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Slocan River Watershed 1998 Benthic Macroinvertebrate Assessment.

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EXECUTIVE SUMMARY

Four indicator streams were selected for the 1998 quantitative benthic macroinvertebrate monitoring program including Airy, Bonanza, Lemon and Winlaw Creeks. Benthic samples from these creeks were sorted, processed and the macroinvertebrates were identified. The resulting data from the macroinvertebrate samples were examined for impacts to a variety of indicators (metrics) and possible impacts from sediment were reviewed. In addition, the levels of trace metals and Total phosphorus from a stratified sampling program carried out in 1997 and 1998 were assessed and compared to B.C. provincial criteria.

Most trace metals were below the criteria set by the MELP and Health and Welfare Canada. However, mean Total aluminum levels systematically exceeded the criteria for drinking water and the 30-day average criteria for aquatic life on all creeks during the 1998 and 1997 spring freshets. Total aluminum levels were below criteria during 1996 and 1998 autumn low flow periods. No other systematic trends were observed with respect to trace metals. However, copper, silver and iron on Bonanza Creek exceeded criteria at certain time periods. Total iron levels exceeded the Health and Welfare Canada objectives for aesthetics for Bonanza and Winlaw Creek (one observation on each creek) during the 1997 spring freshet. Inconsistent monitoring on all of the creeks of iron prevented a through assessment of this particular trace metal.

Findings from this year's study indicate that Winlaw Creek has the most diverse assemblages of feeding groups. Lemon Creek had a slightly lower number of taxa than Winlaw, Airy and Bonanza Creeks. Highest abundances of macroinvertebrates occurred in Lemon and Winlaw Creeks while Airy and Bonanza had lower abundances.

All creeks had a high ratio of predators to total functional feeding groups indicating that there was a sufficient prey base to support a predator population.

Macroinvertebrate data suggested that ~~that~~ stable substrates were potentially limiting in Lemon and Airy Creeks. Stable substrates were likely not limiting in Winlaw or Bonanza Creeks. An assessment of the feeding status of macroinvertebrates showed that scrapers (dependent on algae as a food resource) predominated in abundance over collector-filterers (dependent on organic particles) in Bonanza Creek. However, collector-filterers predominated over scrapers in Winlaw, Airy and Lemon Creeks.

There were a high percentage of EPT organisms (mayflies, stoneflies and caddisflies) in all the streams indicating that impacts by high levels of deposited sediment are unlikely. However, sampling for macroinvertebrates closer to the time flows and sediment levels decline in June is recommended to better quantify impacts that may have been missed due to recolonization effects. Macroinvertebrate production during the spring and summer months is key to the survival and growth of many fish and other species. Thus, an examination of the potential impacts of sediment on macroinvertebrate abundance would best be carried out closer to the time of impact.

Future monitoring of trace metals and nutrients in the study creeks should include: assessment of duplicate samples; consistent monitoring of iron levels in the creeks; a detailed assessment of the various forms of nitrogen and phosphorus in each creek; and monitoring of pH and water hardness at the time of collection of water samples for trace metal monitoring.

In future studies it is recommended that habitat measurements such as water depth, velocity, substrate composition, deposited sediment and embeddedness, and periphyton taxonomy be carried out in order to better characterize macroinvertebrate habitat. In addition, future assessments of benthic macroinvertebrates should be aided by the establishment of region-wide control or reference streams if at all possible.

Interpretation of macroinvertebrate data may 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 is a joint effort by the Slocan Valley Watershed Alliance and the Ministry of Environment, Lands and Parks is part of two larger projects including the Slocan Valley water quality and quantity monitoring program and the FRBC Water Resource Inventory Program.

The Slocan Valley water quality and quantity monitoring program was initiated because of rising concerns over increased erosion and creek 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 specific goals of the 1998 work were to analyze and interpret data from macroinvertebrate samples collected from four streams in the Slocan River Watershed as part of this monitoring program. This information will also provide a valuable addition to the Kootenay Region's FRBC Water Resource Inventory Program database.

The specific objectives of this study were to:

- Carry out quantitative monitoring of the benthic macroinvertebrate community from four 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.

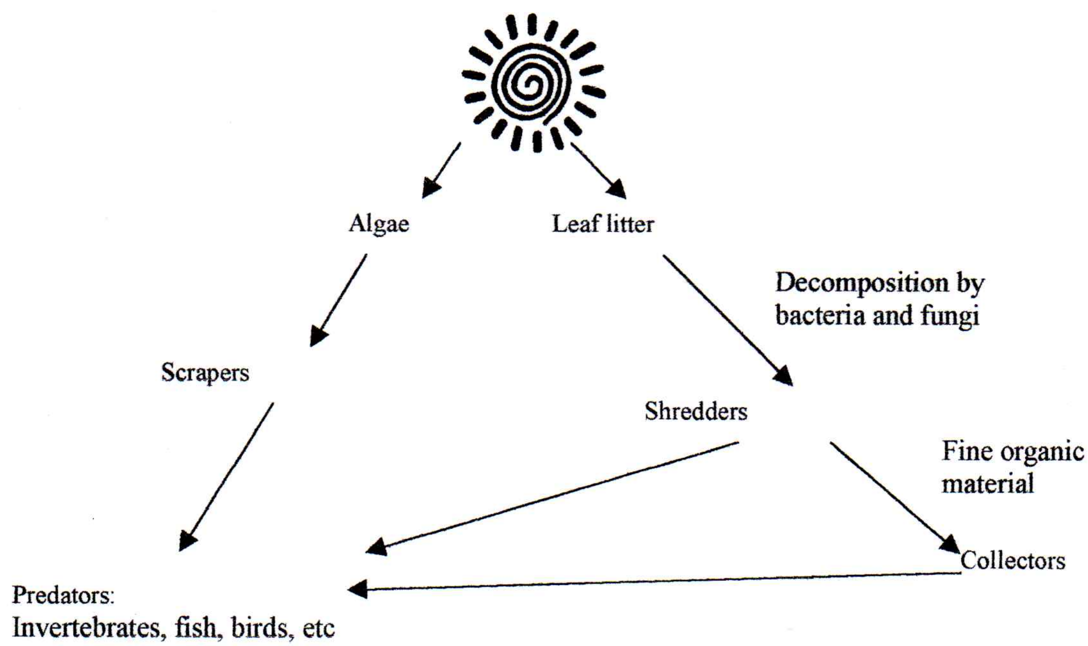
Monitoring of macroinvertebrates in the Slocan Watershed was initiated in 1997 with a program that included qualitative monitoring (unreplicated sampling) of Five Mile, Airy, Bartlett, Bonanaza, Cadden, Duhamel, Elliot, Harris, Hasty, Jerome, Lemon, McFayden and Winlaw Creeks. In this study a number of benthic metrics were used to qualitatively assess stream condition (ARC 1998). However, quantitative data on macroinvertebrate populations of these streams is lacking. As a result, the goal of the present study was to conduct a quantitative sampling program and establish a database that can be used to examine long terms trends in abundance.

Four indicator streams were selected for the 1998 quantitative monitoring program including: Airy, Bonanza, Lemon and Winlaw Creeks. Macroinvertebrates collected from these creeks were sorted, processed and were identified to taxonomic group. The resulting data from the invertebrate samples were examined for impacts to a variety of biometrics (indicators) using methods developed by the U.S. EPA as outlined in their web site (Barbour et al. 1997) and also described in Plafkin et al. (1989).

1.1 Macroinvertebrate as indicators of stream health

Freshwater macroinvertebrates are an essential part of the food web and have been used extensively as indicators of stream health (Barbour et al. 1997). They also provide an important food resource for fish and other species. Typically, there are two distinct pathways for food acquisition that exist in a stream including: autotrophic (based on sunlight and algae/plant production) and heterotrophic pathways (based on leaf litter that falls into the stream from riparian areas). As a result, macroinvertebrates can be differentiated into groups according to their mode of food acquisition (Table 1, Figure 1). Certain invertebrate taxonomic groups are sensitive to impacts such as forest practices, sediment, nutrient abundance, pollution, and other environmental impacts. These types of species are not found under impacted conditions. Other groups are tolerant of impacts and thrive in impacted streams. Thus, the types of organisms that are present in a stream may serve as an indicator of stream condition.

Figure 1 Food web for functional feeding groups



2. METHODS

2.1 Characteristics of creeks and sample sites

Four creeks within the Slocan Watershed; Bonanza, Lemon, Winlaw and Airy Creeks, were selected as indicator streams to be monitored for macroinvertebrates in 1998. Macroinvertebrates were sampled from water quantity monitoring stations described in Yeow and Yeow (1998). The locations of these sites are given in Table 1. These streams were selected because they are large streams with high fisheries values (Table 2) and sources of domestic water for a number of local residents. Some characteristics of these creeks are discussed below and outlined in Table 3.

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

Creek	Closest town/village	Site Location	
		Lattitude (N)	Longitude (W)
Bonanza	Hills	50°06'36".36	117°28'50".30
Lemon	Slocan	49°42'12".65	117°29'03".28
Winlaw	Winlaw	49°36'10".10	117°32'38".45
Airy	Passmore	49°33'31".07	117°42'28".21

Bonanza Creek mainstem is 13.8 km long and flows southeast from Summitt Lake to the north end of Slocan Lake. The mouth of the creek is located 7.5 km north of Roseberry and two kilometers south of Hills along Highway 6. Ephemeral tributaries empty into Summitt Lake. A weir at the outflow of Summitt Lake may provide some minor flow control to Bonanza Creek. There is a small marsh downstream of the outflow area after which the stream becomes more channelized with a higher gradient. It is this portion of the stream that the macroinvertebrates were sampled (approximately 3.5 km from the mouth). As the creek nears Slocan Lake it becomes less channelized and marsh-like as it enters the lake (KFC 1997).. Bonanza Creek is an important spawning area for kokanee and rainbow trout.

Lemon Creek is a fifth order stream with a channel gradient that ranges between two and six percent slope. Total stream length is 405.2 km with the mainstem length extending for 26 km. Lemon Creek is fed by six tributary creeks including; South Lemon, Chapleau, Holmsen, Monument, Crusader and Nilsik. The mouth of Lemon Creek is located 7 km downstream of Slocan Lake and wideflood plain which is part of the Slocan River. It is also upstream of a more confined portion of the Slocan River. As a result, the lower reaches of Lemon Creek support a diverse population of fish that have access to both of these habitats (Zimmer 1999). The macroinvertebrate sampling site was located approximately 800 m from the mouth of Lemon Creek.

Winlaw Creek flows west from Mt. Eccles to the Slocan River. The Winlaw Creek watershed covers an area of 47.5 km^2 and is primarily a low elevation stream with most of the area being under 1800 m in elevation (Apex 1998). The community of Winlaw is located on the fan and there are fifty-five water licences registered on Winlaw Creek (Apex 1998). Winlaw Creek provides important spawning habitat for rainbow trout and bulltrout (AEC 1997). The location of the macroinvertebrate sampling station was approximately 700 m from the the mouth of Winlaw Creek.

Airy Creek is a third order stream with a total stream length of 147.77 km and an area of 56.87 km^2 (DBL 1995). Tindale and Camp 5 Creeks are the two major tributaries to to Airy Creek. The gradient of Airy Creek varies from from 3-25% with a population of rainbow trout inhabitating the lower 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 each creek[1]

Species		Creek Name			
		Bonanza Ck.[1]	Lemon Ck.[2]	Winlaw Ck.[3]	Airy Ck.[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[1]

Measure	Creek Name			
	Bonanza Ck.	Lemon Ck.	Winlaw Ck.	Airy Ck.
Area (km^2)	Not available	58.0	40.7	58.0
Aspect	South	West	West	North
Maximum. Elevation (m)	2200	2200	1700	2600
Gradient %	3.0	2.0	2.5	2.0
Stream type	Riffle-Pool	Cascade-Pool	Riffle-Pool	Riffle-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
Min.-Max. flows ($m^3 \cdot sec^{-1}$) 1998	0.7-8.0	Not available at this time	0.9-5.5	0.09-13.3
Max. suspended sediment concentration ($mg \cdot l^{-1}$) 1997/98	54.3/120.0	266.0 /213.0	168.0 /34.5	177.0 /13.8
Min.-Max. conductivity ($\mu S \cdot cm^{-1}$) 1997	111.0-157.0	Not available at this time	47.3-132.0	10.3-40.3
Min.-Max. conductivity ($\mu S \cdot cm^{-1}$) 1998	122.0-158.0	Not available at this time	49.4-143.0	10.4-37.9

[1] Data from Yeow and Yeow 1997 and 1998

2.2 Field and laboratory methods

2.2.1 Water quality parameters

Water quality and quantity collection, analysis methods and data summary for these 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).

In general, local residents collected data on temperature, weather, took water samples and monitored water levels throughout the study. In addition, volunteers carried out field testing of acidity, alkalinity, hardness, pH and oxygen using a Model AL-36B Hach brand 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).

Analysis of samples for metals and Total phosphorus was carried out for five dates stratified over high and low flows. Periods monitored included: the 1996 autumn low flow (ALF); 1997 spring high flow (SHF); 1998 SHF; and 1998 ALF on Winlaw, Bonanza and Airy Creeks. Metals and Total phosphorus were not monitored on Lemon Creek. ASL analytical Laboratory Ltd. in Vancouver, B.C. performed these laboratory analyses using procedures adapted from APHA (1998).

In the present report, water quality data on metals and nutrients were summarized for high and low flows in 1997 and 1998. These data were evaluated and compared to B.C. MELP water quality guidelines (MELP 1999). Other water quality data were interpreted a cursory level at this time due to time constraints. Further analyses of existing water quality data will be carried out and reported in 1999/2000.

Water hardness and pH were not monitored in 1996-1998 during the stratified monitoring for trace metals. However, water hardness and pH data was collected from 1994 to 1995. As a result, average data from this time period was used to assess the appropriate criteria established by the provincial government (MELP 1999). Mean hardness values for the creeks were 73.6 mg/l (n=6) for Bonanza, 16.4 mg/l (n=7) for Airy, 63.0 mg/l (n=10) for Winlaw and 62.9 mg/l (n=6) for

Lemon. All pH measurements taken at this time for all creeks were greater than 6.5.

2.2.2 Periphyton

Periphyton samples were collected from the same riffle as the benthic invertebrate samples on the same data, October 7, 1998. At each site five replicate cobbles were selected from the stream bottom. Flat cobbles 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 = 3.14 cm^2). Periphyton was removed from the sampling ring using distilled water and a pasteur pipette and transferred to a clean plastic 20 mL bottle. All periphyton was rinsed from the cobble, pipette and the brush. The algal densities appeared to be low and as a result three scrapes of each cobble were composited into one sample bottle. The bottles were placed in a black garbage bag 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 Benthic macroinvertebrates

Benthic invertebrates samples were collected by Fay Wescott (MELP) and Jennifer Yeow (SVWA) on October 7, 1998. A Hess sampler (mesh size 210 μm) 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 10% buffered formalin. Formalin was removed after one week and replaced by 70% ethanol.

Macroinvertebrates were washed and decanted from sediments, detritus and preservative. Preservative was removed using a screen of mesh 100 microns. Benthos was sorted using a dissecting microscope (10X magnification) and macroinvertebrates were removed from detritus and sediment. Individuals were identified to the genus level where possible and to lower levels depending on the size and quality of the specimen. Annelid and chironomid groups were removed and delivered to Denusia 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) and where possible similar keys were used to identify macroinvertebrates. Also, keys used in ARC (1998) were evaluated as to their applicability to British Columbia and the Slocan Watershed tributaries (especially with respect to more local keys, for example, Needham 1997).

Quality assurance checks were done of 10% of the samples ensuring that sorters were checked. Also, representative animals were delivered to expert taxonomist, Danusia Dolecki, for genus verification. 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

Data processed from Slocan River samples was analyzed for impacts to a variety of biometrics in order to assess the state of the macroinvertebrate community (Table). Macroinvertebrate abundance, taxonomic richness (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.

Common indicators of stream condition include the number of taxa, the number of EPT taxa at a site and the ratio of EPT to total taxa. Streams with good habitat and high water quality should have a diverse group of macroinvertebrates. EPT stands for Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (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 Genus identified in a sample. However, if there was no identification to Genus then the next higher taxonomic unit was included in the count (usually Family). Similarly, if there were no identifications to (Family) but there were unidentified Orders, these were included in the count.

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.

The 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 using the formula described below:

$$HBI = (3n_i a_i) / N$$

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 contaminates, there will often be an increasing proportion of chironomids (midges).

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 caddisflys (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 caddisflys (T)) to total number of taxa	No impact- >40% Slight impact - 30-39% Moderate impact- 20-29% Severe impact- <20%
% Dominant taxon	Composition	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%

Table 4 (continued) Metrics used in analysis of benthic invertebrates .

Metric	Measure	Indicator	Assessment/Rating
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+ Collector-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

An analysis of macroinvertebrate functional feeding groups provides important information on the links between food resources and various components of the food web. Typically, there are two distinct pathways for food acquisition that exist in a stream including: autotrophic (based on sunlight and algae/plant production) and heterotrophic pathways (based on leaf litter that falls into the stream from riparian areas). As a result, macroinvertebrates can be differentiated into groups according to their mode of food acquisition (Table 1, Figure 1).

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 3) was used to assess available surfaces for stable attachment and substrate stability (Merritt et al. 1996). If stable substrates are not limiting in a river this ratio should be greater than 0.5-0.6. The ratio of scrapers to (scrapers plus collector-filterers) was used to indicate 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

Trip blanks were evaluated and contamination problems were found to be negligible. Duplicate samples of low level metals and Total phosphorus were not collected and thus were not evaluated.

Most trace metals were below the criteria set by the MELP and Health and Welfare Canada (MELP 1999). However, mean Total aluminum levels systematically exceeded the criteria for drinking water and the 30-day average criteria for aquatic life on all creeks (Appendices 2 and 3) during the 1998 and 1997 spring freshets. Total aluminum levels were below criteria during 1996 and 1998 autumn low flow periods. Aluminum is not considered to be a serious risk to public health. It is rapidly absorbed to sediments and precipitated from solution (Cavanagh et al 1998).

No other systematic trends were observed with respect to trace metals. However, copper, silver and iron on Bonanza Creek exceeded criteria at certain time periods (Appendices 2 and 3). Mean Total copper exceeded the 30-day average criteria for freshwater aquatic life on Bonanza Creek during the 1997 spring freshet. Maximum concentrations (for raw drinking water or aquatic life) of copper were not exceeded during the 1997 spring freshet. Copper is acutely toxic to aquatic life at low concentrations (Cavanagh et al. 1998). Mean Total silver exceeded the 30-day average criteria for freshwater aquatic life on Bonanza Creek during the 1996 autumn low flow period. In addition, four of the six observations monitored during the 1996 low flow exceeded the maximum criteria for freshwater aquatic life. Silver occurs in low levels in natural waters and is toxic to aquatic organisms (Cavanagh et al. 1998)

Iron was monitored in a few instances over time. Total iron levels exceeded the Health and Welfare Canada objectives for aesthetics on both Bonanza and

Winlaw Creeks (one observation on each creek) during the 1997 spring freshet. However, inconsistent monitoring of iron levels did not permit evaluation of the 30-day average criteria.

Initial assessment of Total phosphorus levels suggests that phosphorus may be limiting production during the summer and early autumn low flow periods on Airy and Winlaw Creeks and possibly Bonanza Creek as levels were generally below 0.01 mg/l (Quamme 1999). Nutrient-limitation (low levels of nutrients) may result in low productivity of the study streams. 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 tributaries. Data from 1996 collected from Bonanza Creek shows 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. More detailed monitoring of low level phosphorus and nitrogen is planned for 1999.

The origins of trace metals and nutrients 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 or nutrients to these systems upstream of water collection sites. A more detailed literature review of the impacts of these levels of trace metals on the macroinvertebrate community will be carried out in the 1999 report.

3.2 Periphyton

The results of the periphyton biomass analyses show that periphyton levels were extremely low at the time of sampling (Appendix B). Eighty percent of the samples had no chlorophyll *a* present or levels below detection. The presence of chlorophyll *a* was detected in only one replicate for each stream. These levels were 0.06, 0.28, 0.13, 0.62 Og/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 sites.

Low levels of periphyton observed could be due to a variety of contributing factors including: late season sampling, nutrient limitation, canopy shading, high flows and sloughing of the periphyton mat. Water quality data (Yeow and Yeow 1998) indicates that these streams are phosphorus-limited and likely nitrogen-limited (Oliver 1998) during the summer months. Nutrient limitation could be a contributing factor. Further monitoring of nutrient levels for the 1999 field season is planned.

Also, these streams are high gradient with high flows (Table 3) and unstable substrates. High flows and the lack of stable substrates can cause sloughing of the periphyton mat and lower algal biomass. In addition, periphyton samples were collected in October when stream temperatures begin to decline. Sampling earlier in late August or September when productivity may be higher may be more appropriate.

Finally, low light levels can also contribute to low periphyton production. Canopy cover and shading was not recorded at the time of periphyton sampling. However, some general notes on canopy cover and riparian vegetation were made by Jennifer Yeow including:

> "The Bonanza Creeks sampling site has partial canopy cover with mixed vegetation of shrubs and trees next to the creek. No recent logging activities have occurred next to creek. The sampling station at Airy Creek is open at the sampling location with good riparian vegetation at the stream bank. The Lemon Creek site is located in nearly full sun. The riparian vegetation at the Bonanza Creek site is largely willow, alder, cottonwood with no recent logging history. Winlaw is likely the most shaded of the four streams but

still has partial canopy cover with a mixed variety of trees and shrubs."

Thus, shading of the stream may be a contributing factor in Bonanza and Winlaw Creeks but is less likely to a factor in Airy and Lemon Creeks. Quantitative canopy cover measurements are planned for the 1999 season.

3.3 Benthic invertebrates

3.3.1 Evaluation of biometrics

Abundance data from October 1998 sampling suggests that there was a high variability between replicates within a stream, typical of macroinvertebrate samples. Highest abundances of macroinvertebrates occurred in Lemon and Winlaw Creeks. Airy and Bonanza had lower abundances (Table 6).

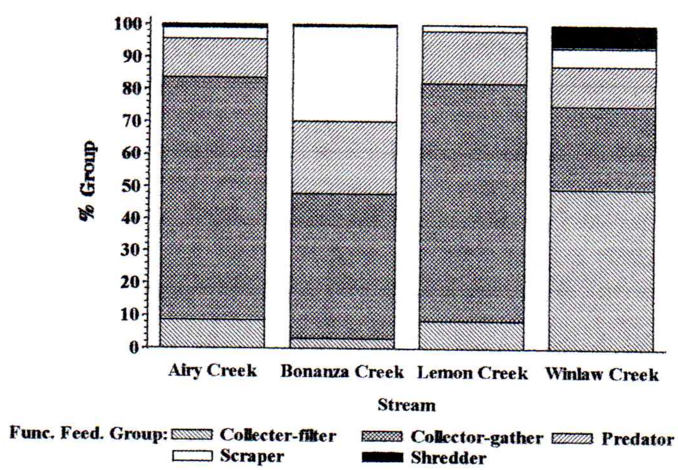
Table 6. Results of impact ratings/assessments for various biometrics

	Creek			
Metric	Airy	Bonanza	Lemon	Winlaw
Mean count (Standard Deviation)	678(436)	203(139)	1,105(730)	1,302(795)
Mean density per m^2 (Standard Deviation)	7,536 (13,331)	2,252 (1543)	12,280 (8,107)	14,907 (8,831)
Total number of taxa	Slight impact	Moderate impact	Moderate impact	Slight impact
Number of EPT taxa	Slight impact	Slight impact	Slight impact	Slight impact
EPT/total taxa	No impact	No impact	No impact	No impact
% Dominant taxon	Slight impact	Slight impact	No impact	Moderate
Hilsenhoff biotic index	Slight impact	Slight impact	Slight impact	Slight impact
EPT/(EPT+ chironomid) ratio	No impact	Slight impact	No impact	No impact
No. taxa by functional feeding group (FFG), and Percent functional feeding group		See	below	
Scraper/(Scraper+Collector-Filterer)	Dominant food source is organic material	Dominant food source is algae	Dominant food source is organic material	Dominant food source is organic material
(Scraper + Collector-Filterer) /(Shredders + Collector-Gatherers)	Stable substrates limiting	Stable substrates not limiting	Stable substrates limiting	Stable substrates not limiting

Functional feeding analyses indicate that Winlaw Creek has the most diverse assemblages of feeding groups, mainly due to a slightly higher percentage of shredders (Figure 2). Numerically, nine percent of the macroinvertebrates from

Winlaw Creek were comprised of shredders. Shredders comprised only one percent of macroinvertebrates in Bonanza, less than one percent in Airy Creeks and were not found in Lemon Creek. Winlaw also had a higher percentage of collector-filterers (41%) compared to Airy (7%), Bonanza (3%) and Lemon (8%) Creeks. Airy, Bonanza, and Lemon Creeks had higher percent abundances of collector-gatherers (70%, 40%, and 77%, respectively) than Winlaw Creek (30%). Bonanza Creek had the highest percentage of scrapers (30%) while Winlaw, Airy and Lemon had lower percentages (8%, 7%, 3%, respectively). All creeks had a high ratio of predators to total functional feeding groups (> 15%) indicating that there was a sufficient prey base to support a predator population (Merritt et al. 1996).

Figure 2. Percent abundance by functional feeding group for Slocan Watershed creeks



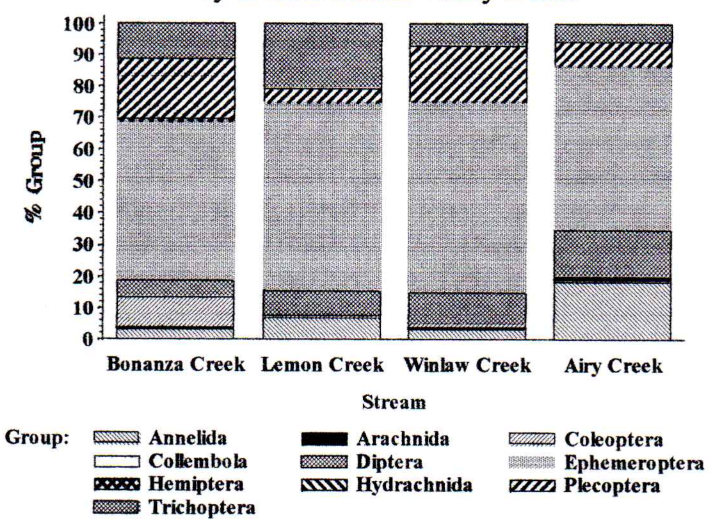
Winlaw Creek had the highest number of taxa in comparison to Bonanza, Airy and Lemon Creeks (Figure 3). Winlaw Creek had the highest number of collector-gatherer taxa despite the fact that numerically collector-gatherers made up a lower percentage of total abundance from Winlaw Creek when compared to the other creeks. Winlaw Creek also had higher numbers of collector-filtering and scraper taxa than the other creeks.

Preliminary data indicates that the ratio of scrapers to scrapers plus collector-filterers was 0.5 or greater for Bonanza Creek. 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, Lemon and Airy Creeks had a ratio less that 0.5 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.

Data showed Bonanza 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 (Figure 5). However, in Airy and Lemon Creek collector-gatherers predominated resulting in habitat stability ratios of less than 0.5-0.6. This suggests that stable substrates may have been limiting in these streams.

Initial assessment of the taxonomic richness suggests that Lemon Creek slightly lower number of taxa compared to Airy, Bonanza and Winlaw Creeks, which had similar numbers of taxa. All streams had a high percent abundance of EPT taxa. EPT organisms comprised 64% of the organisms found in Airy Creek and 76% in Bonanza, 93% in Lemon and 85% in Winlaw Creeks . Dominant families included Baetidae, Heptageniidae, Ephemerellidae, Perlodidae, Chloroperlidae and Hydropsychiidae. Other groups included Chironomidae, other Diptera, Hemiptera, Collembola and Coleoptera.

Figure 3. Percent abundance of macroinvertebrates by taxa for Slocan Valley creeks



3.4 Possible impacts from increased sediment due to forest activities on the macroinvertebrate community

Of high concern to some of the residents of the Slocan Valley are the possible impacts of sediment to streams resulting from forest activities. As a result, literature on potential effects of sediment on the macroinvertebrate community is reviewed.

Potential impacts from sediment on benthic macroinvertebrates originate from two sources including suspended and deposited sediment. The Slocan Water Quanity and Quality Monitoring Program has two years of data (1997/98) on the levels of suspended sediment for a number of streams in the Slocan Valley including the benthic invertebrate sampling sites at Airy, Bonanaza, Lemon and Winlaw Creeks (Table 1). Deposited sediment was not monitored at the benthic invertebrate sampling sites. Visual observation (pers. com. J. Yeow, 1999) suggests that sediment is quickly flushed from these high gradient streams.

Correlations between suspended sediment loads and macroinvertebrate abundances for each stream could be made in the future as further macroinvertebrate data is gathered in the coming years.

Suspended sediment

Background information on the impacts of suspended sediment on macroinvertebrates is lacking. 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).

The potential impacts of suspended sediment on filter feeding macro-invertebrates are high (Waters 1995). The low abundances of collector-filterers (including low abundances of simuliids and the absence of mollusks) in all the streams of the present study suggests that there may be a possible link between levels of suspended sediment or lack of fine organic material and 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.

There was also an inherent problem with the timing of sampling of the 1998 benthic invertebrates in that sampling occurred in October, four months after high flows had dropped and levels of suspended sediment decreased. An examination of the potential impacts of sediment on macroinvertebrate abundance would best be carried out closer to the time of impact. In addition, there are many factors that affect macroinvertebrate abundance such as deposited sediment, embeddedness, water quality parameters, food abundance, fish presence. Multivariate techniques that account for some of these factors is a potential statistical tool to gain further inference about factors affecting macroinvertebrates..

Deposited sediment

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 (with possibly no change in community type or taxonomic richness). However, low to moderate levels of sediment may have higher impacts in streams with high tractive forces (force acting on sediment particles which causes erosion at a critical point) ($T = 1000 \times D \times S$, T = tractive force, D = depth of flow and S = slope of the stream gradient) if sediments move along the bottom and scour macroinvertebrates (Culp et al. 1985).

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). For instance in two B.C. studies one on the Alouette River (Quamme 1996) and one on the Coquitlam River (Pipke and Leniahn 1992), oligochaetes and chironomids thrived at sites impacted by sediment sources compared to unimpacted sites which were dominated by EPT organisms.

Samples collected in the present study in October show that there is a high percentage of EPT organisms in all the streams indicating that the community is likely not impacted by high levels of deposited sediment. This is supported by visual observations (pers. com. J. Yeow, 1999) which 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, if impacts are removed and flushing is rapid (Tsui and McCart 1981, Cline et al. 1992, Quamme 1997).

Macroinvertebrate abundance could be potentially be influenced by low-level deposited sediment if sediments move along the bottom in a “saltating” manner (scouring the bottom). For example, a unique study of Carnation Creek, B.C. compared the effects of low levels of deposited sediment (in a riffle with a low tractive force) and sediment that was not suspended but moved along the bottom in a saltating manner (high tractive force) on macroinvertebrate abundance. In this experiment, sediment deposition had minor only impacts on the macroinvertebrate community and affected only one taxa (*Paraleptophlebia*). However, the saltating sediments reduced total densities by over 50% and influenced the community composition.

As described above, it would be beneficial to monitor invertebrate densities, deposited sediment levels and substrate embeddedness (amount of fine sediment around the cobbles) closer in time to the drop in high flows as well as later in the season.

4. SUMMARY AND CONCLUSIONS

Most trace metals were below the criteria set by the MELP and Health and Welfare Canada. However, mean Total aluminum levels systematically exceeded the criteria for drinking water and the 30-day average criteria for aquatic life on all creeks during the 1998 and 1997 spring freshets. Total aluminum levels were below criteria during 1996 and 1998 autumn low flow periods. No other systematic trends were observed with respect to trace metals. However, copper, silver and iron on Bonanza Creek exceeded criteria at certain time periods. Total iron levels exceeded the Health and Welfare Canada objectives for aesthetics Winlaw Creek (one observation on) during the 1997 spring freshet. Inconsistent monitoring on all of the creeks of iron prevented a through assessment of this particular trace metal.

Findings from this year's study indicate that Winlaw Creek has the most diverse assemblages of feeding groups. Lemon Creek had a slightly lower number of taxa that Winlaw, Airy and Bonanza Creeks. Highest abundances of macroinvertebrates occurred in Lemon and Winlaw Creeks while Airy and Bonanza had lower abundances.

All creeks had a high ratio of predators to total functional feeding groups indicating that there was a sufficient prey base to support a predator population. Preliminary data showed that 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 Winlaw or Bonanza Creeks. Data from 1998 also indicates that scrapers predominate in abundance over collector-filterers in Bonanza Creek and that collector-filterers predominate over scrapers in Winlaw, Airy and Lemon Creeks.

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 be potentially be influenced by low levels deposited sediment especially if sediments move along the bottom and scour invertebrates (Culp et al. 1985).

The present survey may have missed transient impacts because sampling took place in October, four months after flows and sediment levels typically decline. Recolonization of habitat potentially occurring June-September could mask transient impacts especially since Slocan Watershed streams are high gradient and sediment flushes quickly (pers. com. J. Yeow 1999). Macroinvertebrate production during the spring and summer months is key to the survival and growth of many fish and other species. Thus, an examination of the potential impacts of sediment on macroinvertebrate abundance would best be carried out closer to the time of impact.

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.

•Consistent monitoring of iron levels in the creeks.

•A detailed assessment of nutrient limitation (including monitoring the various forms of nitrogen and phosphorus) in each creek.

•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.

•Times series monitoring of benthos starting after high spring flows begin to drop in order to best examine potential impacts from sediment scouring.

•Monitoring of deposited sediment and substrate embeddedness at invertebrate sampling sites.

•Habitat measurements such as water depth, velocity, substrate composition at each replicate sampling site in order to assess habitat variability between replicates and streams.

•Assessment of periphyton taxonomy in each of the streams.

•Cluster analyses of benthic macroinvertebrate data to provide an indication of between site and within site variation in the community.

•If at all possible to establish a set of control or reference streams (not impacted or low impact) when designing a monitoring project.

It will be essential for future research and impact monitoring to establish a database of benthic macroinvertebrate data from reference streams (not impacted) for 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.

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APPENDIX B

Periphyton Biomass

Stream	Replicate	Chlorophyll a µg/cm² Before acidification	Phaeophytin µg/cm² After acidification	Chlorophyll a µg/cm² After acidification
Airy	1	0.03	0.03	0.00
Airy	2	<.01	<.01	<.01
Airy	3	0.11	0.05	0.06
Airy	4	0.20	0.20	0.00
Airy	5	0.31	0.31	0.00
Bonanza	1	<.01	<.01	<.01
Bonanza	2	0.03	0.03	0.00
Bonanza	3	0.28	<.01	0.28
Bonanza	4	0.09	0.09	0.00
Bonanza	5	<.01	<.01	<.01
Lemon	1	0.28	0.28	0.00
Lemon	2	0.20	0.20	0.00
Lemon	3	0.26	0.26	0.00
Lemon	4	0.06	0.06	0.00
Lemon	5	0.82	0.69	0.13
Winlaw	1	0.77	0.15	0.62
Winlaw	2	<.01	<.01	<.01
Winlaw	3	<.01	<.01	<.01
Winlaw	4	<.01	<.01	<.01
Winlaw	5	<.01	<.01	<.01