Technical Report No. 05-04

Aquatic Biomonitoring At Greens Creek Mine, 2004

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

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This sampling effort and report were made possible by the previous Greens Creek Mine biomonitoring work done by staff from Kennecott Greens Creek Mining Company, U.S. Forest Service, Alaska Department of Fish & Game, Alaska Department of Natural Resources, and University of Alaska Fairbanks, and their foundational work is gratefully acknowledged.

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 and 2004.

The purpose of the Greens Creek Mine Biological Monitoring Program is to ensure the continued use of Greens Creek and its tributaries by fish and other aquatic species, and to document the continued health of all levels of the biological community: primary productivity, invertebrate communities, and fish. The intention is that the program will also detect any changes in the aquatic communities over time that may result from changes in water quality associated with surface or groundwater inputs to the streams. Elements of the biological monitoring program have included surveys of periphyton biomass, benthic macroinvertebrate density and community structure, juvenile fish abundance and distribution, concentrations of select elements in fish tissues, and toxicity testing.

In 2004, the stream reaches downstream of mine facilities (Greens Creek Below Pond D Site 54 and Tributary Creek Site 9) continued to sustain abundant and diverse aquatic communities at population levels similar to the reference site (Upper Greens Creek Site 48).

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 in 2004, significantly lower than in 2003, and intermediate in value to samples from 2001 and 2002.

The benthic macroinvertebrate communities at the three sampled sites remained abundant and taxonomically rich, with the populations of many pollution-sensitive taxa well represented. Mean densities at all three sites were lower in 2004 than in 2003. Greens Creek Below Pond D Site 54 had significantly higher benthic macroinvertebrate densities than did Tributary Creek Site 9. The percentage of total benthic macroinvertebrates at the Greens Creek sites that were Chironomidae continued to increase compared to previous years. Aquatic communities at Greens Creek sites 48 and 54 were dominated by mayflies (Ephemeroptera). The Tributary Creek Site 9 aquatic community was more diverse, being only slightly dominated by mayflies with non-insect invertebrates forming a major component of the community. These continuing differences between the Greens Creek and Tributary Creek sites are likely influenced by differences in physical features, including gradient, water velocity, and scour patterns in the different sites.

Juvenile fish populations continued to be relatively abundant at each site in 2004, with higher estimated densities for Dolly Varden (*Salvelinus malma*) and coho salmon (*Oncorhynchus kisutch*) than the regional averages for that channel type. Multiple size classes of Dolly Varden were present at each of the three sites; multiple size classes of coho salmon were present at Tributary Creek Site 9 while a single age class was represented at Greens Creek Below Pond D Site 54. Total fish captures were lower in 2004 than in 2003 in all three sample reaches; at Tributary Creek Site 9, this continued a trend of declining catches. Moderately low water levels somewhat decreased the wetted area available for fish habitat, particularly in Tributary Creek.

Whole body concentrations of metals in 2004 were similar to or less than those found in previous years' samples. Tissues of Dolly Varden from Tributary Creek Site 9 had different metals concentration characteristics than did tissues from Dolly Varden at the two Greens Creek sites (48 and 54) in 2004, although a clear pattern of differential water quality did not emerge between sites downstream of mine facilities and the control site Upper Greens Creek Site 48.

The acute toxicity testing element of the biological monitoring program was discontinued for the 2004 sampling year. The results from the 2001 and 2002 toxicity testing, and the 2001 through 2004 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 Upper Greens Creek Site 48, Greens Creek Below Pond D Site 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 in southeast Alaska.

From findings of that review, the KGCMC Fresh Water Monitoring Plan (FWMP) was updated (KGCMC 2000), including specifications for biomonitoring in areas adjacent to the KGCMC surface facilities associated with the mine and mill. This technical report presents results of the fourth year (2004) of the Greens Creek Mine Biological Monitoring Program as specified in the FWMP, 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), Jacobs et al. (2003), and Durst and Townsend (2004).

The intent of aquatic monitoring at Greens Creek Mine 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 are typically 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, USFS, ADEC, ADF&G, ADNR, and the American Public Health Association (APHA 1992).

PURPOSE

The objective of the Greens Creek Mine Biological Monitoring Program is to establish existing conditions of the aquatic 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 (discontinued in 2003).

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. Some surface exploration activities have occurred intermittently upstream of this site including drilling prior to the 2003 biomonitoring sampling. Biomonitoring occurs at Upper Greens Creek Site 48 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 at this site 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, and reports the results of that monitoring under separate cover. 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.

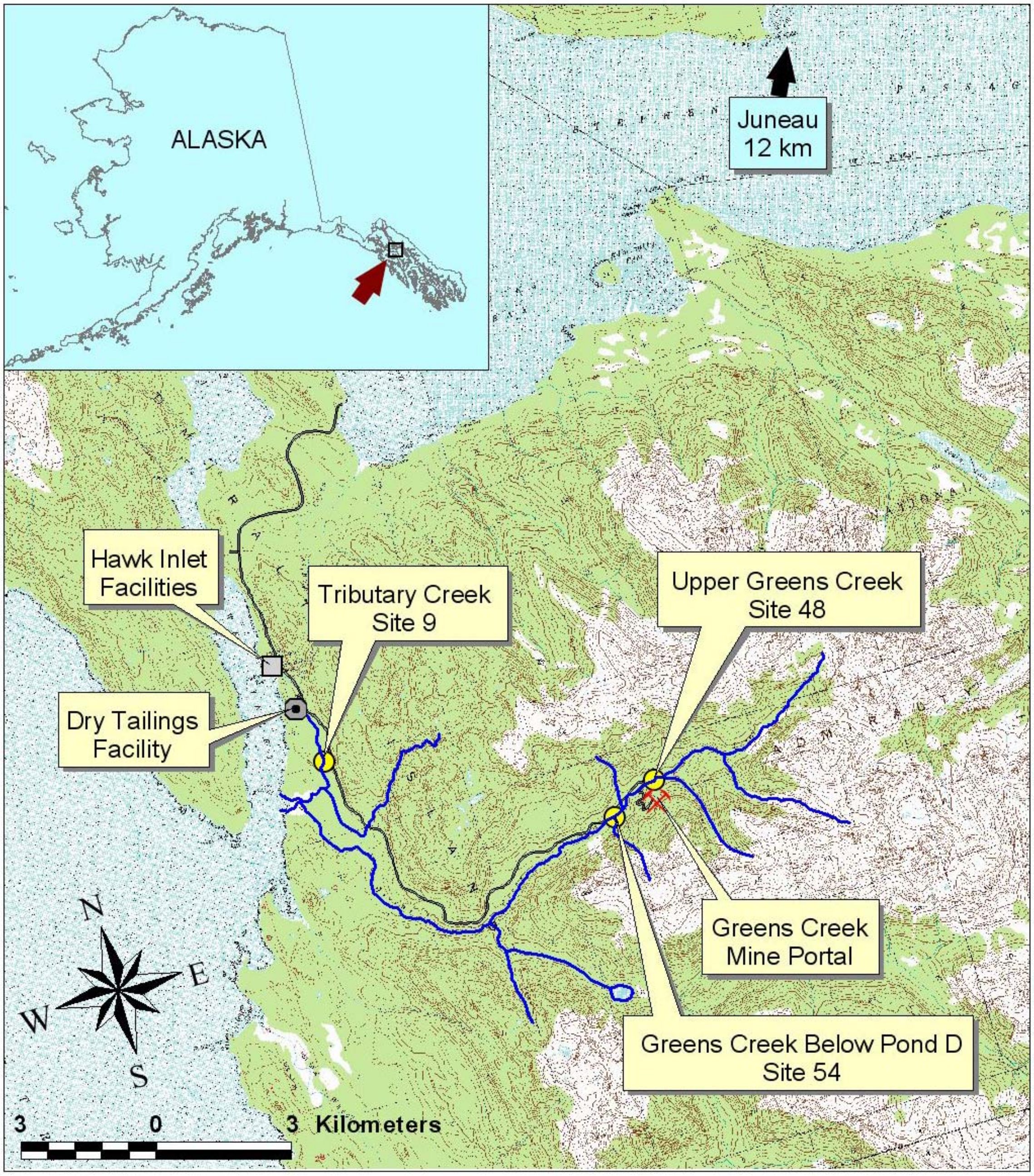

Figure 1. Location of the Greens Creek Mine operation and biomonitoring sampling sites on Admiralty Island in southeast Alaska, southwest of Juneau.

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, and Durst and Townsend 2004). 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 to test for homogeneity of rank means between years and sites. ***Significant*** differences required an $\alpha \leq 0.05$, while ***trends*** required an α value greater than 0.05 but less than or equal to 0.10.

SAMPLE SITES

Upper Greens Creek Site 48

Upper Greens Creek Site 48 was selected as an upstream reference site for comparison to "treatment" sites adjacent to and downstream from the KGCMC facilities. Site 48 lies approximately 0.8 km upstream of a weir that blocks access to upper Greens Creek by anadromous fish. Because of this barrier, the only salmonid species at this site is resident Dolly Varden (*Salvelinus malma*).

The Upper Greens Creek Site 48 sample reach has a Moderate Width Mixed Control (MM2) channel type (Appendix 1), with an average channel 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.

Middle Greens Creek Site 6

Water quality at the Middle Greens Creek Site 6 (upstream of the Bruin Creek confluence) 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 approximately 5 km downstream. This site is near the upper limit of anadromous fish, defined by a weir located about 0.8 km upstream. Both Dolly Varden and coho salmon (*Oncorhynchus kisutch*) have been captured 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. Following the sampling schedule presented in the FWMP, biomonitoring data were collected in 2001 for baseline information (Weber Scannell and Paustian 2002) and 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 is located approximately 0.5 km downstream of Middle Greens Creek Site 6 and approximately 1.2 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 4.6 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 channel 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.

Tributary Creek Site 9

Tributary Creek is a small stream with a dense canopy. This site was previously monitored under the FWMP from 1981 through 1993 and is included in the current biomonitoring program because it is located approximately 1.6 km downstream from the KGCMC dry tailings placement facilities. Tributary Creek has a variety of fish populations including pink (*Oncorhynchus gorbuscha*), chum (*O. keta*), and coho salmon, cutthroat (*O. clarki*) and rainbow (*O. mykiss*) trout, 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 stream gradient of one percent, 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, 2003, and 2004.

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 method used to collect stream periphyton follows the protocol from the ADF&G (1998) and Barbour et al. (1999). 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 glass filter was wrapped in a large paper 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).

Periphyton biomass data are presented using Box and Whisker graphs (Velleman and Hoaglin 1981). The box 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; values beyond the “whiskers” represent outlier values.

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. (1999). 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 density, taxonomic richness, 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 and coho salmon 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 6.4 mm (1/4 in) square mesh galvanized Gee's minnow traps baited with salmon eggs that had been treated with a povidone-iodine (Betadine®) solution. 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, 2003, and 2004; at Greens Creek Below Pond D Site 54, the same 28 m long reach was sampled each of the four years; and in Tributary Creek Site 9, the sampled reach was 44 m long in 2001 and 50 m long in 2002, 2003, and 2004.

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 features such as shallow riffles or small waterfalls over log steps define upper and lower sample reach 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 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. 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 through 2004, all fish retained for metals analysis were Dolly Varden, although samples from Site 54 and Site 9 may have contained a mixture of resident and anadromous forms.

Samples were numbered following the convention established by ADF&G in 2001:

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

An example fish label would read: 072204GC48DVJ01, where 072204 represents July 22, 2004; GC48 represents Upper Greens Creek 48; DV represents Dolly Varden; J represents juvenile; and 01 represents sample replicate number 1.

Quality Control / Quality Assurance of Laboratory Analysis

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

TOXICITY TESTING

Rationale

Toxicity tests are designed to 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 particularly true when multiple toxic components synergistically cause toxicity, although each component may be below a detection limit.

Sample Collection and Analysis

The toxicity testing component of the Greens Creek Biomonitoring Program was suspended before the 2004 biomonitoring sampling period (McGee and Marthaller 2004). Results from

2001 and 2002 provided no indication of toxicity, and operational difficulties with the analytic method identified in the FWMP had made continuation of toxicity testing problematic.

RESULTS AND DISCUSSION

Water levels appeared moderately low at the Greens Creek sites and quite low at the Tributary Creek site during sampling in 2004. This is consistent with gage data obtained by KGCMC from the U.S. Geological Survey's Station 15101490, located just upstream of the mine portal road bridge between Greens Creek sites 48 and 54 (Table 1).

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
2004	July 21	25	0.71
	July 22	22	0.62

UPPER GREENS CREEK SITE 48

Upper Greens Creek Site 48 (Figure 2) was sampled in the morning of 22 July 2004. The weather was fair with some sun; water temperature was not recorded.

Periphyton Biomass

Concentrations of chlorophyll *a*, an estimate of periphyton biomass, were lower in 2004 than in 2003, but higher than in 2001 or 2002 (Appendix 2). Although periphyton biomass was significantly[1] different between all years together, pairwise comparisons showed that the 2004 values were significantly higher than the low values of 2001, and trended[2] higher than values from 2002. The Box and Whisker output plot from Statistix is shown in Figure 3.

Algal communities contained higher proportions of chlorophyll *c* than chlorophyll *b* (Figure 4) in all four years sampled, indicating an algal community dominated by diatoms. Low to

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[1] $\alpha \leq 0.05$

[2] $0.05 < \alpha \leq 0.10$

undetectable concentrations of chlorophyll *b* indicate minimal amounts of filamentous green algae or blue-green bacteria.

Figure 2. Upper Greens Creek Site 48, 22 July 2004.

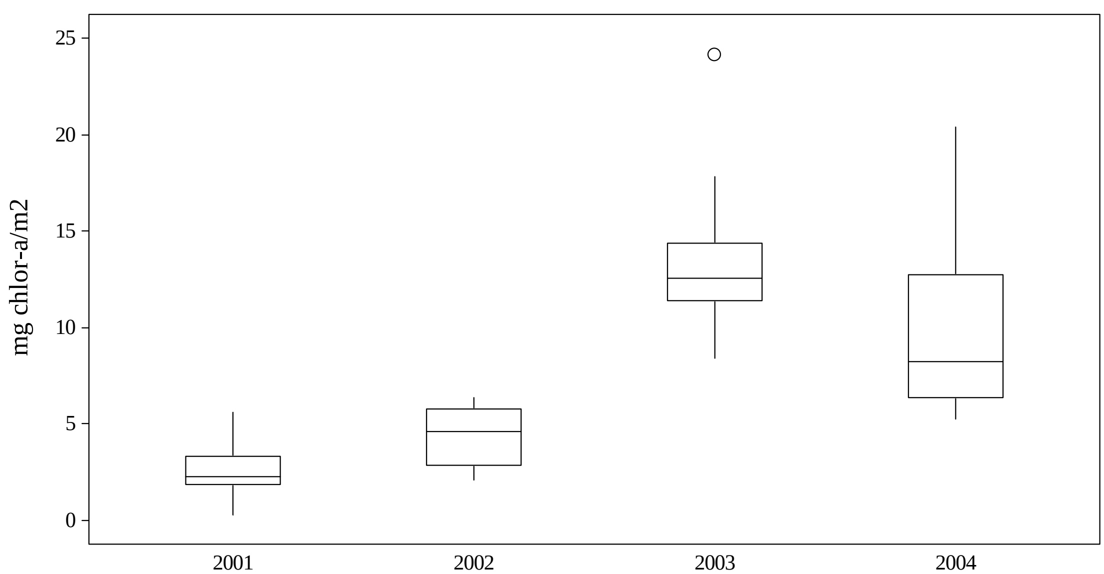

Figure 3. Estimated periphyton biomass densities at Upper Greens Creek Site 48 in 2001 through 2004. Box encompasses middle half of data; horizontal line is median value. One probable outlier value (o) was identified in the 2003 data.

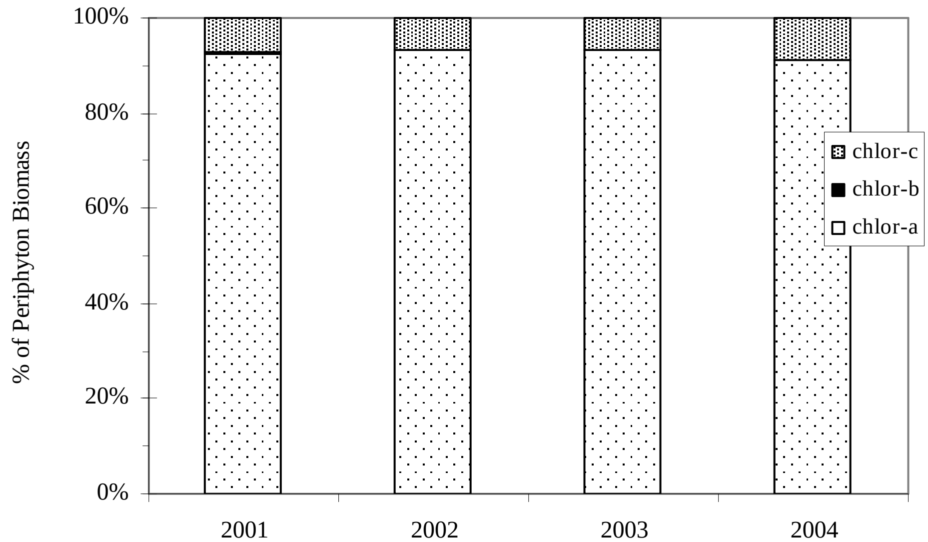

Figure 4. Proportions of chlorophylls *a*, *b*, and *c* in Upper Greens Creek Site 48 samples in 2001 through 2004.

Benthic Macroinvertebrates

The density of benthic macroinvertebrates in Upper Greens Creek Site 48 samples trended higher in 2004 than in 2002, but was not significantly different from the samples in either 2001 or 2003 (Table 2, Figure 5). Differences in taxonomic richness were more pronounced than abundance, with significantly more taxa represented per sample in 2004 (Appendix 3) than in 2001 or 2002.

Table 2. Summary of benthic macroinvertebrate samples at Upper Greens Creek Site 48 in 2001 through 2004.

Year	**Mean Density** aquatic invert/m^2	**Taxonomic Richness**	**Mean Taxa Per Sample**
2001	2368	25	11.8
2002	1408	26	13.0
2003	4734	27	17.6
2004	3358	30	19.4

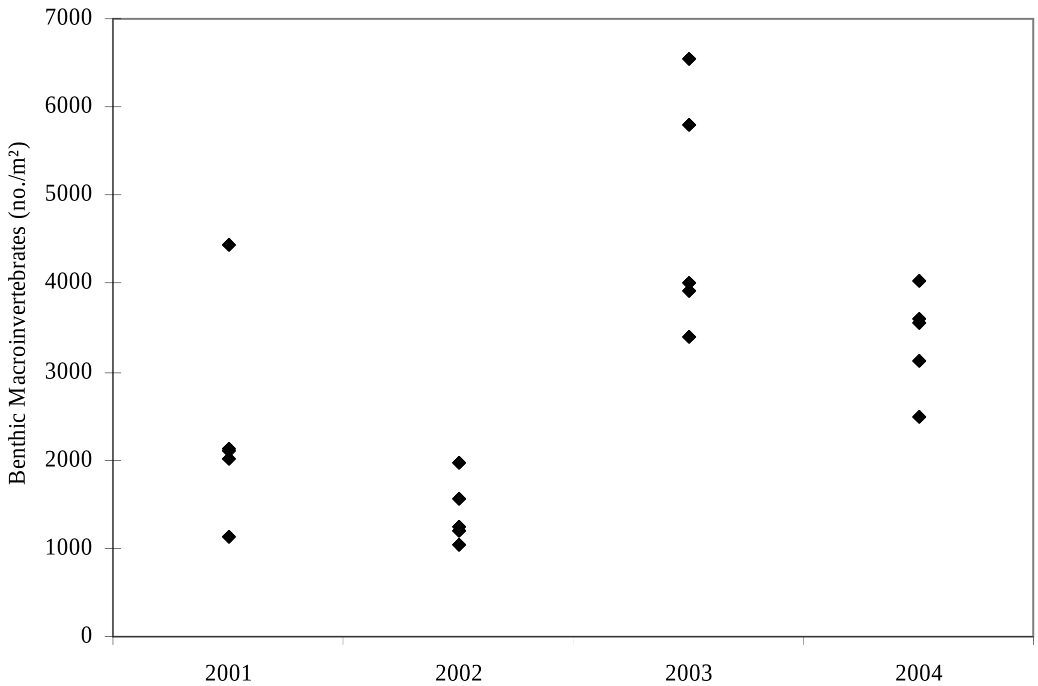

Figure 5. Density of benthic macroinvertebrates (n = 5 samples each year) at Upper Greens Creek Site 48 in 2001 through 2004.

Invertebrate communities were somewhat different among the four 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 decreased water quality, especially metals, the high proportion found at this baseline site signifies very high water quality conditions for aquatic life.

At Upper Greens Creek Site 48, mayflies (Ephemeroptera) dominated the benthic macroinvertebrate samples (Figure 7, Table 3). Common taxa in all four years included the mayflies Baetidae: *Baetis*, Ephemerellidae: *Drunella*, and Heptgeniidae: *Epeorus* and *Rhithrogena*. *Baetis* are rated as "moderately sensitive," *Drunella* are "very to extremely sensitive," *Epeorus* are "sensitive," and *Rhithrogena* are "very sensitive" (Barbour et al. 1999). In all four years, pollution-sensitive taxa dominated the invertebrate community at Upper Greens Creek Site 48 and the mixture of numerous taxa represents a complex community. Appendix 3 lists the benthic macroinvertebrate taxa found at Upper Greens Creek Site 48 in 2001 through 2004.

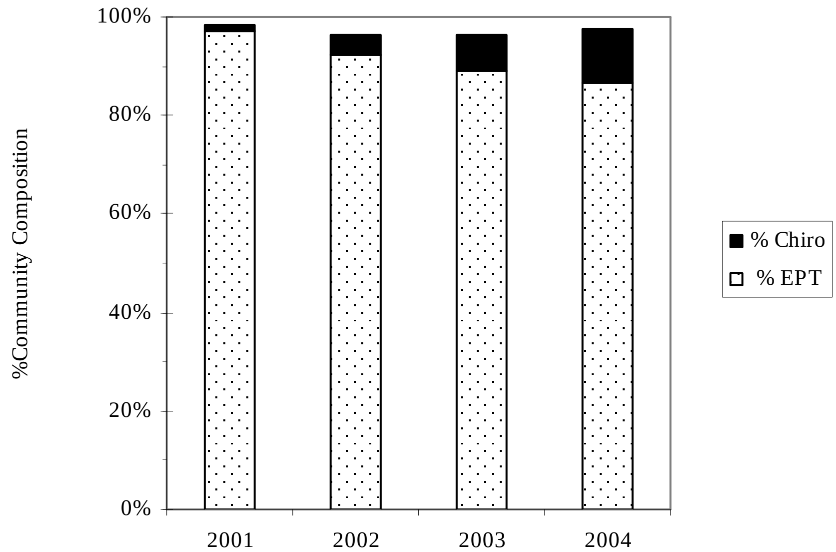

Figure 6. Proportions of EPT taxa and Chironomidae in Upper Greens Creek Site 48 samples in 2001 through 2004.

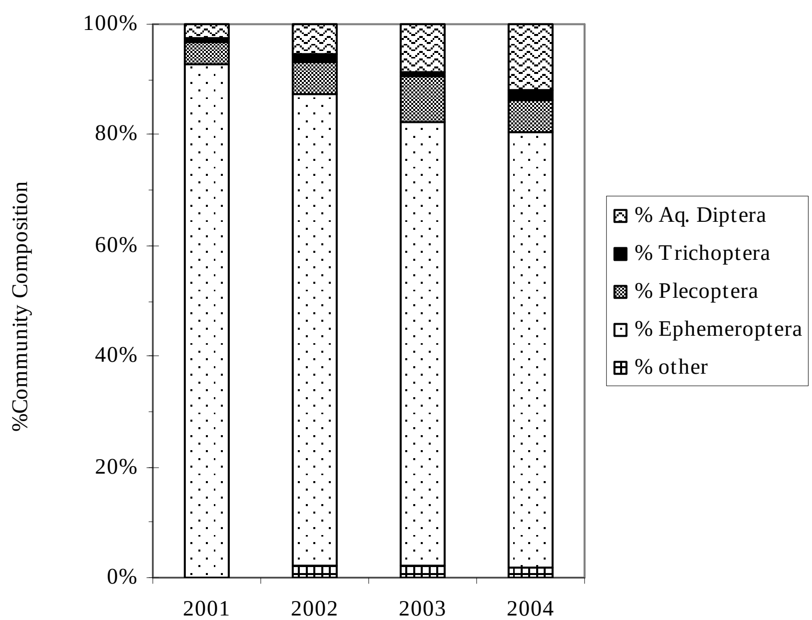

Figure 7. Community composition of benthic macroinvertebrates at Upper Greens Creek Site 48 in 2001 through 2004.

Table 3. Common taxa (>5% of invertebrates found in samples) at Upper Greens Creek Site 48 in 2001 through 2004.

Order	Family	Genus	2001	2002	2003	2004
Ephemeroptera	Baetidae	*Baetis*	26%	22%	19%	23%
	Ephemerellidae	*Drunella*		7%	27%	24%
	Heptageniidae	*Cinygmula*	8%			6%
		Epeorus	38%	27%	16%	12%
		Rhithrogena	16%	27%	12%	12%
Diptera	Chironomidae				7%	11%

Juvenile Fish Populations

The 2004 juvenile fish survey captured 244 Dolly Varden in 30 minnow traps within the same 50-m reach at Upper Greens Creek Site 48 as sampled in 2002 and 2003. Three "block" traps were set downstream of this reach, and one upstream; they captured 15 additional Dolly Varden that are not included in the reported results. The estimated 2004 population size for the reach, based on a 3-pass removal, was 255 Dolly Varden with an approximate density of 0.9 fish/m^2. This was significantly less than in 2003 but more than in 2001 and 2002 (Table 4, Appendix 4). Density estimates in 2004 and 2003 were similar to each other and considerably more than those for 2001 and 2002.

Table 4. 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	0.2
2002	DV	126	45-160*	145 (134, 173)	50	0.2
2003	DV	285	54-180	333 (305, 361)	50	0.9**
2004	DV	244	54-158	255 (246, 264)	50	0.9

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

Fork lengths of captured Dolly Varden represent 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 four years of biomonitoring.

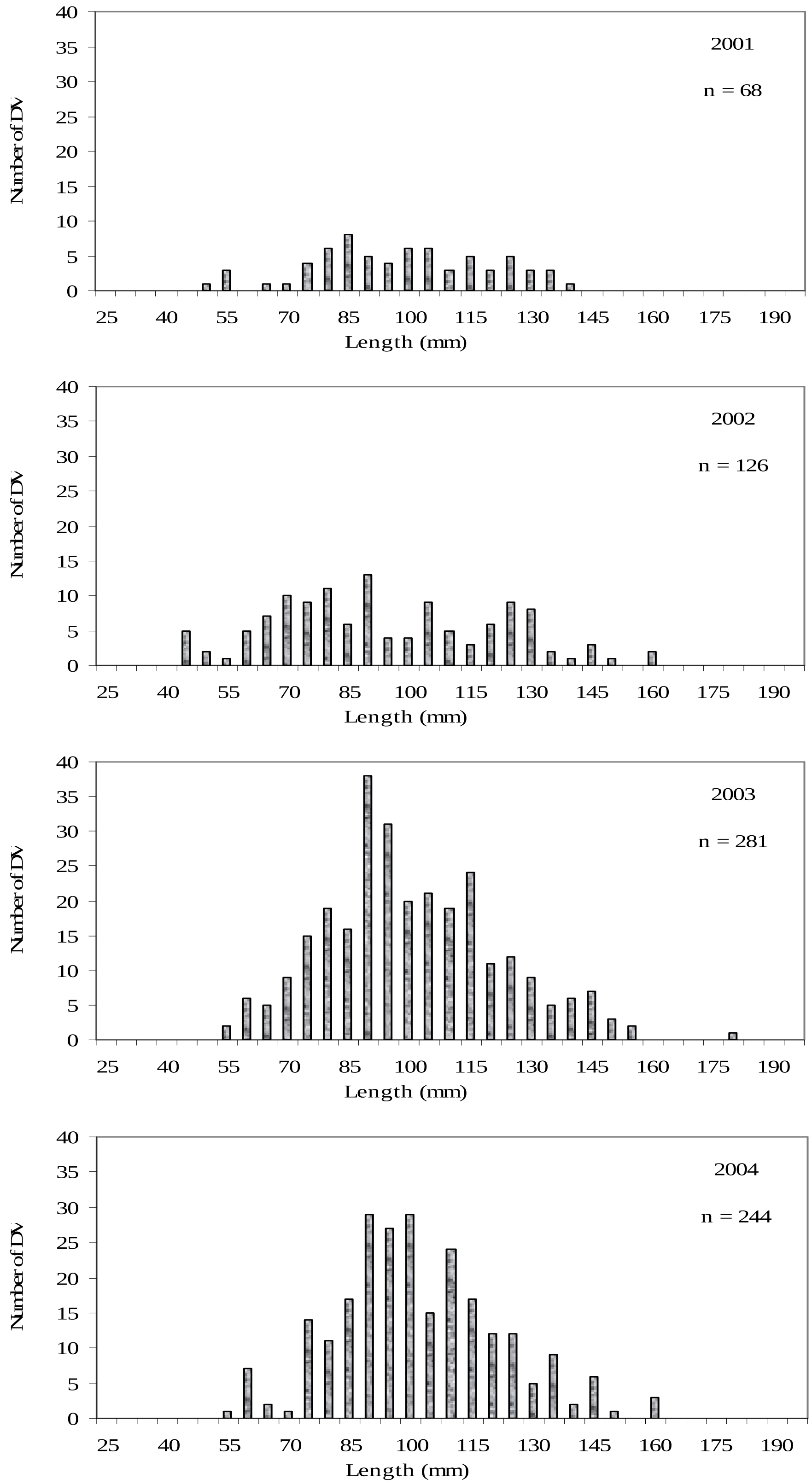

Figure 8. Dolly Varden captured at Upper Greens Creek Site 48 in 2001 through 2004.

Metals Concentrations in Juvenile Fish

Concentrations of metals in Upper Greens Creek Site 48 juvenile Dolly Varden tissues in 2004 were similar to or less than those found in samples from the previous three years of biomonitoring at this site (Figure 9, Appendix 5). For comparison testing, silver concentrations reported as not detected were assumed to be at the detection level of 0.02 mg Ag/kg. Concentrations of silver in 2004 were significantly less than in 2002. The mean rank scores for cadmium, copper, lead, selenium, and zinc concentrations in 2004 were not significantly different ($\alpha > 0.1$) from those of previous years.

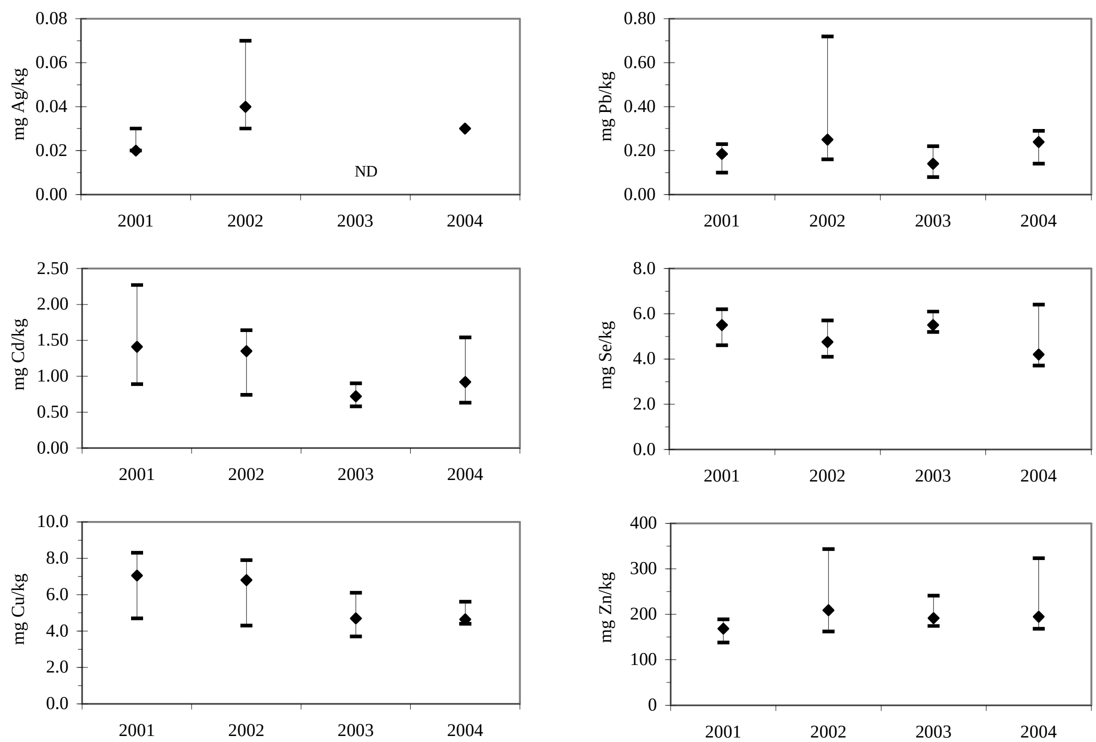

Figure 9. Whole body metals concentrations (medians and ranges) in Dolly Varden captured each year at Upper Greens Creek Site 48 in 2001 through 2004. ND = Not Detected at detection level of 0.02 mg Ag/kg.

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.

GREENS CREEK BELOW POND D SITE 54

Greens Creek Below Pond D Site 54 (Figure 10) was sampled in the afternoon of 21 July 2004. The weather was generally overcast, with some showers; water temperature was 11°C. The next morning, benthic invertebrate sampling was completed at this site, and the water temperature was 10°C.

Figure 10. Greens Creek Below Pond D Site 54, 21 July 2004.

Periphyton Biomass

Concentrations of chlorophyll *a*, an estimate of periphyton biomass, in Greens Creek Below Pond D Site 54 were significantly different between years when 2001 through 2004 were taken together. The 2004 values were higher than and significantly different from those for 2001 and 2002; and lower than but not significantly different from those for 2003. The Box and Whisker output plot from Statistix is shown in Figure 11. Differences noted among the four years sampled followed a similar pattern to, but were 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.

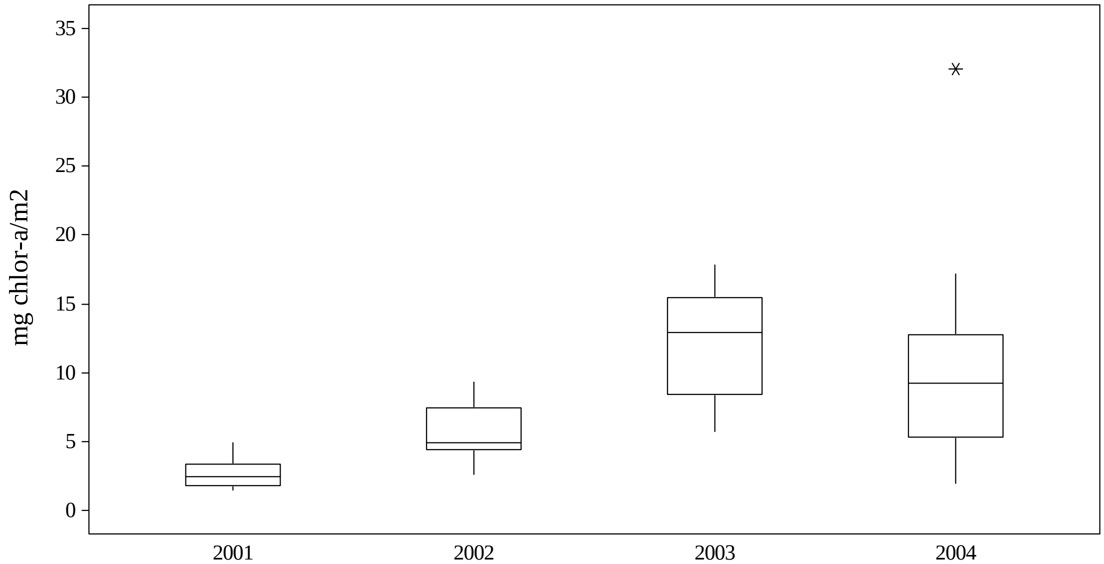

Figure 11. Estimated periphyton biomass densities at Greens Creek Below Pond D Site 54 in 2001 through 2004. Box encompasses middle half of data; horizontal line is median value. One possible outlier value (*) was identified in the 2004 data set.

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).

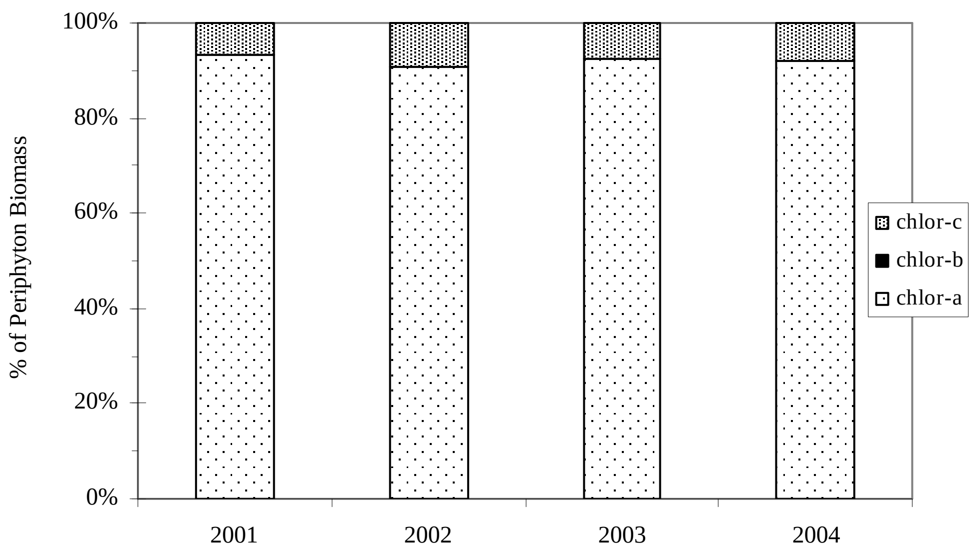

Figure 12. Proportions of chlorophylls *a*, *b*, and *c* in Greens Creek Below Pond D Site 54 samples in 2001 through 2004.

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.

Benthic Macroinvertebrates

The density of benthic macroinvertebrates in Greens Creek Below Pond D Site 54 samples in 2004 was lower than in 2003 and higher than in 2001 and 2002, but not significantly so ($\alpha > 0.10$; Table 5, Figure 13). Taxonomic richness was similar during the four years sampled. In 2004, we collected and identified more aquatic taxa than the other three years, trending more than in 2002.

Table 5. Summary of benthic macroinvertebrate samples at Greens Creek Below Pond D Site 54 in 2001 through 2004.

Year	**Mean Density** aquatic invert/m^2	**Taxonomic Richness**	**Mean Taxa Per Sample**
2001	3564	28	15.2
2002	2932	30	13.8
2003	4670	26	16.2
2004	3934	31	19.0

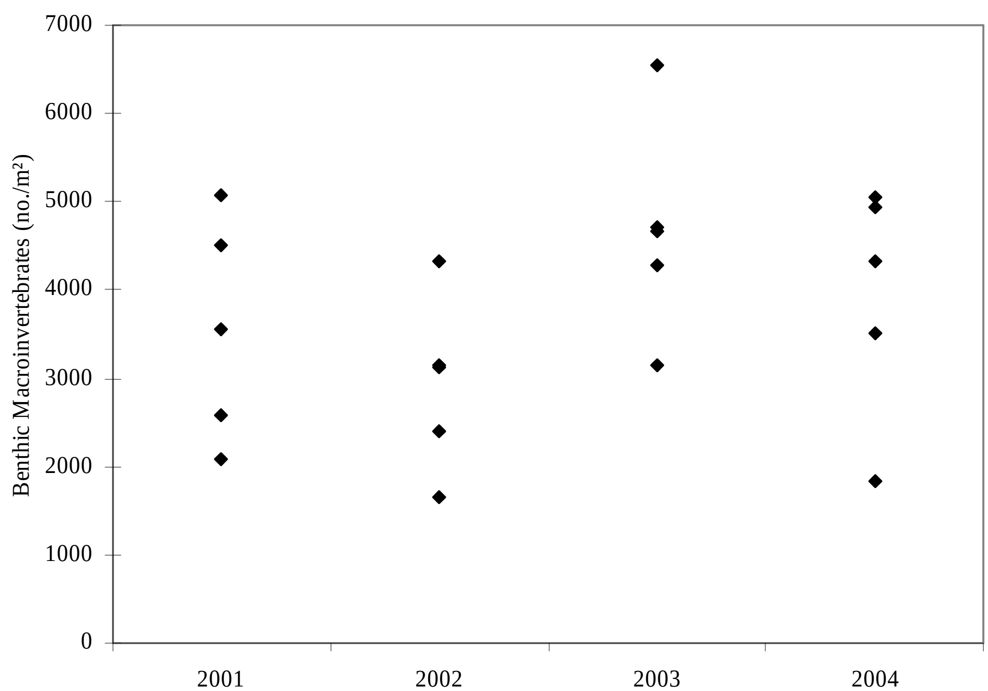

Figure 13. Density of benthic macroinvertebrates (n = 5 samples each year) at Greens Creek Below Pond D Site 54 in 2001 through 2004.

Invertebrate communities in Greens Creek Site 54 continued to be dominated by EPT taxa (Figure 14). In each of four years sampled, Ephemeroptera were the most commonly collected order (Figure 15). In 2004, the Ephemeroptera were dominated by Baetidae: *Baetis,* Ephemerella: *Drunella*, and Heptageniidae: *Cinygumula* ("moderately sensitive"; Barbour et al. 1999), *Epeorus,* and *Rhithrogena*. The dominance of the benthic macroinvertebrate community by these pollution-sensitive taxa (Table 6), combined with the mixture of many species of mayflies, stoneflies, caddisflies, and true flies (Appendix 3) suggests a complex and healthy aquatic ecosystem at this site.

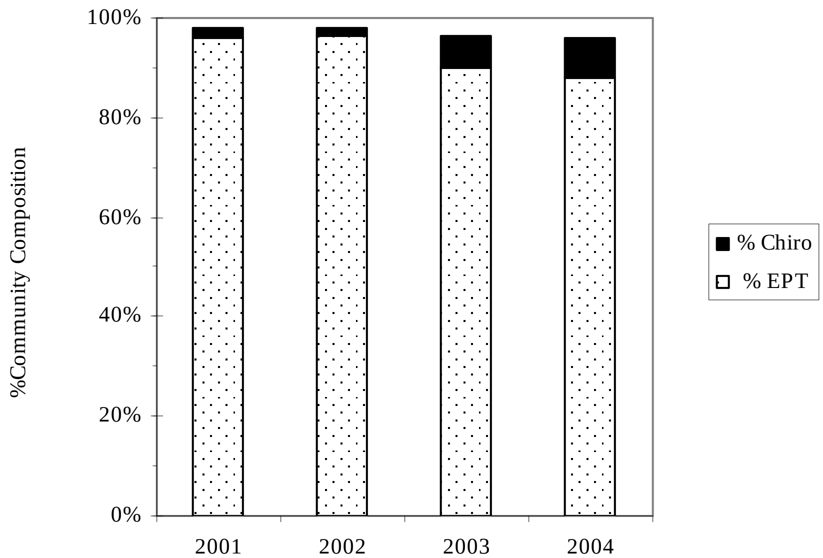

Figure 14. Proportions of EPT taxa and Chironomidae in Greens Creek Below Pond D Site 54 samples in 2001 through 2004.

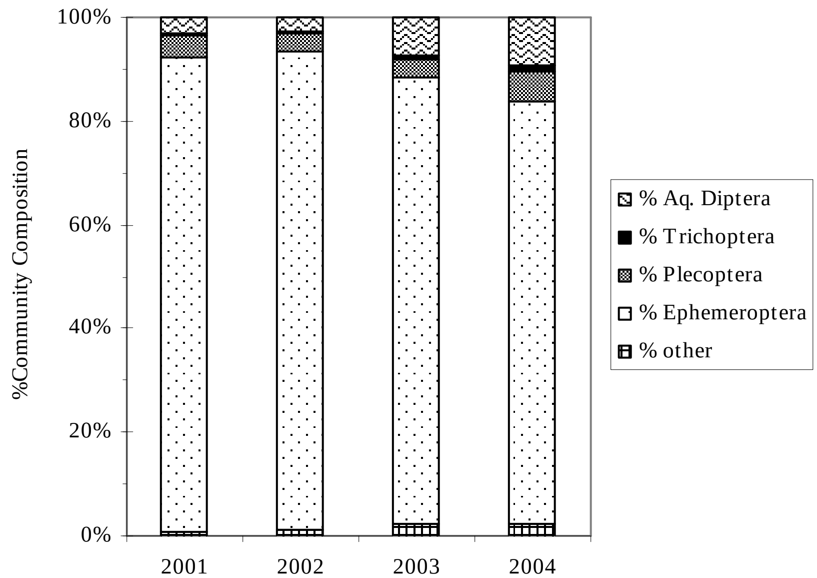

Figure 15. Community composition of benthic macroinvertebrates at Greens Creek Below Pond D Site 54 in 2001 through 2004.

Table 6. Common taxa (>5% of invertebrates found in samples) at Greens Creek Below Pond D Site 54 in 2001 through 2004.

Order	**Family**	**Genus**	**2001**	**2002**	**2003**	**2004**
Ephemeroptera	Baetidae	*Baetis*	14%	15%	9%	15%
	Ephemerellidae	*Drunella*	7%	19%	38%	38%
	Heptageniidae	*Cinygmula*	18%	5%	8%	6%
		Epeorus	53%	43%	17%	12%
		Rhithrogena		10%	13%	9%
Diptera	Chironomidae				6%	8%

Juvenile Fish Populations

The 2004 juvenile fish survey at Greens Creek Below Pond D Site 54 captured 24 coho salmon and 201 Dolly Varden in 30 minnow traps in the same 28-m reach as sampled in the three previous years (Table 7). Two "block" traps each were used immediately downstream and upstream of the sample reach, capturing an additional coho salmon and 33 Dolly Varden that are not included in the reported results. The estimated population of juvenile coho salmon in the Greens Creek Below Pond D Site 54 sample reach in 2004 was significantly higher than in 2001 and 2003, and higher but not significantly so than in 2002 (Table 7, Appendix 4). The estimated populations of Dolly Varden were much larger than those for coho each of the years sampled but showed a different trend, with significantly fewer fish in 2004 than in 2002 and 2003, and significantly more fish in 2004 than in 2001.

Table 7. 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**
2004	DV	201	52-161	234 (211, 257)	28	1.6
2001	CO	---	---	Too few fish	28	---
2002	CO	21	55-85	21 (21, 21)	28	0.07
2003	CO	8	44-52	8 (8, 8)	28	0.04**
2004	CO	24	70-95	31 (20, 42)	28	0.2

* 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 wide range of size classes shown in the length frequency plots (Figure 16) suggest that multiple age classes of Dolly Varden were captured in all four years of biomonitoring.

Juvenile coho salmon caught at the Greens Creek Below Pond D Site 54 in 2002, 2003, and 2004 appear to come from a single age class (Figure 17). The USFS reported too few coho juveniles captured in 2001 for meaningful length frequency analysis.

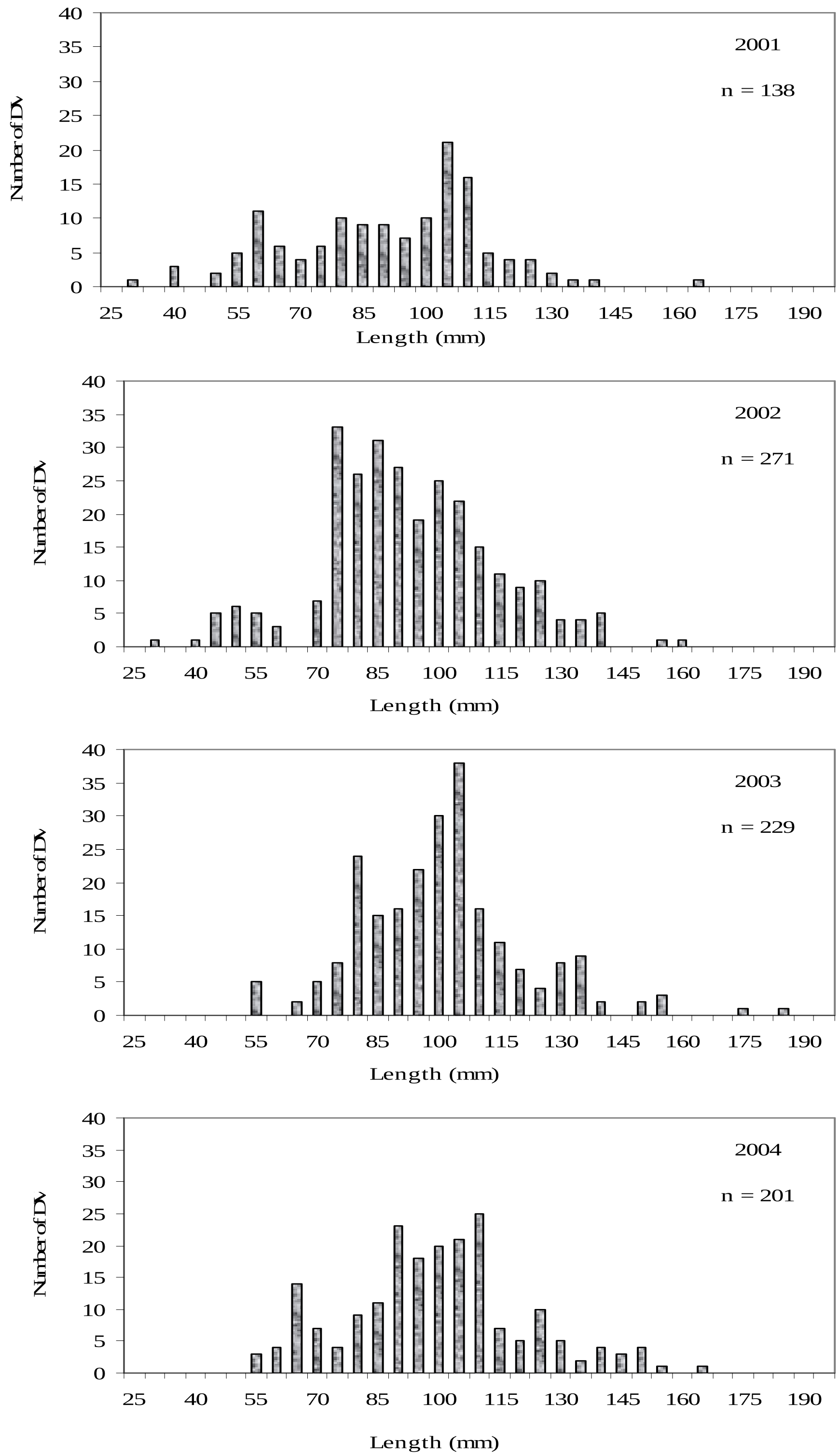

Figure 16. Dolly Varden captured at Greens Creek Below Pond D Site 54 in 2001 through 2004.

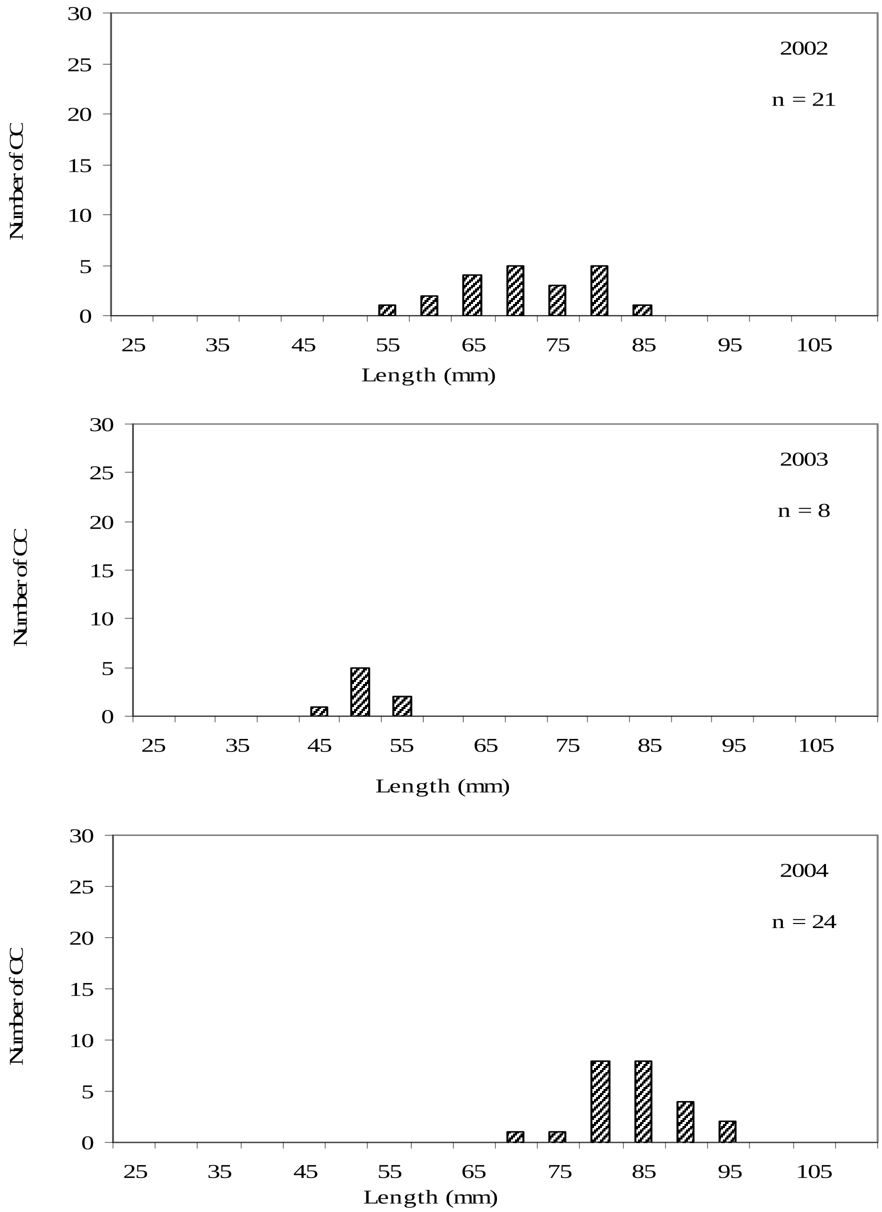

Figure 17. Juvenile coho salmon captured at Greens Creek Below Pond D Site 54 in 2002, 2003, and 2004. Too few coho captured in 2001 for length frequency plot.

Metals Concentrations in Juvenile Fish

Concentrations of metals in juvenile Dolly Varden tissues at Greens Creek Below Pond D Site 54 in 2004 were similar to or less than those found in the previous four years' samples (Figure 18, Appendix 5). In 2004, concentrations of silver were significantly less than in 2002, and concentrations of lead were significantly less than in 2000. Concentrations in 2004 of cadmium, copper, selenium and zinc were not significantly different ($\alpha > 0.1$) from those in previous years.

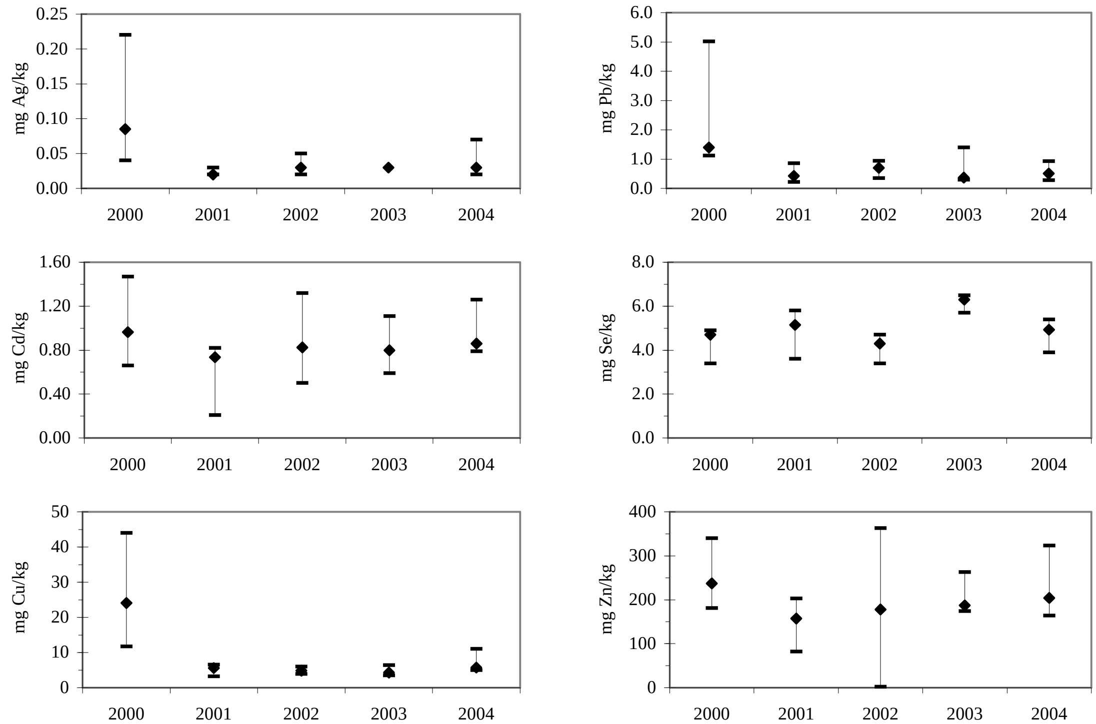

Figure 18. Whole body metals concentrations (medians and ranges) in fish captured at Greens Creek Below Pond D Site 54 in 2000 through 2004. The six fish sampled were coho salmon in 2000, and Dolly Varden in other years.

Summary

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

TRIBUTARY CREEK SITE 9

Tributary Creek Site 9 (Figure 19) was sampled in the morning of 21 July 2004. The weather was cloudy with rain showers, and the water temperature was 14°C.

Figure 19. Tributary Creek Site 9, 21 July 2004.

Periphyton Biomass

Concentrations of chlorophyll *a*, an estimate of periphyton biomass, at Tributary Creek Site 9 were significantly different ($\alpha = 0.07$) among the four years sampled. Biomass in 2004 was intermediate to that in 2001 and 2002; and less, but not significantly so, than in 2003. The Box and Whisker output plot from Statistix is shown in Figure 20. 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 2004 as it did in 2001 and 2003 (Figure 21). Although dominated by diatoms, the algal community at Tributary Creek Site 9 has a larger component of filamentous green algae and blue-green bacteria than has been found at either Greens Creek site.

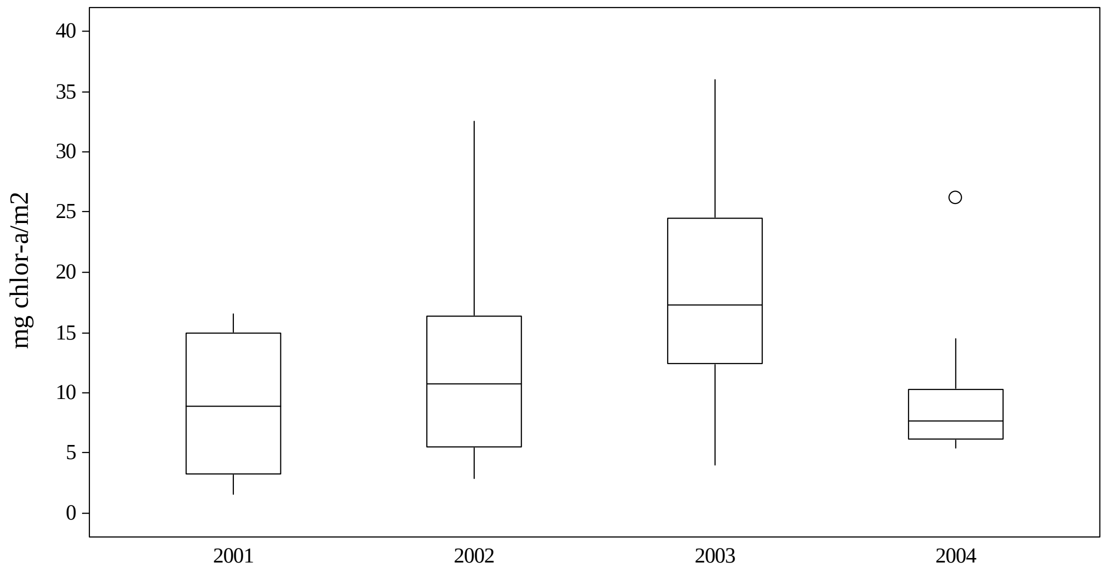

Figure 20. Estimated periphyton biomass densities at Tributary Creek Site 9 in 2001 through 2004. Box encompasses middle half of data; horizontal line is median value. One probable outlier value (o) was identified in the 2004 data set.

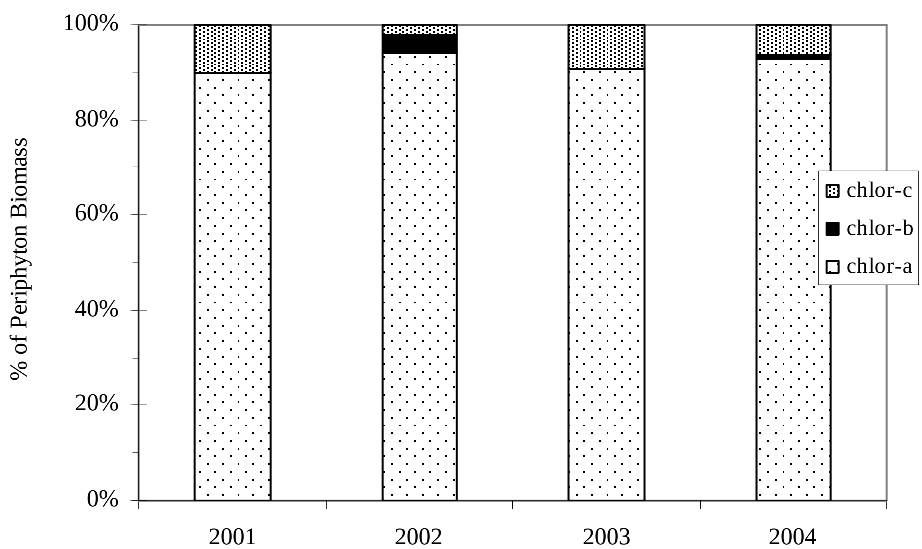

Figure 21. Proportions of chlorophylls *a*, *b*, and *c* in Tributary Creek Site 9 samples in 2001 through 2004.

Benthic Macroinvertebrates

The mean density of benthic macroinvertebrates in 2004 Tributary Creek Site 9 samples was lower than in 2003 and higher than in 2001 or 2002 (Table 8, Figure 22), but these differences were not significant because of the high variability of samples within each year. Taxonomic richness, as expressed by number of taxa in samples, showed a similar pattern in that 2004 and

2002 values were intermediate between 2003's high and 2001's low values. The taxonomic richness in 2004 samples trended less than that in the 2003 samples.

Table 8. Summary of benthic macroinvertebrate samples at Tributary Creek Site 9 in 2001 through 2004.

Year	**Mean Density** aquatic invert/m^2	**Taxonomic Richness**	**Mean Taxa Per Sample**
2001	1018	21	13.6
2002	1496	24	15.2
2003	5032	36	21.0
2004	2064	26	13.8

The EPT taxa are the majority component of the Tributary Creek Site 9 benthic macroinvertebrate community although not as dominant as at the Greens Creek sites, while Chironomidae remain a relatively small, stable component at the Tributary Creek site (Figure 23).

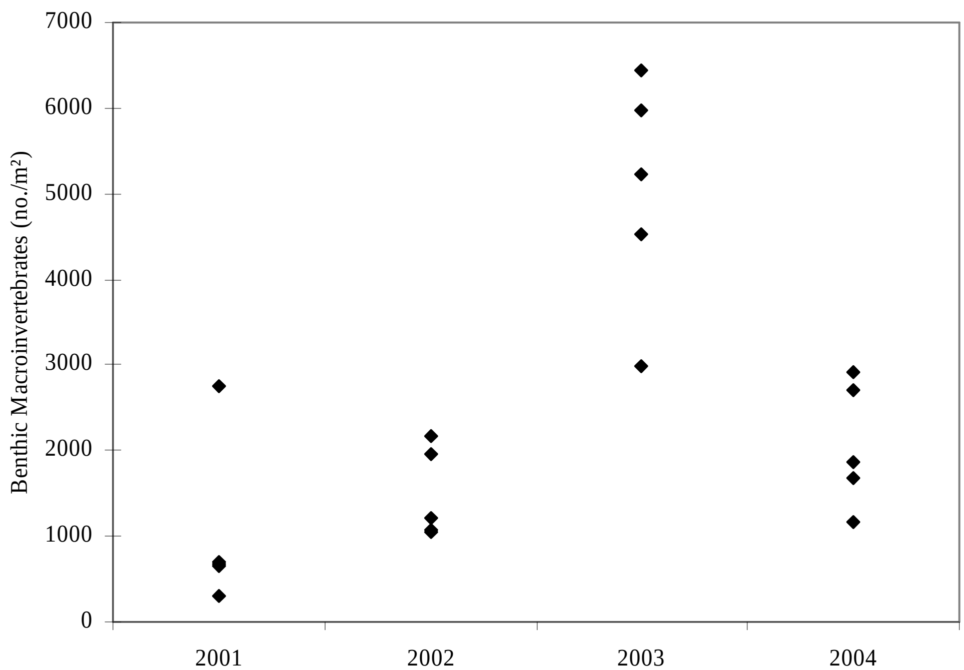

Figure 22. Density of benthic macroinvertebrates (n = 5 samples each year) at Tributary Creek Site 9 in 2001 through 2004.

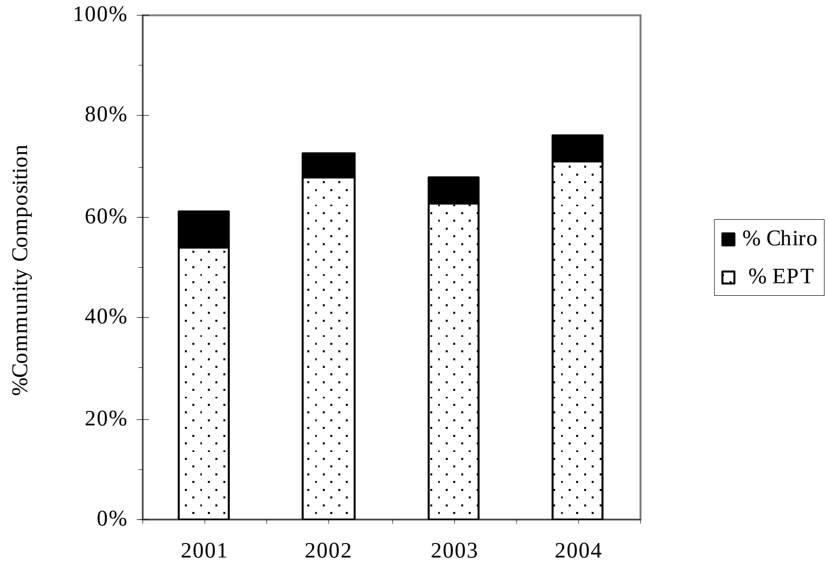

Figure 23. Proportions of EPT taxa and Chironomidae in Tributary Creek Site 9 samples in 2001 through 2004.

Unlike previous years of sampling at Tributary Creek Site 9, and more like Greens Creek Sites 54 and 48 samples, a few invertebrate taxa compose more than half of the benthic macroinvertebrate community (Table 9).

Table 9. Common taxa (>5% of invertebrates found in samples) at Tributary Creek Site 9 in 2001 through 2004.

Order	**Family**	**Genus**	**2001**	**2002**	**2003**	**2004**
Ephemeroptera	Baetidae	*Baetis*	8%	16%	6%	
	Heptageniidae	*Cinygmula*	17%	24%	20%	5%
	Leptophlebiidae	*Paraleptophlebia*	13%	13%	10%	43%
Plecoptera	Chloroperlidae	*Suwallia*	7%			
		Sweltsa		6%		
		Neaviperla			7%	
	Nemouridae	*Zapada*			15%	
Diptera	Chironomidae		7%			5%
	Simuliidae	*Simulium*	8%			
Acarina				6%		
Oligochaeta			8%		14%	11%
Ostracoda			18%		8%	
Isopoda	Gammaride	*Gammarus*		14%		

Pollution-sensitive taxa, such as the mayflies *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 diverse benthic macroinvertebrate community at Tributary Creek Site 9 included such non-insects as springtails (Collembola), worms (Oligochaeta), mites (Acarina), and seed shrimp (Ostracoda) (Appendix 3).

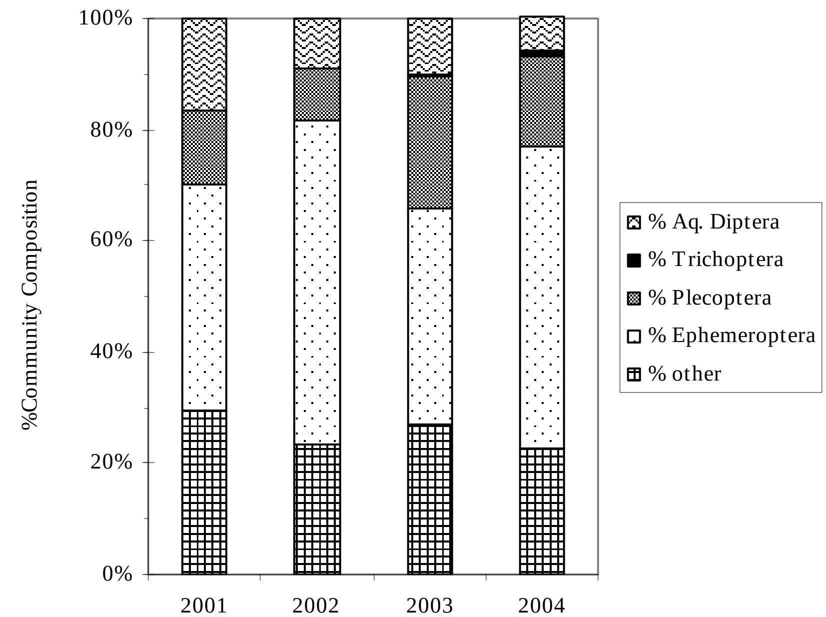

Figure 24. Community composition of benthic macroinvertebrates at Tributary Creek Site 9 in 2001 through 2004.

Juvenile Fish Populations

The 2004 juvenile fish survey in Tributary Creek Site 9 captured 27 coho salmon, 32 Dolly Varden, four rainbow trout, one cutthroat trout, and two sculpin in 20 minnow traps in the same 50-m sample reach as sampled in 2002 and 2003. Two "block" traps each were used immediately downstream and upstream of the sample reach, capturing an additional three coho salmon, eight Dolly Varden, and one sculpin that are not included in the reported results. Estimates of the Dolly Varden population were significantly lower in 2004 than in 2001 and 2002 but significantly higher than in 2003. Coho salmon population estimates were significantly lower in 2004 than in previous years (Table 10, Appendix 4). The effect of limitations on available habitat due to low or fluctuating 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), and was essentially the same as found in 2003.

The range of fork lengths measured in both Dolly Varden and coho salmon captured at Tributary Creek Site 9 in 2004 suggest use by multiple age classes of both species (Figures 25 and 26).

Table 10. 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	0.6
2002	DV	51	38-147	57 (53, 76)	50	0.5
2003	DV	19	54-114	20 (17, 23)	50	0.3**
2004	DV	32	64-109	33 (31, 35)	50	0.6
2001	CO	118	40-105*	120 (119, 128)	44	0.9
2002	CO	44	27-85	46 (45, 57)	50	0.4
2003	CO	52	46-88	53 (51, 55)	50	0.8**
2004	CO	27	40-94	27 (27, 27)	50	0.5

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

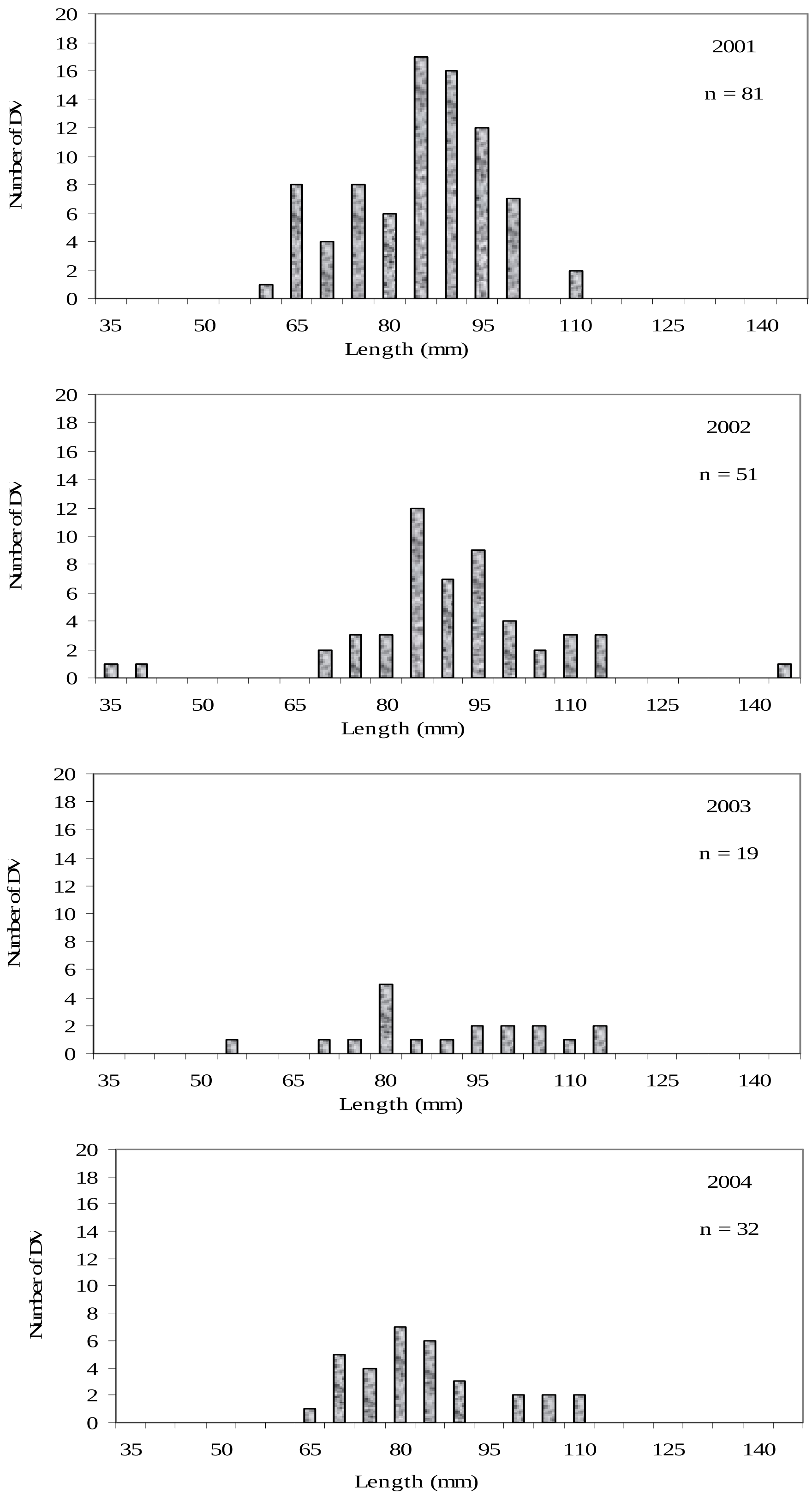

Figure 25. Dolly Varden captured at Tributary Creek Site 9 in 2001 through 2004.

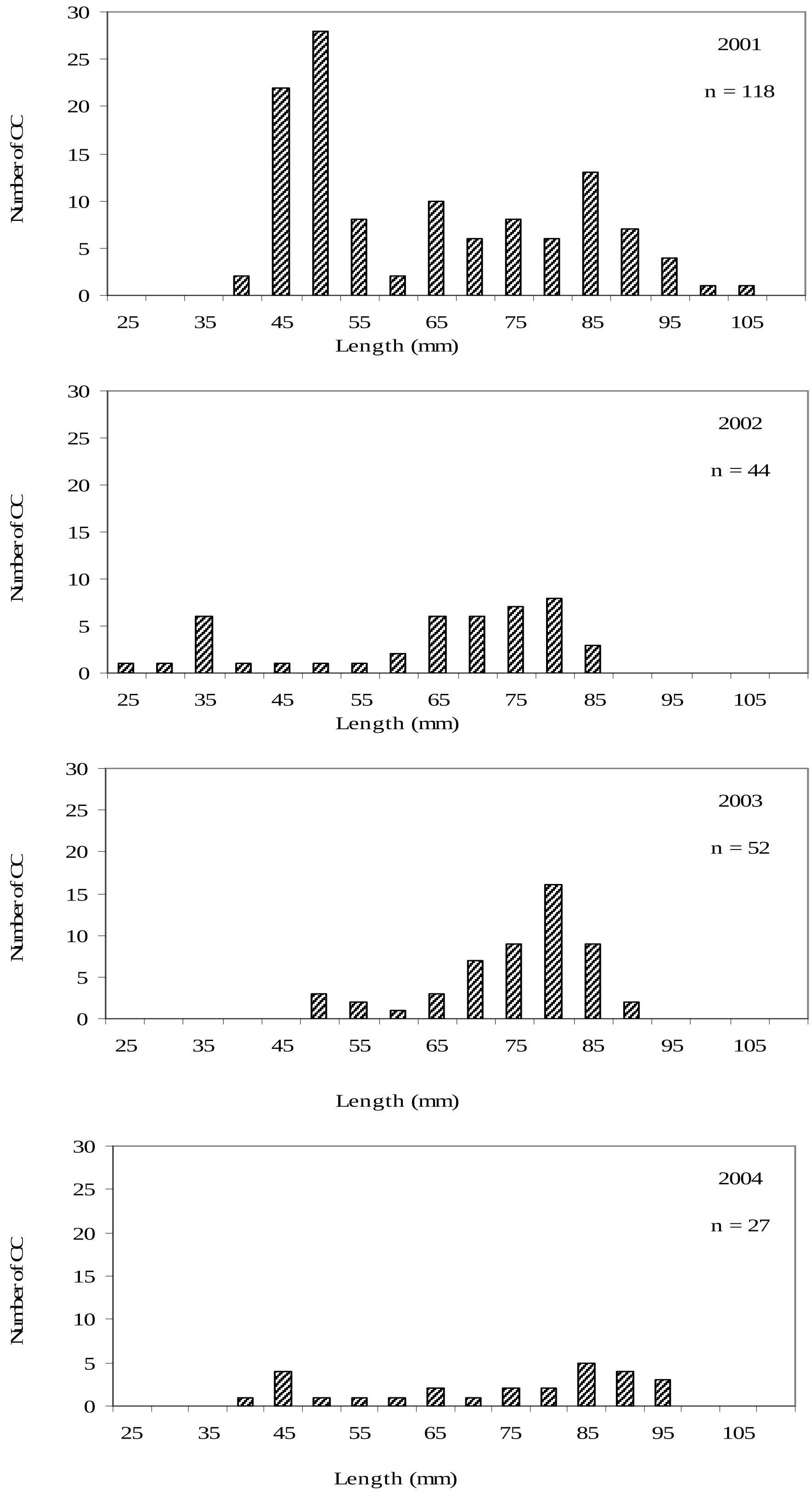

Figure 26. Coho salmon captured at Tributary Creek Site 9 in 2001 through 2004.

Metals Concentrations in Juvenile Fish

Concentrations of metals in juvenile Dolly Varden tissues from Tributary Creek Site 9 were generally similar to or less than those found in previous years' samples (Figure 27, Appendix 5). Concentrations of copper in 2004 samples were significant less than the concentrations in 2000, while concentrations in 2004 samples trended slightly higher for cadmium and selenium than did those in 2000. Concentrations of silver, lead, and zinc were not significantly different ($\alpha > 0.1$) between years

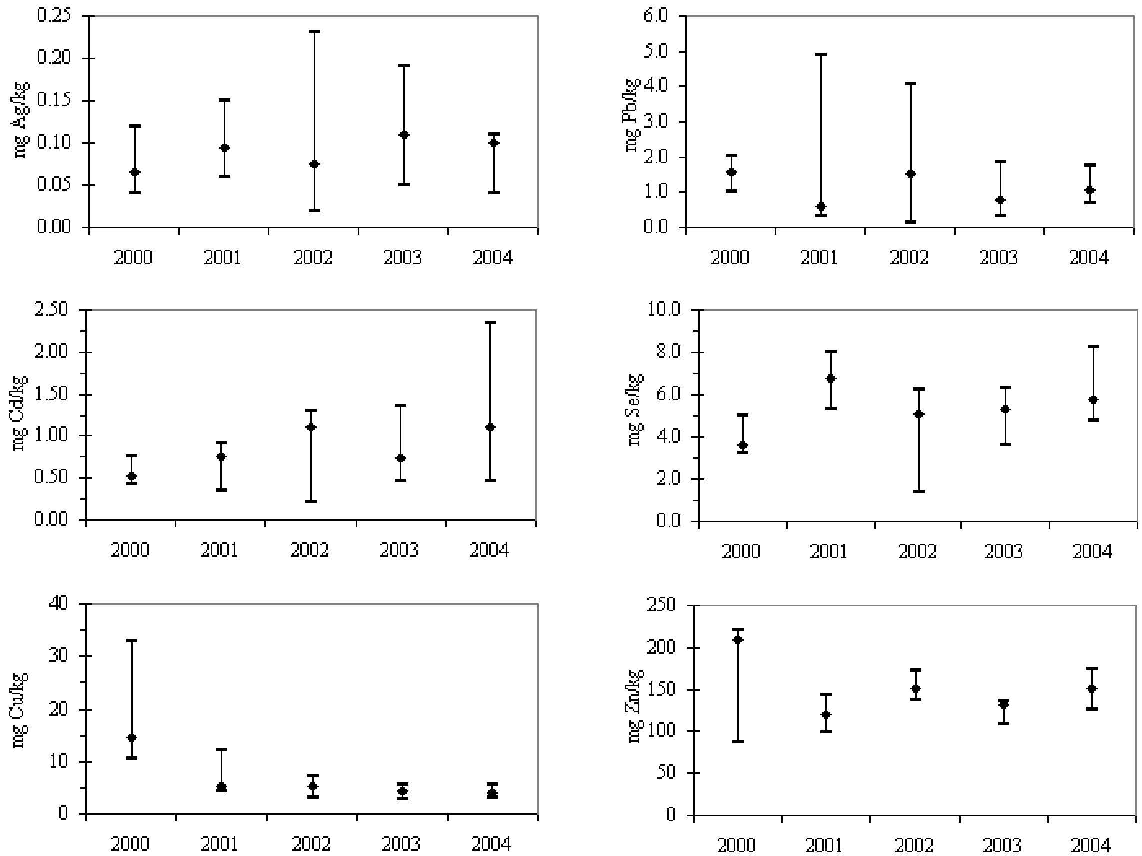

Figure 27. Whole body metals concentrations (medians and ranges) in fish captured at Tributary Creek Site 9 in 2000 through 2004. The six fish sampled each year were Dolly Varden except for two coho salmon in 2000.

Summary

The abundant periphyton, abundance of pollution-sensitive invertebrate species, and relatively 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 at each of the three sites has shown a similar pattern over the four years sampled: an increase each year from 2001 through 2003, then a decrease in 2004 to a level still higher than that observed in 2001. Chlorophyll *a* concentrations were not significantly different among sites in 2004. Taking the three sites together, the 2004 periphyton biomass values were significantly higher than the 2001 values, but not significantly different from 2002 or 2003 (Figure 28).

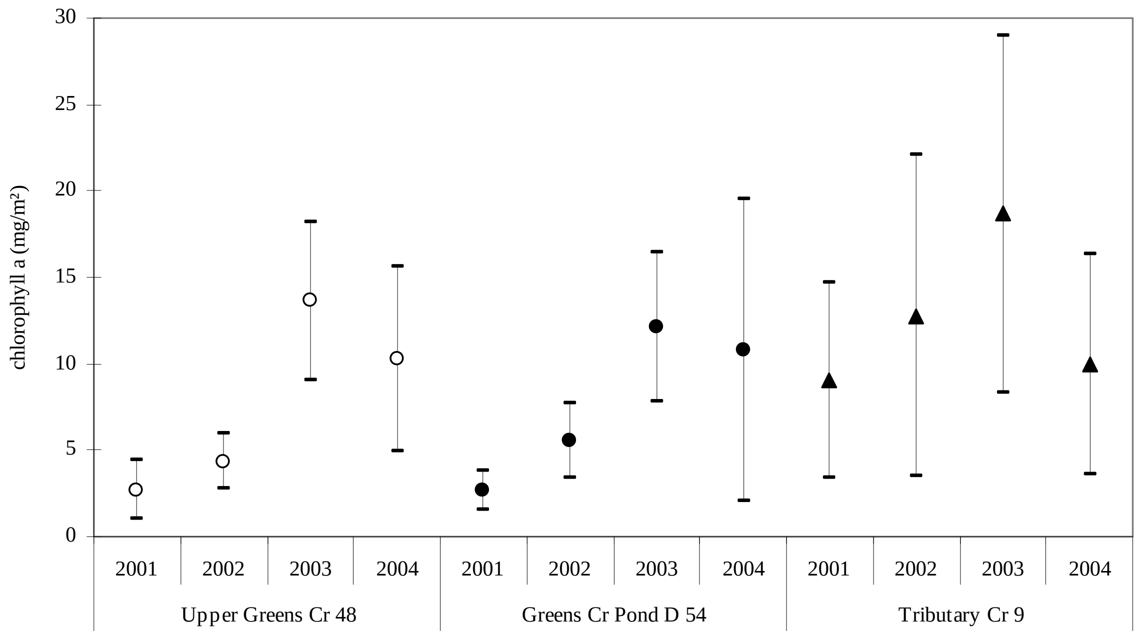

Figure 28. Comparison of estimated periphyton biomass (medians and ranges) among biomonitoring sites sampled in 2001 through 2004.

There were no major differences in community composition of the periphyton sampled at the Greens Creek and Tributary Creek sites in 2004 (Figure 29). No significant differences in chlorophyll *a* or chlorophyll *c* abundances were found between the sites; Tributary Creek Site 9 had a significantly higher, although comparatively minor, level of chlorophyll *b*.

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. Diatoms play an important role in primary production in aquatic systems, and measurable quantities of chlorophyll *c* indicate the importance of diatoms in the community.

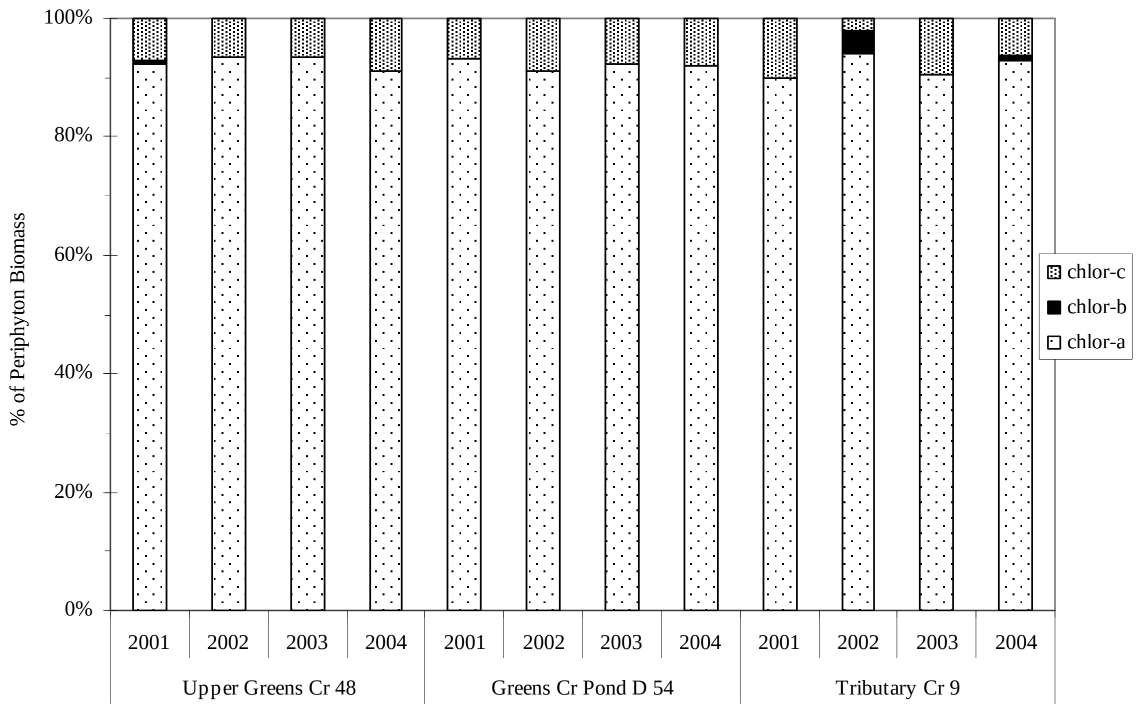

Figure 29. Comparison of proportions of chlorophylls *a*, *b*, *c* among sites in 2001 through 2004.

In the 2001 Upper Greens Creek Site 48, and 2002 and 2004 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 bacteria 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

Benthic macroinvertebrate densities trended lower in samples from all sites in 2004 than in 2003 (Figure 30). Greens Creek Below Pond D Site 54 had significantly higher invertebrate densities than did Tributary Creek Site 9, although neither was significantly different than Upper Greens Creek Site 48. This follows the same pattern as seen for periphyton biomass in 2004.

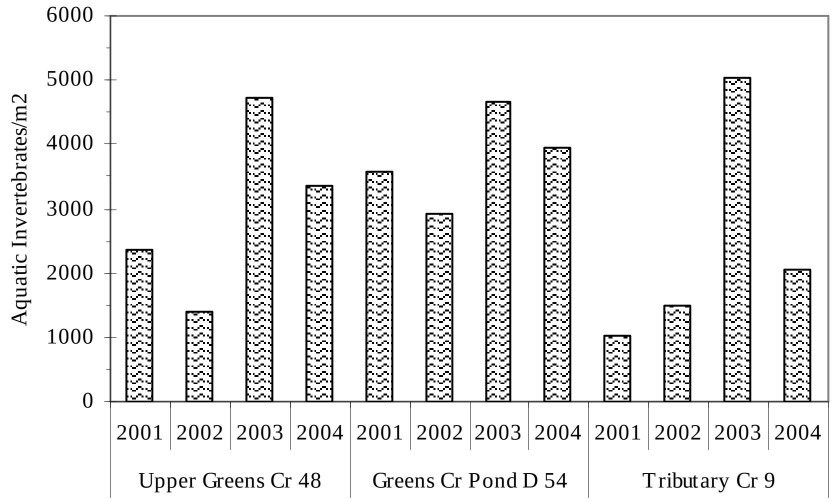

Figure 30. Comparison of benthic macroinvertebrate density among sites in 2001 through 2004.

All three of the biomonitoring sites had complex invertebrate communities with abundant numbers of taxa (taxonomic richness) per sample (Figure 31). More than 50% of the invertebrates in samples from Greens Creek sites 54 and Tributary Creek Site 9 were from two dominant taxa, while three dominant taxa accounted for more than 50% of the invertebrates in samples from Upper Greens Creek Site 48 (Figure 32). The number of taxa in all sites taken together in 2004 trended higher than in 2002, but was not significantly different from the higher number of taxa in 2003 or the lower number in 2001. Differences in the structure of these communities likely reflect differences in channel morphology, influences of tributaries, 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 fewer taxa in these sites may be a result of perturbations due to variations in stream flows and rapid re-colonization during relatively stable water levels.

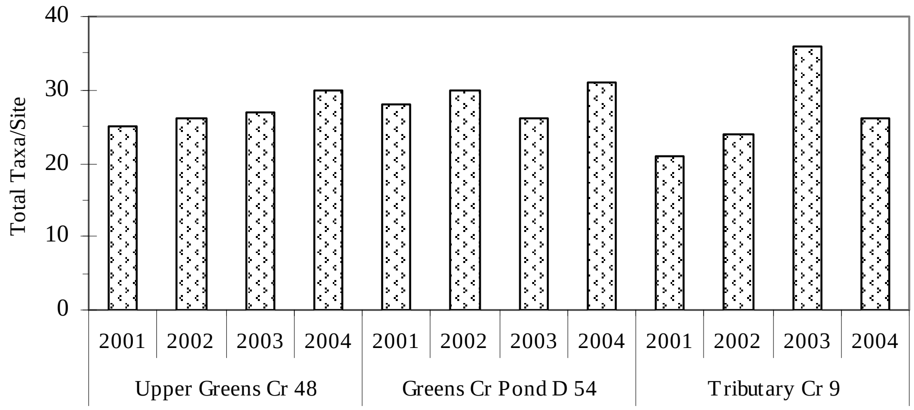

Figure 31. Comparison of benthic macroinvertebrate taxonomic richness among sites in 2001 through 2004.

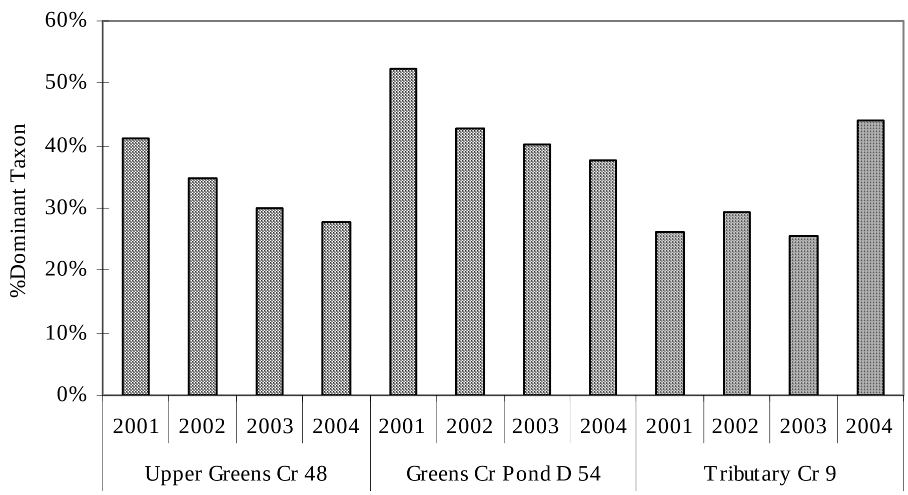

Figure 32. Comparison of benthic macroinvertebrate percent dominant taxa metric among sites in 2001 through 2004.

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 in each of the four years sampled (Figure 33), and much higher than the percent of Chironomidae. The percent of Chironomidae has been relatively constant at the Tributary Creek site but slowly increasing at both Greens Creek sites.

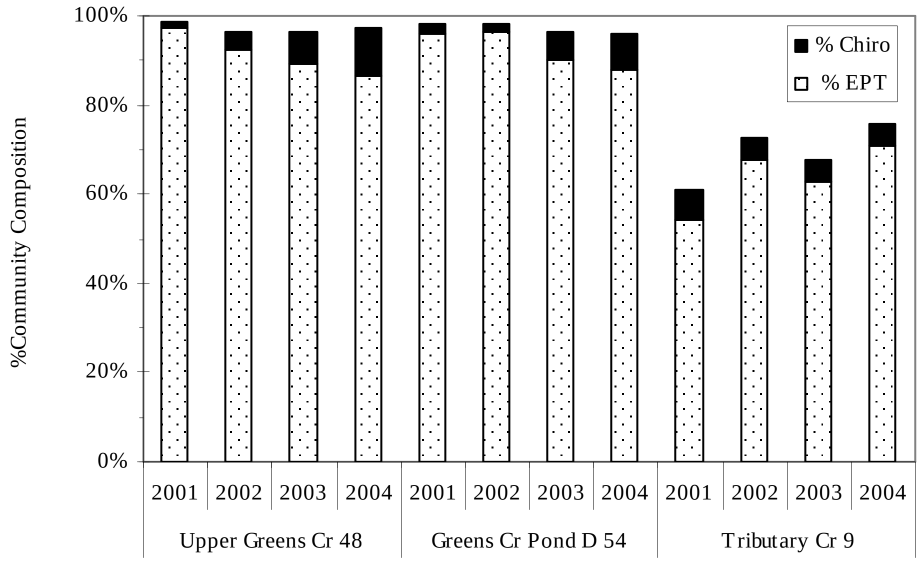

Figure 33. Comparison of proportions of EPT taxa and Chironomidae among sites in 2001 through 2004.

Benthic macroinvertebrate 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 the Greens Creek sites. This difference is likely due to differences in physical characteristics of the stream systems.

Density and taxonomic richness showed all three communities to be well-developed, complex communities with abundant benthic macroinvertebrate populations. 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 continue to 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 benthic macroinvertebrates.

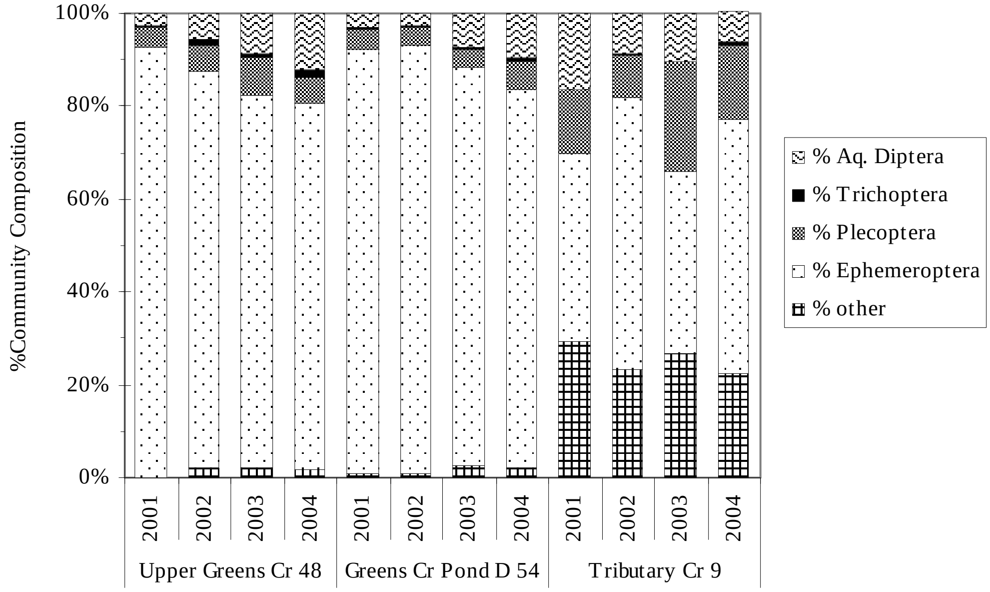

Figure 34. Comparison of community composition of benthic macroinvertebrates among sites in 2001 through 2004.

Juvenile Fish Populations

All three biomonitoring sites supported relatively abundant fish populations in 2004 for the stream types and locations (Paustian et al. 1990). Both Greens Creek sites had population estimates within the range of values seen the previous three years and lower than the high values from 2003. Estimates of fish abundance at Tributary Creek Site 9 appeared to continue the trend toward lower abundance of Dolly Varden and coho salmon; the difference was slight but significant between 2003 and 2004 (Figure 35, Appendix 4).

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 11. Using this metric, the 2004 productivity of Tributary Creek Site 9 was intermediate between the higher values for Greens Creek Below Pond D Site 54 and the lower values for Upper Greens Creek Site 48. Densities were at Upper Greens Creek Site 48 may be lower because it has resident fish only since anadromous fish access is limited by a weir downstream of the sample reach (Weber Scannell and Paustian 2002).

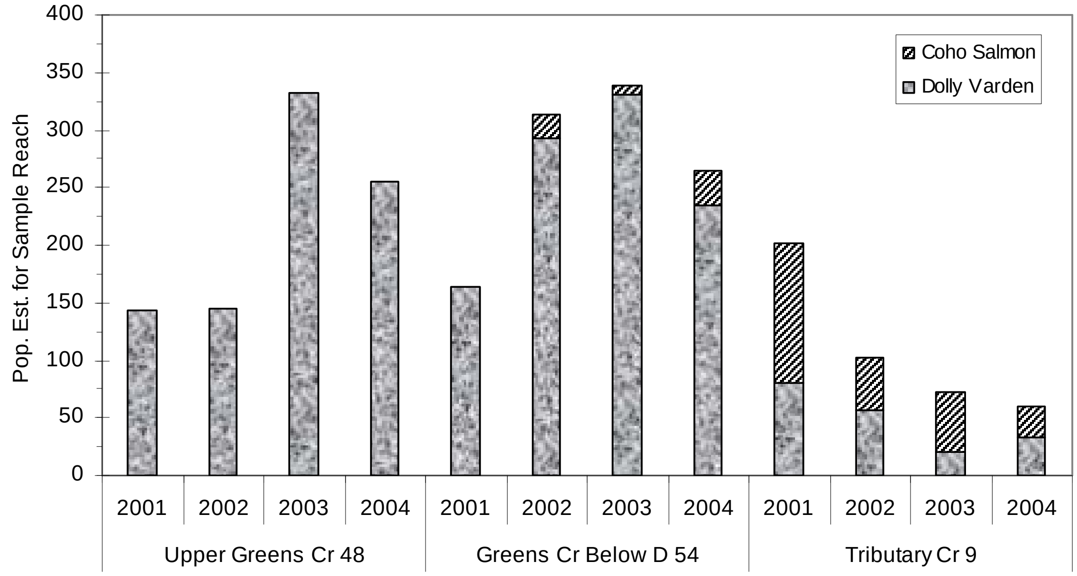

Figure 35. Population estimates for juvenile fish captured at Greens Creek Mine biomonitoring sites in 2001 through 2004.

Table 11. 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**
2004						
Number Fish Caught	*	244	24	201	27	32
Sample Reach, m	50	50	28	28	50	50
Population Estimate, fish	*	255	31	234	27	33
Density Est., fish/m^2	*	0.88	0.21	1.57	0.46	0.56

* 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

Tissues of Dolly Varden from Tributary Creek Site 9 had different metals concentration characteristics than did tissues from Dolly Varden at the two Greens Creek sites (48 and 54) in 2004, although a clear pattern is not apparent (Figure 36). Fish tissues from Tributary Creek had significantly higher concentrations of silver and significantly lower concentrations of zinc than did tissues from either Greens Creek site. Tributary Creek samples had significantly higher concentrations of lead than did Upper Greens Creek Site 48 samples, and significantly lower concentrations of copper than did Greens Creek Below Pond D Site 54. Tissue concentrations of cadmium and selenium were not significantly different ($\alpha > 0.1$) among the three sites in 2004.

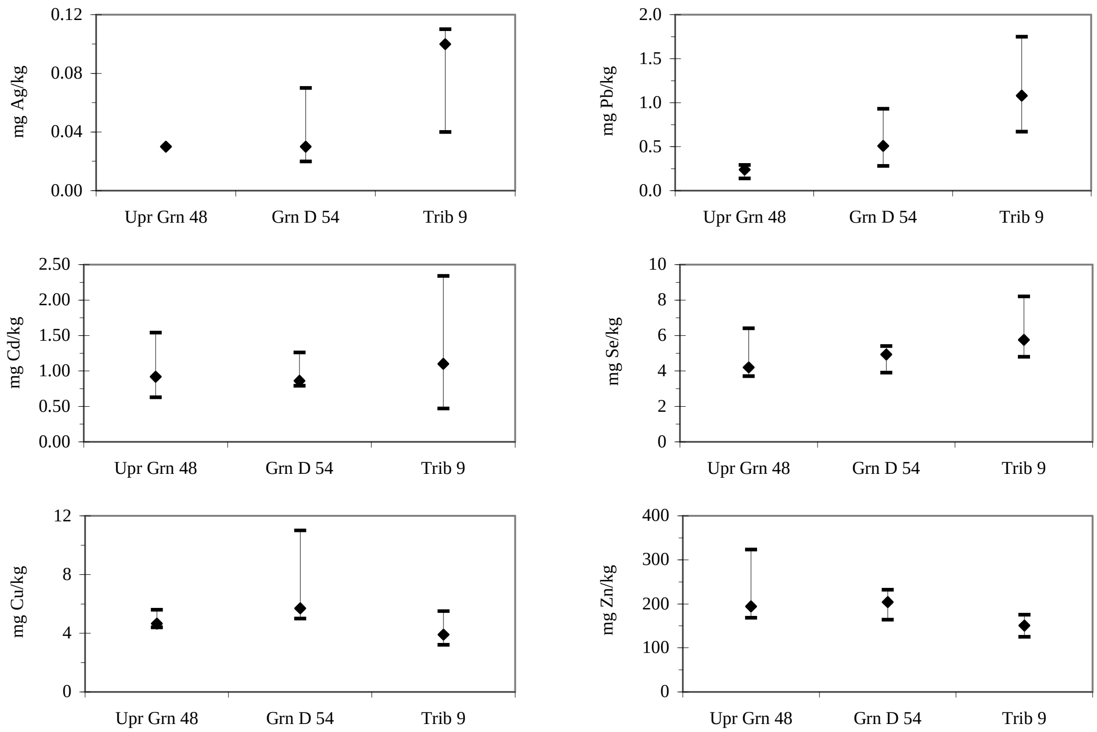

Figure 36. Comparison among sites of whole body metals concentrations (median, maximum, and minimum) in six Dolly Varden captured at each biomonitoring site in 2004. ND = Not Detected at detection level of 0.02 mg Ag/kg

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 dry tailings facility) continued to sustain abundant, diverse aquatic communities in 2004.

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 in 2004, significantly lower than in 2003, and intermediate in value to samples from 2001 and 2002.

The benthic macroinvertebrate communities were taxonomically rich and abundant in 2004, and the populations of many pollution-sensitive taxa were well represented. Benthic macroinvertebrate densities trended lower in 2004 than in 2003. Greens Creek Below Pond D Site 54 has significantly higher densities than did Tributary Creek Site 9. The percentage of benthic macroinvertebrates at both Greens Creek sites that were Chironomidae continued to increase slightly in 2004 compared to previous years.

Juvenile fish populations continue to be relatively abundant at each site, with multiple size classes of Dolly Varden present. Total fish captures were lower in 2004 than in 2003 at each site, and declined for the third year at Tributary Creek Site 9, but were higher than the regional average densities for each channel type. Moderately low water levels in summer 2004 decreased the wetted area available for fish habitat, particularly in Tributary Creek.

Whole body concentrations of metals in fish tissues were similar to 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 of water from the three biomonitoring sites was done in 2004.

Aquatic communities at the sampled sites have remained abundant and diverse. Differences between the Greens Creek and Tributary Creek sites were typically of larger amplitude than were differences between the control and below-mining sites. No indications of reduced productivity, community changes, or metals accumulation attributable to mine operations were noted.

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APPENDIX 1. USFS CHANNEL TYPE DESCRIPTIONS

Descriptions and definitions of channel types as developed by 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. PERIPHYTON BIOMASS DATA

Estimates of periphyton biomass as represented by chlorophyll concentrations (mg/m²).

	2001			2002			2003			2004		
mg/m²	chlor-a	chlor-b	chlor-c	chlor-a	chlor-b	chlor-c	chlor-a	chlor-b	chlor-c	chlor-a	chlor-b	chlor-c
Upper Greens Creek Site 48												
	1.9143	0.0121	0.1393	5.1650	0.0000	0.2948	14.4103	0.0000	1.2645	18.0492	0.0000	2.0334
	1.8257	0.0000	0.1830	4.0309	0.0000	0.2146	17.8250	0.0255	1.5659	6.7284	0.0000	0.6901
	5.6124	0.0000	0.6948	6.2095	0.0000	0.7130	8.4320	0.0890	0.3896	8.9712	0.0000	0.8982
	0.3127	0.0790	0.0582	2.8302	0.0000	0.2460	9.5307	0.0086	0.6354	12.8160	0.0000	1.4537
	2.9595	0.0375	0.3613	5.1572	0.0000	0.7548	11.3567	0.0000	0.7204	5.4468	0.0000	0.6233
	5.4420	0.0000	0.6166	6.3926	0.0000	0.7539	11.7638	0.0156	0.8633	20.3988	0.0000	2.1499
	3.3793	0.0000	0.4670	5.8430	0.0000	0.7291	24.0949	0.0000	2.1368	6.3012	0.0000	0.4491
	1.8669	0.0338	0.1460	2.0910	0.0722	0.2479	13.3054	0.1280	0.9883	11.6412	0.0000	1.3841
	2.6348	0.1374	0.1442	3.2026	0.0000	0.3583	11.5404	0.0000	0.5652	7.4760	0.0000	0.6511
	1.2286	0.0227	0.1649	2.5588	0.0000	0.1507	13.9690	0.0000	0.8948	5.2332	0.0000	0.5452
median	2.2746	0.0174	0.1740	4.5941	0.0000	0.3265	12.5346	0.0043	0.8790	8.2236	0.0000	0.7941
max	5.6124	0.1374	0.6948	6.3926	0.0722	0.7548	24.0949	0.1280	2.1368	20.3988	0.0000	2.1499
min	0.3127	0.0000	0.0582	2.0910	0.0000	0.1507	8.4320	0.0000	0.3896	5.2332	0.0000	0.4491
Middle Greens Creek Site 6												
	5.0689	0.0000	0.7004	---	---	---	---	---	---	---	---	---
	7.1544	0.0349	0.7218	---	---	---	---	---	---	---	---	---
	4.4715	0.0000	0.7804	---	---	---	---	---	---	---	---	---
	1.2695	0.0744	0.2259	---	---	---	---	---	---	---	---	---
	3.1962	0.0000	0.4260	---	---	---	---	---	---	---	---	---
	1.6426	0.0000	0.1421	---	---	---	---	---	---	---	---	---
	0.9033	0.1012	0.1440	---	---	---	---	---	---	---	---	---
	2.5114	0.0000	0.1574	---	---	---	---	---	---	---	---	---
	6.8816	0.0000	1.0188	---	---	---	---	---	---	---	---	---
	7.0238	0.0000	0.9988	---	---	---	---	---	---	---	---	---
median	3.8338	0.0000	0.5632	---	---	---	---	---	---	---	---	---
max	7.1544	0.1012	1.0188	---	---	---	---	---	---	---	---	---
min	0.9033	0.0000	0.1421	---	---	---	---	---	---	---	---	---
Greens Creek Below Pond D Site 54												
	1.5952	0.0065	0.1488	2.6468	0.0000	0.3031	13.2892	0.0000	1.0489	17.1948	0.0000	2.0177
	3.0952	0.0458	0.4090	9.3238	0.0000	1.0170	8.3547	0.0000	0.7884	9.7188	0.0000	0.9266
	3.6108	0.0000	0.2070	7.5189	0.0000	0.2386	14.8960	0.0000	1.4546	8.7576	0.0000	0.6740
	2.9660	0.0000	0.2936	4.2958	0.0000	0.3775	5.9381	0.0000	0.6177	32.0400	0.0000	3.6620
	1.8799	0.0000	0.0106	5.1517	0.0000	0.5282	15.5146	0.0000	1.7368	5.2332	0.0000	0.4232
	1.7783	0.0000	0.1897	2.9762	0.8652	1.2582	10.4992	0.0000	1.0601	3.7380	0.0000	0.3051
	4.9471	0.0000	0.2232	6.2634	0.0000	0.6386	5.7082	0.0000	0.3872	12.8160	0.0000	1.3488
	1.4594	0.0000	0.1011	4.6212	0.0000	0.3984	16.4246	0.0000	1.7150	1.9224	0.0310	0.0888
	1.6900	0.0000	0.1354	4.7095	0.0000	0.4528	12.6034	0.0000	1.0746	10.4664	0.0000	1.0866
	3.4750	0.0000	0.1594	8.0829	0.0000	0.7912	17.8620	0.0000	1.7483	5.9808	0.0000	0.5330
median	2.4229	0.0000	0.1745	4.9306	0.0000	0.4905	12.9463	0.0000	1.0673	9.2382	0.0000	0.8003
max	4.9471	0.0458	0.4090	9.3238	0.8652	1.2582	17.8620	0.0000	1.7483	32.0400	0.0310	3.6620
min	1.4594	0.0000	0.0106	2.6468	0.0000	0.2386	5.7082	0.0000	0.3872	1.9224	0.0000	0.0888
Tributary Creek Site 9												
	6.6232	0.0000	0.7882	8.9053	0.0000	0.5190	12.8934	0.0000	1.2610	9.3984	0.2240	0.8033
	11.1495	0.0000	1.2000	16.4332	0.9503	1.2761	8.5504	0.0000	0.7921	5.7672	0.0000	0.4226
	15.0542	0.0000	1.4721	12.6468	0.1735	0.0000	3.9770	0.0000	0.2889	5.4468	0.0000	0.4836
	16.5773	0.2339	1.5059	5.4410	0.4508	0.0725	12.2904	0.0000	1.1144	6.0876	0.0312	0.3827
	3.1491	0.0000	0.3346	23.7210	1.2053	0.8382	17.0873	0.0000	1.9158	14.5248	0.0213	1.3951
	2.5932	0.0643	0.2794	12.7457	0.4003	0.2162	17.4003	0.0000	1.8759	6.5148	0.1726	0.4038
	1.6081	0.0000	0.0134	32.5316	0.0000	1.8936	33.8710	0.0000	3.9766	10.3596	0.1349	0.7986
	6.6592	0.0000	0.4265	4.4025	1.4958	0.0000	24.5614	0.0000	2.4319	6.8352	0.0423	0.3638
	15.2098	0.8116	1.4358	2.9413	0.3005	0.1720	20.0201	0.0000	1.6884	26.1660	0.5112	2.6076
	11.5499	0.0000	1.5087	8.0068	1.4710	0.2746	36.0168	0.0000	3.8559	8.4372	0.2176	0.5308
median	8.9044	0.0000	0.9941	10.7761	0.4256	0.2454	17.2438	0.0000	1.7821	7.6362	0.0886	0.5072
max	16.5773	0.8116	1.5087	32.5316	1.4958	1.8936	36.0168	0.0000	3.9766	26.1660	0.5112	2.6076
min	1.6081	0.0000	0.0134	2.9413	0.0000	0.0000	3.9770	0.0000	0.2889	5.4468	0.0000	0.3638

APPENDIX 3. BENTHIC MACROINVERTEBRATE DATA

Numbers of benthic macroinvertebrates identified in Upper Greens Creek Site 48 samples.

Taxa			**2001**	**2002**	**2003**	**2004**
Order	**Family**	**Genus**				
Ephemeroptera	Baetidae	*Baetis*	309	152	445	390
	Ephemerellidae	*Caudatella*	2			
		Ephemerella			10	23
		Drunella	47	49	650	406
	Heptageniidae	*Cinygmula*	99	20	117	99
		Epeorus	444	190	384	209
		Rhithrogena	193	187	287	196
	Leptophlebiidae	*Paraleptophlebia*		1		
	Ameletidae	*Ameletus*			4	
Plecoptera	Capniidae	*Capnia*			82	
	Chloroperlidae	*Alloperla*	1	1		1
		Kathroperla			2	3
		Neaviperla			70	6
		Paraperla				6
		Plumiperla	5			5
		Suwallia	8	1		
		Sweltsa	1	4		
	Leuctridae	*Despaxia*		2		
		Paraleuctra	4	3	6	65
		Perlomyia		12		
	Nemouridae	*Podmosta*	7	5		2
		Zapada	23	4	30	7
	Perlodidae	*Isoperla*				1
		Megarcys			1	
		Skwala		9		
Trichoptera	Apataniidae	*Apatania*		1		
	Glossosomatidae	*Glossosoma*			2	16
	Hydropsychidae	*Arctopsyche*	2			
		Hydropsyche			1	
	Limnephilidae	*Onocosmoecus*			1	
	Rhyacophilidae	*Rhyacophila*	5	8	16	15
Coleoptera	Elmidae	*Narpus*				1
	Staphylinidae		1		6	
Diptera	Ceratopogonidae	*Dasyhelea*		1		
	Chironomidae		14	30	172	177
	Deuterophlebiidae	*Deuterophlebia*	2			1
	Empididae	*Chelifera*	1	2	5	1
		Oreogeton	3	2	22	11
	Psychodidae	*Psychoda*	1			
	Simuliidae	*Parasimulium*	2			
		Prosimulium	2			2
		Simulium	6	4		1

Numbers of benthic macroinvertebrates identified in Upper Greens Creek Site 48 samples (continued).

Order	**Family**	**Genus**	**2001**	**2002**	**2003**	**2004**
Diptera (cont.)	Tipulidae	*Antocha*			2	
		Dicranota			3	
		Tipula			2	6
Collembola	Onychiuridae	*Onychiurus*		1		
	Sminthuridae	*Dicyrtoma*	2			
Copepoda	Cyclopoida					1
Acarina				2	20	10
Oligochaeta				5	20	8
Gastropoda	Pelecypoda					1
Ostracoda				8	7	9

Numbers of benthic macroinvertebrates identified in Greens Creek Below Pond D Site 54 samples.

Taxa			**2001**	**2002**	**2003**	**2004**
Order	**Family**	**Genus**				
Ephemeroptera	Baetidae	*Baetis*	248	225	220	299
	Ephemerellidae	*Ephemerella*	2	6	6	47
		Drunella	118	280	894	742
	Heptageniidae	*Cinygmula*	319	75	176	112
		Epeorus	935	626	408	228
		Rhithrogena		140	306	173
	Leptophlebiidae	*Paraleptophlebia*	1		1	
	Ameletidae	*Ameletus*	4			
Plecoptera	Capniidae	*Capnia*			5	
	Chloroperlidae	*Alloperla*	3			1
		Kathroperla			2	2
		Neaviperla		14	22	26
		Paraperla			5	4
		Plumiperla	2			5
		Suwallia				2
		Sweltsa	6			
	Leuctridae	*Despaxia*				15
		Paraleuctra		4		18
		Perlomyia	13	3	19	33
	Nemouridae	*Podmosta*		7		
		Zapada	52	22	14	11
	Perlodidae	*Diura*	1			
		Isoperla	3			
		Skwala		3	15	
		Rickera		1		
Trichoptera	Glossosomatidae	*Glossosoma*				12
	Hydropsychidae	*Arctopsyche*		1		1
	Limnephilidae	*Psychoglypha*	1			
	Rhyacophilidae	*Rhyacophila*	6	5	12	6
Coleoptera	Elmidae	*Narpus*				3
	Staphylinidae		1	1		
Diptera	Chironomidae		33	27	149	148
	Deuterophlebiidae	*Deuterophlebia*		1	1	
	Dolichopodidae		2			
	Empididae	*Chelifera*	2			1
		Oreogeton	10	4	15	25
	Simuliidae	*Prosimulium*		1		5
		Simulium	3	3		
	Tipulidae	*Antocha*	1		3	2
		Dicranota	2	1		
		Hesperoconopa		1	1	
		Pilaria			1	
		Rhabdomastix			3	2

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

Order	**Family**	**Genus**	**2001**	**2002**	**2003**	**2004**
Diptera (cont.)		*Tipula*		1		1
Collembola	Onychiuridae	*Onychiurus*		1		
	Sminthuridae	*Dicyrtoma*		1		
		Sminthurus				2
Copepoda	Cyclopoida				1	1
Acarina			9	3	6	11
Oligochaeta			3	7	49	18
Gastropoda	Valvatidae		1	1		
Ostracoda			1	1	1	11

Numbers of benthic macroinvertebrates identified in Tributary Creek Site 9 samples.

Taxa			**2001**	**2002**	**2003**	**2004**
Order	**Family**	**Genus**				
Ephemeroptera	Baetidae	*Baetis*	41	123	160	21
		Procloeon	5			
	Ephemerellidae	*Caudatella*	3			
		Drunella		3	10	
		Ephemerella		14	7	4
		Epeorus		8		
	Heptageniidae	*Cinygma*	1			
		Cinygmula	89	177	507	49
		Epeorus			1	
		Rhithrogena			1	
	Leptophlebiidae	*Paraleptophlebia*	66	96	249	442
	Ameletidae	*Ameletus*		15	46	46
Plecoptera	Chloroperlidae	*Neaviperla*			174	24
		Paraperla		11		
		Plumiperla				38
		Suwallia	34		24	20
		Sweltsa		42		
	Leuctridae	*Despaxia*	3		6	5
		Paraleuctra	7		1	
		Perlomyia		3		
	Nemouridae	*Podmosta*		1		
		Zapada	23	12	388	41
	Perlodidae	*Isoperla*	1			38
Trichoptera	Apataniidae	*Apatania*		1		
	Brachycentridae	*Brachycentrus*			1	
	Lepidostomatidae	*Lepidostoma*				1
	Limnephilidae	*Ecclisomyia*			1	
		Onocosmoecus				1
	Rhycophilidae	*Rhycophila*		1	5	3
Coleoptera	Elmidae	*Narpus*	2	6	32	14
	Dytiscidae	*Megadytes*			2	
Diptera	Ceratopogonidae	*Bezzia*			1	
		Dasyhelea	3			
		Probezzia			9	
	Chironomidae		35	36	125	52
	Empididae	*Chelifera*		1		
		Hemerodromia			1	
		Oreogeton	4	2	24	8
	Psychodidae	*Psychoda*				
	Simuliidae	*Simulium*	40	22	81	4
	Tipulidae	*Antocha*			10	
		Dicranota			2	
		Pilaria			2	
		Rhabdomastix			1	
		Tipula	4	5		2

Numbers of benthic macroinvertebrates identified in Tributary Creek Site 9 samples (continued).

Order	**Family**	**Genus**	**2001**	**2002**	**2003**	**2004**
Branchiopoda	Chydoridae				2	
Collembola	Sminthuridae	*Dicyrtoma*		2		
		Sminthurus			3	34
Copepoda	Cyclopoida				6	5
	Harpacticoida				5	
Acarina			15	20	72	39
Oligochaeta			40	45	349	111
Gastropoda			1		1	2
Isopoda	Gammaridae	*Gammarus*				1
Ostracoda			92	102	207	27

APPENDIX 4. JUVENILE FISH CAPTURE DATA

Location	Fish Species	Number Fish Captured Set 1	Set 2	Set 3	Total	MLE Pop. Est.	Standard Error	95% Conf Interval
2001								
Uppr Greens Cr 48	DV	---	---	---	118	144	74.76	84 - 448
Middle Greens Cr 6	DV	---	---	---	131	175	21.67	149 – 240
	CO	---	---	---	>0	---	---	---
Grns Cr Below D 54	DV	---	---	---	138	164	12.32	150 - 200
	CO	---	---	---	>0	---	---	---
Tributary Cr 9	DV	---	---	---	81	81	0.78	81 - 81
	CO	---	---	---	118	120	2.14	119 - 128
	CT	---	---	---	>0	---	---	---
	Sc	---	---	---	4	4	0.21	4 - 4
2002								
Uppr Greens Cr 48	DV	74	29	23	126	145	9.43	134 - 173
Grns Cr Below D 54	DV	168	72	31	171	293	8.09	282 - 315
	CO	14	6	1	21	21	0.85	21 – 21
Tributary Cr 9	DV	29	14	8	51	57	5.17	53 - 76
	CO	29	9	6	44	46	2.51	45 - 57
	CT	0	0	1	1	---	---	---
	Sc	0	1	1	2	---	---	---
2003								
Uppr Greens Cr 48	DV	157	72	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	---	---
2004								
Uppr Greens Cr 48	DV	168	48	28	244	255	4.70	246 - 264
Grns Cr Below D 54	DV	118	36	47	201	234	11.43	211 - 257
	CO	9	9	6	24	31	5.53	20 - 42
Tributary Cr 9	DV	21	6	5	32	33	1.22	31 - 35
	CO	23	2	2	27	27	0.00	27 - 27
	CT	1	0	0	1	1	---	---
	RT	3	1	0	4	4	0	4 - 4
	Sc	1	1	0	2	2	0	2 - 2

Species: DV = Dolly Varden, CO = coho salmon, CT = cutthroat trout, RT = rainbow trout / steelhead, SC = sculpin species

Data for 2001 and 2002 from USDA Forest Service

APPENDIX 5. 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	48	Dolly Varden	26.02	131
072301GC48DVJ02	23-Jul-01	Upper	48	Dolly Varden	28.81	137
072301GC48DVJ03	23-Jul-01	Upper	48	Dolly Varden	18.84	119
072301GC48DVJ04	23-Jul-01	Upper	48	Dolly Varden	21.13	121
072301GC48DVJ05	23-Jul-01	Upper	48	Dolly Varden	13.71	111
072301GC48DVJ06	23-Jul-01	Upper	48	Dolly Varden	21.08	121
072402GC48DVJ01	24-Jul-02	Upper	48	Dolly Varden	23.23	133
072402GC48DVJ02	24-Jul-02	Upper	48	Dolly Varden	15.04	120
072402GC48DVJ03	24-Jul-02	Upper	48	Dolly Varden	17.52	122
072402GC48DVJ04	24-Jul-02	Upper	48	Dolly Varden	20.75	127
072402GC48DVJ05	24-Jul-02	Upper	48	Dolly Varden	24.77	134
072402GC48DVJ06	24-Jul-02	Upper	48	Dolly Varden	21.66	128
072203GC48DVJ01	22-Jul-03	Upper	48	Dolly Varden	8.9	90
072203GC48DVJ02	22-Jul-03	Upper	48	Dolly Varden	9.9	98
072203GC48DVJ03	22-Jul-03	Upper	48	Dolly Varden	12.1	103
072203GC48DVJ04	22-Jul-03	Upper	48	Dolly Varden	12.5	112
072203GC48DVJ05	22-Jul-03	Upper	48	Dolly Varden	11.9	108
072203GC48DVJ06	22-Jul-03	Upper	48	Dolly Varden	10.5	100
072204GC48DVJ01	22-Jul-04	Upper	48	Dolly Varden	8.6	96
072204GC48DVJ02	22-Jul-04	Upper	48	Dolly Varden	6.8	88
072204GC48DVJ03	22-Jul-04	Upper	48	Dolly Varden	11.5	101
072204GC48DVJ04	22-Jul-04	Upper	48	Dolly Varden	9.3	98
072204GC48DVJ05	22-Jul-04	Upper	48	Dolly Varden	7.6	93
072204GC48DVJ06	22-Jul-04	Upper	48	Dolly Varden	7.5	91
072301GC06DVJ01	23-Jul-01	Middle	6	Dolly Varden	28.4	139
072301GC06DVJ02	23-Jul-01	Middle	6	Dolly Varden	30.49	140
072301GC06DVJ03	23-Jul-01	Middle	6	Dolly Varden	43.9	167
072301GC06DVJ04	23-Jul-01	Middle	6	Dolly Varden	34.8	155
072301GC06DVJ05	23-Jul-01	Middle	6	Dolly Varden	15.69	109
072301GC06DVJ06	23-Jul-01	Middle	6	Dolly Varden	49.1	168
062100GCCOJ01	21-Jun-00	Greens	54	Coho Salmon	4.4	72
062100GCCOJ02	21-Jun-00	Greens	54	Coho Salmon	6.1	82
062100GCCOJ03	21-Jun-00	Greens	54	Coho Salmon	4.9	73
062100GCCOJ04	21-Jun-00	Greens	54	Coho Salmon	3.4	68
062100GCCOJ05	21-Jun-00	Greens	54	Coho Salmon	5.9	73
062100GCCOJ06	21-Jun-00	Greens	54	Coho Salmon	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

Sample Number	Date Collected	Creek	Site	Fish Species	Weight (gm)	ForkLength (mm)
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
072203GC54DVJ01	22-Jul-03	Greens	54	Dolly Varden	21.1	123
072203GC54DVJ02	22-Jul-03	Greens	54	Dolly Varden	10.6	101
072203GC54DVJ03	22-Jul-03	Greens	54	Dolly Varden	9.2	88
072203GC54DVJ04	22-Jul-03	Greens	54	Dolly Varden	14.8	109
072203GC54DVJ05	22-Jul-03	Greens	54	Dolly Varden	10.6	95
072203GC54DVJ06	22-Jul-03	Greens	54	Dolly Varden	9.7	92
072104GC54DVJ01	21-Jul-04	Greens	54	Dolly Varden	9.9	103
072104GC54DVJ02	21-Jul-04	Greens	54	Dolly Varden	10.0	104
072104GC54DVJ03	21-Jul-04	Greens	54	Dolly Varden	6.6	86
072104GC54DVJ04	21-Jul-04	Greens	54	Dolly Varden	9.3	96
072104GC54DVJ05	21-Jul-04	Greens	54	Dolly Varden	9.9	93
072104GC54DVJ06	21-Jul-04	Greens	54	Dolly Varden	12.9	104
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
072104TR09DVJ01	21-Jul-04	Tributary	9	Dolly Varden	5.5	84
072104TR09DVJ02	21-Jul-04	Tributary	9	Dolly Varden	8.5	96
072104TR09DVJ03	21-Jul-04	Tributary	9	Dolly Varden	14.1	105
072104TR09DVJ04	21-Jul-04	Tributary	9	Dolly Varden	5.8	85
072104TR09DVJ05	21-Jul-04	Tributary	9	Dolly Varden	6.4	81
072104TR09DVJ06	21-Jul-04	Tributary	9	Dolly Varden	10.4	86

Concentration of select metals in juvenile fish collected in 2000, 2001, 2002, 2003, and 2004.

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
072204GC48DVJ01	< 0.02	0.63	4.7	0.15	4.3	206	23.7
072204GC48DVJ02	< 0.02	0.83	5.6	0.26	4.0	175	23.4
072204GC48DVJ03	< 0.02	1.54	4.6	0.21	4.1	183	23.5
072204GC48DVJ04	< 0.02	0.80	5.2	0.28	3.7	168	23.8
072204GC48DVJ05	< 0.02	1.25	4.4	0.14	6.4	220	21.4
072204GC48DVJ06	0.03	1.01	4.5	0.29	5.6	323	23.9
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
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

Concentration of select metals in juvenile fish collected in 2000, 2001, 2002, 2003, and 2004 (continued).

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
072104GC54DVJ01	0.02	0.79	11.0	0.57	4.6	232	23.8
072104GC54DVJ02	<0.02	0.88	5.5	0.54	5.0	206	22.6
072104GC54DVJ03	<0.02	1.26	5.1	0.36	5.3	164	23.7
072104GC54DVJ04	0.03	0.79	5.9	0.28	5.4	191	22.9
072104GC54DVJ05	<0.02	0.83	5.0	0.48	3.9	202	22.1
072104GC54DVJ06	0.07	1.12	7.0	0.93	4.9	216	21.4
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
72402TR09DVJ06	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
072104TR09DVJ01	0.10	0.96	3.2	1.19	5.4	169	23.0
072104TR09DVJ02	0.10	1.24	3.8	0.67	5.9	138	23.0
072104TR09DVJ03	0.10	2.02	4.0	1.75	5.7	125	23.3
072104TR09DVJ04	0.04	0.47	3.7	0.93	4.8	175	22.6
072104TR09DVJ05	0.09	2.34	4.3	1.44	8.2	140	24.0
072104TR09DVJ06	0.11	0.83	5.5	0.97	5.8	161	17.6