Technical Report No. 04-04

Aquatic Biomonitoring At Greens Creek Mine, 2003

by James D. Durst
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Alaska Department of Natural Resources   Office of Habitat Management and Permitting

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EXECUTIVE SUMMARY

The Alaska Department of Fish and Game (ADF&G) Habitat and Restoration Division and the U.S. Forest Service, in cooperation with the U.S. Fish and Wildlife Service, began an aquatic biomonitoring program in Greens Creek and Tributary Creek in 2001 and again performed the sampling in 2002. The Alaska Department of Natural Resources Office of Habitat Management and Permitting, as successor to ADF&G Habitat and Restoration, conducted the sampling in 2003.

The purpose of the biomonitoring program has been to document the health of aquatic communities in Greens Creek and Tributary Creek and to document the abundance and taxonomic richness of existing aquatic habitats so comparisons can be made with future conditions at the monitored sites. Elements of the 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 Below Pond D Site 54 and Tributary Creek Site 9 continued to sustain complex, diverse aquatic communities at population levels similar to the reference site, Upper Greens Creek Site 48. The summer of 2003 was very dry at Greens Creek Mine, and the low water levels allowed for higher productivity in the streams but a decreased wetted area available for fish habitat, particularly in Tributary Creek.

Periphyton biomass and community composition continue to appear robust and were significantly higher in 2003 than in 2001 and 2002, 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 Below Pond D Site 54 were not significantly different from the reference site, Upper Greens Creek Site 48.

The benthic macroinvertebrate communities are taxonomically rich and abundant, and the populations of many pollution-sensitive taxa are well represented. Mean densities were similar between sites and significantly higher in 2003 than in 2001 and 2002. A slightly higher percentage of total aquatic invertebrates at the Greens Creek sites were Chironomidae compared to previous years. Aquatic communities at Greens Creek sites 48 and 54 were dominated by mayflies (Ephemeroptera), while at Tributary Creek Site 9 the community composition was only

slightly dominated by mayflies, with non-insect invertebrates forming a large component of the community. 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 be relatively abundant at each site, with multiple size classes present. Total fish captures were higher in 2003 than in previous years at both Greens Creek sites and lower at Tributary Creek Site 9. The latter is likely related to low water levels.

Whole body concentrations of metals in fish tissues were similar to or less than those found in previous years' samples. Concentrations of silver and lead were somewhat lower at the Greens Creek sites than at Tributary Creek, whereas the opposite was the case for zinc. The Greens Creek sites had slightly higher concentrations of selenium than in previous years. Although some differences were noted between sites and stream systems, no clear pattern of differential water quality emerged between sites downstream of mine facilities and the control site Upper Greens Creek Site 48.

No testing of acute toxicity in water from the three biomonitoring sites was done in 2003. The results from the 2003 periphyton, benthic invertebrate, and juvenile fish biomonitoring program elements provide no evidence to suggest toxicity of the waters at 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. Differences between the stream systems (Greens Creek and Tributary Creek) were typically of larger amplitude than were differences between the control and below-mining sites. We noted no indications of reduced productivity, community changes, or metals accumulation attributable to operations of the Greens Creek Mine.

INTRODUCTION

In 2000, an interagency regulatory team made up of representatives from the Alaska Department of Environmental Conservation (ADEC), the Alaska Department of Fish and Game (ADF&G), the Alaska Department of Natural Resources (ADNR), the Alaska Department of Law, the United States Environmental Protection Agency (USEPA), the United States Forest Service (USFS), and the United States Fish and Wildlife Service were invited by the Kennecott Greens Creek Mining Company (KGCMC) to conduct an environmental audit of the Greens Creek Mine operations within the Admiralty Island National Monument.

From findings of that review, the KGCMC Fresh Water Monitoring Plan (FWMP) 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 third year (2003) of biological monitoring of the Greens Creek Mine operation, conducted by the ADNR Office of Habitat Management and Permitting as successor to ADF&G Habitat and Restoration Division. Results from previous years' biomonitoring can be found in Weber Scannell and Paustian (2002) and Jacobs et al. (2003).

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 is designed to detect early changes to the aquatic community that may result from changes in water chemistry through either surface or groundwater inputs to the system.

Results from biomonitoring usually are compared to baseline conditions, or to a reference site that is unaffected if baseline data are unavailable. 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. Periphyton biomass, estimated by chlorophyll concentrations;
2. Abundance and community structure of benthic macroinvertebrate populations;
3. Distribution and abundance of juvenile fish;
4. Whole body concentrations of Ag, Cd, Cu, Pb, Se, and Zn in juvenile fish; and
5. Standardized laboratory toxicity testing.

LOCATION AND SCHEDULE OF MONITORING

Three of the sites routinely monitored under the FWMP were selected for routine biomonitoring. Upper Greens Creek Site 48 monitors Greens Creek upstream of all mine and mill activities. Biomonitoring occurs here annually and serves as a control site. Greens Creek Below Pond D Site 54 monitors Greens Creek downstream of all mine and mill facilities. Biomonitoring occurs at this site annually and serves as a treatment site. Tributary Creek Site 9 monitors Tributary Creek downstream of the tailings impoundment. Biomonitoring occurs annually to detect any changes over time. A fourth site, Middle Greens Creek Site 6 (upstream of Site 54 but below the mine portal and several facilities), was sampled 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) and is monitored on a 5-year schedule. KGCMC monitors the ambient water quality at these and other FWMP sites on a monthly basis. Water quality samples were collected at each of the biomonitoring sites within the month of the biomonitoring effort. Figure 1 shows the location of the Greens Creek Mine and the biomonitoring sampling locations.

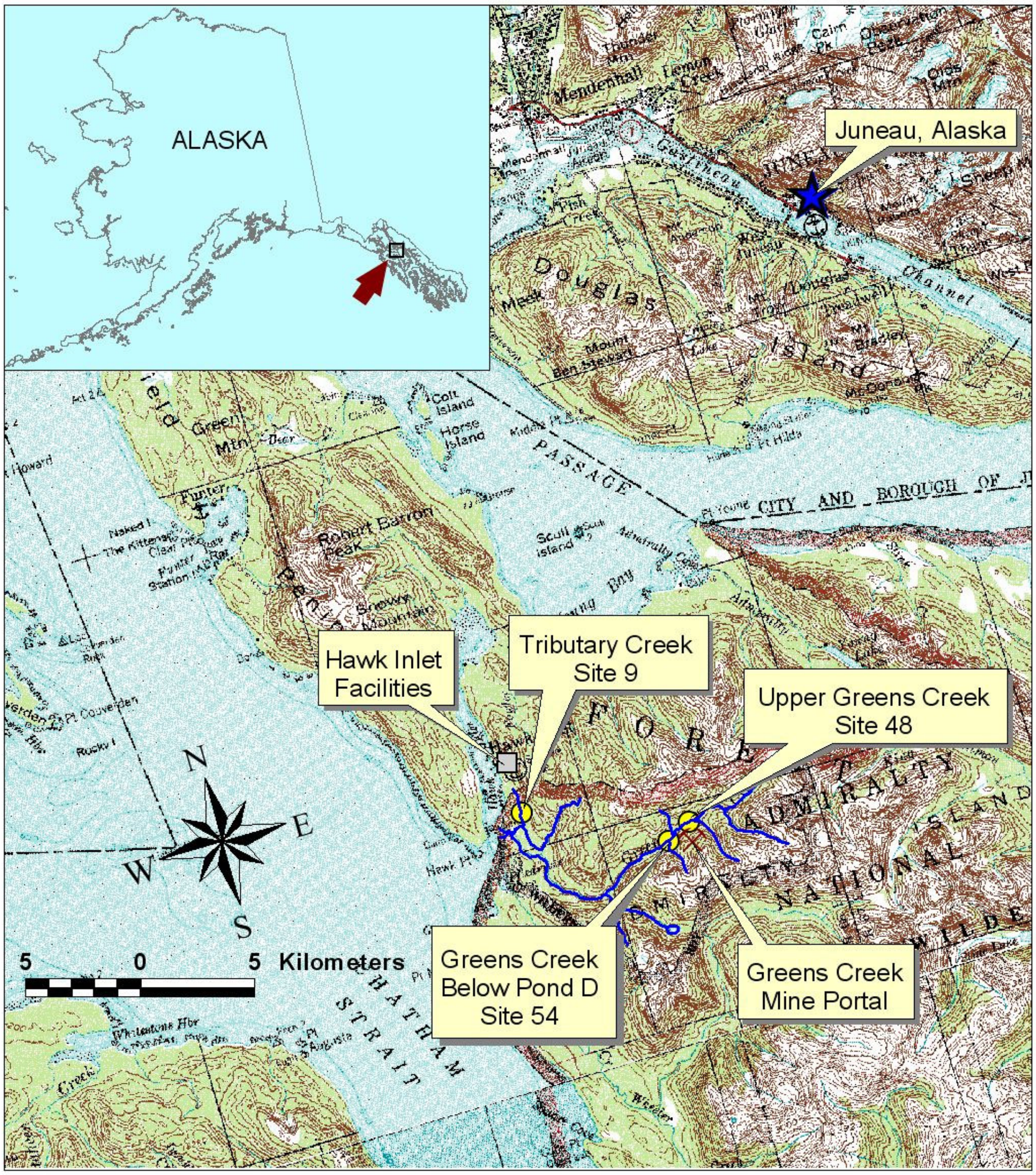

Figure 1. Location of the Greens Creek Mine operation and biomonitoring sampling sites on Admiralty Island in southeast Alaska, about 30 km southwest of Juneau.

METHODS

Sample design and methods followed procedures in the KGCMC Fresh Water Monitoring Program (KGCMC 2000), and as reported for the previous years of this biomonitoring study (Weber Scannell and Paustian 2002, Jacobs et al. 2003). Photographs were taken to document site conditions and sampling areas in each survey reach.

Data analyses were performed using hand calculators, Microsoft® Excel 2002, and Statistix® 8 (Analytical Software 2003). Kruskal-Wallis One-Way AOV, a nonparametric alternative to a one-way analysis of variance (ANOVA), was used to test for differences between years and sites. All-pairwise comparisons were conducted on the mean ranks for each group at various values of rejection level α to test for homogeneity between years and sites. Significant differences required an $\alpha = 0.05$ unless noted otherwise in the text.

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 the loosened 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 1,600 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

Benthic macroinvertebrate abundance and taxonomic richness are useful measures of stream health. Characterizing community structure and abundance of benthic macroinvertebrates at sample sites can show trends in stream health and water quality.

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 and cup attached to the sampler. The sample was removed, placed in pre-labeled 500 ml Nalgene® bottles, and then preserved in 70% denatured ethanol. Macroinvertebrate samples were later sorted from all debris and identified to the lowest practical taxonomic level.

Analyses included comparisons of abundance, community composition, and percent dominant taxa. The latter is a metric that usually identifies the absence of environmentally sensitive species or dominance of less sensitive taxa.

JUVENILE FISH POPULATIONS

Rationale

Monitoring juvenile fish populations to determine potential trends in the numbers of Dolly Varden (*Salvelinus malma*) and coho salmon (*Oncorhynchus kisutch*) in stream reaches near the surface mine facilities helps evaluate the health of vertebrate populations in the Greens Creek and Tributary Creek drainages.

Sample Collection and Analysis

Fish population estimates were made using a modification of Aho (2000) with a three-pass removal method developed by the USFS (Bryant 2000), using 7.9 x 15.9 mm (5/16 x 5/8 in) diamond mesh plastic-coated minnow traps baited with salmon eggs that had been treated with a povidone-iodine (Betadine®) solution. Minnow traps used in previous years were 6.4 mm (1/4 in) square mesh zinc-coated traps. Approximately 25 minnow traps were deployed for each sampling event along each sample reach, identified by the aluminum tree tags set by the USFS during previous years' sampling. Sample reaches varied in length among sites because of the limited availability of suitable habitat to set traps. At Upper Greens Creek Site 48, the sampled reach was 75 m long in 2001 and 50 m long in 2002 and 2003; at Greens Creek Below Pond D Site 54, the same 28 m long reach was sampled in 2001, 2002, and 2003; and in Tributary Creek Site 9, the sampled reach was 44 m long in 2001 and 50 m long in 2002 and 2003.

Traps were placed throughout the sample section focusing on pools, undercut banks, bank alcoves, under root-wads or logjams, and other habitats where fish were likely to be captured. In higher velocity sites, rounded stream rocks were placed in the traps to keep them in place. 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, measured to fork length, and placed in a mesh holding bag in the stream. The procedure was repeated for the third 1.5 hr trapping period.

Fish population estimates for 2003 were developed using the multiple-pass depletion method of Lockwood and Schneider (2000), an iterative method that produces a maximum likelihood estimate (MLE) of fish numbers with a 95% confidence interval.

Six Dolly Varden from the first trapping period at each site were 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 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 moderate-sized juvenile Dolly Varden captured in baited minnow traps at each sample site were collected for whole body metals analysis. Concern for potential contamination of fish collected for metals testing by zinc from galvanized traps used in 2001 and 2002 lead us to use plastic-coated minnow traps in 2003. Collected fish were measured to fork length, 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 2000, samples from Greens Creek Below Pond D Site 54 and Tributary Creek Site 9 both contained a mixture of coho salmon and Dolly Varden. In 2001, 2002, and 2003 all fish retained for metals analysis were Dolly Varden, although samples from Sites 48 and 9 may have contained a mixture of resident and anadromous forms.

Samples were numbered following the convention established 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 Below Pond D 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. One 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 in anticipation of analysis for acute (1 hr) Microtox toxicity. In previous years, ADF&G staff worked with University of Alaska Fairbanks (UAF) staff to make use of the Microtox bioassay to evaluate water toxicity. Because of the difficulty in getting reagents delivered in a timely and useable condition, and staff changes at ADF&G, OHMP, and UAF, we were not able to perform the Microtox toxicity testing in 2003 and the samples were discarded.

RESULTS AND DISCUSSION

Water levels appeared quite low at all sites during sampling. This was confirmed by gage data obtained by KGCMC from U.S. Geological Survey (USGS) Station 15101490, located at the road bridge between Greens Creek sites 48 and 54 (Table 1). Record low monthly mean flows were reported by the USGS for May, June, and July 2003 since the station was established in 1989.

Table 1. Mean daily discharge in Greens Creek during biomonitoring sampling periods.

Year	Sampling Dates	Discharge, cubic feet/sec	Discharge, cubic meters/sec
2001	July 25	72	2.04
	July 26	73	2.07
2002	July 25	91	2.58
	July 26	123	3.48
2003	July 22	16	0.45
	July 23	15	0.43

UPPER GREENS CREEK SITE 48

Upper 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. Site 48 lies approximately 1 km upstream of the weir that blocks access to upper Greens Creek by anadromous fish. Therefore, the only salmonid species at this site are resident Dolly Varden.

The Upper Greens Creek Site 48 sample reach has a Moderate Width Mixed Control (MM2) channel type (Appendix 1), with an average stream width of 9 m and a gradient of 2-4 percent. This is a typical stream for the middle to lower portions of moderately sized basins in southeast Alaska (Paustian et al. 1992, Weber Scannell and Paustian 2002). 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.

Upper Greens Creek Site 48 was sampled in the afternoon of 22 July 2003. The weather was overcast, air temperature was 15.0°C, and water temperature was 9.5°C.

Figure 2. Upper Greens Creek Site 48, 22 July 2003.

Periphyton Biomass

Concentrations of chlorophyll *a*, an estimate of periphyton biomass, were significantly higher in 2003 than in 2001 or 2002 ($\alpha = 0.01$). Concentrations in 2001 and 2002 were not significantly different from each other ($\alpha = 0.10$; Figure 3). The box in the Box and Whisker graph shows the middle half of the data, the intersecting line is the median, the vertical lines at the top and the bottom of the box indicate the range of "typical" data values, and open circles indicate outlier values.

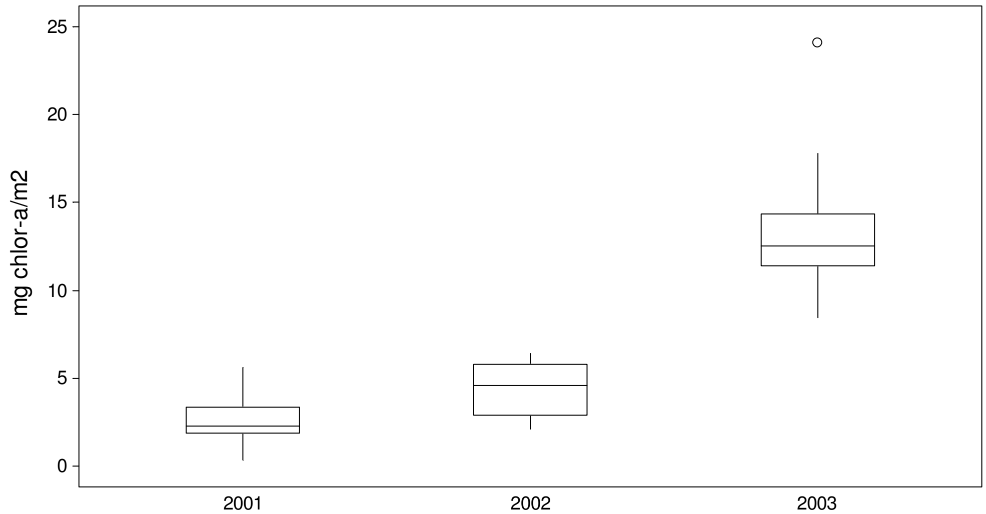

Figure 3. Estimated periphyton biomass densities at Upper Greens Creek Site 48 in 2001, 2002, and 2003. Box encompasses middle half of data; horizontal line is median value.

Algal communities contained higher proportions of chlorophyll *c* than chlorophyll *b* (Figure 4) in all three 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.

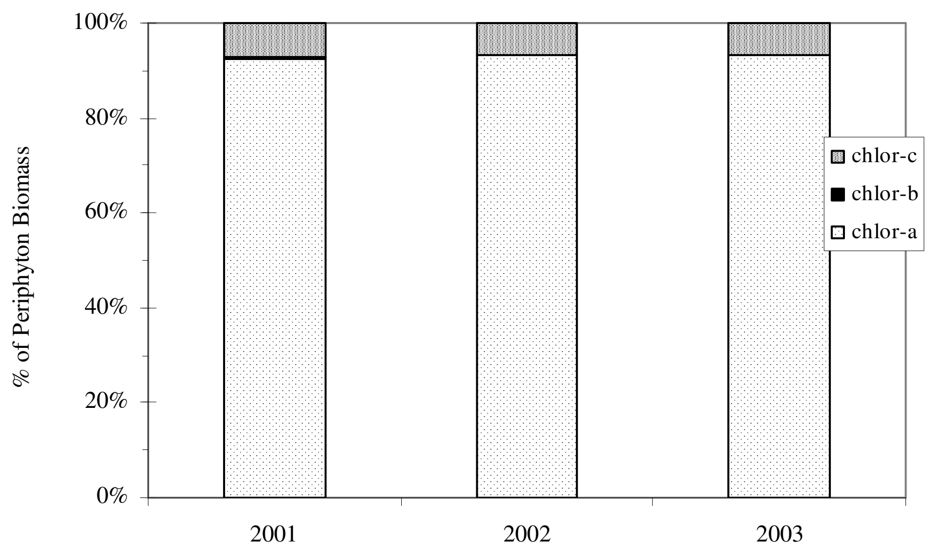

Figure 4. Proportions of chlorophylls *a*, *b*, and *c* in Upper Greens Creek Site 48 in 2001, 2002, and 2003.

Benthic Macroinvertebrates

The mean density of aquatic invertebrates in upper Greens Creek Site 48 was significantly higher in 2003 (4734/m², $\alpha = 0.01$) than in 2002 (1408/m^2), and also higher than in 2001 (2368/m^2) although differences were not significant (Figure 5).

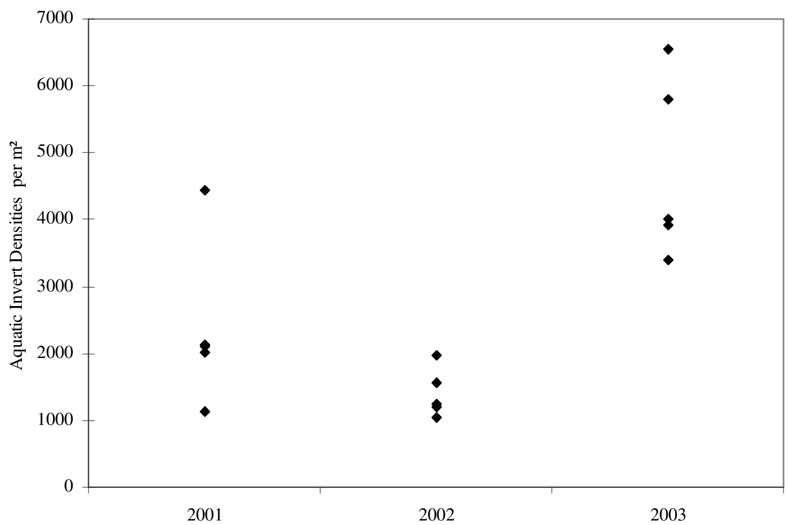

Figure 5. Density of aquatic invertebrates (n = 5 samples each year) at Upper Greens Creek Site 48 in 2001, 2002, and 2003.

Taxonomic richness was similar during the three years sampled. In 2001 we collected and identified 25 distinct taxa with an average of 11.8 taxa per sample; in 2002 we had 24 distinct taxa and an average of 13.0 taxa per sample; and in 2003 we had 27 distinct taxa with an average of 17.6 taxa per sample (Appendix 2).

Invertebrate communities were somewhat different among the three years sampled, with slightly higher proportions of Chironomidae occurring each year (Figure 6). However, the EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera) continued to be 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.

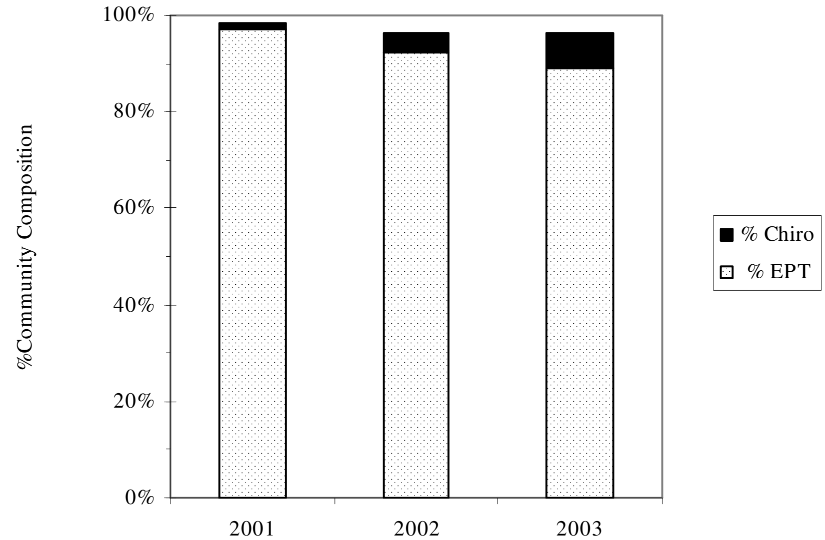

Figure 6. Proportions of EPT taxa and Chironomidae at Upper Greens Creek Site 48 in 2001, 2002, and 2003.

The aquatic invertebrate community was dominated by mayflies (Ephemeroptera, primarily Baetidae: *Baetis;* Ephemerellidae: *Drunella;* and Heptageniidae: *Cinygmula, Epeorus* and *Rhithrogena)* in all three years sampled (Figure 7). Appendix 2 lists the macroinvertebrate taxa found at Upper Greens Creek Site 48 in 2001, 2002, and 2003.

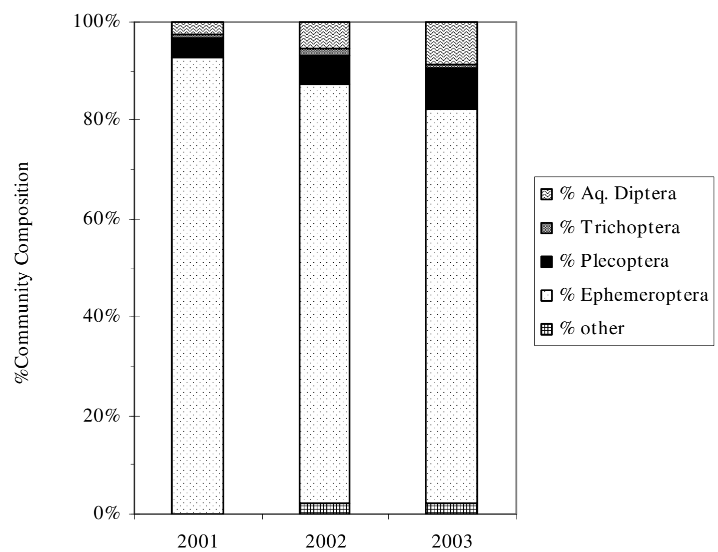

Figure 7. Community composition of aquatic invertebrates at Upper Greens Creek Site 48 in 2001, 2002, and 2003.

Table 2. Common taxa (>5% of invertebrates found in samples) at Upper Greens Creek Site 48 in 2001, 2002, and 2003.

Order	Family	Genus	2001	2002	2003
Ephemeroptera	Baetidae	*Baetis*	26%	22%	19%
	Ephemerellidae	*Drunella*		7%	27%
	Heptageniidae	*Cinygmula*	8%		
		Epeorus	38%	27%	16%
		Rhithrogena	16%	27%	12%
Diptera	Chironomidae				7%

At Upper Greens Creek Site 48, mayflies (Ephemeroptera) dominated the aquatic invertebrate samples (Table 2). Common taxa in all three years included the mayflies Baetidae: *Baetis*, Ephemerellidae: *Drunella*, and Heptgeniidae: *Epeorus* and *Rhithrogena*. *Baetis* are rated as "moderately sensitive," *Epeorus* are "sensitive," and *Rhithrogena* are "very sensitive" (Barbour et al. 1997). In all three years, pollution sensitive taxa dominated the invertebrate community at Upper Greens Creek Site 48 and the mixture of numerous taxa represents a complex community.

Juvenile Fish Populations

The 2003 juvenile fish survey captured 285 Dolly Varden in 28 minnow traps within the same 50-m reach at Upper Greens Creek Site 48 as sampled in 2002. No "block" traps were used at this site in 2003 to free up traps to better saturate available habitat in the sample reach. Because of low stream flow conditions, the riffles above and below the sample reach were quite shallow. Based on the numbers of captures in traps near the sample reach ends, movement into the sample reach during the 4.5-hour sample period was negligible. The estimated population size for the reach, based on a 3-pass removal, was 333 Dolly Varden with an approximate density of 0.9 fish/m². Population and density estimates in 2001 and 2002 were similar to each other and considerably less than those for 2003 (Table 3, Appendix 3).

Table 3. Juvenile fish population estimates for Upper Greens Creek Site 48.

Year Sampled	Fish Species	No. Fish Caught	FLength, mm	Popn Estimate, fish (95% CI)	Sample Reach, m	Density, fish/m^2
2001	DV	68	50-140*	144 (84, 448)	72	0.20
2002	DV	126	45-160*	145 (134, 178)	50	0.23
2003	DV	285	54-180	333 (305, 361)	50	0.9**

* Lengths represent upper end of 5-mm summary intervals reported by USFS.
** Based on estimated wetted area value.

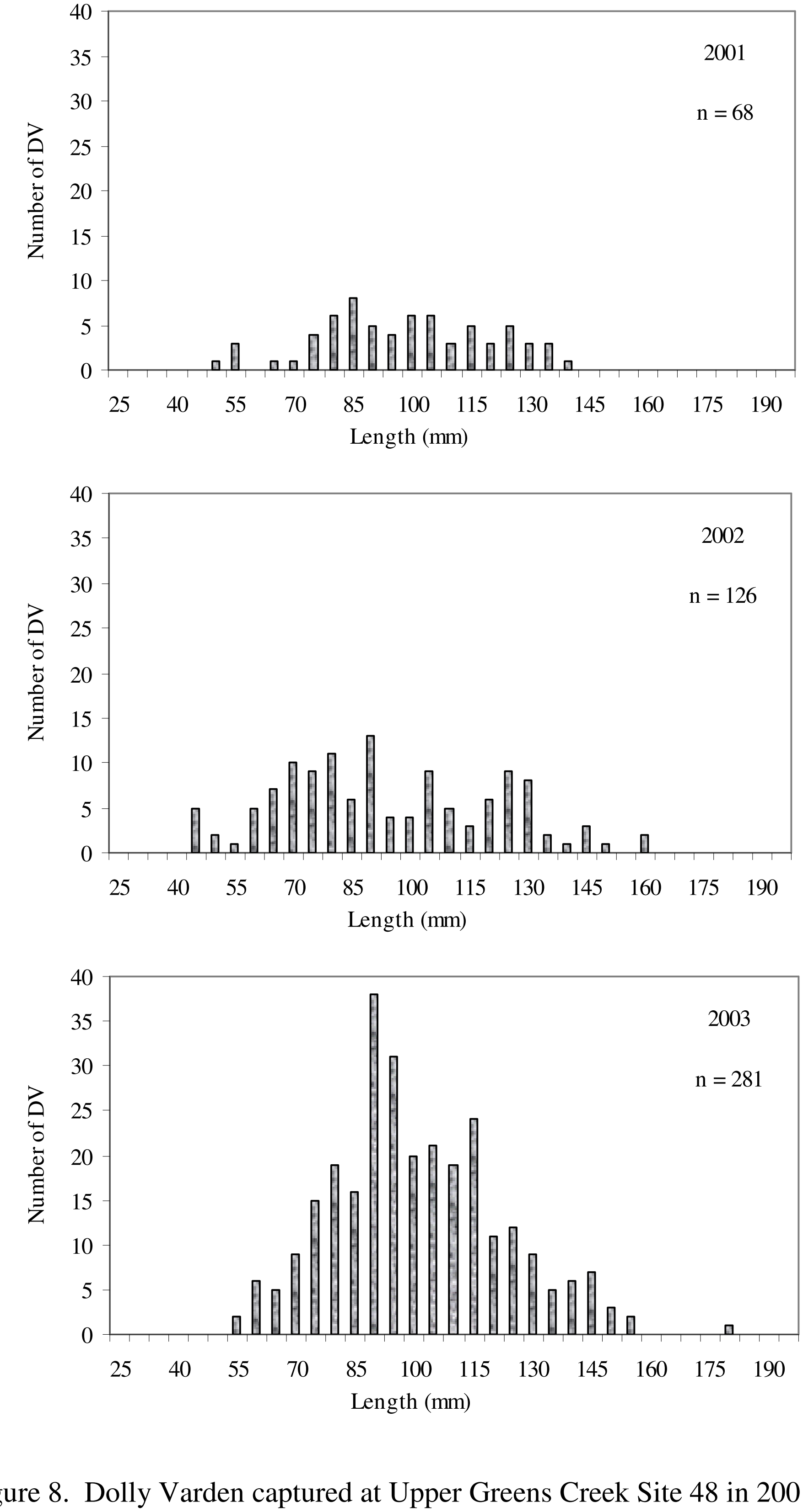

Figure 8. Dolly Varden captured at Upper Greens Creek Site 48 in 2001, 2002, and 2003.

Fork lengths of captured Dolly Varden represented a wide range of fish sizes. We have no validation data to correlate fish lengths with age as determined through scale or otolith analyses, but the length frequency plots (Figure 8) suggest that multiple age classes of Dolly Varden were captured in all three years of biomonitoring.

Metals Concentrations in Juvenile Fish

Concentrations of metals in juvenile Dolly Varden tissues were similar to or less than those found in 2001 and 2002 (Figure 9, Appendix 4). For comparison testing, silver concentrations were assumed to be the detection level (0.02 mg Ag/kg). Concentrations of silver and lead in 2003 were significantly less ($\alpha = 0.05$) than in 2002. Concentrations of cadmium and copper in 2003 were significantly less than in 2001. The mean rank scores for selenium and zinc concentrations in 2003 were not significantly different from previous years, although the selenium concentrations were slightly higher.

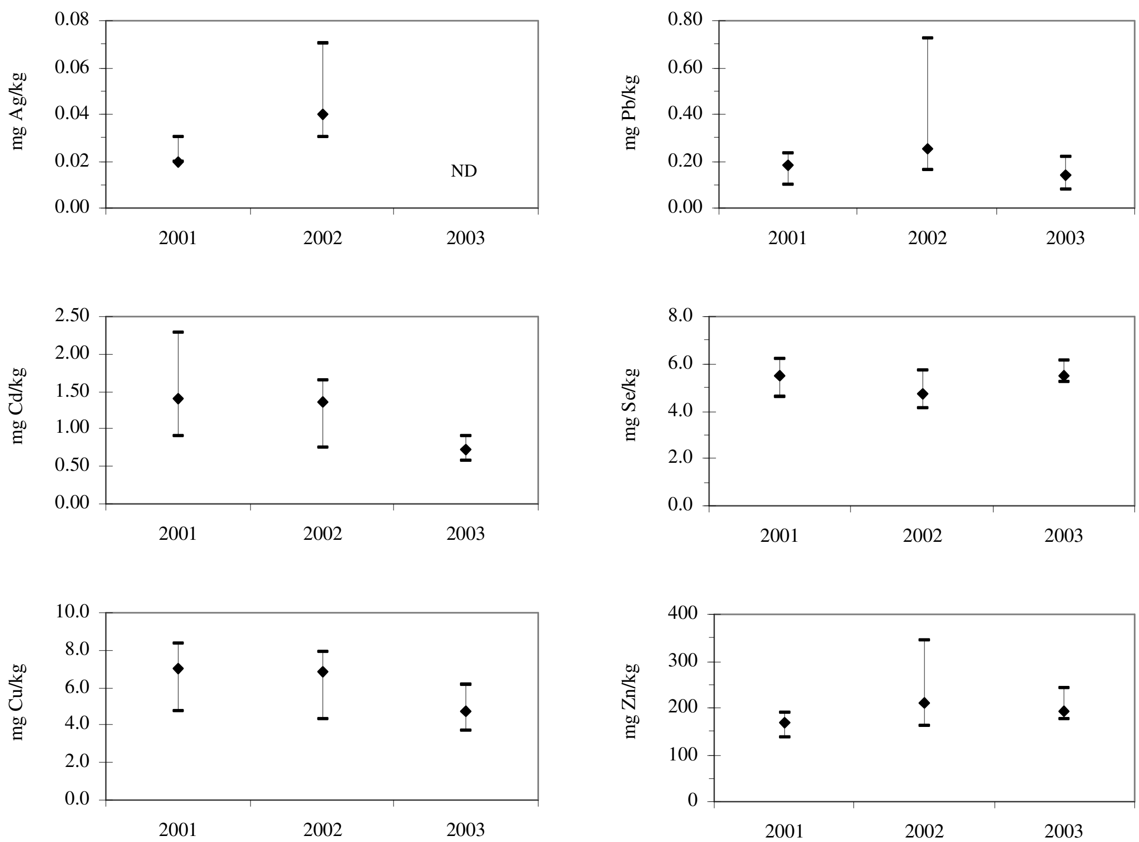

Figure 9. Whole body metals concentrations (medians and ranges) in Dolly Varden captured at Upper Greens Creek Site 48 in 2001, 2002 and 2003. ND = Not Detected at detection level of 0.02 mg Ag/kg.

Toxicity Testing

Water samples taken at Upper Greens Creek Site 48 for acute toxicity tests were not analyzed in 2003. In 2001 we did not detect any toxicity in any of the dilutions of Upper Greens Creek Site 48 water with either the chronic or the acute Microtox toxicity tests. In 2002 we did not find toxic effects from any of the dilutions of Greens Creek Site 48 water in the acute Microtox toxicity tests. Because dilutions ranged from 5% to 45% of Greens Creek Site 48 waters, our calculated IC-20 values for 2001 and 2002 were >100%. The results from the 2003 periphyton, benthic invertebrate, and juvenile fish biomonitoring program elements provide no evidence to suggest toxicity of the waters at the Upper Greens Creek Site 48.

Summary

The abundant periphyton and benthic macroinvertebrate communities, prevalence of pollution-sensitive invertebrate species, and stable metals concentrations over time in Dolly Varden in Upper Greens Creek Site 48 signify a functioning and healthy aquatic community. The Dolly Varden population density and size distribution is within expectations for this type of stream channel reach with a downstream barrier to anadromous fish.

MIDDLE GREENS CREEK SITE 6

Middle 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. Biomonitoring data were collected in 2001 for baseline information (Weber Scannell and Paustian 2002); the site will be sampled again as part of the biomonitoring program in 2006.

GREENS CREEK BELOW POND D SITE 54

Greens Creek Below Pond D Site 54 (Figure 10) is located about 0.5 km downstream of Middle Greens Creek Site 6 and about 1 km downstream of the weir that limits the upstream migration of anadromous fish in Greens Creek. Anadromous fish access to Site 54 was created by KGCMC in 1989 when a fish pass was installed in a waterfall area about 5 km downstream. Both Dolly Varden and coho salmon have been documented in this reach.

The Greens Creek Below Pond D Site 54 sample reach has a Moderate Width Mixed Control (MM2) channel type (Appendix 1), with an average stream width of 10 m and a gradient of 2-4 percent. This is a typical stream for the middle to lower portions of moderately sized basins in southeast Alaska (Paustian et al. 1992, Weber Scannell and Paustian 2002). Cobble was the dominant streambed material and large woody debris has been integral to pool formation and fish habitat cover.

Greens Creek Below Pond D Site 54 was sampled in the morning of 22 July 2003. The weather was overcast, air temperature was 13.5°C, and water temperature was 9.5°C.

Figure 10. Greens Creek Below Pond D Site 54, 22 July 2003.

Periphyton Biomass

Concentrations of chlorophyll *a*, an estimate of periphyton biomass, in Greens Creek Below Pond D Site 54 were somewhat different ($\alpha = 0.10$) in 2001, 2002, and 2003, and were significantly higher ($\alpha = 0.01$) in 2003 than in 2001(Figure 11). Differences among the three years were similar to but more pronounced than those found at Upper Greens Creek Site 48, and are likely a result of climatic conditions, including water temperature and flow rates during the month before sampling.

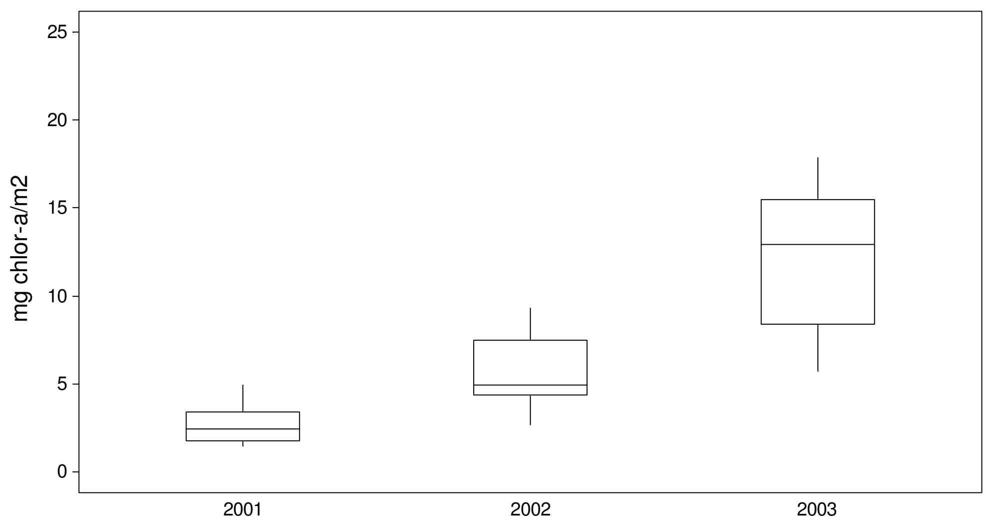

Figure 11. Estimated periphyton biomass densities at Greens Creek Below Pond D Site 54 in 2001, 2002, and 2003. Box encompasses middle half of data; horizontal line is median value.

The periphyton community was similar to that found in Upper Greens Creek Site 48, with chlorophyll *a* the dominant pigment and a higher proportion of chlorophyll *c* than chlorophyll *b* (Figure 12). As in Upper Greens Creek Site 48, the higher proportions of chlorophyll *c* at Greens Creek Below Pond D Site 54 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.

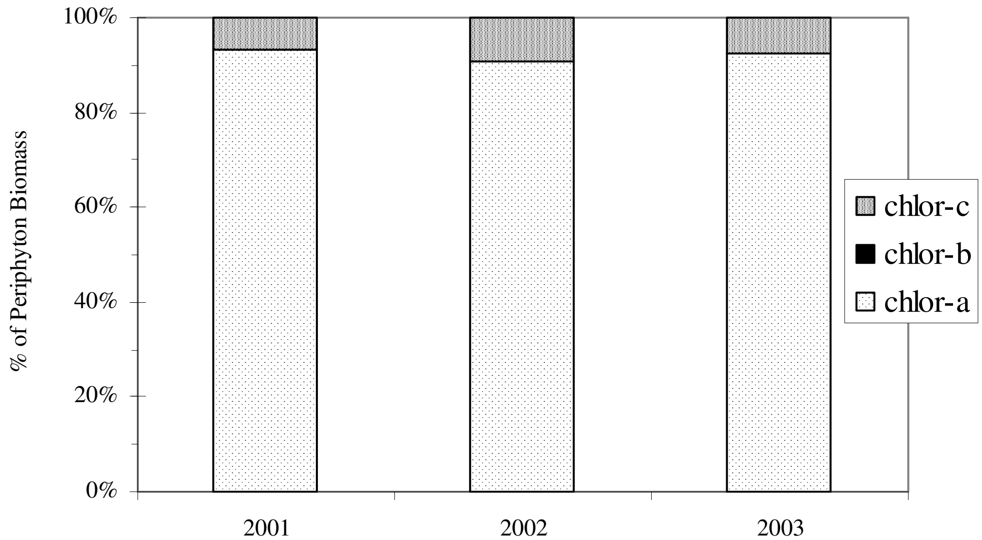

Figure 12. Proportions of chlorophylls *a*, *b*, and *c* in Greens Creek Below Pond D Site 54 in 2001, 2002, and 2003.

Benthic Macroinvertebrates

The average density of aquatic invertebrates in Greens Creek Below Pond D Site 54 was higher in 2003 (4670/m²) than in 2002 (2932/m²) although not significantly so ($\alpha = 0.11$). Average density in 2001 (3564/m²) was not significantly different from that in either 2002 or 2003 (Figure 13). Taxonomic richness was similar during the three years sampled. In 2001, we collected and identified 28 distinct aquatic taxa with an average of 15.2 taxa per sample; in 2002 we had 30 distinct taxa with an average of 13.8 taxa per sample; and in 2003 we had 26 distinct taxa with an average of 16.2 taxa per sample (Appendix 2).

Invertebrate communities in Greens Creek Site 54 were dominated by EPT taxa (Figure 14). In 2001, 2002, and 2003, Ephemeroptera were the most commonly collected order (Figure 15). In 2003, the Ephemeroptera were dominated by Baetidae: *Baetis,* Ephemerella: *Drunella*, and Heptageniidae: *Cinygumula, Epeorus*, and *Rhithrogena*. The dominance of the aquatic invertebrate community by these pollution-sensitive taxa (Table 4), combined with the mixture of many species of mayflies, stoneflies, caddisflies, and true flies (Appendix 2) suggests a complex and healthy aquatic ecosystem at this site.

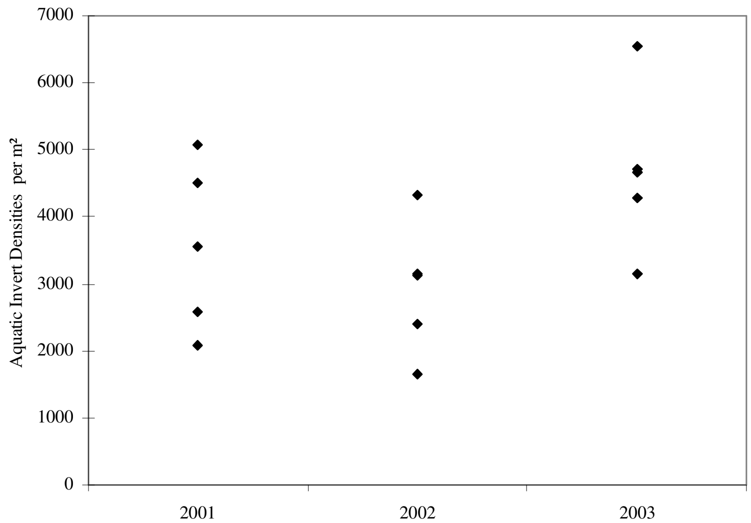

Figure 13. Density of aquatic invertebrates (n = 5 samples each year) at Greens Creek Below Pond D Site 54 in 2001, 2002, and 2003.

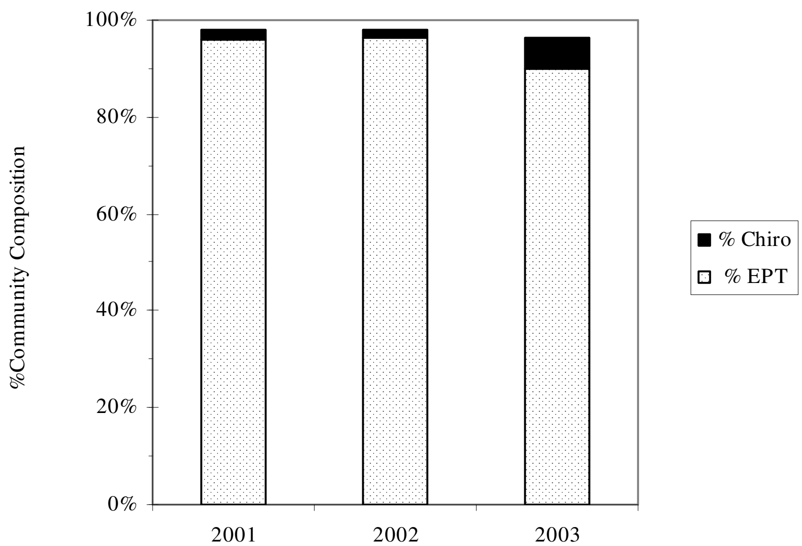

Figure 14. Proportions of EPT taxa and Chironomidae at Greens Creek Below Pond D Site 54 in 2001, 2002, and 2003.

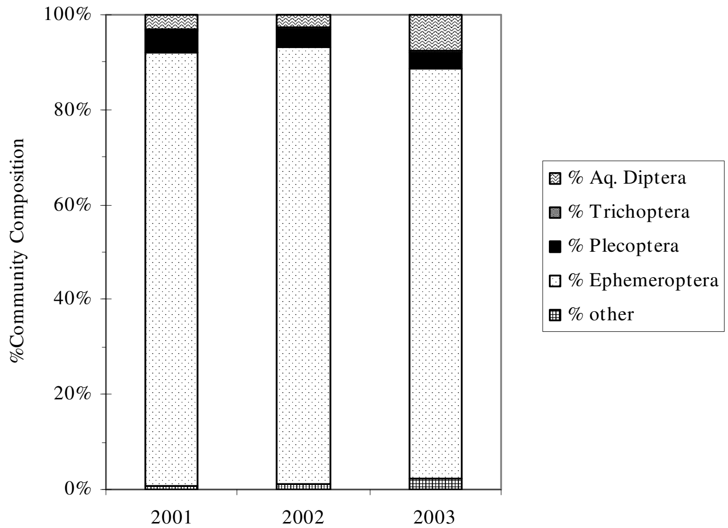

Figure 15. Community composition of aquatic invertebrates at Greens Creek Below Pond D Site 54 in 2001, 2002, and 2003.

Table 4. Common taxa (>5% of invertebrates found in samples) at Greens Creek Below Pond D Site 54 in 2001, 2002, and 2003.

Order	Family	Genus	2001	2002	2003
Ephemeroptera	Baetidae	*Baetis*	14	15	9
	Ephemerellidae	*Drunella*	7	19	38
	Heptageniidae	*Cinygmula*	18	5	8
		Epeorus	53	43	17
		Rhithrogena		10	13
Diptera	Chironomidae				6

Juvenile Fish Populations

The 2003 juvenile fish survey at Greens Creek Below Pond D Site 54 captured 8 coho salmon and 232 Dolly Varden in 16 minnow traps in the same 28-m reach as sampled in 2001, 2002, and 2003. Two "block" traps were used immediately below the sample reach, one on each side of the stream. These traps captured an additional 15 Dolly Varden that are not included in the reported results. In 2001, the USFS reported catching too few juvenile coho salmon at Greens Creek Below Pond D Site 54 to estimate the population; in 2002 and 2003 juvenile coho salmon captures were high enough to estimate populations but too low for the 95% confidence interval to be meaningful (Table 5, Appendix 3). Dolly Varden were captured in greater abundance, with a wide range of size classes.

Table 5. Juvenile fish population estimates for Greens Creek Below Pond D Site 54.

Year Sampled	Fish Species	No. Fish Caught	FLength mm	Popn Estimate, Fish (95% CI)	Sample Reach, m	Density, fish/m^2
2001	DV	138	30-165*	164 (150, 200)	28	0.6
2002	DV	271	33-160	293 (282, 315)	28	1.0
2003	DV	232	51-184	331 (275, 387)	28	1.8**
2001	CO	---	---	Too few fish	28	---
2002	CO	21	55-85	21	28	0.07
2003	CO	8	44-52	8	28	0.04**

* Lengths represent upper end of 5-mm summary intervals reported by USFS.
** Based on estimated wetted area value.

We have no validation data to correlate fish lengths with age as determined through scale or otolith analyses, but the length frequency plots (Figure 16) suggest that multiple age classes of Dolly Varden were captured in all three years of biomonitoring.

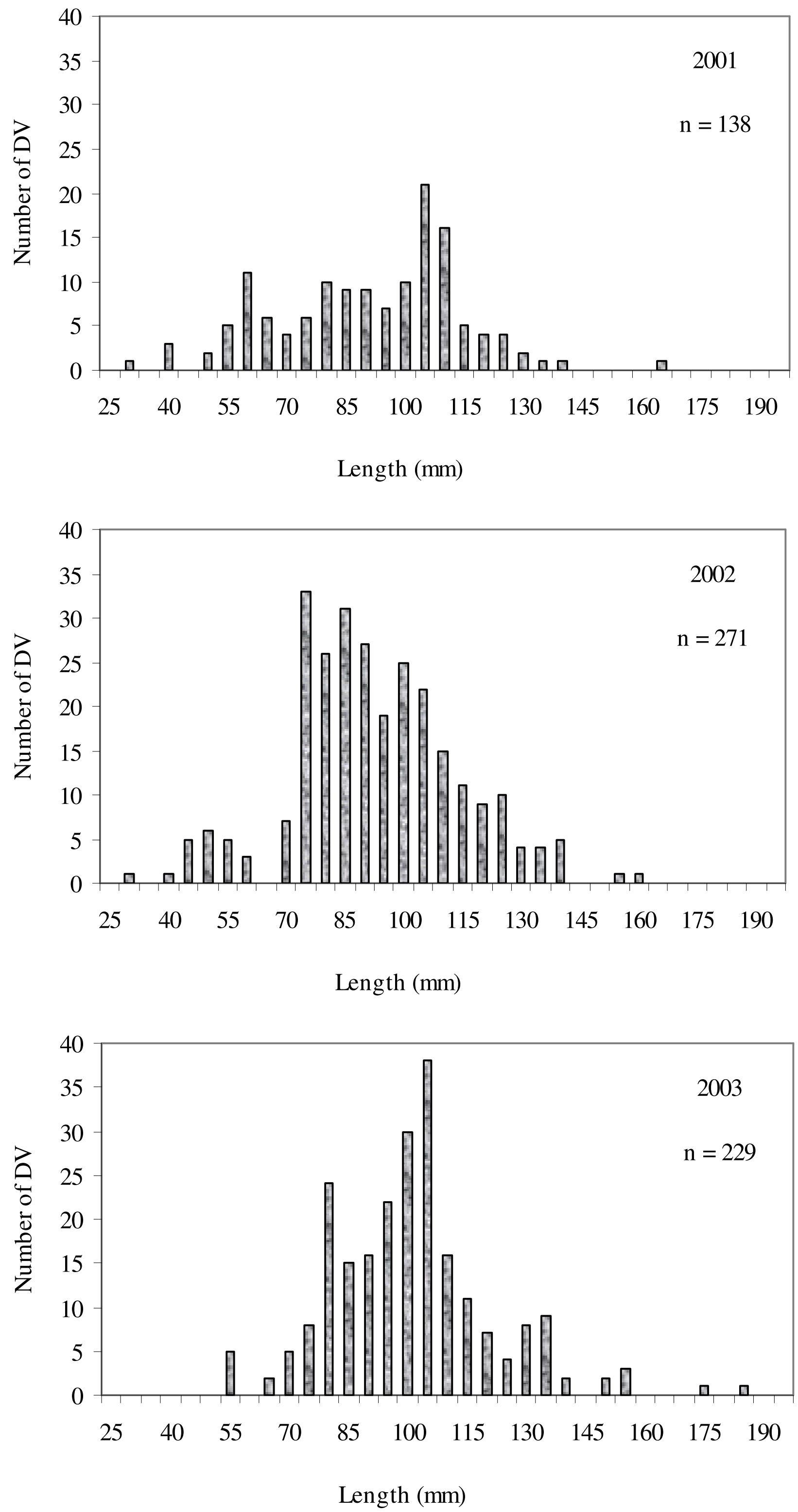

Figure 16. Dolly Varden captured at Greens Creek Below Pond D Site 54 in 2001, 2002 and 2003.

Juvenile coho salmon caught at the Greens Creek Below Pond D Site 54 in 2002 and 2003 appear to come from a single age class (Figure 17).

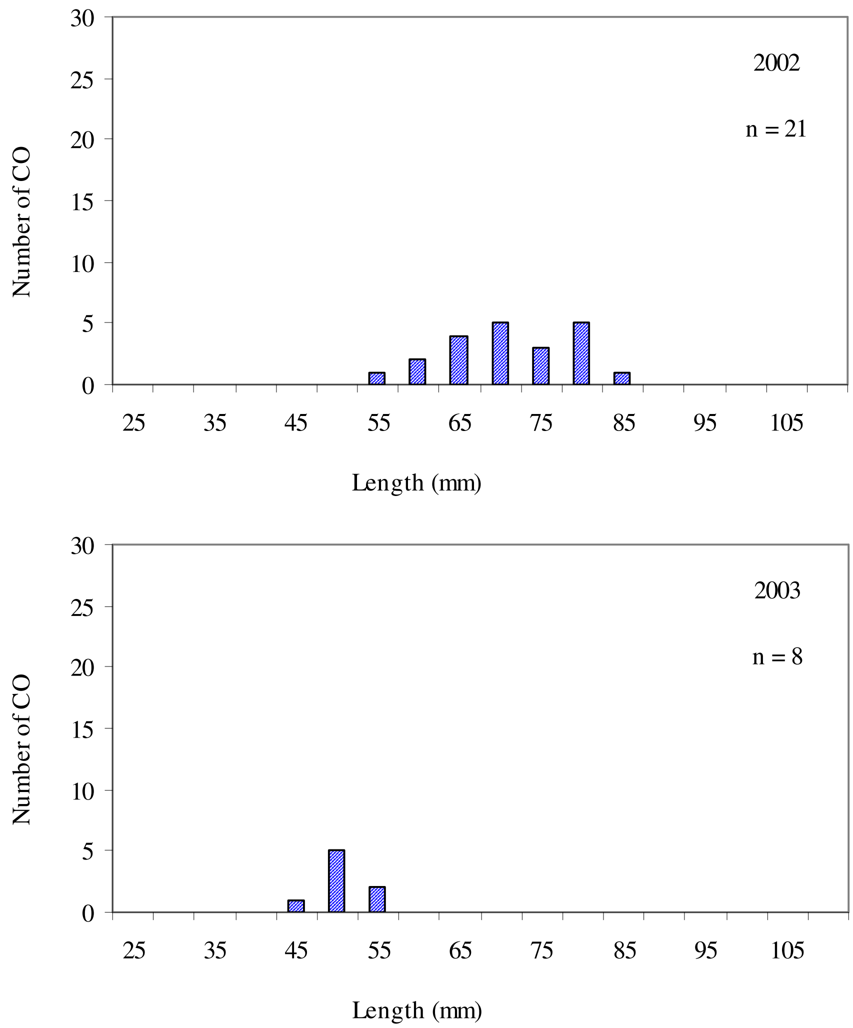

Figure 17. Juvenile coho salmon captured at Greens Creek Below Pond D Site 54 in 2001, 2002, and 2003.

Metals Concentrations in Juvenile Fish

Concentrations of metals in juvenile Dolly Varden tissues were generally similar to or less than those found in 2000, 2001, and 2002 (Figure 18, Appendix 4). Concentrations of silver, copper, and lead were similar in 2001 through 2003, and significantly less ($\alpha = 0.05$) than in 2000. Selenium concentrations in 2000 through 2002 were not significantly different from each other; 2003 concentrations were significantly higher than that group but not from the values for 2001 alone. Zinc concentrations were quite variable, with no significant differences between those in

2003 and those in previous years. There were no significant differences between years in cadmium concentrations.

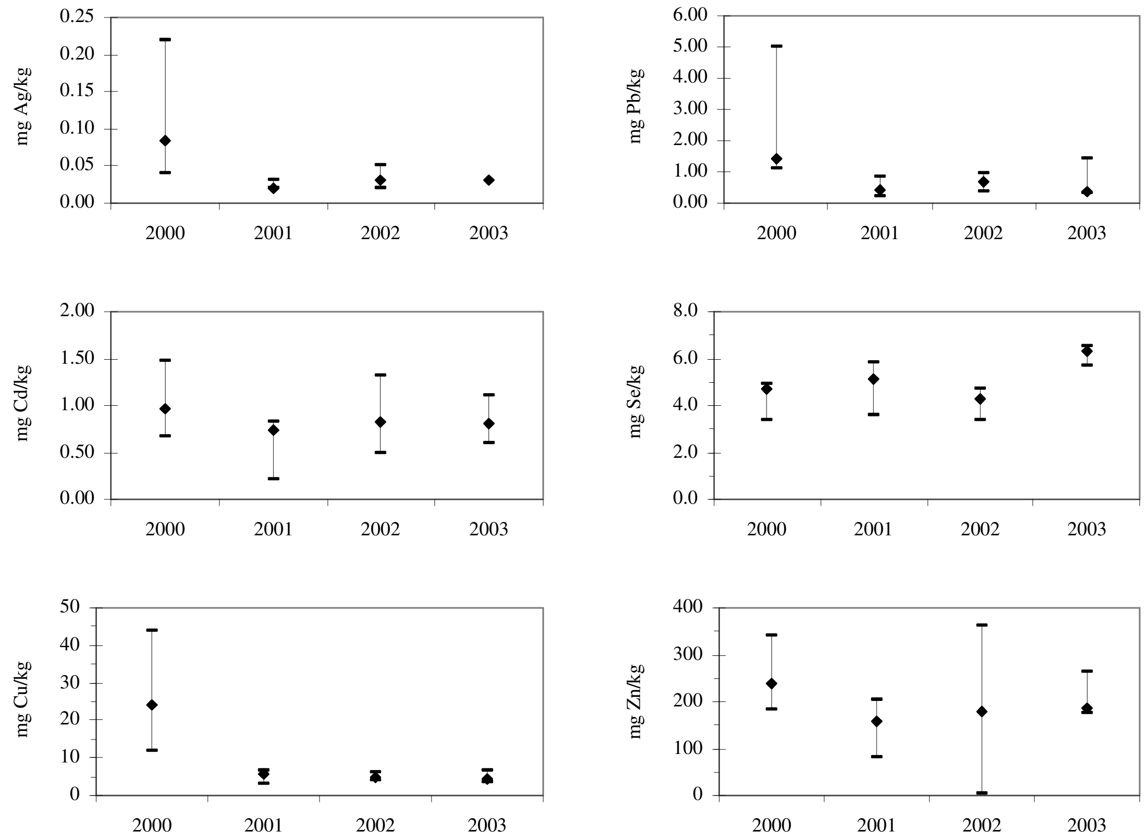

Figure 18. Whole body metals concentrations (medians and ranges) in fish captured at Greens Creek Below Pond D Site 54 in 2000, 2001, 2002 and 2003. Fish were coho salmon in 2000, Dolly Varden in other years.

Toxicity Testing

Water samples taken at Greens Creek Below Pond D Site 54 for acute toxicity tests were not analyzed in 2003. In 2001 we did not detect any toxicity in any of the dilutions of Upper Greens Creek Site 54 water with either the chronic or acute Microtox toxicity tests. In 2002 we did not find toxic effects from any of the dilutions of Greens Creek Site 54 water in the acute Microtox toxicity tests. Because dilutions ranged from 5% to 45% of Greens Creek Below Pond D Site 54 waters, our calculated IC-20 values for 2001 and 2002 were >100%. The results from the 2003 periphyton, benthic invertebrate, and juvenile fish biomonitoring program elements provide no evidence to suggest toxicity of the waters at the Greens Creek Below Pond D Site 54.

Summary

The abundant periphyton and benthic macroinvertebrate communities, prevalence of pollution-sensitive invertebrate species, and stable metals concentrations over time in Dolly Varden in Greens Creek Below Pond D Site 54 signify a functioning and healthy aquatic community. The Dolly Varden and coho salmon population densities and size distributions are within expectations for this type of stream channel reach with access to anadromous fish.

TRIBUTARY CREEK SITE 9

Tributary Creek is a small stream with a dense canopy (Figure 19). 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, and sculpin (species not determined).

The sample reach in Tributary Creek Site 9 has a Narrow Low Gradient Flood Plain (FP3) Channel Type (Appendix 1), typical of a valley bottom or flat lowlands. The creek averages 2½ m wide with a 1% stream gradient, and has fine gravel as the dominant substrate (Paustian et al. 1992, Weber Scannell and Paustian 2002). The sampling reach was 44 m long in 2001, and 50 m long in 2002 and 2003.

Tributary Creek Site 9 was sampled in the morning of 23 July 2003. The weather was mostly sunny, air temperature was 14.5°C, and water temperature was 12.5°C.

Figure 19. Tributary Creek Site 9, 23 July 2003.

Periphyton Biomass

Concentrations of chlorophyll *a*, an estimate of periphyton biomass, at Tributary Creek Site 9 were similar in 2001 and 2002 and slightly higher in 2003 (Figure 20). Biomass in 2003 was significantly higher than in 2001 ($\alpha = 0.05$), whereas 2002 biomass values were not significantly different from those of either 2001 or 2003. As at the Greens Creek sites (48 and 54), the Tributary Creek Site 9 algal community contained higher proportions of chlorophyll *c* than chlorophyll *b* in 2001 and 2003 and nearly equal proportions in 2002 (Figure 21). Although dominated by diatoms, filamentous green algae and blue-green bacteria are important components of the algal community at Tributary Creek Site 9.

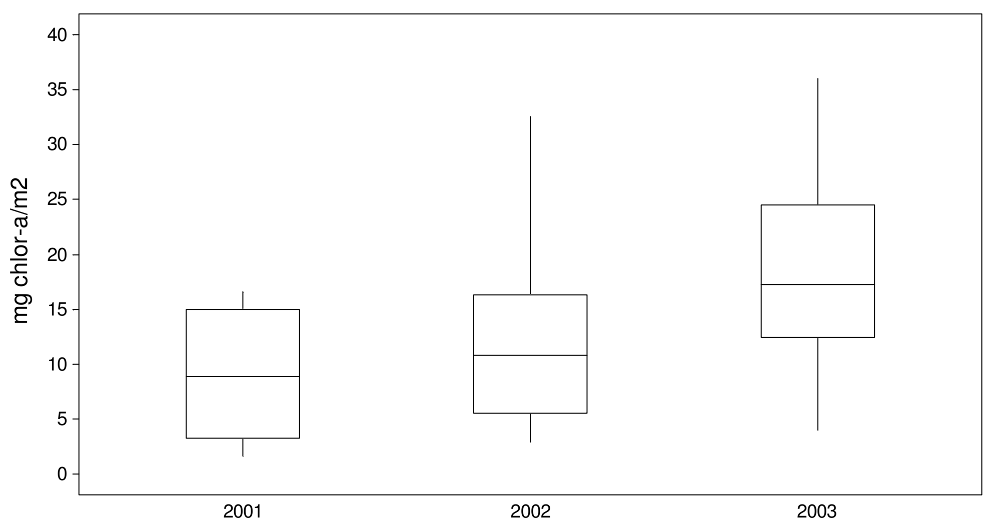

Figure 20. Estimated periphyton biomass densities at Tributary Creek Site 9 in 2001, 2002, and 2003. Box encompasses middle half of data; horizontal line is median value.

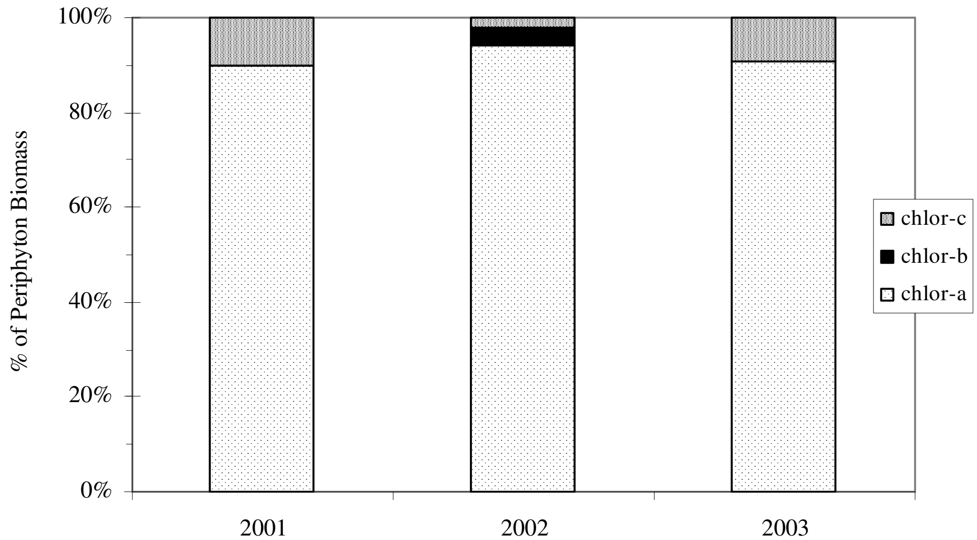

Figure 21. Proportions of chlorophylls *a*, *b*, and *c* at Tributary Creek Site 9 in 2001, 2002, and 2003.

Benthic Macroinvertebrates

As in Greens Creek Sites 48 and 54, the average density of aquatic invertebrates in Tributary Creek Site 9 was higher in 2003 (5032/m²) than in 2001 (1018/m²) or 2002 (1496/m²; Figure 22). Those in 2001 and 2003 differed significantly ($\alpha = 0.01$). Taxonomic richness, as expressed by number of taxa in samples, also increased some in 2002 and 2003. In 2001 we collected and identified 21 distinct aquatic taxa with an average of 13.6 taxa per sample; in 2002 we had 24 distinct taxa and an average of 15.2 taxa per sample; and in 2003 we had 36 distinct taxa with an average of 21.0 taxa per sample (Appendix 2).

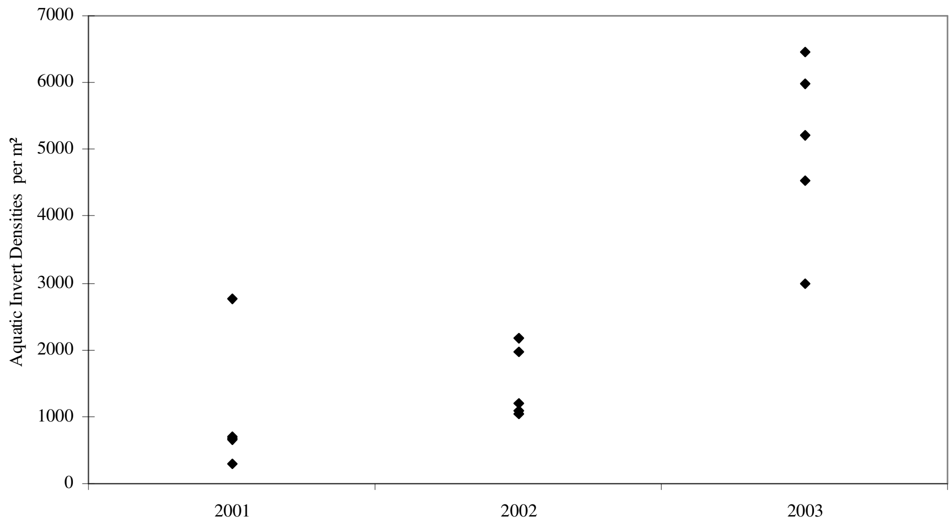

Figure 22. Density of aquatic invertebrates (n = 5 samples each year) at Tributary Creek Site 9 in 2001, 2002, and 2003.

As at the Greens Creek sites, the EPT taxa are the major component of Tributary Creek Site 9 aquatic invertebrates, while Chironomidae remain a relatively small, stable component (Figure 23).

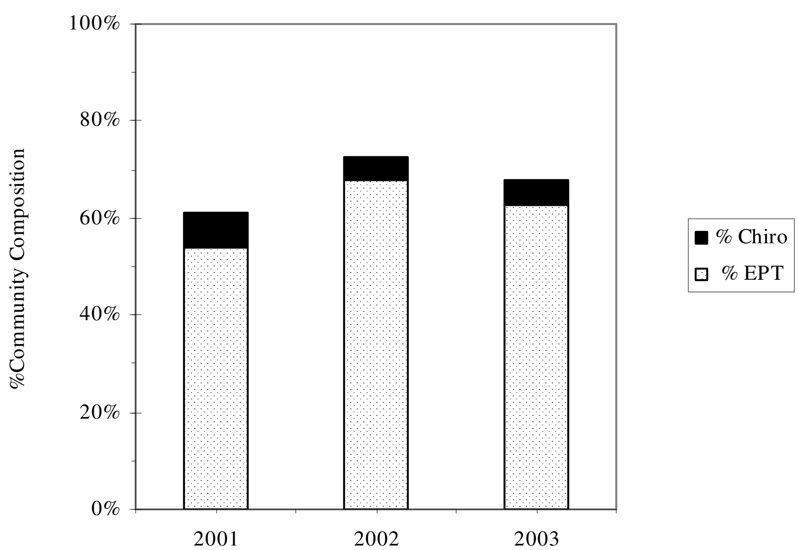

Figure 23. Proportions of EPT taxa and Chironomidae at Tributary Creek Site 9 in 2001, 2002, and 2003.

Unlike Greens Creek Sites 54 and 48 where one or two invertebrate taxa compose more than half of the community, the Tributary Creek Site 9 has a complex invertebrate community of mayflies, stoneflies, caddisflies, true flies, and non-insect groups containing lower proportions of many taxa (Table 6). Pollution-sensitive taxa, such as the mayflies *Baetis*, *Cinygmula*, and *Paraleptophlebia* were well represented (Figure 24). The presence of these orders reflects the stream channel characteristics of a small, valley-bottom stream with attached wetland areas. The non-insect group included springtails (Collembola), worms (Oligochaeta), mites (Acarina), and seed shrimp (Ostracoda).

Table 6. Common taxa (>5% of invertebrates found in samples) at Tributary Creek Site 9 in 2001, 2002, and 2003.

Order	Family	Genus	2001	2002	2003
Ephemeroptera	Baetidae	*Baetis*	8%	16%	6%
	Heptageniidae	*Cinygmula*	17%	24%	20%
	Leptophlebiidae	*Paraleptophlebia*	13%	13%	10%
Plecoptera	Chloroperlidae	*Suwallia*	7%		
		Sweltsa		6%	
		Neaviperla			7%
	Nemouridae	*Zapada*			15%
Diptera	Chironomidae		7%		
	Simuliidae	*Simulium*	8%		
Acarina				6%	
Oligochaeta			8%		14%
Ostracoda			18%		8%
Isopoda	Gammaride	*Gammarus*		14%	

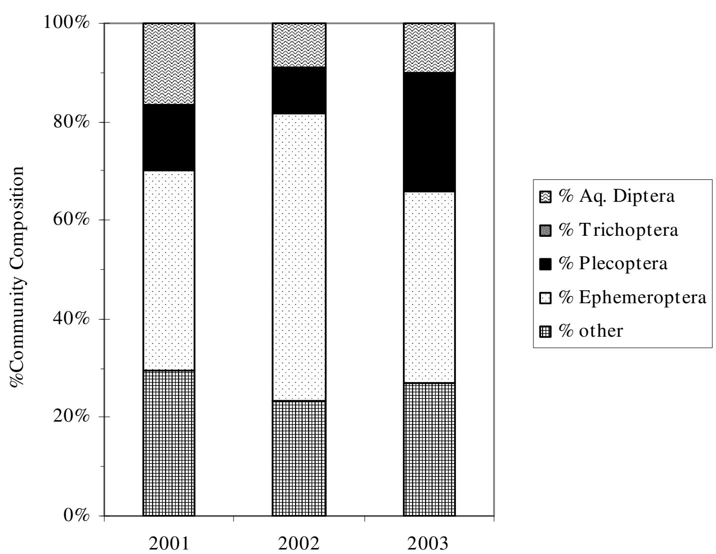

Figure 24. Community composition of aquatic invertebrates at Tributary Creek Site 9 in 2001, 2002, and 2003.

Juvenile Fish Populations

A variety of fishes rear in Tributary Creek, including coho salmon, Dolly Varden, cutthroat trout, and sculpin. Coho, pink, and chum salmon spawn in the creek but not necessarily at the sampling site. Cutthroat trout and sculpin are minor components of the fish community in this portion of Tributary Creek.

The 2003 juvenile fish survey in Tributary Creek Site 9 captured 52 coho salmon, 19 Dolly Varden, one cutthroat trout, and one sculpin in 19 minnow traps in the same 50-m sample reach as sampled in 2002. The low flow conditions in 2003 limited the ability to place minnow traps, and no "block" traps were placed because the nearly dry riffles above and below the sample reach appeared to provide adequate barriers to fish movement. Captures of Dolly Varden were lower in 2003 than in 2001 and 2002, while coho salmon captures were higher than in 2002 and lower than in 2001 (Table 7, Appendix 3). The effect of limitations on available habitat due to low water levels is unknown for either species composition or density, but the total density of fish in available habitat areas (1.1 fish/m²) was intermediate between densities found in 2001 (1.6 fish/m²) and in 2002 (0.8 fish/m²).

The range of fork lengths measured in both Dolly Varden and coho salmon captured at Tributary Creek Site 9 in 2003 suggest use by multiple age classes of both species (Figures 25 and 26).

Table 7. Juvenile fish population estimates for Tributary Creek Site 9.

Year Sampled	Fish Species	No. Fish Caught	FLength, mm	Popn Estimate, fish (95% CI)	Sample Reach, m	Density, fish/m^2
2001	DV	81	60-110*	81 (81, 81)	44	0.65
2002	DV	51	38-147	57 (53, 76)	50	0.46
2003	DV	19	54-114	20 (17, 23)	50	0.3**
2001	CO	118	40-105*	120 (119, 128)	44	0.94
2002	CO	44	27-85	46 (45, 47)	50	0.35
2003	CO	52	46-88	53 (51, 55)	50	0.8**

* Lengths represent upper end of 5-mm summary intervals reported by USFS.
** Based on estimated wetted area value.

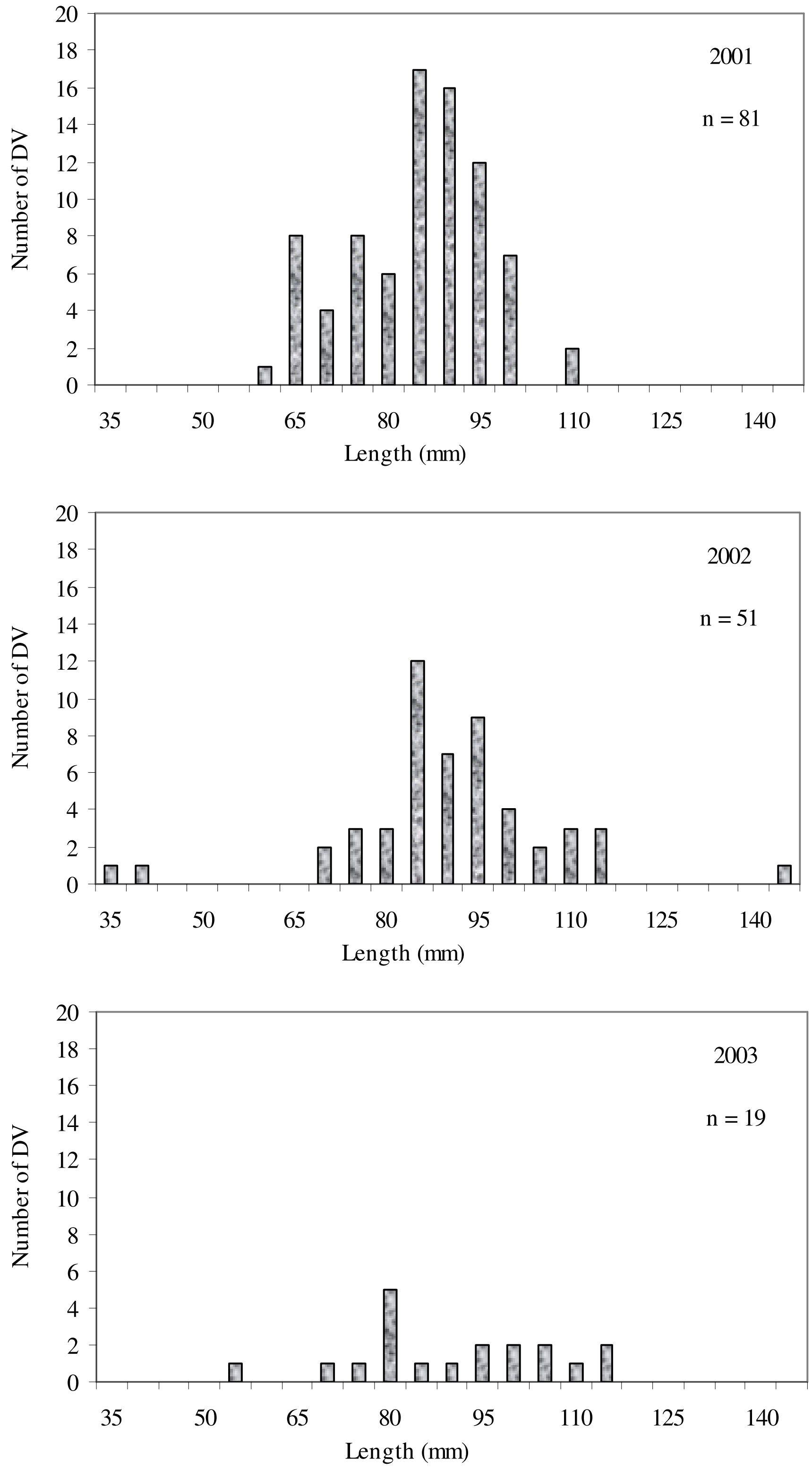

Figure 25. Dolly Varden captured at Tributary Creek Site 9 in 2001, 2002, and 2003.

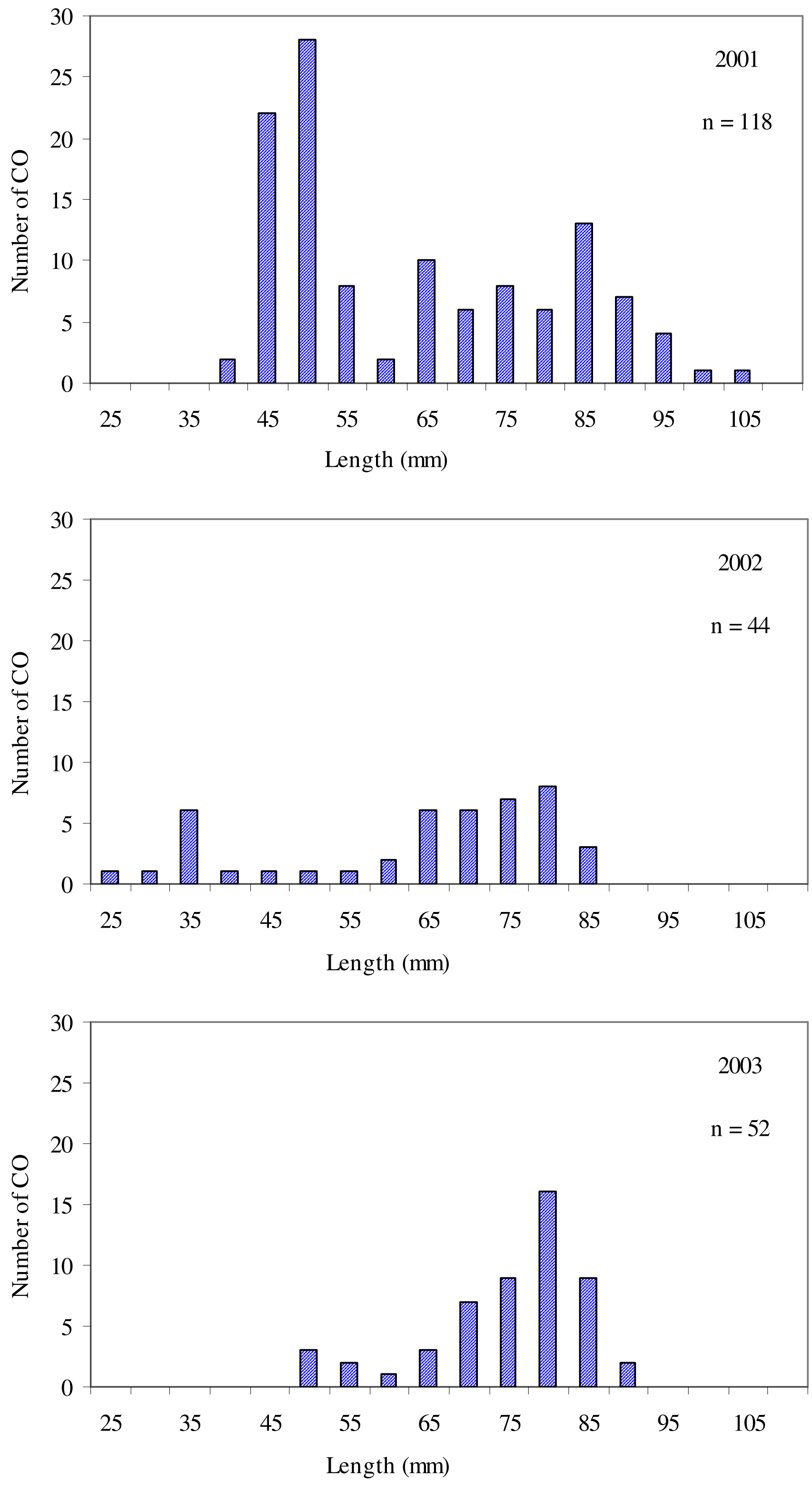

Figure 26. Coho salmon captured at Tributary Creek Site 9 in 2001, 2002, and 2003.

Metals Concentrations in Juvenile Fish

Concentration of metals in juvenile Dolly Varden tissues from Tributary Creek Site 9 were similar or less than those found in 2000, 2001, and 2002 (Figure 27, Appendix 4). Concentrations of silver, cadmium, and lead were not significantly different ($\alpha > 0.1$) between years. Concentrations of copper were significantly higher ($\alpha = 0.05$) in 2000 than in other years, and concentrations of selenium and zinc were significantly different between 2000 and 2001 only.

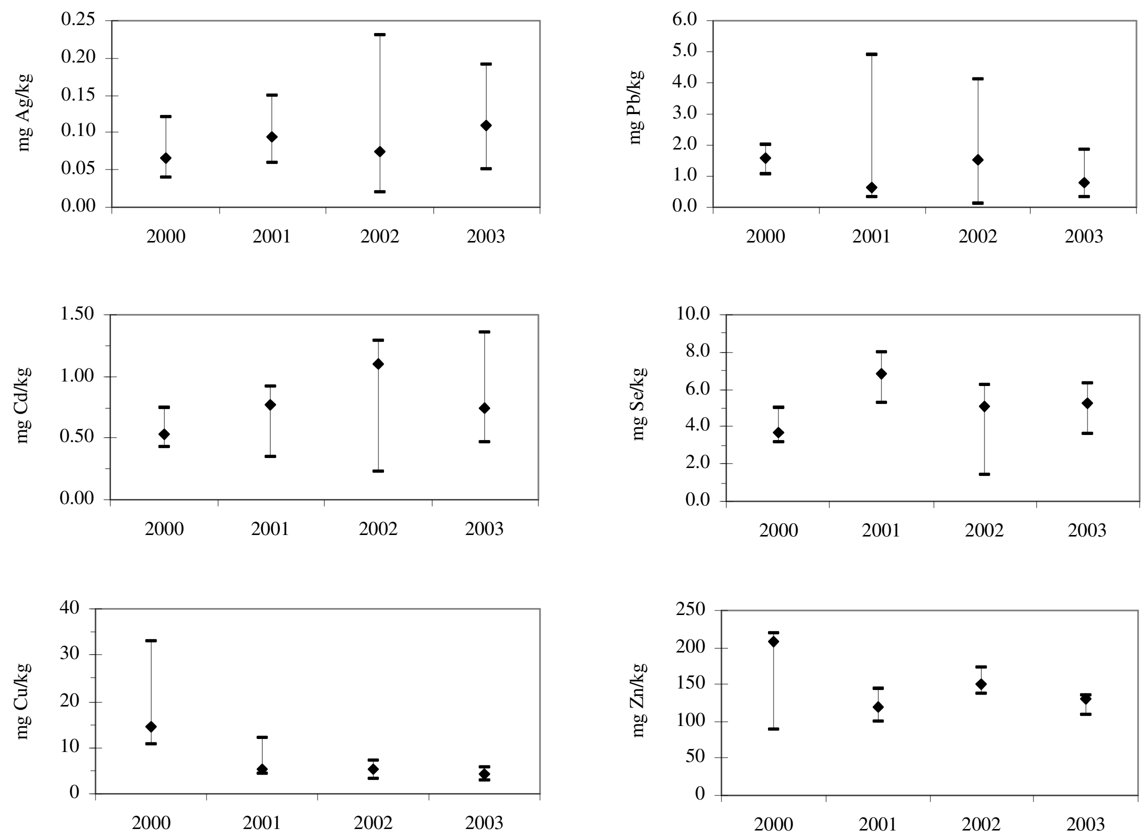

Figure 27. Whole body metals concentrations (medians and ranges) in fish captured at Tributary Creek Site 9 in 2000, 2001, 2002, and 2003. All fish Dolly Varden except two coho salmon in 2000.

Toxicity Testing

Water samples taken at Tributary Creek Site 9 for acute toxicity tests were not analyzed in 2003. In 2001 we did not detect any toxicity in any of the dilutions of Tributary Creek Site 9 water with either the chronic or acute Microtox toxicity tests. In 2002 we did not find toxic effects from any of the dilutions of Tributary Creek Site 9 water in the acute Microtox toxicity tests. Because dilutions ranged from 5% to 45% of Tributary Creek Site 9 waters, our calculated IC-20 values for 2001 and 2002 were >100%. The results from the 2003 periphyton, benthic invertebrate, and juvenile fish biomonitoring program elements provide no evidence to suggest toxicity of the waters at the Tributary Creek Site 9.

Summary

The abundant periphyton and diverse benthic macroinvertebrate communities, abundance of pollution-sensitive invertebrate species, and stable metals concentrations over time in Dolly Varden in Tributary Creek Site 9 all indicate a functioning and healthy aquatic community. The Dolly Varden and coho salmon population densities and size distributions are within expectations for this type of stream channel reach with access to anadromous fish.

Comparisons Among Sites

Periphyton Biomass

Periphyton biomass was higher in 2003 than in previous years. Chlorophyll *a* concentrations were not significantly different among sites in 2003, although Tributary Creek continued to have the higher median value. Taking the three sites together, the 2003 values were significantly (α= 0.05) higher than those for 2001 or 2002 (Figure 28). This was not surprising given the lower water levels in 2003 since water velocities were lower and stream temperatures were likely warmer than in previous years.

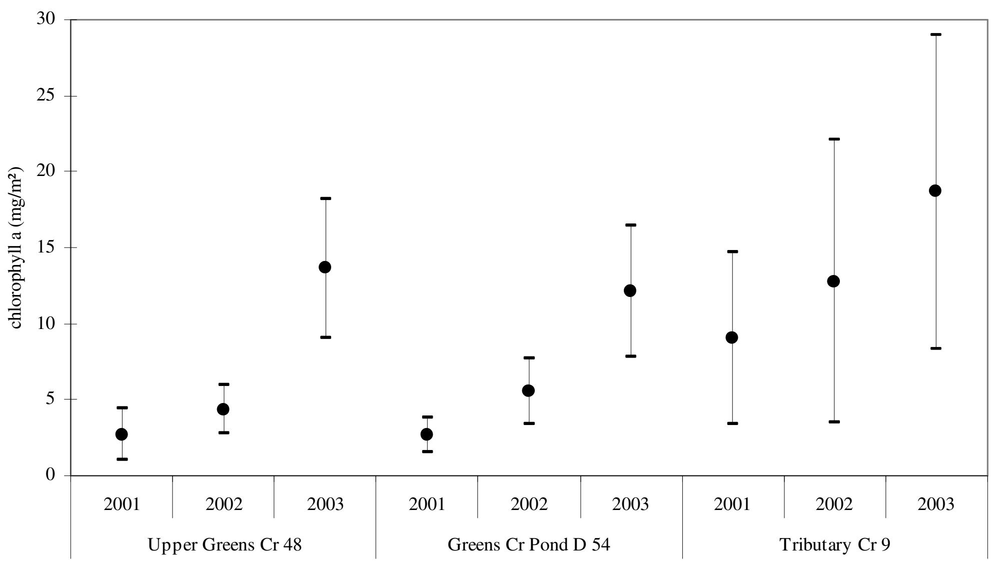

Figure 28. Comparison of estimated periphyton biomass (medians and ranges) among biomonitoring sites sampled in 2001, 2002, and 2003.

There were no significant differences in community composition of the periphyton sampled at the Greens Creek and Tributary Creek sites in 2003 (Figure 29). 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, are 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 1999), of which diatoms form a major group in the periphyton community. Measurable quantities of chlorophyll *c* indicate the importance of diatoms in the community.

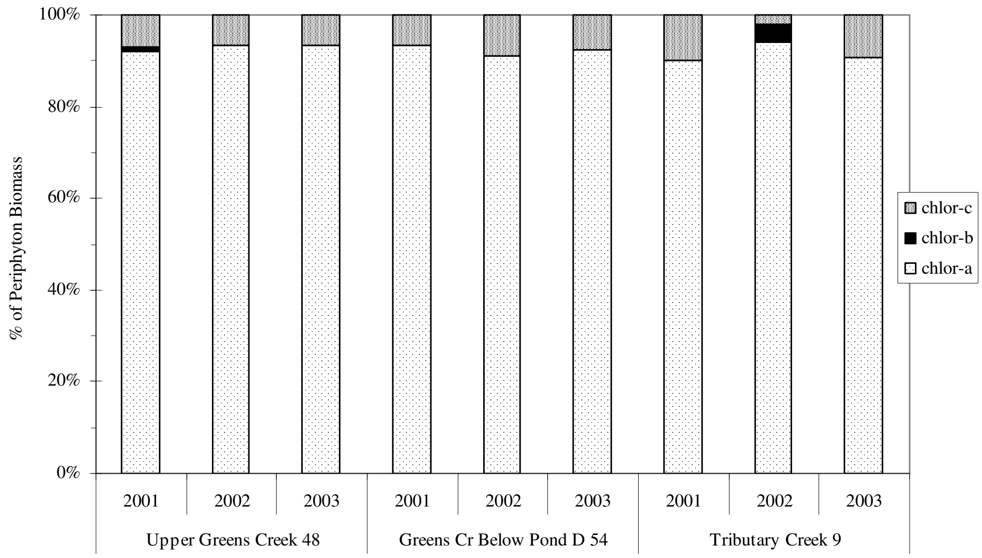

Figure 29. Comparison of proportions of chlorophylls *a*, *b*, *c* among sites in 2001, 2002, and 2003.

In the 2001 Upper Greens Creek Site 48 and 2002 Tributary Creek Site 9 samples, chlorophyll *b* was higher than in other samples, suggesting that at the time of sampling there was a larger 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 streams and years, the differences in algal communities are not unexpected. The periphyton communities in all biomonitoring sites are well within ranges of healthy aquatic systems (Wetzel 1983).

Benthic Macroinvertebrates

Average aquatic invertebrate densities were quite similar at all sites in 2003 and significantly higher ($\alpha = 0.01$) than at any site in 2001 or 2002 (Figure 30). We believe that this is a primarily related to the lower water levels and higher periphyton production in 2003.

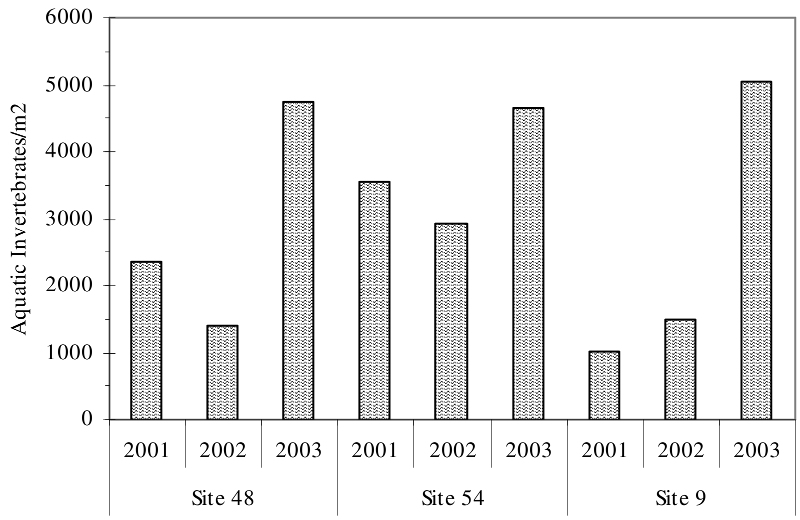

Figure 30. Comparison of aquatic invertebrate density among sites in 2001, 2002, and 2003.

All three of the biomonitoring sites had complex invertebrate communities with fairly large numbers of distinct taxa per sample (Figure 31). 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 32). 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 as few taxa as do more variable habitats (Hynes 1970). The predominance of one or two taxa in the Greens Creek sites is likely a result of perturbations due to higher stream flows and rapid re-colonization during lower water levels.

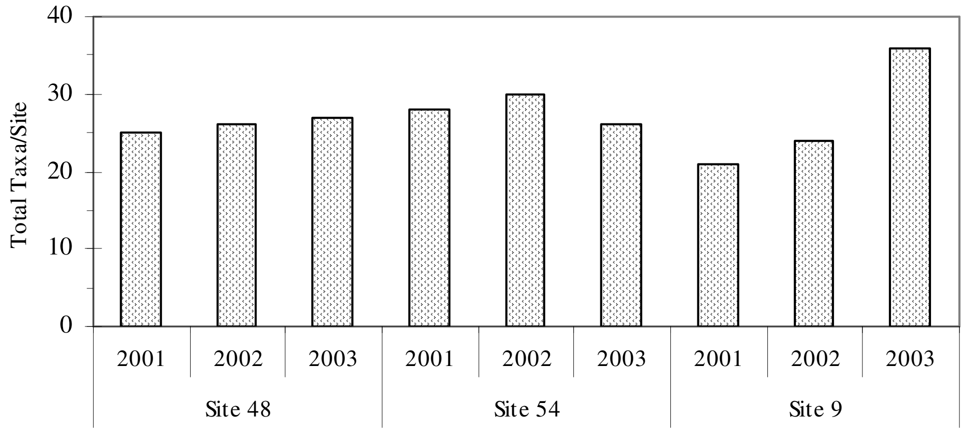

Figure 31. Comparison of benthic macroinvertebrate taxonomic richness among sites in 2001, 2002, and 2003.

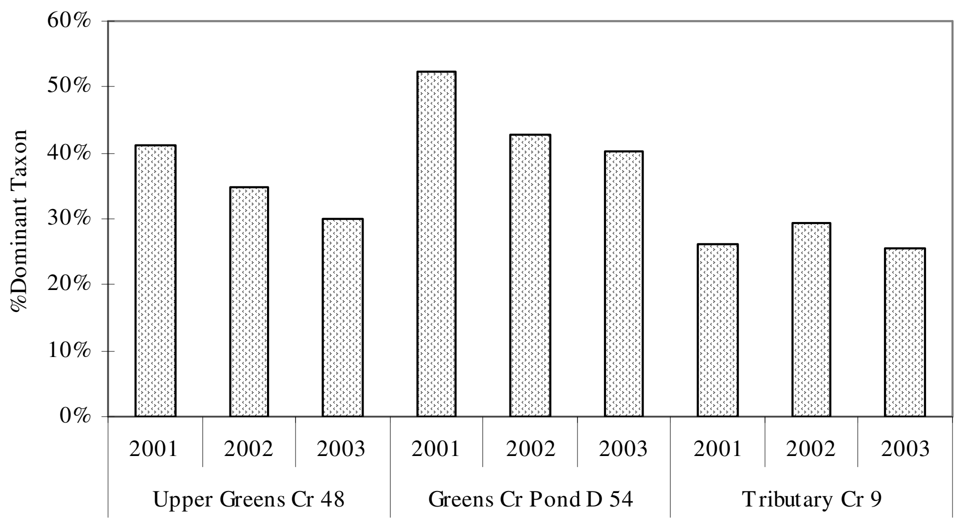

Figure 32. Comparison of benthic macroinvertebrate percent dominant taxa among sites in 2001, 2002, and 2003.

The percent EPT metric, based on the concept that most Ephemeroptera , Plecoptera, and Trichoptera taxa are sensitive to pollutants (Merritt and Cummins 1996), was high in all of the biomonitoring sites (Figure 33), and much higher than the percent of Chironomidae.

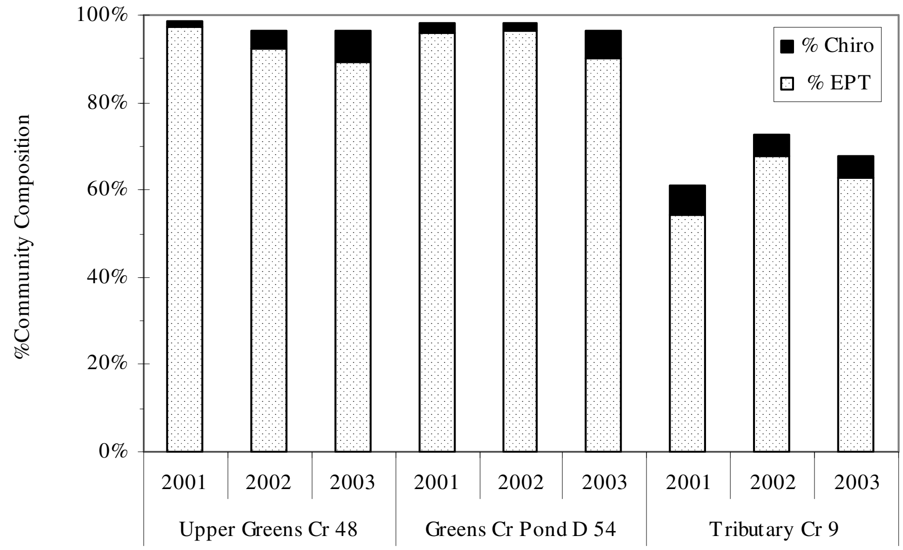

Figure 33. Comparisons of proportions of EPT taxa and Chironomidae among sites in 2001, 2002, and 2003.

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 34). Aquatic communities at both Greens Creek sites were dominated by mayflies (Ephemeroptera), with small contributions by stoneflies (Plecoptera) and true flies (aquatic Diptera). At Tributary Creek Site 9, the community was only slightly dominated by mayflies and contained 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.

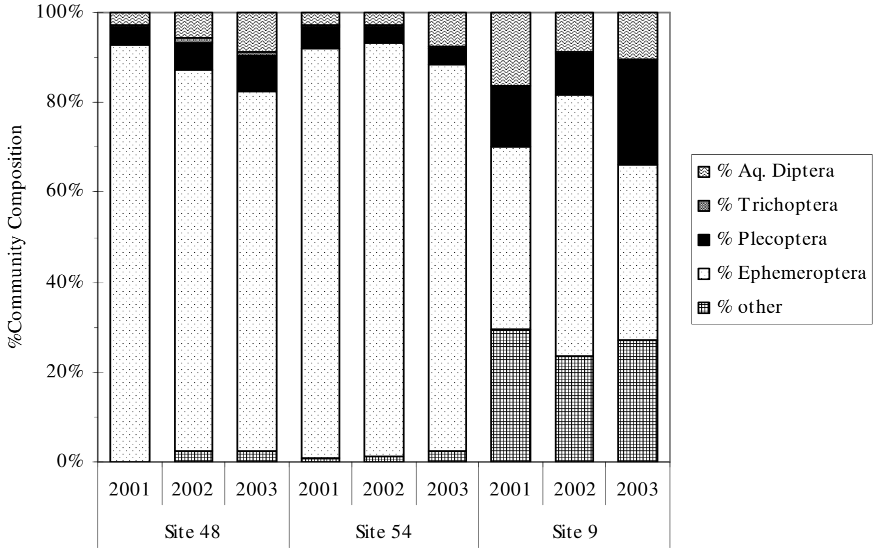

Figure 34. Comparison of community composition of aquatic invertebrates among sites in 2001, 2002, and 2002.

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 perturbations by pollution or natural stressors in the future would likely cause a substantial change in the abundance or diversity of aquatic invertebrates.

Juvenile Fish Populations

All three biomonitoring sites supported relatively abundant fish populations in 2003 for the stream types and locations (Paustian et al. 1990). In terms of population estimates per sample reach, 2003 captures in both Greens Creek sites were higher than in either 2001 or 2002, while Tributary Creek Site 9 had lower numbers (Figure 35, Appendix 3). Comparisons among all sites must be tempered by the differences in size and channel type between Greens Creek and Tributary Creek, as reflected in the fish density values (population estimate per m^2 of wetted area in each sample reach) shown in Table 8. Using this metric, the 2003 production in Tributary Creek was higher than all three sites in 2002 and both Greens Creek sites in 2001. Densities were lowest in Greens Creek Site 48, which has resident fish only because anadromous fish access is limited by a weir downstream of the sample reach (Weber Scannell and Paustian 2002).

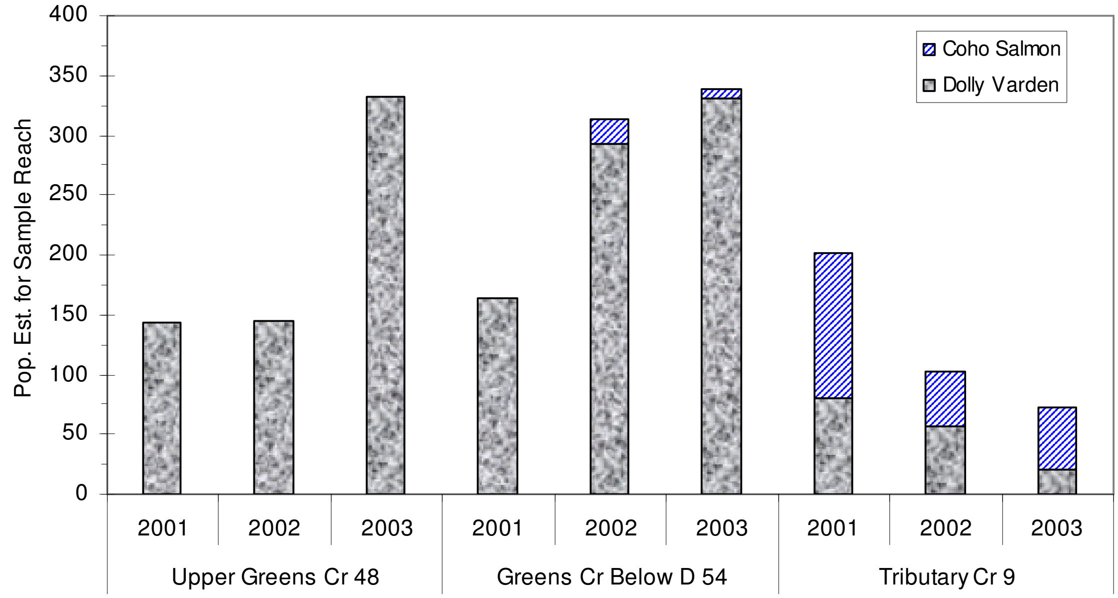

Figure 35. Population estimates for juvenile fish captured at Greens Creek Mine biomonitoring sites in 2001, 2002, and 2003.

Table 8. Estimated fish densities in the Greens Creek Mine biomonitoring site reaches.

	Upper Greens Creek Site 48		**Greens Creek Below Pond D Site 54**		**Tributary Creek Site 9**	
	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho salmon	Dolly Varden
2001						
Number Fish Caught	*	68	***	138	118	81
Sample Reach, m	72	72	28	28	44	44
Population Estimate, fish	*	144	***	164	120	81
Density Est., fish/m^2	*	0.2	***	0.6	0.94	0.65
2002						
Number Fish Caught	*	126	21	271	44	51
Sample Reach, m	50	50	28	28	50	50
Population Estimate, fish	*	145	21	293	46	57
Density Est., fish/m^2	*	0.23	0.07	1.0	0.35	0.46
2003						
Number Fish Caught	*	285	8	232	52	19
Sample Reach, m	50	50	28	28	50	50
Population Estimate, fish	*	333	8	331	53	20
Density Est., fish/m^2	*	0.9**	0.04**	1.8**	0.8**	0.3**

* Coho salmon not present since above barrier to anadromous fish.
** Based on estimated wetted area value.
*** FS reported too few fish captured to provide estimates.

Metals Concentrations in Juvenile Fish

Dolly Varden from Greens Creek sites 48 and 54 had significantly ($\alpha = 0.05$) lower silver concentrations that did Dolly Varden from Tributary Creek, and significantly higher zinc concentrations (Figure 36). Lead concentrations were significantly lower in Upper Greens Creek Site 48 fish than in Tributary Creek Site 9 fish, while those in Greens Creek Below Pond D Site 54 fish were not significantly different from those in the other site. This was largely because of a higher reported lead concentration for one fish from Site 54. Selenium concentrations in Greens Creek Below Pond D Site 54 fish were slightly significantly higher ($\alpha = 0.1$) than in fish from the other two sites, and concentrations of cadmium and copper were not significantly different ($\alpha > 0.1$) among sites in 2003.

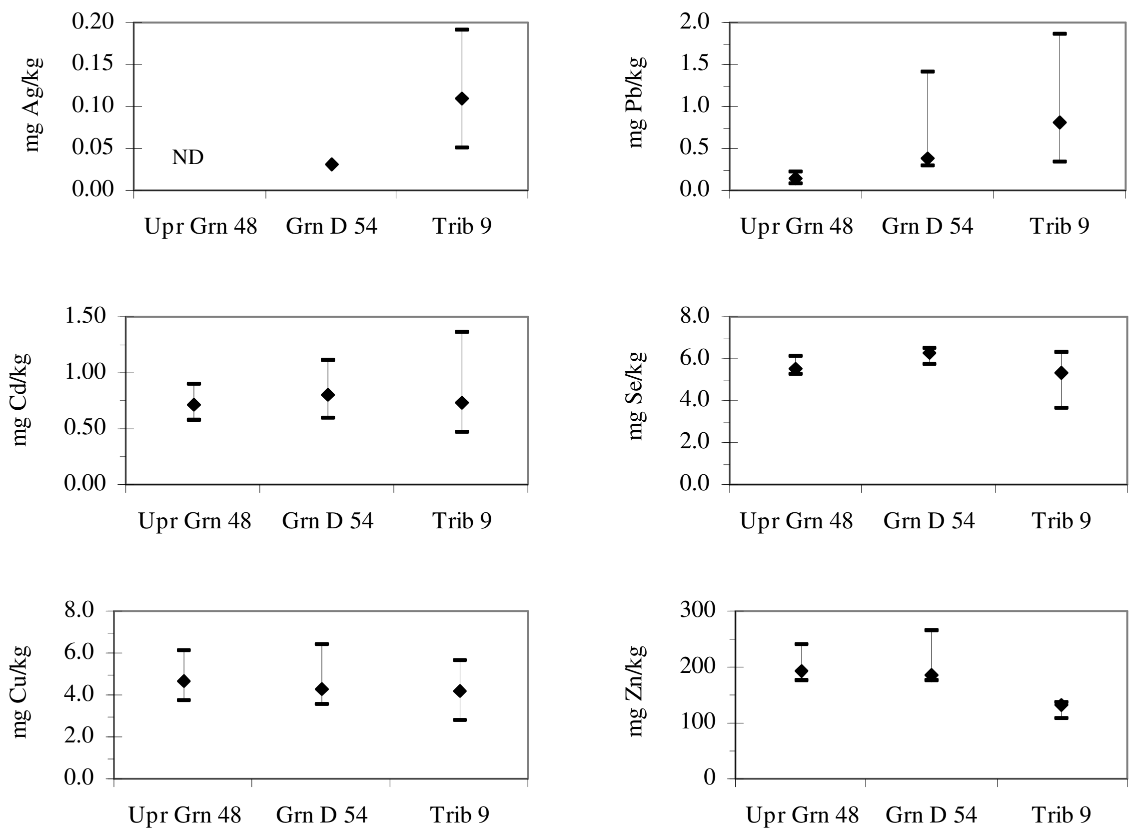

Figure 36. Comparison among sites of whole body metals concentrations (median, maximum, and minimum) in Dolly Varden captured in 2003. ND = Not Detected at detection level of 0.02 mg Ag/kg

Toxicity Testing

Acute toxicity testing was conducted on water samples from each of the three sites sampled in 2001 and 2002. No toxicity was detected during any of the tests and the IC-20 value for each site was >100%. Tests for chronic toxicity were completed in 2001, but the method failed repeatedly in 2002. In 2001, there was no toxic response and the IC-20 value for each site was >100%.

No Microtox toxicity testing was done in 2003. The results from the 2003 periphyton, benthic invertebrate, and juvenile fish biomonitoring program elements provide no evidence to suggest toxicity of the waters at the three biomonitoring sites.

CONCLUSIONS

The two biomonitoring sites on Greens Creek (Upper Greens Creek Sites 48 above all facilities and Greens Creek Below Pond D Site 54) and one on Tributary Creek (Tributary Creek Site 9 below the tailings facility) continued to sustain complex, diverse aquatic communities. Low water levels in summer 2003 allowed for higher productivity in the streams but decreased the wetted area available for fish habitat, particularly in Tributary Creek.

Periphyton biomass and community composition continue to appear robust, with a pronounced diatom component and minimal amounts of filamentous green algae or blue-green bacteria. Chlorophyll *a* concentrations were similar between sites and significantly higher in 2003 than in previous years.

The benthic macroinvertebrate communities are taxonomically rich with high densities, and the populations of many pollution-sensitive taxa are well represented. Mean densities were similar between sites and significantly higher than in previous years. A slightly higher percentage of total aquatic invertebrates were Chironomidae compared to previous years at the Greens Creek sites.

Juvenile fish populations continue to be relatively abundant at each site, with multiple size classes present. Total fish captures were higher in 2003 than in previous years at the Greens Creek sites and lower in Tributary Creek. The latter is likely related to low water levels.

Whole body concentrations of metals in fish tissues were similar to or less than those found in previous years' samples. Some differences were noted between sites and stream systems, but no clear pattern emerged.

No testing of acute toxicity in water from the three biomonitoring sites was done in 2003.

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APPENDIX 1. USFS CHANNEL TYPE DESCRIPTIONS

The following descriptions and definitions of channel types are from Paustian et al. (1992).

MM2 – Moderate Width Mixed Control 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 – Narrow Low Gradient Flood Plain 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. BENTHIC MACROINVERTEBRATE DATA

Numbers of aquatic invertebrates identified in Upper Greens Creek Site 48 samples.

Taxa			**2001**	**2002**	**2003**
Order	**Family**	**Genus**			
Ephemeroptera	Baetidae	*Baetis*	309	152	445
	Ephemerellidae	*Caudatella*	2		
		Ephemerella			10
		Drunella	47	49	650
	Heptageniidae	*Cinygmula*	99	20	117
		Epeorus	444	190	384
		Rhithrogena	193	187	287
	Leptophlebiidae	*Paraleptophlebia*		1	
	Ameletidae	*Ameletus*			4
Plecoptera	Capniidae	*Capnia*			82
	Chloroperlidae	*Alloperla*	1	1	
		Kathroperla			2
		Neaviperla			70
		Plumiperla	5		
		Suwallia	8	1	
		Sweltsa	1	4	
	Leuctridae	*Despaxia*		2	
		Paraleuctra	4	3	6
		Perlomyia		12	
	Nemouridae	*Podmosta*	7	5	
		Zapada	23	4	30
	Perlodidae	*Megarcys*			1
		Skwala		9	
Trichoptera	Apataniidae	*Apatania*		1	
	Glossosomatidae	*Glossosoma*			2
	Hydropsychidae	*Arctopsyche*	2		
		Hydropsyche			1
	Limnephilidae	*Onocosmoecus*			1
	Rhyacophilidae	*Rhyacophila*	5	8	16
Coleoptera	Staphylinidae		1		6
Diptera	Ceratopogonidae	*Dasyhelea*		1	
	Chironomidae		14	30	172
	Deuterophlebiidae	*Deuterophlebia*	2		
	Empididae	*Chelifera*	1	2	5
		Oreogeton	3	2	22
	Psychodidae	*Psychoda*	1		
	Simuliidae	*Parasimulium*	2		
		Prosimulium	2		
		Simulium	6	4	

Numbers of aquatic invertebrates identified in Upper Greens Creek Site 48 samples (continued).

Order	**Family**	**Genus**	**2001**	**2002**	**2003**
	Tipulidae	*Antocha*			2
		Dicranota			3
		Tipula			2
Collembola	Onychiuridae	*Onychiurus*		1	
	Sminthuridae	*Dicyrtoma*	2		
Acarina				2	20
Oligochaeta				5	20
Ostracoda				8	7

Numbers of aquatic invertebrates identified in Greens Creek Below Pond D Site 54 samples.

Taxa			**2001**	**2002**	**2003**
Order	**Family**	**Genus**			
Ephemeroptera	Baetidae	*Baetis*	248	225	220
	Ephemerellidae	*Ephemerella*	2	6	6
		Drunella	118	280	894
	Heptageniidae	*Cinygmula*	319	75	176
		Epeorus	935	626	408
		Rhithrogena		140	306
	Leptophlebiidae	*Paraleptophlebia*	1		1
	Ameletidae	*Ameletus*	4		
Plecoptera	Capniidae	*Capnia*			5
	Chloroperlidae	*Alloperla*	3		
		Kathroperla			2
		Neaviperla		14	22
		Paraperla			5
		Plumiperla	2		
		Sweltsa	6		
	Leuctridae	*Paraleuctra*		4	
		Perlomyia	13	3	19
	Nemouridae	*Podmosta*		7	
		Zapada	52	22	14
	Perlodidae	*Diura*	1		
		Isoperla	3		
		Skwala		3	15
		Rickera		1	
Trichoptera	Hydropsychidae	*Arctopsyche*		1	
	Limnephilidae	*Psychoglypha*	1		
	Rhyacophilidae	*Rhyacophila*	6	5	12
Coleoptera	Staphylinidae		1	1	
Diptera	Chironomidae		33	27	149
	Deuterophlebiidae	*Deuterophlebia*		1	1
	Dolichopodidae		2		
	Empididae	*Chelifera*	2		
		Oreogeton	10	4	15
	Simuliidae	*Prosimulium*		1	
		Simulium	3	3	
	Tipulidae	*Antocha*	1		3
		Dicranota	2	1	
		Hesperoconopa		1	1
		Pilaria			1
		Rhabdomastix			3
		Tipula		1	
Collembola	Onychiuridae	*Onychiurus*		1	
	Sminthuridae	*Dicyrtoma*		1	

Numbers of aquatic invertebrates identified in Greens Creek Below Pond D Site 54 samples (continued).

Order	**Family**	**Genus**	**2001**	**2002**	**2003**
Copepoda	Cyclopoida				1
Acarina			9	3	6
Oligochaeta			3	7	49
Gastropoda	Valvatidae		1	1	
Ostracoda			1	1	1

Numbers of aquatic invertebrates identified in Tributary Creek Site 9 samples.

Taxa			**2001**	**2002**	**2003**
Order	**Family**	**Genus**			
Ephemeroptera	Baetidae	*Baetis*	41	123	160
		Procloeon	5		
	Ephemerellidae	*Caudatella*	3		
		Drunella		3	10
		Ephemerella		14	7
		Epeorus		8	
	Heptageniidae	*Cinygma*	1		
		Cinygmula	89	177	507
		Epeorus			1
		Rhithrogena			1
	Leptophlebiidae	*Paraleptophlebia*	66	96	249
	Ameletidae	*Ameletus*		15	46
Plecoptera	Chloroperlidae	*Neaviperla*			174
		Paraperla		11	
		Suwallia	34		24
		Sweltsa		42	
	Leuctridae	*Despaxia*	3		6
		Paraleuctra	7		1
		Perlomyia		3	
	Nemouridae	*Podmosta*		1	
		Zapada	23	12	388
	Perlodidae	*Isoperla*	1		
Trichoptera	Apataniidae	*Apatania*		1	
	Brachycentridae	*Brachycentrus*			1
	Limnephilidae	*Ecclisomyia*			1
	Rhycophilidae	*Rhycophila*		1	5
Coleoptera	Elmidae	*Narpus*	2	6	32
	Dytiscidae	*Megadytes*			2
Diptera	Ceratopogonidae	*Bezzia*			1
		Dasyhelea	3		
		Probezzia			9
	Chironomidae		35	36	125
	Empididae	*Chelifera*		1	
		Hemerodromia			1
		Oreogeton	4	2	24
	Psychodidae	*Psychoda*			
	Simuliidae	*Simulium*	40	22	81
	Tipulidae	*Antocha*			10
		Dicranota			2
		Pilaria			2
		Rhabdomastix			1
		Tipula	4	5	
Branchiopoda	Chydoridae				2

Numbers of aquatic invertebrates identified in Tributary Creek Site 9 samples (continued).

Order	**Family**	**Genus**	**2001**	**2002**	**2003**
Collembola	Sminthuridae	*Dicyrtoma*		2	
		Sminthurus			3
Copepoda	Cyclopoida				6
	Harpacticoida				5
Acarina			15	20	72
Oligochaeta			40	45	349
Gastropoda			1		1
Ostracoda			92	102	207

APPENDIX 3. JUVENILE FISH CAPTURE DATA

Location	Fish Species	Number Fish Captured				MLE Pop. Est.	Standard Error	95% Conf. Interval
		Set 1	Set 2	Set 3	Total			
2001								
Uppr Greens Cr 48								
	DV	---	---	---	---	144	74.76	84 - 448
Grns Cr Below D 54								
	DV	---	---	---	---	164	12.32	150 - 200
	CO	---	---	---	*	---	---	---
Tributary Cr 9								
	DV	---	---	---	---	81	0.78	81 - 81
	CO	---	---	---	---	120	2.14	119 - 128
	CT	---	---	---	*	---	---	---
	Sc	---	---	---	---	4	0.21	4 - 4
2002								
Uppr Greens Cr 48								
	DV	---	---	---	---	145	9.43	134 - 173
Grns Cr Below D 54								
	DV	---	---	---	---	57	5.17	53 - 76
	CO	---	---	---	---	46	2.51	45 - 57
Tributary Cr 9								
	DV	---	---	---	---	57	5.17	53 - 76
	CO	---	---	---	---	46	2.51	45 - 57
	CT	---	---	---	*	---	---	---
	Sc	---	---	---	*	---	---	---
2003								
Uppr Greens Cr 48								
	DV	157	75	56	285	333	14.04	305 - 361
Grns Cr Below D 54								
	DV	92	81	59	232	331	27.76	275 - 387
	CO	5	3	0	8	8	0.00	8 - 8
Tributary Cr 9								
	DV	13	4	2	19	20	1.52	17 - 23
	CO	37	11	4	52	53	1.20	51 - 55
	CT	1	0	0	1	1	---	---
	Sc	0	0	1	1	1	---	---
Species: DV = Dolly Varden, CO = coho salmon, CT = cutthroat trout, Sc = sculpin								
Data for 2001 and 2002 from U.S. Forest Service. * = actual number captured not reported.								

APPENDIX 4. METALS IN JUVENILE FISH DATA

Information on fish collected for analysis of metals in tissues. Sample Number contains codes for date collected, creek, site, fish species, age, and replicate number.

Sample Number	Date Collected	Creek	Site	Fish Species	Weight (gm)	ForkLength (mm)
072301GC48DVJ01	23-Jul-01	Upper Greens	48	Dolly Varden	26.02	131
072301GC48DVJ02	23-Jul-01	Upper Greens	48	Dolly Varden	28.81	137
072301GC48DVJ03	23-Jul-01	Upper Greens	48	Dolly Varden	18.84	119
072301GC48DVJ04	23-Jul-01	Upper Greens	48	Dolly Varden	21.13	121
072301GC48DVJ05	23-Jul-01	Upper Greens	48	Dolly Varden	13.71	111
072301GC48DVJ06	23-Jul-01	Upper Greens	48	Dolly Varden	21.08	121
072402GC48DVJ01	24-Jul-02	Upper Greens	48	Dolly Varden	23.23	133
072402GC48DVJ02	24-Jul-02	Upper Greens	48	Dolly Varden	15.04	120
072402GC48DVJ03	24-Jul-02	Upper Greens	48	Dolly Varden	17.52	122
072402GC48DVJ04	24-Jul-02	Upper Greens	48	Dolly Varden	20.75	127
072402GC48DVJ05	24-Jul-02	Upper Greens	48	Dolly Varden	24.77	134
072402GC48DVJ06	24-Jul-02	Upper Greens	48	Dolly Varden	21.66	128
072203GC48DVJ01	22-Jul-03	Upper Greens	48	Dolly Varden	8.9	90
072203GC48DVJ02	22-Jul-03	Upper Greens	48	Dolly Varden	9.9	98
072203GC48DVJ03	22-Jul-03	Upper Greens	48	Dolly Varden	12.1	103
072203GC48DVJ04	22-Jul-03	Upper Greens	48	Dolly Varden	12.5	112
072203GC48DVJ05	22-Jul-03	Upper Greens	48	Dolly Varden	11.9	108
072203GC48DVJ06	22-Jul-03	Upper Greens	48	Dolly Varden	10.5	100
072301GC06DVJ01	23-Jul-01	Middle Greens	6	Dolly Varden	28.4	139
072301GC06DVJ02	23-Jul-01	Middle Greens	6	Dolly Varden	30.49	140
072301GC06DVJ03	23-Jul-01	Middle Greens	6	Dolly Varden	43.9	167
072301GC06DVJ04	23-Jul-01	Middle Greens	6	Dolly Varden	34.8	155
072301GC06DVJ05	23-Jul-01	Middle Greens	6	Dolly Varden	15.69	109
072301GC06DVJ06	23-Jul-01	Middle Greens	6	Dolly Varden	49.1	168
062100GCCOJ01	21-Jun-00	Greens Below D	54	Coho Salmon	4.4	72
062100GCCOJ02	21-Jun-00	Greens Below D	54	Coho Salmon	6.1	82
062100GCCOJ03	21-Jun-00	Greens Below D	54	Coho Salmon	4.9	73
062100GCCOJ04	21-Jun-00	Greens Below D	54	Coho Salmon	3.4	68
062100GCCOJ05	21-Jun-00	Greens Below D	54	Coho Salmon	5.9	73
062100GCCOJ06	21-Jun-00	Greens Below D	54	Coho Salmon	6	75
072301GC54DVJ01	23-Jun-01	Greens Below D	54	Dolly Varden	21.5	121
072301GC54DVJ02	23-Jun-01	Greens Below D	54	Dolly Varden	19.32	119
072301GC54DVJ03	23-Jun-01	Greens Below D	54	Dolly Varden	15.73	107
072301GC54DVJ04	23-Jun-01	Greens Below D	54	Dolly Varden	13.64	109
072301GC54DVJ05	23-Jun-01	Greens Below D	54	Dolly Varden	13.52	105
072301GC54DVJ06	23-Jun-01	Greens Below D	54	Dolly Varden	27.54	138
072402GC54DVJ01	24-Jul-02	Greens Below D	54	Dolly Varden	17.96	118
072402GC54DVJ02	24-Jul-02	Greens Below D	54	Dolly Varden	22.26	128
072402GC54DVJ03	24-Jul-02	Greens Below D	54	Dolly Varden	17.7	115
072402GC54DVJ04	24-Jul-02	Greens Below D	54	Dolly Varden	18.94	115
072402GC54DVJ05	24-Jul-02	Greens Below D	54	Dolly Varden	21.09	124
072402GC54DVJ06	24-Jul-02	Greens Below D	54	Dolly Varden	20.88	123

Sample Number	Date Collected	Creek	Site	Fish Species	Weight (gm)	ForkLength (mm)
072203GC54DVJ01	22-Jul-03	Greens Below D	54	Dolly Varden	21.1	123
072203GC54DVJ02	22-Jul-03	Greens Below D	54	Dolly Varden	10.6	101
072203GC54DVJ03	22-Jul-03	Greens Below D	54	Dolly Varden	9.2	88
072203GC54DVJ04	22-Jul-03	Greens Below D	54	Dolly Varden	14.8	109
072203GC54DVJ05	22-Jul-03	Greens Below D	54	Dolly Varden	10.6	95
072203GC54DVJ06	22-Jul-03	Greens Below D	54	Dolly Varden	9.7	92
062100TRCOJ01	21-Jun-00	Tributary	9	Coho Salmon	9.7	102
062100TRCOJ02	21-Jun-00	Tributary	9	Coho Salmon	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
072303TR09DVJ01	23-Jul-03	Tributary	9	Dolly Varden	10.7	106
072303TR09DVJ02	23-Jul-03	Tributary	9	Dolly Varden	6.8	89
072303TR09DVJ03	23-Jul-03	Tributary	9	Dolly Varden	17.4	112
072303TR09DVJ04	23-Jul-03	Tributary	9	Dolly Varden	11.6	95
072303TR09DVJ05	23-Jul-03	Tributary	9	Dolly Varden	9.5	91
072303TR09DVJ06	23-Jul-03	Tributary	9	Dolly Varden	8.4	84

Concentration of select metals in juvenile fish collected in 2000, 2001, 2002, and 2003.

Sample Number	**Ag (mg/kg)**	**Cd (mg/kg)**	**Cu (mg/kg)**	**Pb (mg/kg)**	**Se (mg/kg)**	**Zn (mg/kg)**	**Solids %**
MRL	**0.02**	**0.02**	**0.1**	**0.02**	**1**	**0.5**	
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
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
072203GC48DVJ01	< 0.02	0.65	4.2	0.14	5.6	191	23.8
072203GC48DVJ01	< 0.02	0.90	5.1	0.22	5.5	180	23.6
072203GC48DVJ01	< 0.02	0.82	5.6	0.16	5.4	241	23.7
072203GC48DVJ01	< 0.02	0.78	6.1	0.11	6.1	192	23.5
072203GC48DVJ01	< 0.02	0.63	3.9	0.14	5.2	174	23.8
072203GC48DVJ01	< 0.02	0.58	3.7	0.08	5.5	218	24.2
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
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

Sample Number	Ag (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Se (mg/kg)	Zn (mg/kg)	Solids %
MRL	**0.02**	**0.02**	**0.1**	**0.02**	**1**	**0.5**	
072203GC54DVJ01	0.03	0.85	6.4	1.40	6.1	188	25.1
072203GC54DVJ02	<0.02	0.67	4.2	0.32	6.4	174	22.9
072203GC54DVJ03	<0.02	0.75	4.3	0.35	6.5	186	22.8
072203GC54DVJ04	<0.02	1.11	5.8	0.38	5.7	188	24.0
072203GC54DVJ05	<0.02	0.59	3.5	0.29	5.7	174	23.9
072203GC54DVJ06	<0.02	0.91	4.1	0.43	6.5	263	23.8
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
072303TR09DVJ01	0.06	0.46	2.8	0.34	6.3	134	21.9
072303TR09DVJ02	0.10	1.01	4.0	0.82	6.0	131	22.8
072303TR09DVJ03	0.16	1.35	4.4	1.85	5.7	108	24.3
072303TR09DVJ04	0.19	0.69	5.6	1.30	3.6	136	22.5
072303TR09DVJ05	0.05	0.72	4.4	0.56	4.9	131	22.2
072303TR09DVJ06	0.12	0.76	3.9	0.78	4.7	125	23.2