that this is the result of higher levels of deposited sediment resulting from sediment pulses that occurred in 1999 (Yeow and Yeow 2000). However, deposited sediment occupying spaces between gravels and cobbles was not well captured by the Wolman Pebble Count and may be better captured using a McNeil sampler and conducting a particle size analysis.

Visual observations (J. Yeow, *pers. comm.*) suggest that sediment is quickly flushed from these streams. A number of studies indicate that rapid recovery of macroinvertebrates can occur if impacts from sediment are episodic, or if impacts are removed and flushing is rapid (Tsui and McCart 1981, Cline *et al.* 1992, Quamme 1997). In addition, in 1999 oligochaetes and burrowing chironomids were generally in low to moderate abundance. Of the ten Genus of chironomids found in these streams only two genera, *Brilia* and *Thienemannimyia*, are typically classed as having burrowing habits.

CONDUCTIVITY

Conductivity is a measure of the concentration of dissolved salts in the water. The conductivity of streams in the Slocan Valley area is likely highly influenced by the presence of inorganic dissolved solids (chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron and aluminum) originating from the local bedrock.

Conductivity in Bonanza Creek in 1999 ranged between 110 μS/cm and 160 μS/cm. Conductivity levels in Lemon and Airy Creeks were much lower in 1999, ranging between 28 μS/cm to 93 μS/cm and 8 μS/cm to 66 μS/cm, respectively. Levels ranged between 41 μS/cm and 127 μS/cm in Winlaw Creek (1999). Conductivity data is discussed in more detail in Yeow and Yeow (2000).

According to Ptolemy *et al*. (1991), typical BC streams at low flow have conductivity levels ranging between 6 μS/cm and 970 μS/cm, with a median value of 83 μS/cm. In contrast, streams in the Kootenay Region were found to have higher median conductivity levels of 131 μS/cm, typical of interior streams. Therefore, Bonanza Creek falls within the range of a typical Kootenay Region stream. Winlaw Creek is slightly lower than the median value for the Kootenay Region at base flow. Lemon and Airy Creeks fall within the lower ranges of typical Kootenay Region streams.

Conductivity is sometimes used as a surrogate for nutrient status and may be considered a rough indication of the productivity of a system. Bonanza and Winlaw Creek had higher conductivity levels compared to Lemon and Airy Creeks throughout 1999. A similar trend was observed with respect to nitrogen levels (measured only for one date in late September 1999). Total phosphorus levels were low in all streams (see Section 0).

Conductivity data from the Slocan Valley (1997-1999) has shown an inverse relationship with flow in many streams (Yeow and Yeow 2000). Higher concentrations of ions are observed in streams at baseline flow due to groundwater influences. These concentrations become diluted at higher flows during snowmelt and rainstorm periods. Little research has been done to examine the effects of seasonal changes in the concentrations of dissolved ions on macroinvertebrate populations (Newbury 1984).

TEMPERATURE

In general, data records from 1996-99 show that summer water temperatures generally did not rise above 15°C (BC Water Quality Criteria) on any of the creeks with the exception of late August in 1997, when there was a slight exceedance on Bonanza Creek and an exceedance on Airy Creek (approx. 17°C). Data from 1996-1999 for Lemon and Winlaw Creeks shows that these creeks are cooler during the summer months than other Airy or Bonanza Creeks. Lemon Creek rarely rises above 10°C and Winlaw rarely exceeds 13°C during the summer months. Whereas, Airy and Bonanza Creeks typically approach 15°C at maximum temperatures.

Water temperatures in Bonanza Creek, Airy and Winlaw Creeks varied from 1–15°C and 1–14°C, 1 –12°C respectively in 1999. The maximum water temperatures in Lemon Creek was 10°C in 1999 but the winter low temperature was not captured in the data set because temperatures were not monitored during January or December 1999.

The life history parameters of macroinvertebrates are highly influenced by temperature (reviewed in Sweeney 1994). The temperature regimes of the Slocan Creeks likely influence egg development, larval development time and growth, pupation and adult emergence and adult size and fecundity. For example, some of the types of correlations typically found between macroinvertebrate life history parameters and temperature include (Sweeney 1994):

1. An inverse relationship between egg development and temperature.
2. An optimum temperature for hatching success.
3. Increasing temperatures (up to a point) can result in faster development of the larval stage and greater growth rates.
4. Temperatures influence the number of generations per year or the number of years per generation depending on the species.
5. Adult emergence may be delayed by cooler temperatures or shortened by warmer temperatures.
6. Correlated variations in adult size (and possibly adult fecundity). However, these correlations vary widely depending on the species and extent of temperature change.

The cooler water temperatures observed in Lemon and Winlaw Creeks may affect macroinvertebrate populations differently than Airy and Bonanza Creek where summer temperatures are warmer. However, an intensive literature would have to be carried out to determine temperature-specific effects on different taxa found in those streams.

4. SUMMARY AND CONCLUSIONS

Most trace metals in the surveyed streams were below the criteria set by the MELP and Health and Welfare Canada. However, mean total aluminum levels were systematically higher in the spring than in the fall on most creeks. Dissolved aluminum was not monitored during 1999, and could not be evaluated against water quality criteria.. However, levels of total aluminum suggest that aluminum is unlikely to be a drinking water concern (Cavanaugh 1998), nor is it likely to affect macroinvertebrates (Burton and Allan 1986).

Total copper levels observed during the present study were well below B.C. Water Quality Criteria for raw drinking water (5.0 mg/l). In addition, total copper levels exceeded fresh water/aquatic life criteria at certain time periods (Appendix A/B). Mean Total copper exceeded the 30-day average criteria on Winlaw, Elliot, Jerome and Bonanza Creeks during the 1999 low flow and on Elliot and Bonanza Creeks during spring freshet. Lemon Creek could not be assessed as to exceedance of the 30-day average criteria because only one sample was collected in 1999. Maximum total copper levels exceeded aquatic life criteria once during spring freshet on Bonanza Creek.

Findings from this year’s study indicate that highest abundances of macroinvertebrates occurred in Winlaw while Lemon, Airy and Bonanza had lower abundances. Winlaw, Airy and Lemon Creeks have the most diverse assemblages of feeding groups. Bonanza Creek had the least diverse assemblage of feeding groups. Winlaw and Airy Creeks also the had highest numbers of taxa in comparison to Airy, Bonanza, and Lemon Creeks.

Winlaw, Lemon and Airy Creeks had a habitat stability ratio of greater than 0.5-0.6 indicating that stable substrates were potentially limiting in these creeks. Stable substrates were not found to be limiting in Bonanza Creeks. Data from 1999 also indicates that scrapers predominate in abundance over collector-filterers in Bonanza Creek, Winlaw and Airy Creeks and that collector-filterers predominate over scrapers in Lemon Creek.

Airy Creek had a high ratio of predators to total functional feeding groups, indicating that there was a sufficient prey base to support a predator population. However, Winlaw, Lemon and Bonanza Creeks had lower ratios of predators to total functional feeding groups indicating there may not be a sufficient prey base to support a predator population.

A high percentage of EPT organisms in all the streams indicates that the community is likely not impacted by high levels of deposited sediment. However, background literature suggests that macroinvertebrate abundance could potentially be influenced by low levels deposited sediment especially if sediments move along the bottom and scour invertebrates (Culp *et al.* 1985).

In addition, parameters including water quantity, sediment, conductivity, and temperature monitored extensively by the Slocan Valley Water Quantity and Quality monitoring program were reviewed as to potential influences on the macroinvertebrate community.

4.1 Recommendations and Future Research

Future monitoring of trace metals and nutrients in Airy, Bonanza, Lemon and Winlaw Creeks should include:

- assessment of duplicate samples as well as trip blanks if possible.
- monitoring of pH and water hardness at the time of collection of water samples for trace metal monitoring.

It is recommended that future benthic macroinvertebrate monitoring of Slocan River tributaries include:

- long-term assessments of the macroinvertebrate community in Lemon, Bonanza, Winlaw and Airy Creeks.
- conducting a detailed particle size analysis of sediment based on core samples at macroinvertebrate sampling sites.
- assessment of the macroinvertebrate community in areas potentially impacted by deposited sediment.
- assessment of periphyton taxonomy in each of the streams.

It will be essential for future research and impact monitoring to establish a database of benthic macroinvertebrate data from reference (i.e., not impacted) streams of different sizes for the West Kootenay Region.

In addition, it may improve interpretation of macroinvertebrate data if multivariate statistical and other techniques were used to examine impacts of water quality, sediment levels and other habitat measures on macroinvertebrate community data.

5. LITERATURE CITED

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6. APPENDICES (See original report or accompanying files)