Technical Report No. 03-04

Aquatic Biomonitoring At Greens Creek Mine, 2002

by Laura Jacobs
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Bill Morris

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Alaska Department of Fish and Game

Habitat and Restoration Division

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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EXECUTIVE SUMMARY

The Alaska Department of Fish and Game and the US Forest Service, in cooperation with the US Fish and Wildlife Service, began an aquatic biomonitoring program in Greens Creek and Tributary Creek in 2001. The purpose of the program has been to document the health of aquatic communities and to establish abundance and taxonomic richness of existing aquatic habitats so comparisons can be made with future conditions of the monitored sites. Both years of the biomonitoring program have included surveys of periphyton abundance, aquatic invertebrate density and community structure, juvenile fish abundance and distribution, concentrations of select elements in fish tissues, and toxicity testing.

The biomonitoring sites in Greens Creek Site 54 and Tributary Creek Site 9 continued to sustain complex, diverse aquatic communities at population levels similar to the reference site, Greens Creek Site 48. Periphyton biomass and community composition continue to appear robust, particularly in Tributary Creek where stream flows are low, scouring flood events are rare, and annual variations in flow appear to be buffered by numerous wetlands in the watershed. Estimates of periphyton biomass in Greens Creek Site 54 were similar to the reference site, Greens Creek Site 48.

Aquatic invertebrate communities are taxonomically rich and abundant. The number of taxa, or taxonomic richness, was similar among Greens Creek Sites 48 and 54, and Tributary Creek Site 9 during both years. Aquatic invertebrate densities were highest in Greens Creek Site 54 during both years of monitoring, and lowest in Tributary Creek Site 9.

Populations of the many pollution-sensitive taxa remain intact. Aquatic communities at both Greens Creek Sites 48 and 54 were dominated by mayflies (Ephemeroptera), with small contributions by stoneflies (Plecoptera) and true flies (aquatic Diptera). In Tributary Creek Site 9, however, the community composition was only slightly dominated by mayflies, and non-insect invertebrates formed a large component of the community. Aquatic Diptera, and Plecoptera also were identified as important components of the aquatic community in Tributary Creek and were found in larger proportions there than at Greens Creek Sites 48 and 54. These differences are likely influenced by differences in physical features, including gradient, water velocity, and scour patterns in the different sites.

Juvenile fish populations continue to thrive, with many age classes present at each site. In 2001, the highest fish density (Dolly Varden and coho salmon combined) was found in Tributary Creek Site 9, and in 2002, the highest density was in Greens Creek Site 54.

Metals concentrations in Dolly Varden tissues do not appear to be any higher in Greens Creek Site 54 or Tributary Creek Site 9 than in the reference site, Greens Creek Site 48. The median values for each of the six measured metals in this year's biomonitoring study were similar among Greens Creek Sites 48 and 54 and Tributary Creek Site 9.

We found no indication of acute toxicity in water from the three biomonitoring sites.

Overall, the aquatic communities in Greens Creek Sites 48 and 54 and Tributary Creek Site 9 have remained abundant and diverse. We found no indication of acute toxicity in water from the three biomonitoring sites.

INTRODUCTION

In 2000, an interagency regulatory team made up of representatives from Kennecott Greens Creek Mining Company (KGCMC), Alaska Department of Natural Resources (ADNR), United States Environmental Protection Agency (USEPA), United States Forest Service (USFS), United States Fish and Wildlife Service (USFWS), Alaska Department of Fish and Game (ADF&G), Alaska Department of Law (DOL), and Alaska Department of Environmental Conservation (ADEC) were invited by KGCMC to conduct an environmental audit of the Greens Creek Mining operation within the Admiralty Island National Monument. From findings of that review, the KGCMC Fresh Water Monitoring plan was updated, including specifications for biomonitoring in areas adjacent to the KGCMC surface facilities associated with the mine and mill. This document presents results of the second year (2002) of biological monitoring of the Greens Creek Mining operation.

The intent of biological monitoring is to document the continued use of Greens Creek and Tributary Creek by fish and other aquatic species, and to document the continued health of the aquatic communities. Biomonitoring will detect early changes to the aquatic community that may result from changes in water chemistry, either through surface or groundwater inputs to the system.

Results from biomonitoring usually are compared to baseline conditions, or if baseline data are unavailable, to a reference site that is unaffected. Few baseline biomonitoring studies as intensive as this current program were conducted before development of the Greens Creek Mine. The existing biomonitoring program is designed to compare present to future conditions at the mine, with consideration given to any previous monitoring. All biological monitoring follows standard protocols acceptable to USEPA, ADEC, USFS, ADF&G, and American Public Health Association (1992).

PURPOSE

The objective of the biomonitoring program is to establish existing conditions of the biological communities in selected reaches of Greens Creek and Tributary Creek near the KGCMC surface facilities. Future sampling during the mine life or during reclamation and closure can be compared to the conditions defined under the current biomonitoring program to detect any changes that may have occurred in aquatic communities.

The biological monitoring program for the Greens Creek mining and milling operations addresses the following factors:

1. Distribution and abundance of juvenile fish;
2. Whole body concentrations of Cd, Cu, Pb, Se, Ag, and Zn in juvenile fish;
3. Periphyton biomass, estimated by chlorophyll concentrations;
4. Abundance and community structure of benthic macroinvertebrate populations;
5. Standardized laboratory toxicity testing.

LOCATION AND SCHEDULE OF MONITORING

Three sites were selected for routine biomonitoring: Greens Creek Site 48 (Greens Creek upstream of mining activities), Greens Creek Site 54 (Greens Creek below Pond D), and Site 9 (Tributary Creek). Greens Creek Site 6 (Middle Greens Creek) was sampled one time in 2001 to provide information on baseline conditions (in this instance, baseline is meant to describe the conditions at the beginning of the biomonitoring program). KGCMC routinely monitors the ambient water quality at these sites on a monthly basis. Water quality samples were collected at each of the biomonitoring sites within the month of that biomonitoring effort. Table 1 summarizes the biomonitoring factors that were sampled at each site; Figure 1 shows the location of the Greens Creek Mine.

Table 1. Sample sites and schedule for biomonitoring sites at the Greens Creek mine.

Site Name	Monitoring Objective	Compare to:	Frequency	Factors	Time to Sample
Upper Greens Creek (Site 48)	Routine, Control		Annually for 5 years, then review	FA, FM, P, MI, TOX	mid-late July
Middle Greens Creek (Site 6)	Baseline		Baseline Sample on 5-year schedule, unless indication of WQ exceedance	FA, FM, P, MI, TOX	mid-late July
Greens Creek below Pond D (Site 54)	Routine, treatment	Control	Annually for 5 years, then review	FA, FM, P, MI, TOX	mid-late July
Tributary Creek (Site 9)	Baseline	Change over time	Annually for 5 years, then review	FA, FM, P, MI, TOX	mid-late July

WQ: water quality
FA: fish abundance and distribution
MI: macroinvertebrate abundance, community structure
P periphyton biomass
TOX: micro-toxicity tests
FM: fish metals content

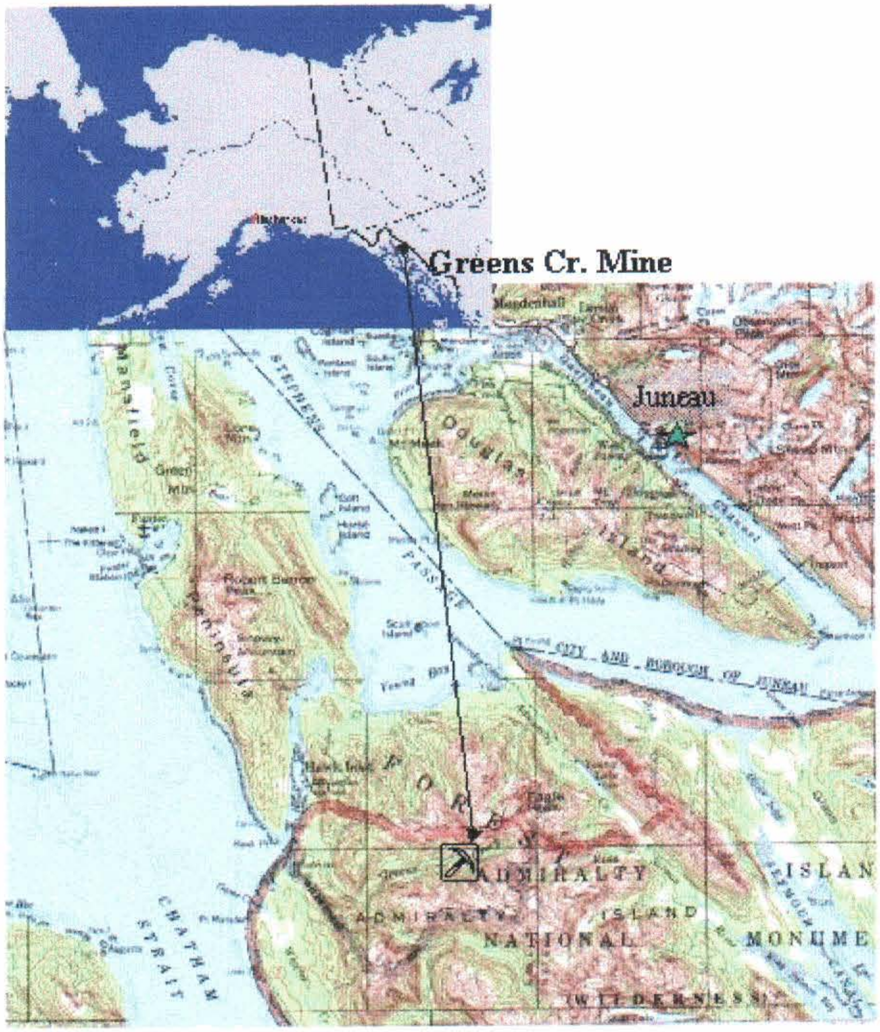

Figure 1. Location of the Greens Creek Mine, Admiralty Island, Alaska.

METHODS

PERIPHYTON BIOMASS

Rationale

Periphyton, or attached algae, is sensitive to changes in water quality. Their abundance confirms that productivity is occurring at specific locations within a water body.

Sample Collection and Analysis

The protocol for collecting stream periphyton follows the protocol from the ADF&G (1998) and Barbour et al. (1997). Periphyton was sampled during a period of stable flow. Ten rocks were collected from the stream benthos in each study reach. A 5-cm x 5-cm square of high-density foam was placed on the rock. Using a small toothbrush, all material around the foam square was removed and rinsed away with clean water. The foam was removed from the rock, the rock was brushed with a clean toothbrush, and then the periphyton was rinsed onto a 0.45 µm glass fiber filter, attached to a vacuum pump. After extracting as much water as possible, approximately 1 ml saturated $MgCO_3$ was added to the filter to prevent acidification and conversion of chlorophyll to phaeophytin. The filter was wrapped in a large filter (to absorb any additional water), labeled, placed in a sealed plastic bag, and packed over desiccant. Filters were frozen on site in a lightproof container with desiccant, and then transported to Fairbanks where they were kept frozen until laboratory analysis.

Methods for extraction and measurement of chlorophyll followed USEPA protocol (USEPA 1997). Filters were removed from the freezer, cut into small pieces, and placed in a centrifuge tube with 10 ml of 90% buffered acetone. Centrifuge tubes were placed in a metal rack, covered with aluminum foil, and held in a dark refrigerator for 24 hr. After extraction, samples were centrifuged for 20 minutes at 1600 rpm, and then read on a Shimadzu Spectrophotometer UV-601 at optical densities (OD) 664 nm, OD 647 nm, and OD 630 nm. In addition, a reading was taken at OD 750 nm to correct for turbidity. An acetone blank was used to correct for the solvent. Samples were then treated with 0.1 ml of 0.1 N hydrochloric acid to convert chlorophyll to phaeophytin, and read at OD 665 nm and OD 750 nm. Based upon these readings, amounts of chlorophylls *a*, *b*, *c* and phaeophytin were determined according to Standard Methods (APHA 1992).

Benthic Macroinvertebrates

Rationale

The primary objective of sampling benthic macroinvertebrates was to characterize community structure and abundance of benthic macroinvertebrates at sample sites. Benthic macroinvertebrate abundance and taxonomic richness are useful measures of stream health.

Sample Collection and Analysis

Five benthic samples were collected from each sample site with a modified Hess sampler. We used a stratified random sample design, modified from Barbour et al. (1997). Samples were collected exclusively from riffle areas where the greatest taxonomic richness and densities are typically found. This sample design eliminated variability from sampling pools or other marginal habitats where pollution-sensitive macroinvertebrates are less likely to occur. For each sample, the substrate was first manually disturbed, and then rocks were brushed and removed. After the larger substrate was removed, the fine gravels were disturbed to a depth of approximately 10-15 cm. Macroinvertebrates disturbed from the stream bottom were collected in a 1-m, 300 μm mesh net, attached to the sampler. The sample was removed, placed in pre-labeled, 500 ml Nalgene bottles. Samples were then preserved in 70% denatured ethanol.

Macroinvertebrate samples were later sorted from all debris and identified to the lowest practical taxonomic level. Larger samples were sub-sampled using a gridded tray. Randomly selected grids were sorted and identified until a minimum of 300 macroinvertebrates was found. Four samples were re-sorted to determine the accuracy in recovering macroinvertebrates. We found that recovery was approximately 98%.

Abundance of Rearing Fish

Rationale

The purpose of monitoring juvenile fish populations was to determine potential trends in the numbers of Dolly Varden (*Salvelinus malma*) and coho salmon (*Oncorhynchus kisutch*) in stream segments near the surface mine facilities in the Greens Creek and Tributary Creek drainages. Sample design and methods followed procedures in the " Fresh Water Monitoring Program" (KGCMC 2000). Precise GPS coordinates were measured at the upstream end of four stream reaches (28 m to 135 m in length). A complete set of digital photos was taken to document site conditions at each survey reach.

Sample Collection and Analysis

Fish population estimates were made with a three-pass removal method by the USFS, using 0.65 cm mesh minnow traps baited with salmon eggs that had been treated with an iodine solution

(Betadyne) (Bryant 2000). During the first season of biomonitoring (in 2001), a sample reach was identified and marked with aluminum tree tags and metal stakes driven into the stream bank. Approximately 25 minnow traps were deployed for each sampling event at each sample site. Sample reaches varied in length among sites because of the limited availability of suitable habitat to set traps. At Greens Creek Site 48, we sampled a reach 75 m in length in 2001 and 50 m in 2002; in Greens Creek Site 54, a sample reach of 28 m was sampled both in 2001 and 2002; and in Tributary Creek Site 9, we sampled a 44-m reach in 2001 and 50 m in 2002.

Traps were placed throughout the sample section focusing on pools, undercut banks, bank alcoves, and under root-wads or logjams. Where possible, natural obstructions, like shallow riffles or small waterfalls over log steps, defined upper and lower section boundaries to minimize fish movement into the sample section during sampling.

Minnow traps were set for about 1.5 hr, at which time all captured fish were transferred to plastic buckets with holes drilled in the sides. Buckets were placed in the stream to keep water aerated and the captured fish in less stressful conditions. The traps were re-baited and reset for another 1.5 hr period. While the second set was fishing, fish captured during the first set were identified to species, counted, and measured to fork length.

A subset of the fish population sample was retained for whole body analysis of metals. Fish not retained for the metals analyses were returned to the stream immediately after sampling was completed.

METALS CONCENTRATIONS IN WHOLE BODY JUVENILE FISH

Rationale

The response time for juvenile fish to accumulate metals is rapid; for example, ADF&G has documented metals accumulation in juvenile Dolly Varden within five to six weeks after dispersing from their overwintering grounds to mineralized and unmineralized tributaries (Weber Scannell and Ott 2001). Should changes occur at the Greens Creek Mine that result in higher concentrations of metals in the creek, tissue sampling of juvenile fish should reflect these changes.

Sample Collection and Analysis

Six juvenile Dolly Varden were caught in baited minnow traps at each sample site and measured to fork length. The fish were individually packed in clean, pre-labeled bags, placed in an acid-washed cooler, and frozen on-site until transport to Fairbanks. We followed the techniques of

Crawford and Luoma (1993) for minimizing contamination of the samples. In Fairbanks, the fish were weighed without removal from the bags (we corrected for the weight of the sample bag). The fish were submitted to a private analytical laboratory, where they were digested, dried, and analyzed for Ag, Cd, Cu, Pb, Se, and Zn on a dry-weight basis, with percent moisture reported. In 2001 and 2002, all fish retained for metals analysis were Dolly Varden, although samples from Sites 48, and 54 (Greens Creek Site 6 in 2001) contained a mixture of resident and anadromous forms. In 2000, samples from Greens Creek Site 54 and Tributary Creek Site 9 both contained a mixture of coho salmon and Dolly Varden.

Samples were numbered following the convention used by ADF&G:

Date/Stream Code/Species Code/Age Code/Sample Number

An example fish label would read: 071201GC54DVJ01, where 070201 represents July 2, 2001; GC54 represents Greens Creek Site 54; DV represents Dolly Varden; J represents juvenile; and 01 represents sample replicate #1.

Quality Control / Quality Assurance of Laboratory Analysis

The analytical laboratory provided Level III quality assurance/quality control information for each analyte, including matrix spikes, standard reference materials, laboratory calibration data, sample blanks, and sample duplicates.

Toxicity Testing

Rationale

Toxicity tests measure the combined toxic effects of all constituents in a particular sample, because some substances can be toxic in amounts that are below detection limits. This is especially true when multiple toxic components synergistically cause toxicity, although each component may be below a detection limit. A commonly available test is the Microtox test, which uses the luminescent bacteria *Vibrio fischeri*. When grown under optimum conditions, the bacteria produce light as a by-product of their cellular respiration. Bacterial bioluminescence is directly related to cell respiration, and any inhibition of cellular activity results in a decreased rate of respiration and a corresponding decrease in the rate of luminescence (Azur 1999).

Sample Collection and Analysis

Water samples were collected at the same time other biomonitoring sampling was done. Samples were kept refrigerated until they were analyzed for acute (1 hr) Microtox toxicity. Solutions of 0% to 45% of the test (creek) water were mixed with reagent water and tested for acute toxicity.

The percent of the population affected by the toxicant was determined for each dilution. The IC-20 represents the estimated toxicant concentration that would cause a 20 percent reduction in a non-lethal biological measurement of the test organism. In the case of the tests conducted in this study, the non-lethal biological measurement was growth of the test species, *Vibrio fischeri*.

RESULTS AND DISCUSSION

Greens Creek Site 48

Greens Creek Site 48 (Figure 2) was selected as an upstream reference site for comparison to "treatment" sites adjacent to and downstream from the KGCMC facilities. This site lies approximately 1 km upstream of the weir that blocks access to anadromous fish. Therefore, the only salmonid species at this site are resident Dolly Varden.

The Greens Creek Site 48 sample reach has been characterized as a MM2 Channel Type (Appendix 1) with an average width of 10 m and a gradient of 2-4 percent (Paustian et al. 1999, Weber Scannell and Paustian 2001). Cobble was the dominant substrate and large woody material was a key factor in pool formation and fish habitat cover. A stream reach of 50 m was sampled for fish populations.

Figure 2. Greens Creek Site 48.

Periphyton Biomass

Median concentrations of chlorophyll *a*, an estimate of periphyton biomass, were significantly higher in 2002 (Wilcoxin Rank Sum Test, $p = 0.04$) than in 2001 (Figure 3).

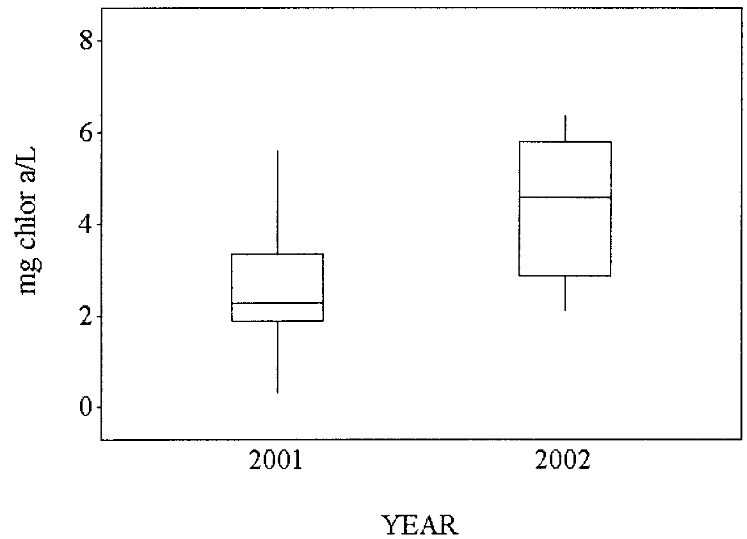

Figure 3. Estimated periphyton biomass in Greens Creek Site 48, 2001 and 2002. The box in the Box and Whisker graph shows the middle half of the data, the intersecting line is the median and the vertical lines at the top and the bottom of the box indicate the range of "typical" data values.

Algal communities contained higher proportions of chlorophyll *c* than chlorophyll *b* (Figure 4) in both years sampled, indicating an algal community dominated by diatoms. Low to undetectable concentrations of chlorophyll *b* indicate minimal amounts of filamentous green algae or blue-green bacteria.

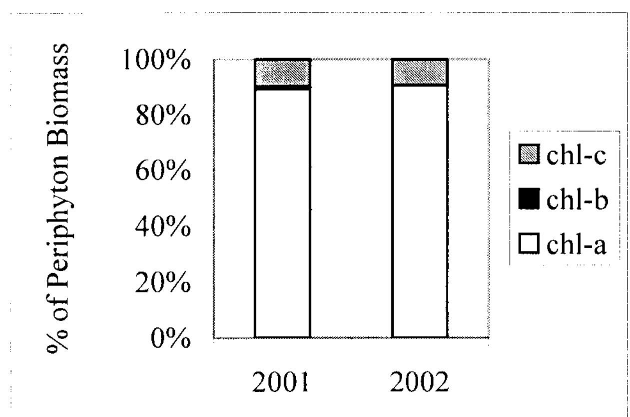

Figure 4. Proportions of chlorophyll *a*, *b*, and *c* in Greens Creek Site 48, 2001 and 2002.

Aquatic Invertebrate Community

The average density of aquatic invertebrates in upper Greens Creek Site 48 was somewhat lower in 2002 (1408/m^2) than in 2001 (2368/m^2), although differences were not significant (Wilcoxin Rank Sum Test, P = 0.09, Figure 5).

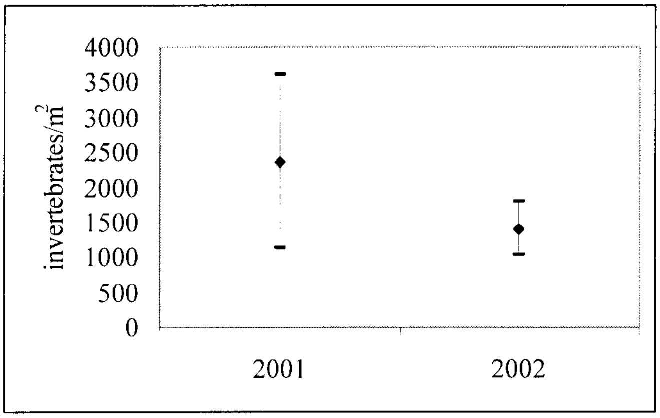

Figure 5. Density of aquatic invertebrates (average, plus and minus 1 standard deviation) in Greens Creek Site 48, 2001 and 2002.

Taxonomic richness was similar between the two years sampled. In 2001, we collected a total of 25 distinct taxa with an average of 12 taxa per sample. In 2002, we identified 24 distinct taxa and an average of 13 taxa per sample.

Invertebrate communities were somewhat different between the years sampled, with slightly higher proportions of Chironomidae in 2002 than 2001 (Figure 6). In both years, the EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera) were most prevalent. Given that most of the EPT taxa are sensitive to water quality, especially metals, the high proportion found at this site signifies excellent water quality conditions for aquatic life.

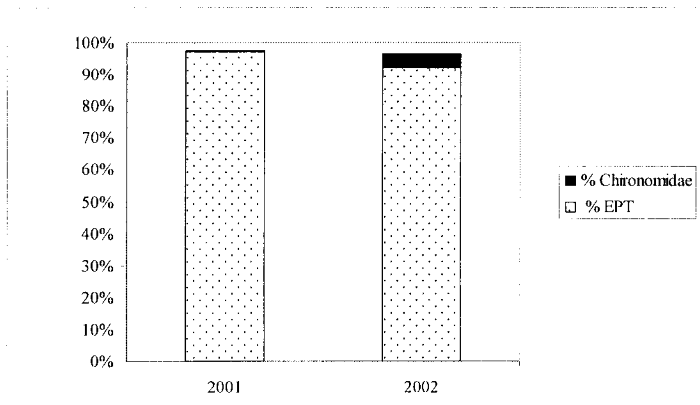

Figure 6. Proportions of EPT taxa and Chironomidae in Greens Creek Site 48, 2001 and 2002.

The aquatic invertebrate community was dominated by mayflies (Ephemeroptera, primarily Baetidae: *Baetis;* Ephemerellidae: *Drunella;* and Heptageniidae: *Cinygmula, Epeorus* and *Rhithrogena)* in both 2001 and 2002 (Figure 7). Appendix 2 lists the macroinvertebrate taxa found in Greens Creek Site 48.

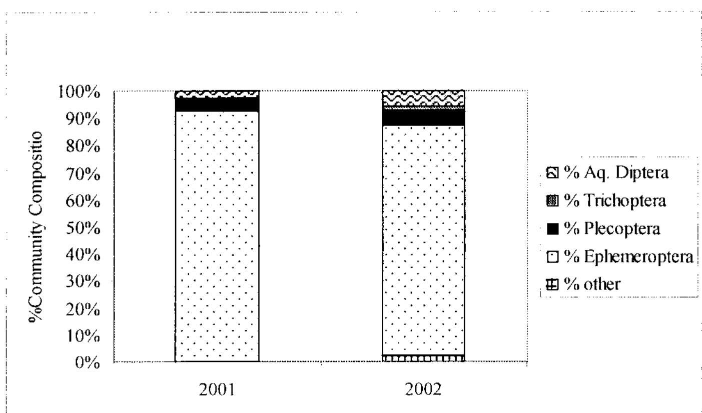

Figure 7. Community composition of aquatic invertebrates in Greens Creek Site 48, 2001 and 2002.

Percent Dominant Taxon is a metric that usually identifies the absence of environmentally sensitive species or dominance of a less-sensitive taxa. In Greens Creek Site 48, the mayfly Heptegeniidae: *Epeorus* comprised 38% of the invertebrate community in 2001 and 27% in 2002. Other, almost equally common taxa in both years were the mayflies Baetidae: *Baetis* and Heptgeniidae: *Rhithrogena. Baetis* are rated as "moderately sensitive," *Epeorus* are "sensitive," and *Rhithrogena* are "very sensitive" (Barbour et al. 1997). In both years, pollution sensitive taxa dominated the invertebrate community in Greens Creek Site 48 and the mixture of numerous taxa represents a complex community.

Juvenile Fish Community

The 2002 fish population survey, conducted within a 50-m reach, resulted in capture of 126 Dolly Varden with an estimated population size for the reach, based on a 3-pass removal, of 145 Dolly Varden. Population estimates in 2001 were similar with 144 fish per 72-m reach (Table 2). Density estimates also were similar, with an estimated 0.20 fish/m^2 in 2001 and 0.23 fish/m^2 in 2002.

Table 2. Juvenile fish population estimates for Greens Creek Site 48, 2001 and 2002.

Year Sampled	Fish Species	Total Fish Caught	Population Estimate, Fish/reach	Sample Reach, m	Density, fish/m^2
2001	DV	68	144	72	0.20
2002	DV	126	145	50	0.23

The fork length of captured fish ranged from 50 mm to 140 mm in 2001 (Figure 8) and from 45 mm to 160 mm in 2002 (Figure 9). Because growth rates of resident Dolly Varden populations are highly variable, no estimates of the number of age classes present were made; however, the presence of small fish in both years and lack of access from downstream reaches suggest successful spawning in this site.

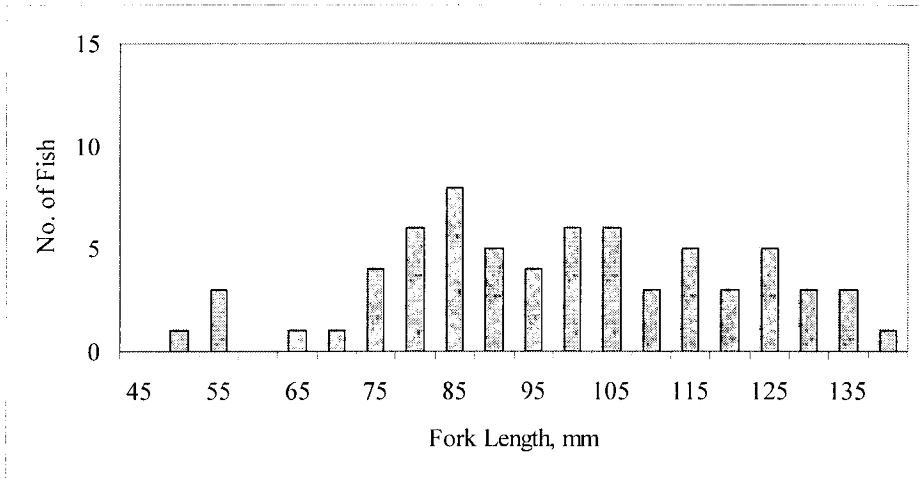

Figure 8. Dolly Varden captured at Greens Creek Site 48, 2001.

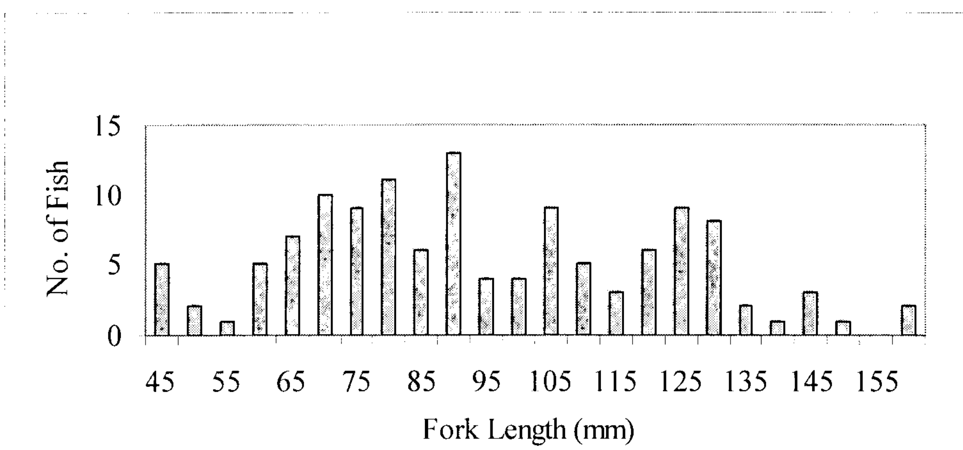

Figure 9. Dolly Varden captured in Greens Creek Site 48, 2002.

Concentrations of metals in juvenile fish were similar in 2001 and 2002, with slightly higher median concentrations of Ag and Zn in 2002 (Figure 10, Appendix 3).

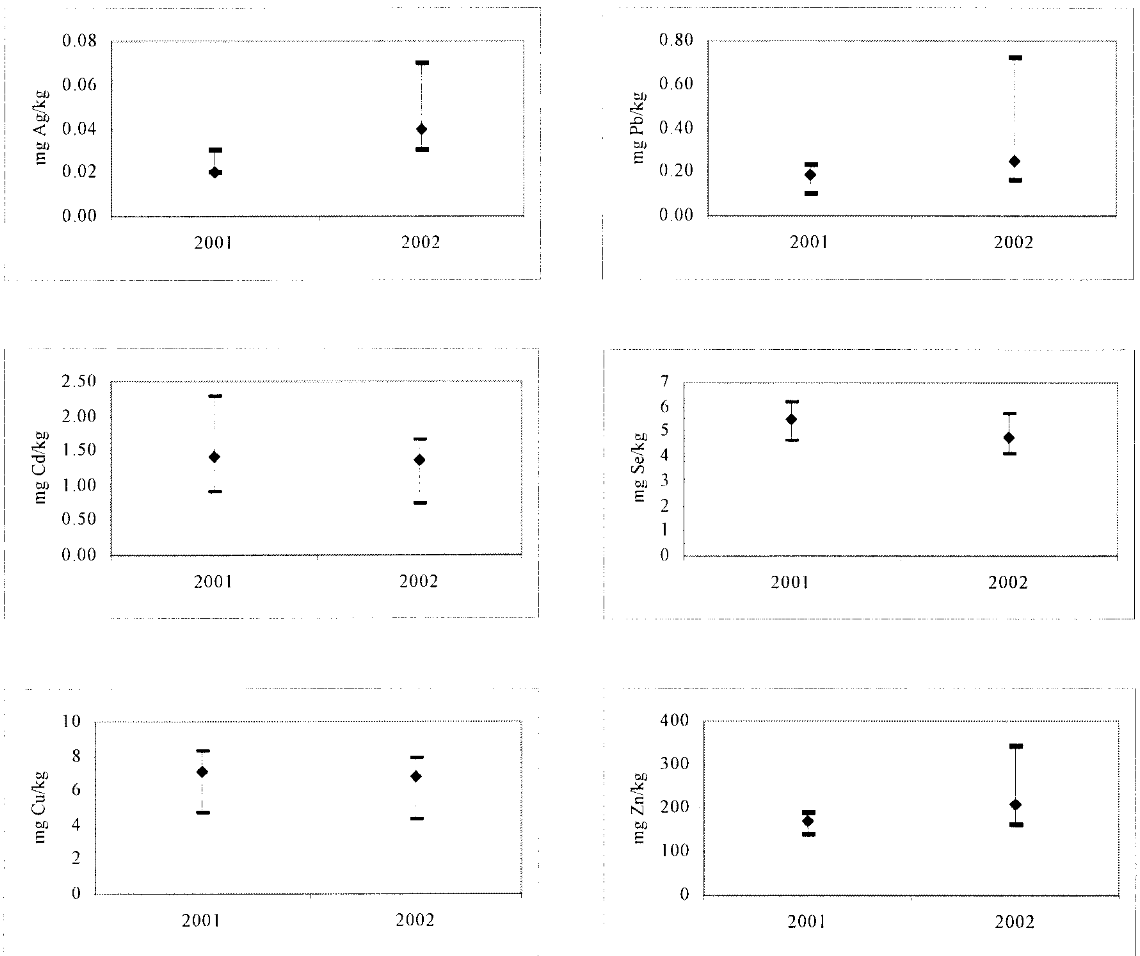

Figure 10. Metals (median, maximum, and minimum) in whole body fish captured in Greens Creek Site 48, 2001 and 2002.

Toxicity Testing

We did not find toxic effects from any of the dilutions of Greens Creek Site 48 water in the acute Microtox toxicity tests (test dilutions ranged from 5% to 45% of Greens Creek Site 48 waters). The growth of the test species, *Vibrio fischeri*, was the same for the control as well as all test dilutions. As a result, the calculated IC-20 value was >100%.

Summary

The high aquatic invertebrate density and prevalence of pollution-sensitive invertebrate species in Greens Creek Site 48 signify a functioning and healthy aquatic community. The population of fish, although limited to resident species, is of a size and age distribution that is expected for this type of stream channel.

MIDDLE GREENS CREEK

Greens Creek Site 6 (below the confluence of Bruin Creek) has been monitored continuously under the FWMP since 1978. The site was located to detect potential effects on Greens Creek from activities in the KGCMC mine, mill, and shop areas. Access of anadromous fish to this stream reach was created by KGCMC in 1989 by installing a fish pass in a waterfall about 5 km downstream. This site is near the upper limit of anadromous fish, defined by a weir located about 1 km upstream. Both Dolly Varden and coho salmon have been found in this reach. Biomonitoring information from this site will be used to detect possible changes in aquatic communities that occur from natural causes or as a result of mine activities. Data were collected in 2001 for baseline information (Weber Scannell and Paustian 2002), and the site will not be sampled again until 2006.

GREENS CREEK SITE 54

Greens Creek Site 54 (Figure 11) is located about 0.5 km downstream of Site 6 (Middle Greens Creek) and about 1 km downstream of the weir that limits the upstream migration of anadromous fish. Anadromous fish access to this stream reach was created by KGCMC in 1989 by installing a fish pass in a waterfall area about 5 km downstream. Both Dolly Varden and coho salmon have been documented in this reach.

The Greens Creek Site 54 sample reach was characterized as a MM2 Channel Type (Appendix 1), with an average channel width of 10 m and a stream gradient of 2-4 percent (Weber Scannell and Paustian 2001, Paustian et al. 1999). Cobble was the dominant streambed material and large woody debris has been integral to pool formation and fish habitat cover.

Figure 11. Greens Creek Site 54.

Periphyton Biomass

Median quantities of periphyton biomass in Greens Creek Site 54 were significantly higher in 2002 than in 2001 (Wilcoxin Rank Sum Test, $p = 0.002$, Figure 12). Differences between the two years were similar to those found in Greens Creek Site 48, and are likely a result of climatic conditions, including water temperature and flow rates during the month before sampling.

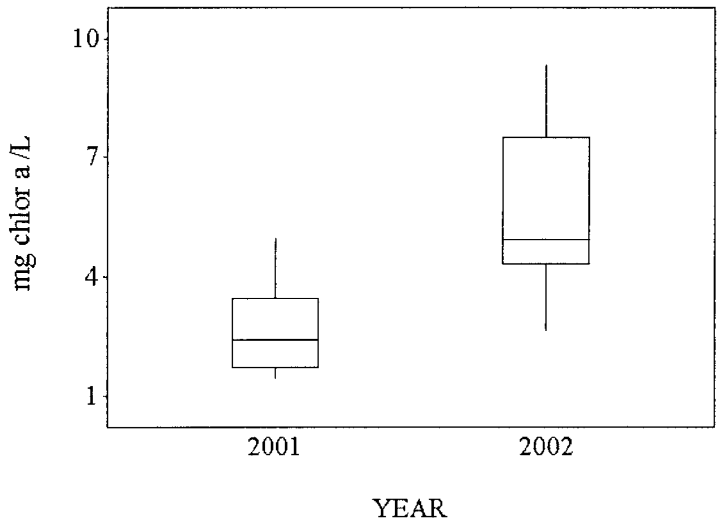

Figure 12. Periphyton biomass in Greens Creek Site 54, 2001 and 2002.

The periphyton community was similar to that found in Greens Creek Site 48, with chlorophyll *a* the dominant pigment and a higher proportion of chlorophyll *c* than chlorophyll *b* (Figure 13). As in Greens Creek Site 48, the higher proportions of chlorophyll *c* indicate an algal community dominated by diatoms while low concentrations of chlorophyll *b* correspond to low populations of filamentous green algae and blue-green bacteria.

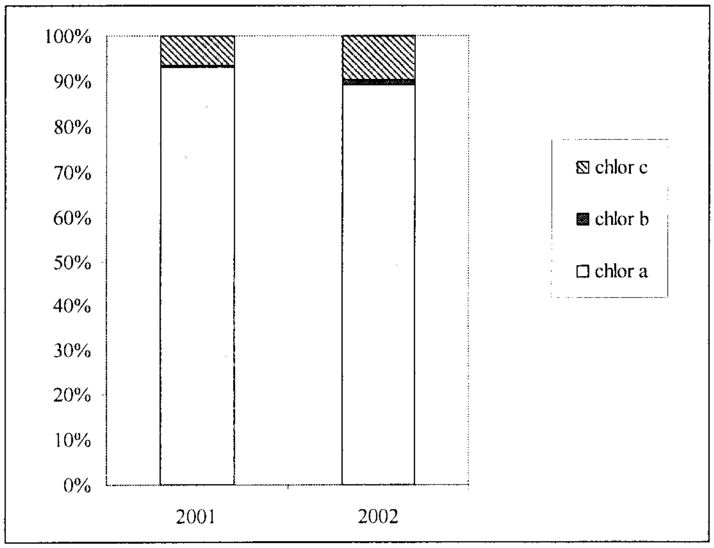

Figure 13. Proportions of chlorophylls *a, b* and *c* in Greens Creek Site 54, 2001 and 2002.

Aquatic Invertebrate Community

The average density of aquatic invertebrates in Greens Creek Site 54 was slightly lower in 2002 than in 2001; although differences were not significant (Wilcoxin Rank Sum Test, P = 0.42, Figure 14). Taxonomic richness was similar between the two years sampled. In 2001, we collected a total of 28 distinct aquatic taxa with an average of 15.2 taxa per sample and in 2002 we collected a total of 30 distinct taxa with an average of 13.8 taxa per sample (Appendix 2).

Invertebrate communities in Greens Creek Site 54 were dominated by EPT taxa with few Chironomidae (Figure 15). In both years, Ephemeroptera were the most commonly collected order (Figure 16). In 2001, we found that 52.5% of the total invertebrates collected were the mayfly Heptageniidae: *Epeorus*, 17.9% were Heptageniidae:*Cinygumula,* and 14% were Baetidae: *Baetis*. Communities were similar in 2002, when 42.6% of the total invertebrates were Heptageniidae: *Epeorus*, 5.1% were Heptageniidae:*Cinygumula*, and 15.3% were Baetidae: *Baetis*. The dominance of the aquatic invertebrate community by pollution-sensitive taxa (Figure 16), combined with the mixture of many species of mayflies, stoneflies, caddiesflies, and true flies indicates a complex and healthy aquatic ecosystem.

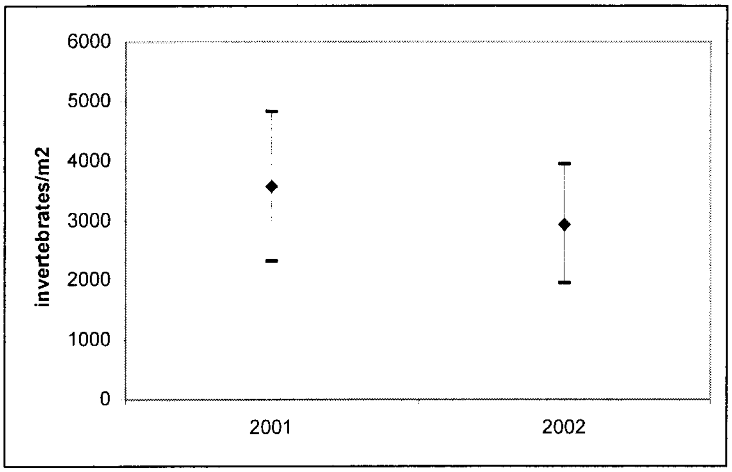

Figure 14. Density of aquatic invertebrates (average plus and minus 1 standard deviation) in Greens Creel Site 54, 2001 and 2002.

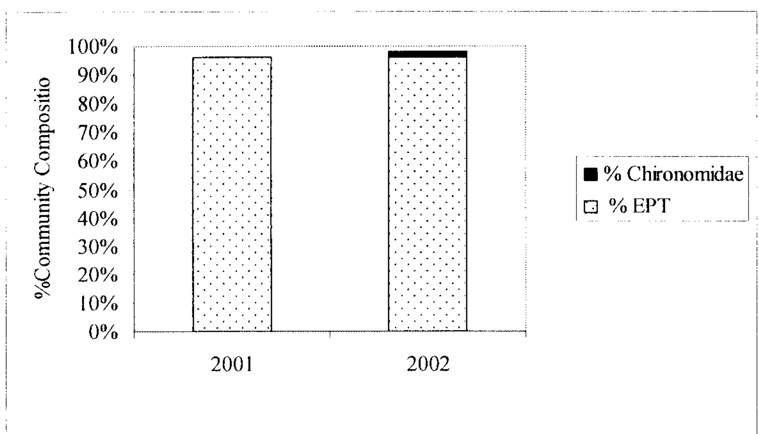

Figure 15. Proportions of EPT taxa and Chironomidae in Greens Creek Site 54, 2001 and 2002.

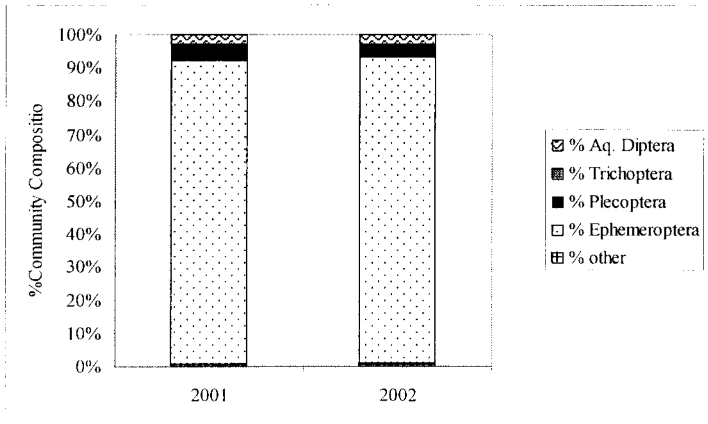

Figure 16. Community composition of aquatic invertebrates in Greens Creek Site 54, 2001 and 2002.

Juvenile Fish Community

Juvenile coho salmon and Dolly Varden were sampled in the same 28-m reach during both sample events in 2001 and 2002. In 2001, the USFS reported catching too few juvenile coho salmon in Greens Creek Site 54 to estimate the population (Table 3). During 2002, however, juvenile coho salmon were caught in sufficient quantities to estimate a population of 21 fish for the 28-m reach, or approximately 0.07 fish/m^2. Juvenile Dolly Varden were found in greater abundance, with population estimates of 164 fish in 2001 and 293 fish in 2002. The estimated density of juvenile Dolly Varden was higher in 2002 (1.0 fish/m^2) than in 2001 (0.6 fish/m^2).

Table 3. Juvenile fish population estimates for Greens Creek Site 54, 2001 and 2002.

Year	Fish Species	Total Fish Collected	Population Estimate, fish/reach	Sample Reach, m	Density, fish/m^2
2001	DV	138	164	28	0.6
2002	DV	271	293	28	1.0
2001	CO		Too few fish	28	Not calculated
2002	CO	21	21	28	0.07

The size distribution of juvenile Dolly Varden in 2001 caught within the Greens Creek Site 54 sample reach suggested the presence of four age classes: from age 0 to age 3 plus a possible age-4 fish at 165 mm (Armstrong and Morrow 1980, Figure 17). Length-frequency information of juvenile Dolly Varden caught in 2002 suggests the presence of the same age classes as in 2001, but with a slightly different distribution (Figure 18). The age 2 and age 3 fish were caught with the highest frequency. The larger estimated population size within the same size sample reach may indicate movement into the area by age 2 and age 3 fish possibly after older fish migrated out, usually by age 3 or 4 (Armstrong and Morrow 1980).

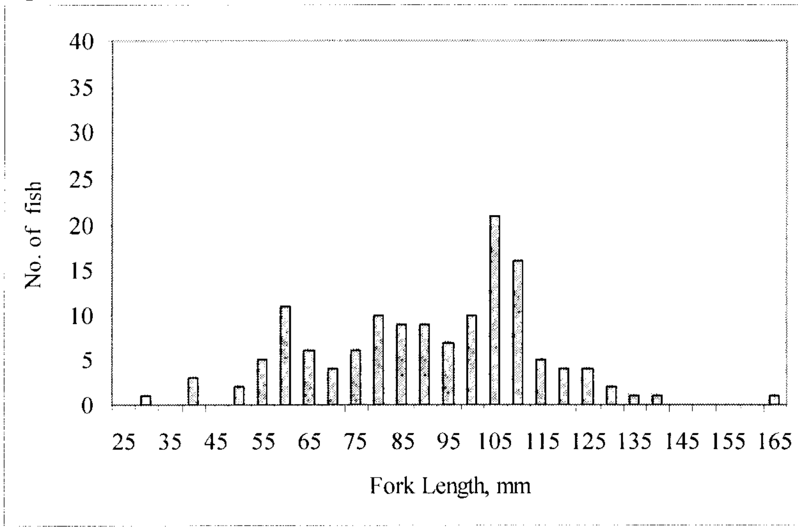

Figure 17. Juvenile Dolly Varden captured in Greens Creek Site 54, 2001.

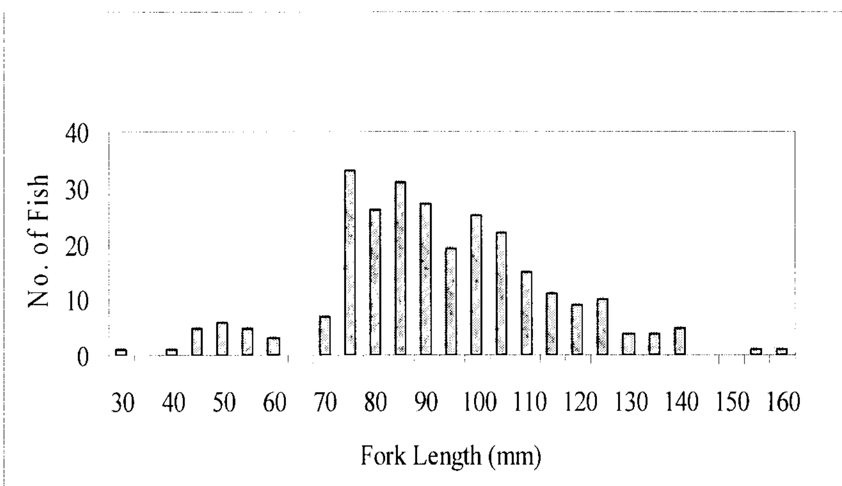

Figure 18. Juvenile Dolly Varden captured in Greens Creek Site 54, 2002.

Juvenile coho salmon caught within the Greens Creek Site 54 sample reach during 2002 probably represent age 0 fish (Figure 19). The low numbers of juvenile coho salmon during the 2001 sample event may indicate displacement or low survival of fry from that cohort.

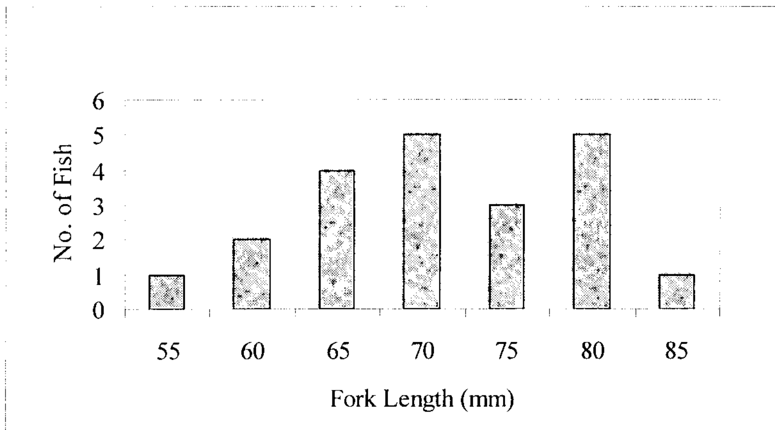

Figure 19. Juvenile coho salmon captured in Greens Creek Site 54, 2002.

Metals in Juvenile Fish

Concentrations of most metals in juvenile fish were similar among the years 2000 through 2002 (Figure 20, Appendix 3), although copper was lower in both 2001 and 2002.

Toxicity Testing

We did not find toxic effects from any of the dilutions of Greens Creek Site 54 water in the acute Microtox toxicity tests (test dilutions ranged from 5% to 45% of Greens Creek Site 54 waters). The growth of the test species, *Vibrio fischeri*, was the same for the control and all test dilutions. As a result, the calculated IC-20 value was >100%.

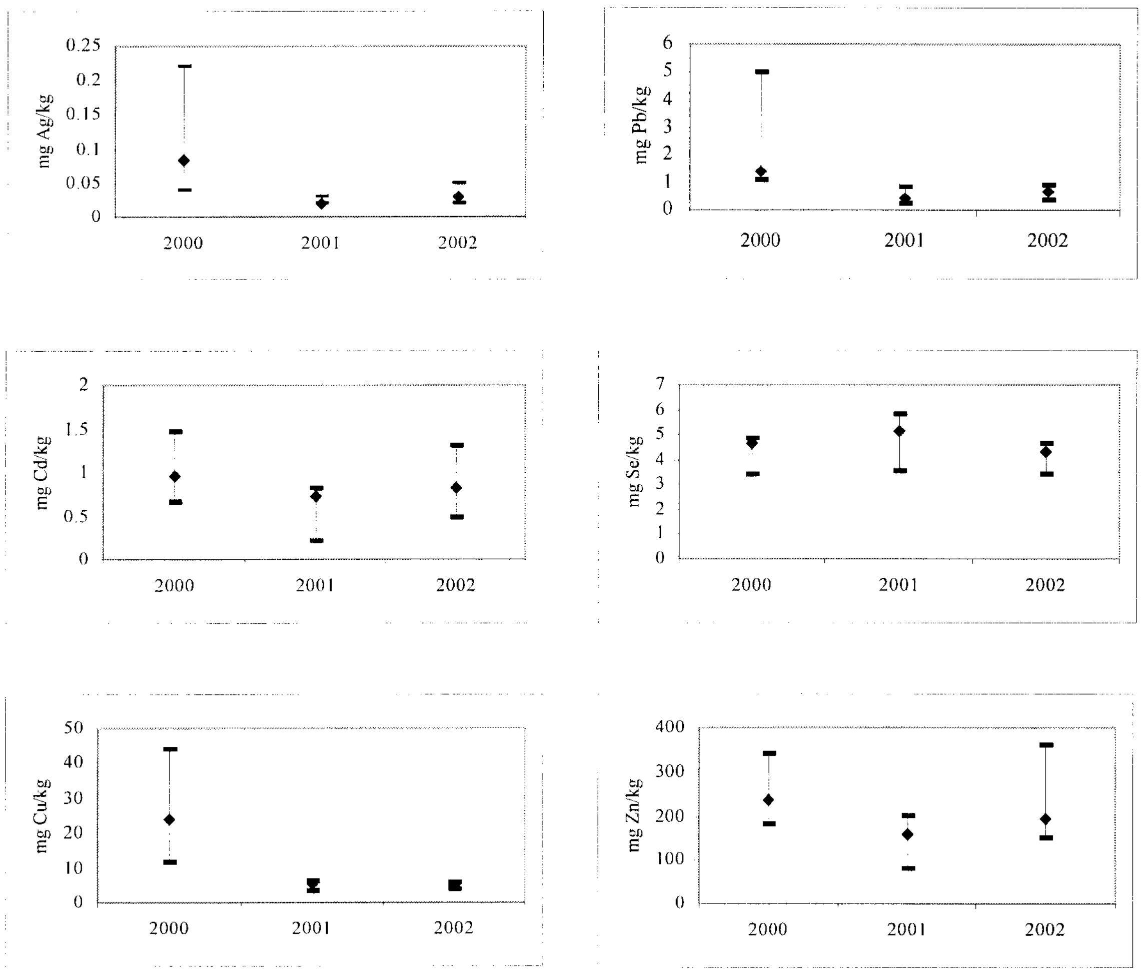

Figure 20. Metals in whole body fish in Greens Creek Site 54, 2000, 2001 and 2002.

TRIBUTARY CREEK SITE 9

Tributary Creek is a small stream with a dense canopy (Figure 21). This site was previously monitored under the FWMP from 1981 through 1993 and is included in the current biomonitoring program because it is located downstream from the KGCMC dry tailings placement facilities. This creek has populations of pink (*Oncorhynchus gorbuscha*), chum (*O. keta*), and coho salmon, cutthroat trout (*O. clarki*), Dolly Varden char and sculpin (no species given).

The sample reach in Tributary Creek Site 9 was characterized as a FP3 Channel Type (Appendix 1), typical of a valley bottom or flat lowlands. The creek is 2 m wide with a 1% stream gradient, and fine gravel as the dominant substrate (Weber Scannell 2001, Paustian et al. 1999). During the 2001 sampling event, the reach was 44 m in length, while in 2002 it was 50 m in length.

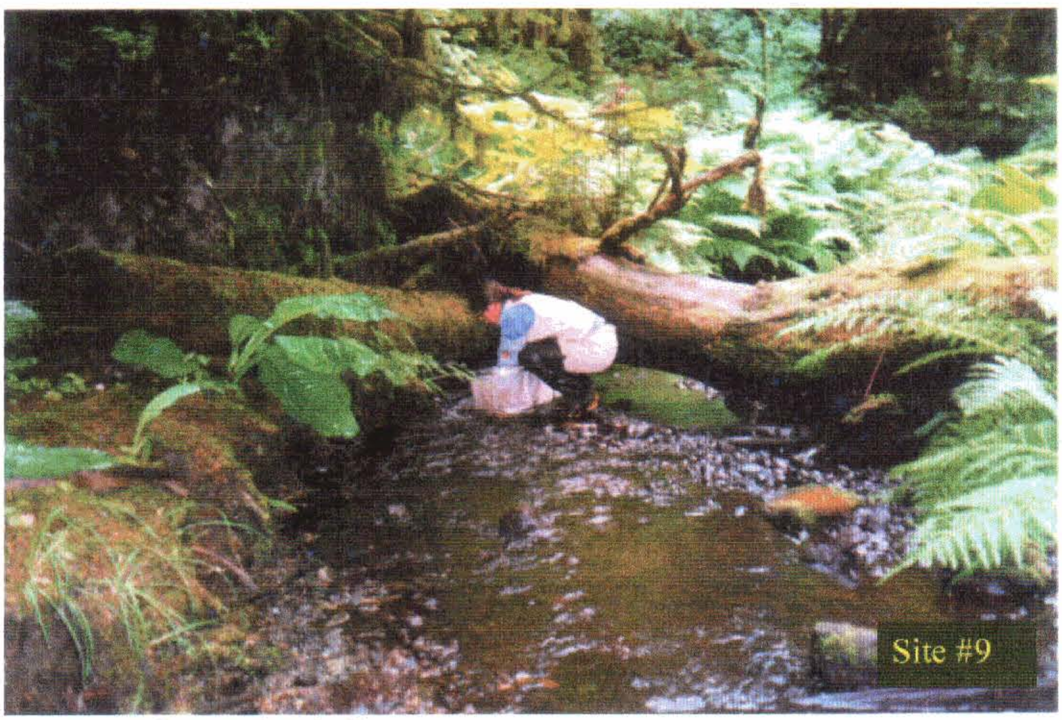

Figure 21. Tributary Creek Site 9.

Periphyton Biomass

Periphyton biomass, expressed as mg/L chlorophyll *a*, was similar in 2001 and 2002 (Wilcoxin Rank Sum Test, $p = 0.44$, Figure 22). Algal communities contained higher proportions of chlorophyll *c* than chlorophyll *b* in 2001 and nearly equal proportions in 2002 (Figure 23). Unlike Greens Creek Sites 54 and 48, diatoms, filamentous green algae and blue-green bacteria are important components of the algal communities in Tributary Creek.

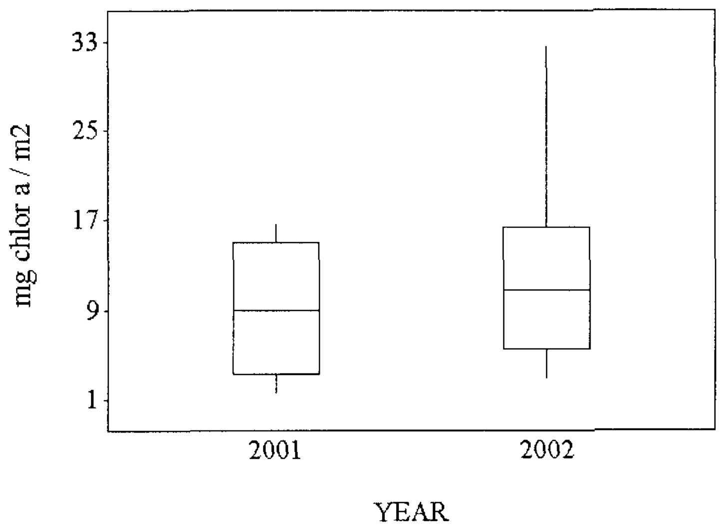

Figure 22. Periphyton biomass in Tributary Creek Site 9, 2001 and 2002.

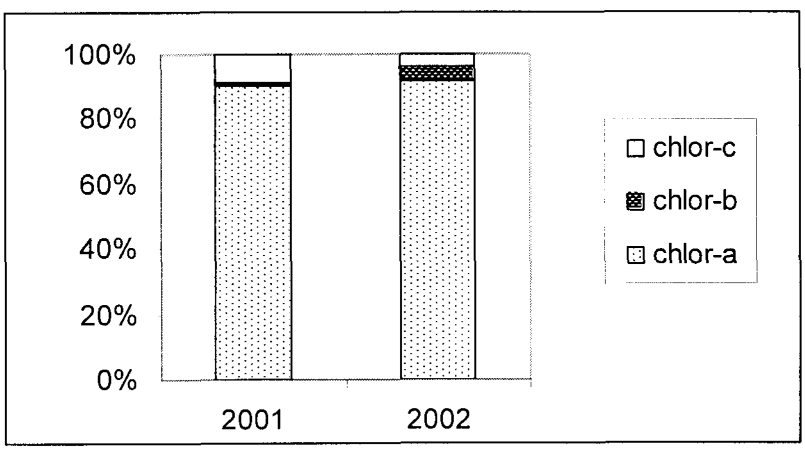

Figure 23. Proportions of chlorophyll *a*, *b* and *c* in Tributary Creek Site 9, 2001 and 2002.

Aquatic Invertebrate Community

As in Greens Creek Sites 48 and 54, the density of aquatic invertebrates in Tributary Creek was similar in 2001 and 2002 (Wilcoxin Rank Sum Test, $p = 0.15$, Figure 24). Taxonomic richness, as expressed by number of taxa sampled in Tributary Creek Site 9, also was similar in 2001 and 2002. In 2001, we identified 21 distinct aquatic taxa and an average of 13.6 taxa per sample. In 2002, we found 24 distinct taxa and an average of 15.2 taxa per sample.

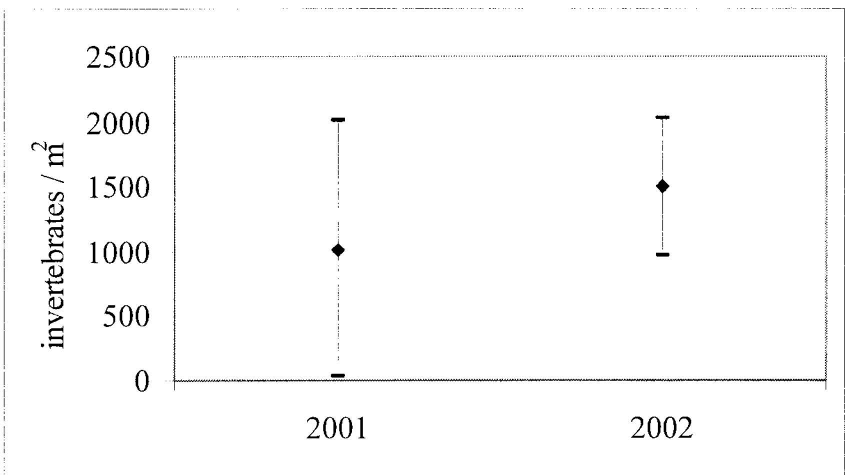

Figure 24. Density of aquatic invertebrates in Tributary Creek Site 9, 2001 and 2002.

Invertebrate communities in Tributary Creek Site 9 have a large component of non-insects, which are not as commonly found in the Greens Creek sites (Figure 25). The presence of these orders reflects the stream channel characteristics of a small, valley-bottom stream with attached wetland areas. As in the Greens Creek sites, the EPT taxa are the major component.

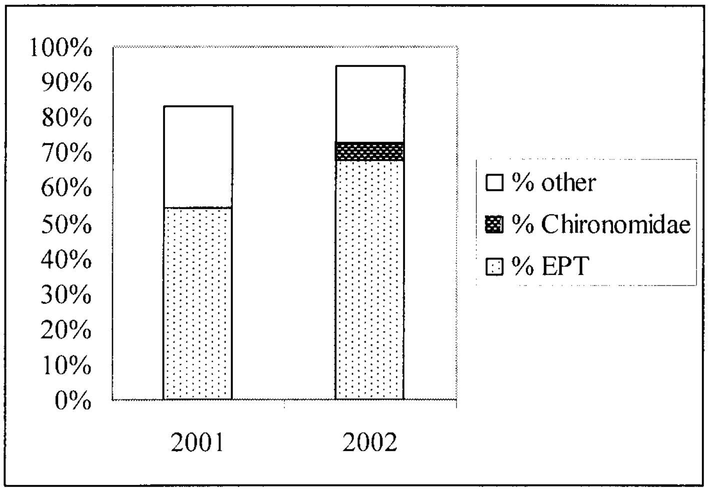

Figure 25. Proportions of EPT taxa and Chironomidae in Tributary Creek Site 9, 2001 and 2002.

Tributary Creek Site 9 has a complex invertebrate community of mayflies, stoneflies, caddisflies, true flies, and non-insect groups (Figure 26). The non-insect group included springtails (Collembola), worms (Oligochaeta), mites (Acarina), and seed shrimp (Ostracoda). Unlike Greens Creek Sites 54 and 48 where one or two invertebrate taxa comprise more than half of the community, the invertebrate population in Tributary Creek Site 9 contains lower proportions of many taxa (Table 4). Pollution-sensitive taxa, such as the mayflies *Baetis*, *Ephemerella*, *Cinygmula*, and *Paraleptophlebia* were prevalent.

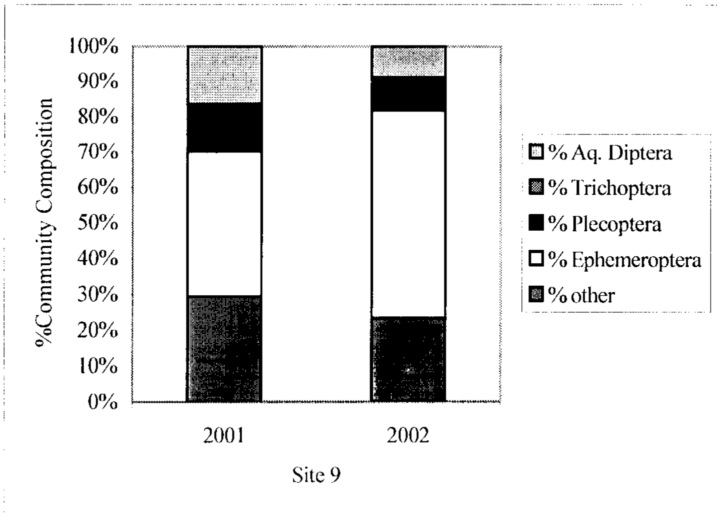

Figure 26. Community composition of aquatic invertebrates in Tributary Creek Site 9, 2001 and 2002.

Table 4. Most commonly found taxa in Tributary Creek Site 9.

Order	Family	Genus	2001	2002
Ephemeroptera	Baetidae	*Baetis*	8%	16%
	Heptageniidae	*Cinygmula*	17%	24%
	Leptophlebiidae	*Paraleptophlebia*	13%	13%
Plecoptera	Chloroperlidae	*Sweltsa*		6%
	Chloroperlidae	*Suwallia*	7%	
Acarina				6%
Oligochaeta			8%	
Ostracoda			18%	
Isopoda	Gammaride	*Gammarus*		14%

Juvenile Fish Community

A variety of fish rear in Tributary Creek, including coho salmon, Dolly Varden, cutthroat trout, and sculpin. Coho, pink, and chum salmon spawn in the creek. Cutthroat trout and sculpin (4 total collected) are minor components of the fish community in Tributary Creek.

Fewer fish were caught in 2002 than in 2001 (Table 5). Age 0 juvenile Dolly Varden were found in 2002 (Figure 28) but not in 2001 (Figure 27). The length-frequency of Dolly Varden collected in both years suggests the presence of several age groups, possibly age 0 (2002 only), age 1 and age 2 and a few age 3. The presence of age 0 fish indicates successful recruitment to this creek; however, their absence suggests only that they were not trapped in the short period this creek was sampled.

Table 5. Juvenile fish population estimates for Tributary Creek Site 9, 2001 and 2002.

Year	**Fish**	**Total fish caught**	**Population Estimate, fish/reach**	**Sample Reach, m**	**Density, fish/m^2**
2001	DV	81	81	50	0.65
2002	DV	51	57	50	0.46
2001	CO	118	120	50	0.94
2002	CO	44	46	50	0.35

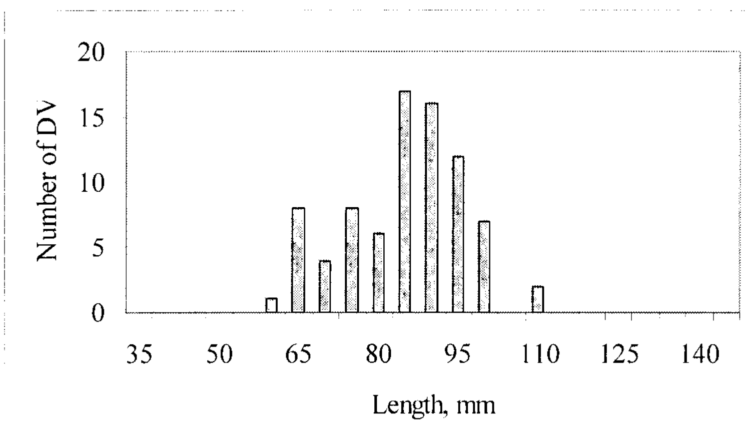

Figure 27. Juvenile Dolly Varden captured in Tributary Creek Site 9, 2001.

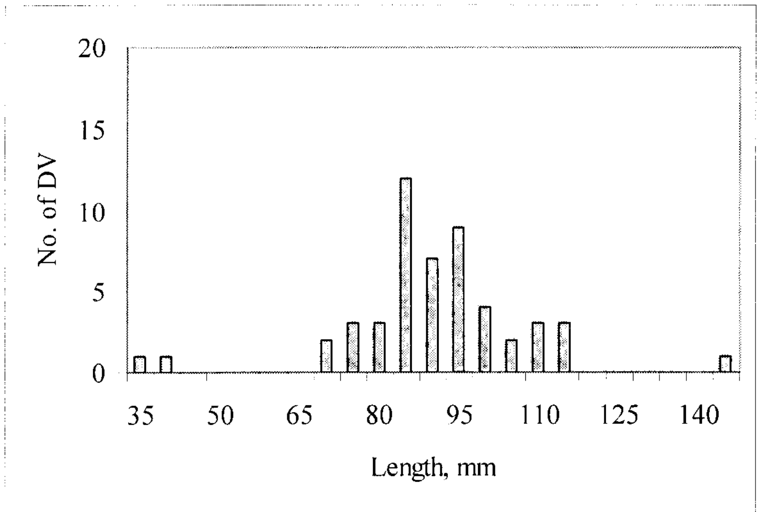

Figure 28. Juvenile Dolly Varden captured in Tributary Creek Site 9, 2002.

In 2001, we caught 118 juvenile coho salmon in Tributary Creek Site 9. Catches were substantially lower in 2002 when only 44 juvenile coho salmon were caught. The juvenile coho salmon at this site are likely a mixture of age classes, from age 0 to age 3 (Figures 29 and 30). Likely this species lives in Tributary Creek for one to two years before migrating to sea (Morrow 1980).

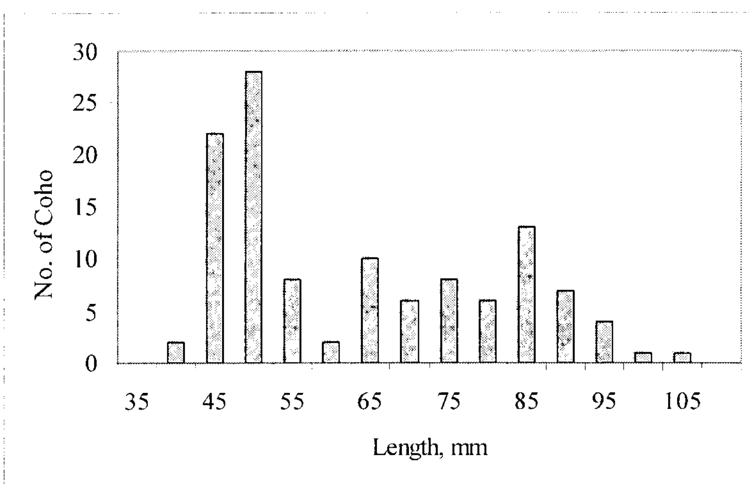

Figure 29. Juvenile coho salmon captured in Tributary Creek Site 9, 2001.

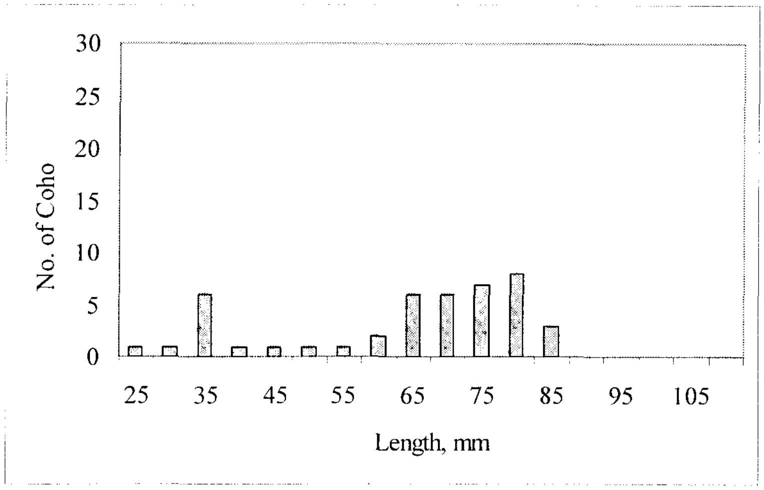

Figure 30. Juvenile coho salmon captured in Tributary Creek Site 9, 2002.

Metals in Juvenile Fish

There were slight fluctuations in all metals concentrations in juvenile fish tissues between the three years of measurements (Figure 31, Appendix 3). Levels of cadmium steadily increased from a median value of 0.53 mg/kg levels measured in 2000 to 1.11 mg/kg measured in 2002, although they remain within the range of values measured in Greens Creek Site 6, our reference site.

Toxicity Testing

We did not find toxic effects from any of the dilutions of Tributary Creek Site 9 water in the acute Microtox toxicity tests (test dilutions ranged from 5 to 45% of Tributary Creek Site 9 waters). The growth of the test species, *Vibrio fischeri*, was the same for the control as well as all test dilutions. As a result, the calculated IC-20 value was >100%.

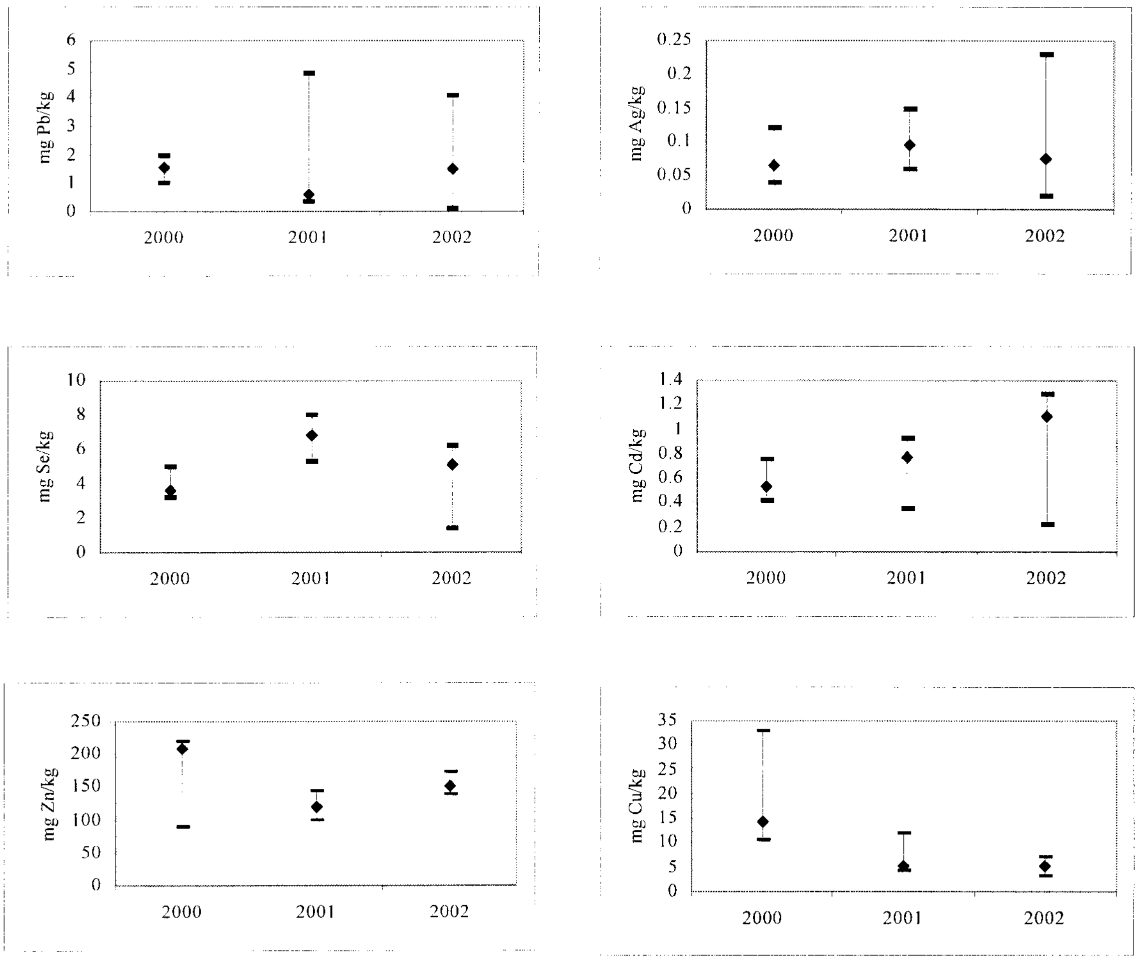

Figure 31. Metals in whole body fish in Tributary Creek Site 9, 2000, 2001 and 2002.

Comparisons Among Sites

Periphyton Biomass

Periphyton biomass was similar among the three Greens Creek sample sites and similar among the years sampled (Figure 32). Tributary Creek, a warmer, slow-flowing system had substantially higher amounts of periphyton.

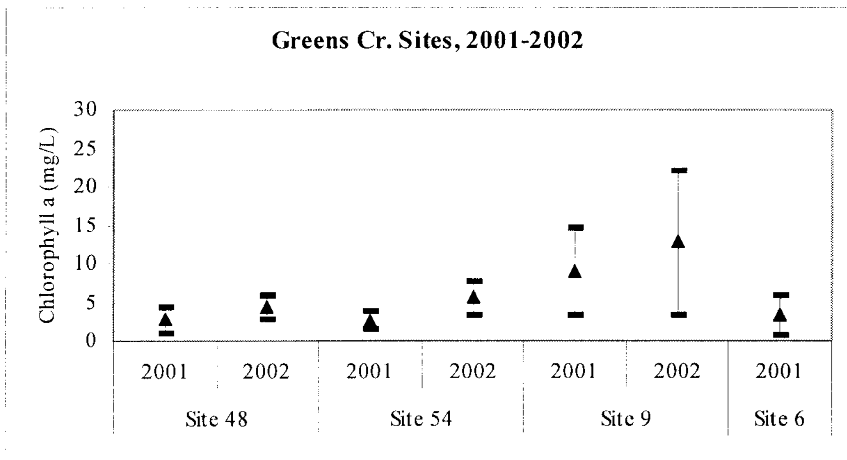

Figure 32. Comparisons of estimated periphyton biomass among sites, 2001 and 2002.

There were slight differences in community composition of the periphyton sampled at the Greens Creek and Tributary Creek sites (Figure 33). Chlorophyll *a* is the primary photosynthetic pigment, is present in all algae, and is a useful indicator of a healthy algal community (Wetzel 1983). The low concentrations of chlorophyll *b*, sometimes below detection limits, is not unusual. Chlorophyll *b* is an accessory pigment and is usually found in combination with other photosynthetic pigments. When measured above detection limits, Chlorophyll *b* is an indication of the presence of green algae and euglenophytes. Chlorophyll *c* is also an accessory pigment, and is only found in the photosynthetic Chromista and dinoflagellates (Waggoner and Speer 2000), of which diatoms form a major group in the periphyton community. Measurable quantities of chlorophyll *c* indicate the importance of diatoms in the community.

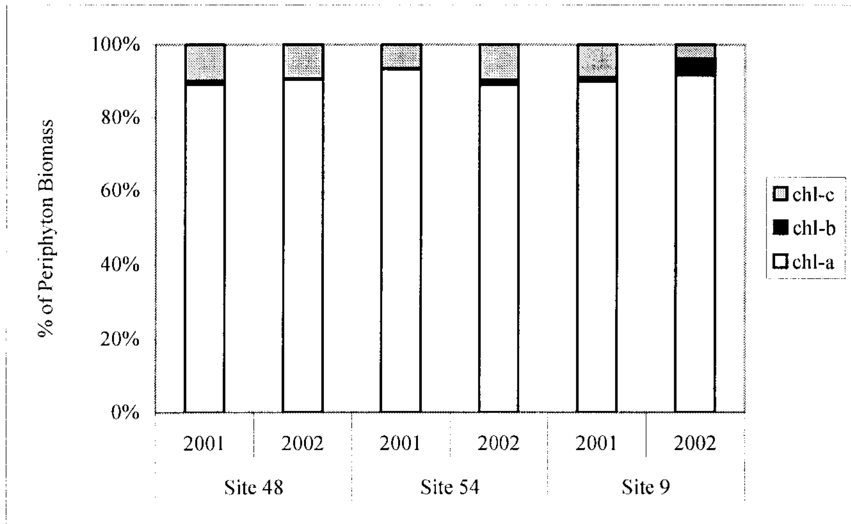

Figure 33. Comparison of proportions of chlorophylls *a*, *b*, *c* among sites, 2001 and 2002.

The contribution by chlorophylls *b* and *c* are different in Tributary Creek than the Greens Creek sites. In Tributary Creek, chlorophyll *b* was nearly equal to chlorophyll *c*, suggesting that at the time of sampling in 2002, there was a large percentage of green and blue-green algae in the periphyton community (Wetzel 1983). Given the differences in channel morphology, flow regimes and streamside vegetation between Greens Creek and Tributary Creek, the differences in algal communities are not unexpected.

Despite the lower periphyton biomass and slight difference in community composition in Tributary Creek Site 9 compared to the rest of the biomonitoring sites (Sites 48, 54, and 6), the periphyton communities in all biomonitoring sites are well within ranges of healthy aquatic systems (Wetzel 1983).

Aquatic Invertebrate Community

Aquatic invertebrate densities were highest in Greens Creek Site 54 during both years of monitoring, and lowest in Site 9 (Figure 34). Although invertebrate density was lowest in Tributary Creek Site 9, the density at this site is considered to be typical of a healthy community (Barber et al 1997).

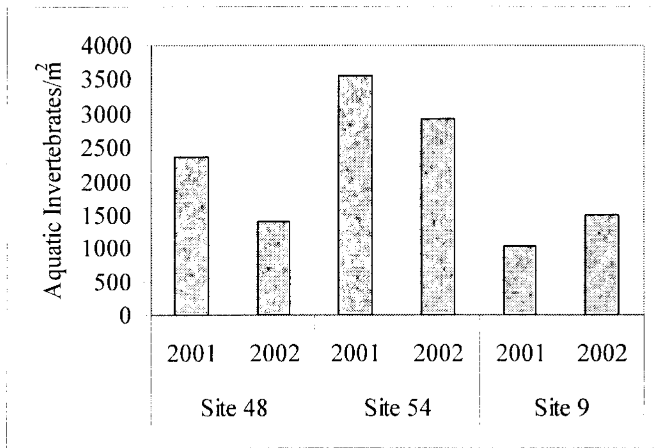

Figure 34. Comparison of aquatic invertebrate density among sites, 2001 and 2002.

All of the biomonitoring sites had complex invertebrate communities with fairly large numbers of distinct taxa per sample (Figure 35). More than 50% of the invertebrates in Greens Creek Sites 54 and 48 were one or two taxa; however, communities in Tributary Creek Site 9 contained lower proportions of many taxonomic groups (Figure 36). Differences in the structure of these communities reflect differences in channel morphology, frequency of flood events, streamside vegetation, and flow rates. Aquatic habitats with fairly even stream flows, such as Tributary Creek Site 9, usually do not have communities dominated by a few taxa (Hynes 1970). The predominance of one or two taxa is likely a result to perturbation, in Greens Creek the dominant taxa are sensitive to pollution. Therefore, the community is likely responding to high streamflows and exhibiting rapid re-colonization.

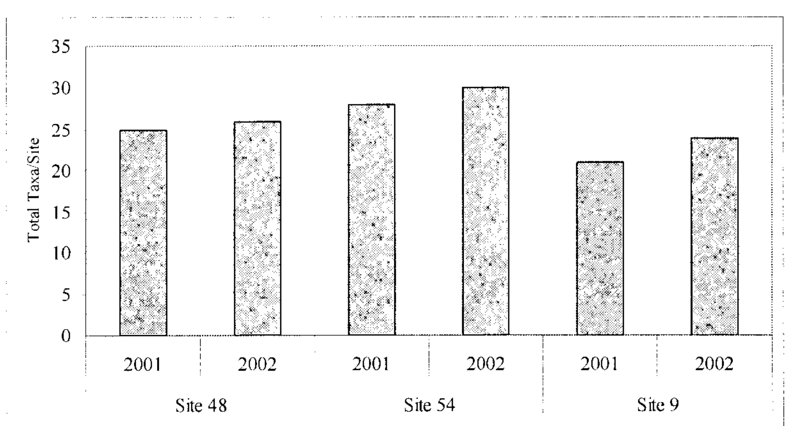

Figure 35. Comparison of taxonomic richness among sites, 2001 and 2002.

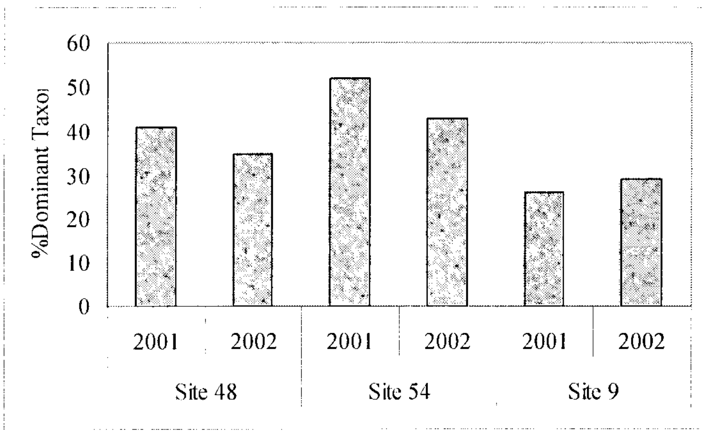

Figure 36. Comparison of percent dominant taxa among sites, 2001 and 2002.

Percent EPT, which is based on the concept that most Ephemeroptera – Plecoptera – Trichoptera taxa are sensitive to pollutants (Merritt and Cummins 1996) was high in all of the biomonitoring sites (Figure 37).

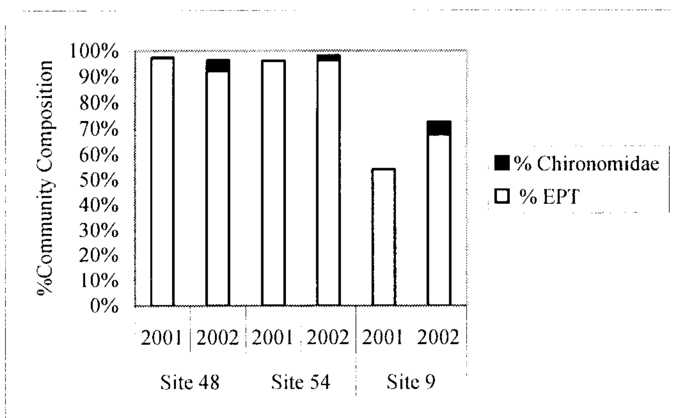

Figure 37. Comparisons of proportions of EPT taxa and Chironomidae among sites, 2001 and 2002.

Aquatic invertebrate communities in Greens Creek Sites 48 and 54 were more similar to one another than to those in Tributary Creek Site 9 (Figure 38). Aquatic communities at both Sites 48 and 54 were dominated by mayflies (Ephemeroptera), with small contributions by stoneflies (Plecoptera) and true flies (aquatic Diptera). In Tributary Creek Site 9, however, the community was only slightly dominated by mayflies with numerous non-insect invertebrates. Aquatic Diptera, and Plecoptera also were more important components of the aquatic community in

Tributary Creek Site 9 than in Greens Creek Sites 48 and 54. This difference is likely due to differences in physical characteristics of the stream systems.

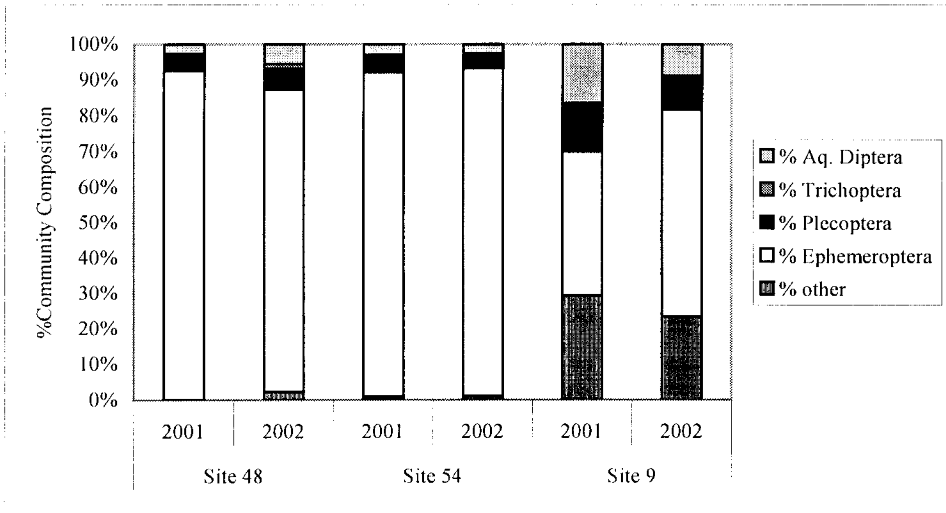

Figure 38. Comparison of community composition of aquatic invertebrates among sites, 2001 and 2002.

We used a number of different metrics to detect any responses of aquatic invertebrate communities to possible metals pollution. Density and taxonomic richness showed all three communities to be well-developed, complex communities with high invertebrate abundance. The percent dominant taxa showed the communities to have high proportions of pollution-sensitive invertebrates, and where a community was dominated by one or two groups, those groups were sensitive to pollution. Because all three communities show a prevalence of pollution-sensitive species, we believe that any future perturbations by pollution or natural stressors will cause a substantial change in the abundance or diversity of aquatic invertebrates.

Juvenile Fish Community

In 2001, the total fish density (Dolly Varden and coho combined) was highest in Tributary Creek Site 9 when we caught an estimated 1.59 fish/m^2 of stream habitat. In 2002, the estimated fish density was highest in Greens Creek Site 54 where we caught an estimated 1.07 fish/m^2 (Table 6). Densities were lowest in Greens Creek Site 48, where fish access is limited by a weir and the stream only contains resident Dolly Varden (Weber Scannell and Paustian 2002). All three biomonitoring sites support healthy fish communities.

Table 6. Estimated fish densities in the biomonitoring sites.

	Greens Creek Site 48		Greens Creek Site 54		Tributary Creek Site 9	
2001						
Fish species	Coho salmon	Dolly Varden	Coho salmon	Dolly Varden	Coho salmon	Dolly Varden
Total fish caught	0	68		138	118	81
Sample Reach, m	72	72	28	28	50	50
Population Estimate, fish/reach	0	144	few fish	164	120	81
Density, fish/m^2	0	0.2	Not calculated	0.6	0.94	0.65
2002						
Total fish caught	0	126	21	271	44	51
Sample Reach, m	50	50	28	28	50	50
Population Estimate, fish/reach	0	145	21	293	46	57
Density, fish/m^2	0	0.23	0.07	1.0	0.35	0.46

Metals in Juvenile Fish

The median values for each of the six measured metals in this year's biomonitoring study were similar among the two sites on Greens Creek Sites 48 and 54 and Tributary Creek Site 9 (Figure 39). We could not detect any evidence that metals in fish tissues from Greens Creek Site 54, near the mine, or Tributary Creek Site 9, below the tailings facility, were elevated above the reference site, Greens Creek Site 48.

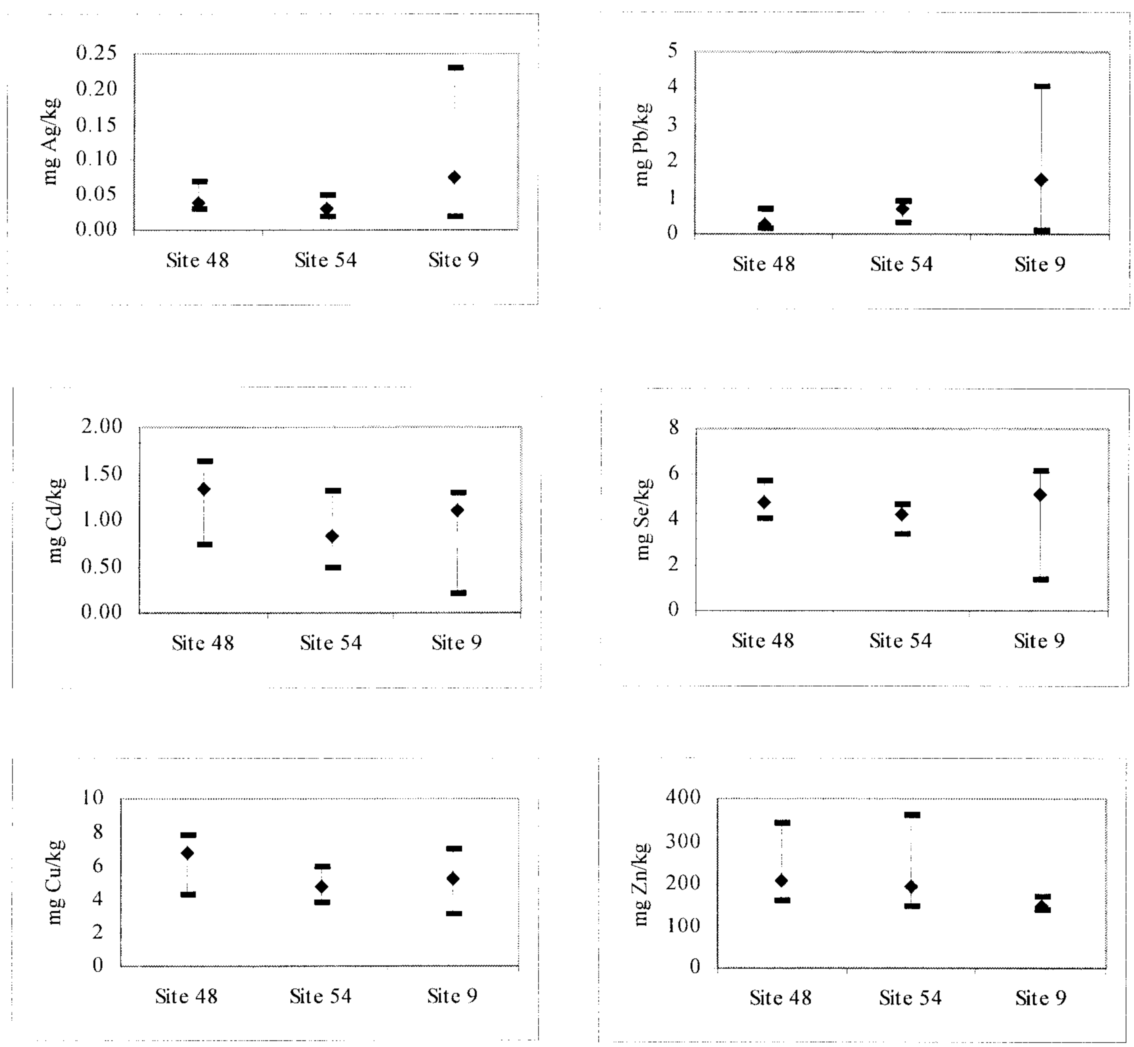

Figure 39. Comparison of metals in whole body fish among sites, 2002.

Toxicity Testing

Acute toxicity testing of water from each the three sample sites was conducted during 2002. No toxicity was detected during any of the tests, and growth of *Vibrio fischeri* was similar to the control for all dilutions. Because there was no toxic response, the IC-20 value for each site was >100%.

The results from testing for chronic toxicity are not presented here because of difficulties with test procedures. Quality control of the test reagent turned out to be unacceptable for each of the four shipments we made during 2002. Several attempts were made to conduct the testing, with each attempt ending in failure because of faulty test reagent.

CONCLUSIONS

The two biomonitoring sites on Greens Creek Sites 48 and 54 and one inTributary Creek Site 9 continued to sustain complex, diverse aquatic communities at population levels similar to other systems in the area. Periphyton biomass and community composition continue to appear robust, particularly in Tributary Creek where stream flows are low, scouring flood events are rare, and annual variations in flow appear to be buffered by the ubiquitous wetlands in the watershed. The aquatic invertebrate communities are taxonomically rich with high densities. In addition, the populations of the many pollution-sensitive taxa remain intact. Juvenile fish populations continue to thrive, with many age classes present at each site. Metals in juvenile fish tissues do not appear to be any greater than that measured in the reference site, and concentrations at all sites were similar to those measured during 2001. We found no indication of acute toxicity in water from the three biomonitoring sites.

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APPENDIX 1. USFS DEFINITIONS OF CHANNEL TYPES

The following definitions of channel types, used in this report, are from Paustian et al. 1999.

MM2 Channel Type

An MM2 channel is defined as "normally found in the middle to lower portion of moderate size drainage basins. MM2 streams are often confined by mountainslope, footslope, and hillslope landforms, but they can develop a narrow flood plain. Bedrock knickpoints with cascades or falls may be present.

MM2 channels are generally accessible to anadromous species, with several species of spawners using the moderate amounts of available spawning area (ASA). These channels have moderate amounts of rearing area which are used by coho, Dolly Varden char, and steelhead juveniles. Pools are relatively deep and are highly dependent on large woody debris. Overwintering habitat is primarily associated with these pools. When located next to accessible lakes, these channels provide good quality spawning for sockeye salmon and steelhead trout.

Large woody debris significantly influences channel morphology and fish habitat quality. Large wood volume is generally high. Large wood accumulations form pool and stream bank rearing habitat, as well as stabilize spawning substrate behind log steps. Maintenance of large woody debris sources is an important management concern.

Banks are composed primarily of unconsolidated cobble and gravel size materials, therefore, stream bank sensitivity is rated high. The volume and energy of flood discharge in MM2 channels are the major factors affecting bank erosion. Disturbance of streamside vegetation root mats may contribute to accelerated channel scour and lateral channel migration.

Flood plains associated with MM2 channel types are generally narrow, however, side channels and flood overflow channels are commonly found along MM2 reaches. Flood plain stability can be a concern in these uncontained channel segments.

FP3 Channel Type

FP3 streams are located in the valley bottoms and may also occur within flat lowlands or low elevation drainage divides. Frequently, FP3 streams lie adjacent to the toe of footslopes or hillslopes, adjacent to the main trunk, valley bottom channels. The flood plain of large, low gradient alluvial channels may be dissected by FP3 streams. Where FP3 streams occur parallel to the foot slopes or in the valley bottom locations, they are typically fed by high gradient streams. Less frequently, FP3 streams are situated on mountain slope benches.

The riparian plant associations for FP3 streams are dominated by the Sitka spruce series and the western hemlock series. Salmonberry and alder shrub communities are the principal non-forest riparian plant communities. Willow, shrub and sedge/sphagnum bog communities are the primary non-forest riparian communities in the FP3 phase. Sitka alder and willow shrub communities are the predominant riparian vegetation associated with the FP3 phase.

FP3 channels are frequently accessible to anadromous species. Coarse and fine gravels compose 49% of the substrate, therefore, available spawning area is high. These channels receive moderate to high spawning use by all anadromous species.

APPENDIX 2. AQUATIC INVERTEBRATE DATA

Greens Creek Site 48, 2001 and 2002.

Taxa			2001	2002
Ephemeroptera	Baetidae	*Baetis*	309	152
	Ephemerellidae	*Caudatella*	2	
		Drunella	47	49
	Heptageniidae	*Cinygmula*	99	20
		Epeorus	444	190
		Rhithrogena	193	187
	Leptophlebiidae	*Paraleptophlebia*		1
Plecoptera	Chloroperlidae	*Alloperla*	1	1
		Plumiperla	5	
		Suwallia	8	1
		Sweltsa	1	4
	Leuctridae	*Despaxia*		2
		Paraleuctra	4	3
		Perlomyia		12
	Nemouridae	*Podmosta*	7	5
		Zapada	23	4
	Perlodidae	*Skwala*		9
Trichoptera	Apataniidae	*Apatania*		1
	Hydropsychidae	*Arctopsyche*	2	
	Rhyacophilidae	*Rhyacophila*	5	8
Coleoptera	Staphylinidae		1	
Diptera	Ceratopogonidae	*Dasyhelea*		1
	Chironomidae		14	30
	Deuterophlebiidae	*Deuterophlebia*	2	
	Empididae	*Chelifera*	1	2
		Oreogeton	3	2
	Psychodidae	*Psychoda*	1	
	Simuliidae	*Parasimulium*	2	
		Prosimulium	2	
		Simulium	6	4
Collembola	Onychiuridae	*Onychiurus*		1
	Sminthuridae	*Dicyrtoma*	2	
Acarina				2
Oligochaeta				5
Ostracoda				8

Greens Creek Site 54, 2001 and 2002.

Taxa			**2001**	**2002**
Ephemeroptera	Baetidae	*Baetis*	248	225
	Ephemerellidae	*Ephemerella*	2	6
		Drunella	118	280
	Heptageniidae	*Cinygmula*	319	75
		Epeorus	935	626
		Rhithrogena		140
	Leptophlebiidae	*Paraleptophlebia*	1	
	Ameletidae	*Ameletus*	4	
Plecoptera	Chloroperlidae	*Alloperla*	3	
		Neaviperla		14
		Plumiperla	2	
		Sweltsa	6	
	Leuctridae	*Paraleuctra*		4
		Perlomyia	13	3
	Nemouridae	*Podmosta*		7
		Zapada	52	22
	Perlodidae	*Diura*	1	
		Isoperla	3	
		Skwala		3
		Rickera		1
Trichoptera	Hydropsychidae	*Arctopsyche*		1
	Limnephilidae	*Psychoglypha*	1	
	Rhyacophilidae	*Rhyacophila*	6	5
Coleoptera	Staphylinidae		1	1
Diptera	Chironomidae		33	27
	Deuterophlebiidae	*Deuterophlebia*		1
	Dolichopodidae		2	
	Empididae	*Chelifera*	2	
		Oreogeton	10	4
	Simuliidae	*Prosimulium*		1
		Simulium	3	3
	Tipulidae	*Antocha*	1	
		Dicranota	2	1
		Hesperoconopa		1
		Tipula		1
Collembola	Onychiuridae	*Onychiurus*		1
	Sminthuridae	*Dicyrtoma*		1
Acarina			9	3
Oligochaeta			3	7
Gastropoda	Valvatidae		1	1
Ostracoda			1	1

Tributary Creek Site 9, 2001 and 2002.

Taxa			2001	2002
Ephemeroptera	Baetidae	*Baetis*	41	123
		Procloeon	5	
	Ephemerellidae	*Caudatella*	3	
		Drunella		3
		Ephemerella		14
		Epeorus		8
	Heptageniidae	*Cinygma*	1	
		Cinygmula	89	177
	Leptophlebiidae	*Paraleptophlebia*	66	96
	Ameletidae	*Ameletus*		15
Plecoptera	Chloroperlidae	*Paraperla*		11
		Suwallia	34	
		Sweltsa		42
	Leuctridae	*Despaxia*	3	
		Paraleuctra	7	
		Perlomyia		3
	Nemouridae	*Podmosta*		1
		Zapada	23	12
	Perlodidae	*Isoperla*	1	
Trichoptera	Apataniidae	*Apatania*		1
	Rhycophilidae	*Rhycophila*		1
Coleoptera	Elmidae	*Narpus*	2	6
Diptera	Ceratopogonidae	*Dasyhelea*	3	
	Chironomidae		35	36
	Empididae	*Chelifera*		1
		Oreogeton	4	2
	Psychodidae	*Psychoda*		
	Simuliidae	*Simulium*	40	22
	Tipulidae	*Tipula*	4	5
Collembola	Sminthuridae	*Dicyrtoma*		2
Acarina			15	20
Oligochaeta			40	45
Gastropoda			1	
Ostracoda			92	102

APPENDIX 3. JUVENILE FISH TISSUE DATA

Information on fish collected for analysis of metals in tissues, 2000, 2001 and 2002.

Sample Number	Date collected	Creek	Site	Fish	Weight (gm)	Length (FL) mm
062100GCCOJ01	21-Jun-00	Greens	54	Coho	4.4	72
062100GCCOJ02	21-Jun-00	Greens	54	Coho	6.1	82
062100GCCOJ03	21-Jun-00	Greens	54	Coho	4.9	73
062100GCCOJ04	21-Jun-00	Greens	54	Coho	3.4	68
062100GCCOJ05	21-Jun-00	Greens	54	Coho	5.9	73
062100GCCOJ06	21-Jun-00	Greens	54	Coho	6	75
072301GC54DVJ01	23-Jun-01	Greens	54	Dolly Varden	21.5	121
072301GC54DVJ02	23-Jun-01	Greens	54	Dolly Varden	19.32	119
072301GC54DVJ03	23-Jun-01	Greens	54	Dolly Varden	15.73	107
072301GC54DVJ04	23-Jun-01	Greens	54	Dolly Varden	13.64	109
072301GC54DVJ05	23-Jun-01	Greens	54	Dolly Varden	13.52	105
072301GC54DVJ06	23-Jun-01	Greens	54	Dolly Varden	27.54	138
072402GC54DVJ01	24-Jul-02	Greens	54	Dolly Varden	17.96	118
072402GC54DVJ02	24-Jul-02	Greens	54	Dolly Varden	22.26	128
072402GC54DVJ03	24-Jul-02	Greens	54	Dolly Varden	17.7	115
072402GC54DVJ04	24-Jul-02	Greens	54	Dolly Varden	18.94	115
072402GC54DVJ05	24-Jul-02	Greens	54	Dolly Varden	21.09	124
072402GC54DVJ06	24-Jul-02	Greens	54	Dolly Varden	20.88	123
062100TRCOJ01	21-Jun-00	Tributary	9	Coho	9.7	102
062100TRCOJ02	21-Jun-00	Tributary	9	Coho	5.3	75
062100TRDVJ03	21-Jun-00	Tributary	9	Dolly Varden	12.8	112
062100TRDVJ04	21-Jun-00	Tributary	9	Dolly Varden	13.8	105
062100TRDVJ05	21-Jun-00	Tributary	9	Dolly Varden	13.4	105
062100TRDVJ06	21-Jun-00	Tributary	9	Dolly Varden	11.3	100
072301TR09DVJ01	23-Jul-01	Tributary	9	Dolly Varden	9.05	97
072301TR09DVJ02	23-Jul-01	Tributary	9	Dolly Varden	9.66	97
072301TR09DVJ03	23-Jul-01	Tributary	9	Dolly Varden	9.5	97
072301TR09DVJ04	23-Jul-01	Tributary	9	Dolly Varden	10.37	98
072301TR09DVJ05	23-Jul-01	Tributary	9	Dolly Varden	6.42	86
072301TR09DVJ06	23-Jul-01	Tributary	9	Dolly Varden	7.83	93
072402TR09DVJ01	24-Jul-02	Tributary	9	Dolly Varden	10.8	103
072402TR09DVJ02	24-Jul-02	Tributary	9	Dolly Varden	10.43	97
072402TR09DVJ03	24-Jul-02	Tributary	9	Dolly Varden	11.16	100
072402TR09DVJ04	24-Jul-02	Tributary	9	Dolly Varden	7.93	90
072402TR09DVJ05	24-Jul-02	Tributary	9	Dolly Varden	9.19	90
072402TR09DVJ06	24-Jul-02	Tributary	9	Dolly Varden	9.33	100
072301GC48DVJ01	23-Jul-01	Greens	48	Dolly Varden	26.02	131
072301GC48DVJ02	23-Jul-01	Greens	48	Dolly Varden	28.81	137
072301GC48DVJ03	23-Jul-01	Greens	48	Dolly Varden	18.84	119
072301GC48DVJ04	23-Jul-01	Greens	48	Dolly Varden	21.13	121
072301GC48DVJ05	23-Jul-01	Greens	48	Dolly Varden	13.71	111
072301GC48DVJ06	23-Jul-01	Greens	48	Dolly Varden	21.08	121

Sample Number	Date collected	Creek	Site	Fish	Weight (gm)	Length (FL) mm
072402GC48DVJ01	24-Jul-02	Greens	48	Dolly Varden	23.23	133
072402GC48DVJ02	24-Jul-02	Greens	48	Dolly Varden	15.04	120
072402GC48DVJ03	24-Jul-02	Greens	48	Dolly Varden	17.52	122
072402GC48DVJ04	24-Jul-02	Greens	48	Dolly Varden	20.75	127
072402GC48DVJ05	24-Jul-02	Greens	48	Dolly Varden	24.77	134
072402GC48DVJ06	24-Jul-02	Greens	48	Dolly Varden	21.66	128
072301GC06DVJ01	23-Jul-01	Greens	6	Dolly Varden	28.4	139
072301GC06DVJ02	23-Jul-01	Greens	6	Dolly Varden	30.49	140
072301GC06DVJ03	23-Jul-01	Greens	6	Dolly Varden	43.9	167
072301GC06DVJ04	23-Jul-01	Greens	6	Dolly Varden	34.8	155
072301GC06DVJ05	23-Jul-01	Greens	6	Dolly Varden	15.69	109
072301GC06DVJ06	23-Jul-01	Greens	6	Dolly Varden	49.1	168

Concentration of select elements in juvenile fish, 2000, 2001 and 2002.

Sample Number	**Ag (mg/kg)**	**Cd (mg/kg)**	**Cu (mg/kg)**	**Pb (mg/kg)**	**Se (mg/kg)**	**Zn (mg/kg)**	**% Solids**
	0.02 (MRL)	**0.02 (MRL)**	**0.1 (MRL)**	**0.02 (MRL)**	**1 (MRL)**	**0.5 (MRL)**	
062100GCCOJ01	0.04	0.95	15.3	1.4	4.9	251	20.5
062100GCCOJ02	0.09	0.66	11.7	1.21	4.7	224	20.2
062100GCCOJ03	0.22	1.07	24.2	1.4	3.4	206	20.4
062100GCCOJ04	0.1	0.97	24	1.12	3.5	181	21.4
062100GCCOJ05	0.05	0.96	44	1.53	4.9	304	20.7
062100GCCOJ06	0.08	1.47	36.1	5.02	4.7	340	20.2
072301GC54DVJ01	0.03	0.46	4.3	0.33	5.7	126	22.6
072301GC54DVJ02	0.02	0.21	3.2	0.22	3.6	82	26.1
072301GC54DVJ03	0.03	0.73	6.3	0.59	4.7	144	23.5
072301GC54DVJ04	0.02	0.82	5.4	0.86	4.9	172	21.1
072301GC54DVJ05	0.02	0.79	6.5	0.45	5.8	203	22.8
072301GC54DVJ06	0.02	0.74	5.8	0.4	5.4	171	22.1
072402GC54DVJ01	0.03	0.5	4.4	0.94	3.4	363	21.2
072402GC54DVJ02	0.03	0.52	4.5	0.35	4.7	150	23.2
072402GC54DVJ03	0.05	0.95	6	0.66	4.4	161	21.9
072402GC54DVJ04	0.03	1.03	5.2	0.66	4.2	216	21.3
072402GC54DVJ05	0.05	1.32	5.2	0.74	3.9	194	21.4
072402GC54DVJ06	0.02	0.7	3.9	0.78	4.4	195	20.9
062100TRCOJ01	0.04	0.42	16.2	1.03	3.2	213	22.9
062100TRCOJ02	0.07	0.5	16.5	2.01	3.7	220	22.5
062100TRDVJ03	0.12	0.75	11.2	1.63	3.8	194	23.1
062100TRDVJ04	0.07	0.56	10.6	1.53	3.6	87.9	22.2
062100TRDVJ05	0.06	0.58	12.8	1.59	3.5	204	22.1
062100TRDVJ06	0.05	0.45	32.8	1.57	5.	213	23.
072301TR09DVJ01	0.09	0.35	4.3	0.56	6.8	127	22.1
072301TR09DVJ02	0.1	0.77	5.2	0.67	8	118	21.3
072301TR09DVJ03	0.15	0.92	5.4	4.88	5.3	144	22.2
072301TR09DVJ04	0.15	0.86	6.7	2.19		99.1	22.6
072301TR09DVJ05	0.08	0.76	4.9	0.33	6.2	106	22.2
072301TR09DVJ06	0.06	0.37	12	0.38	6.8	122	20.6
072402TR09DVJ01	0.02	0.22	3.7	0.12	1.4	144	20.9
072402TR09DVJ02	0.07	1.2	5.5	1.66	3.3	172	22.8
072402TR09DVJ03	0.13	1.06	6.1	3.4	5	138	23.2
072402TR09DVJ04	0.23	1.29	7.1	4.08	5.2	168	23.1
072402TR09DVJ05	0.08	1.15	5.2	1.39	6.2	150	23
072402TR09DVJ06	0.04	0.84	3.2	0.33	5.4	152	17.8
072301GC48DVJ01	0.02	1.76	8.3	0.2	6.1	180	21.6
072301GC48DVJ02	0.03	0.89	7.2	0.17	4.6	146	23.7
072301GC48DVJ03	0.02	2.27	5.7	0.2	6.2	189	20.7
072301GC48DVJ04	0.02	1.56	6.9	0.17	5.2	182	22.8
072301GC48DVJ05	0.03	0.89	4.7	0.23	5.4	138	21.8
072301GC48DVJ06	0.02	1.26	7.4	0.1	5.6	157	20.3

Sample Number	Ag (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Se (mg/kg)	Zn (mg/kg)	% Solids
	0.02 (MRL)	**0.02 (MRL)**	**0.1 (MRL)**	**0.02 (MRL)**	**1 (MRL)**	**0.5 (MRL)**	
072402GC48DVJ01	0.03	1.64	6.8	0.72	4.8	239	24.3
072402GC48DVJ02	0.07	0.85	7	0.28	4.1	210	19.2
072402GC48DVJ03	0.03	0.74	4.3	0.17	4.9	162	22.1
072402GC48DVJ04	0.04	1.4	6.1	0.16	4.7	185	21.2
072402GC48DVJ05	0.05	1.3	7.9	0.46	4.3	208	21.5
072402GC48DVJ06	0.04	1.56	6.8	0.22	5.7	343	20.9
072301GC06DVJ01	0.04	1.94	16.7	1.24	5	173	20.8
072301GC06DVJ02	0.03	0.84	4.6	1	4.5	167	22.8
072301GC06DVJ03	0.03	0.82	5.3	1.94	4.3	171	21.7
072301GC06DVJ04	0.03	1.52	5.4	1.78	4.5	215	21.6
072301GC06DVJ05	0.02	0.89	11.1	0.33	5.3	126	22.2
072301GC06DVJ06	0.04	0.73	8	1.96	4.6	169	21.9