Technical Report No. 08-03

Aquatic Biomonitoring at Greens Creek Mine, 2007

by James D. Durst
Laura L. Jacobs

May 2008

Alaska Department of Natural Resources **Office of Habitat Management and Permitting**

Cover: Biomonitoring sampling gear at Greens Creek Below Pond D Site 54, 20 July 2007. ADNR/OHMP photo.

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Suggested Citation:

Durst, James D., and Laura L. Jacobs. 2008. Aquatic biomonitoring at Greens Creek Mine, 2007. Technical Report No. 08-03. Alaska Department of Natural Resources, Office of Habitat Management and Permitting, Juneau, Alaska. 84 pp.

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ACKNOWLEDGEMENTS

We thank Kennecott Greens Creek Mining Company for their continued financial, logistical, and field sampling support of this biomonitoring project, particularly the assistance given by Bill Oelklaus, Kerry Lear and Ted Morales. Pete Schneider and Sarah Shoemaker (USDA Forest Service) and Nellie Ballou, Robyn Grayston, Kerry Lear, Ted Morales, and Chris Wallace (Kennecott Greens Creek Mining Company) ably assisted with field sampling and project continuity.

Several staff from the Alaska Department of Natural Resources, Office of Habitat Management and Permitting assisted the authors in this year's effort; in particular, Jackie Timothy was integral to the field sampling, William Morris performed the chlorophyll analyses, and Robert McLean and Jack Winters provided technical review and editing. Nora Foster, of NRF Taxonomic Services, conducted the invertebrate analyses. We appreciate the support of Dr. Joe Margraf, Dr. Mark Wipfli, and Ms. Kathy Pearse of the University of Alaska Cooperative Fish and Wildlife Research Unit for their laboratory equipment we used for chlorophyll analyses.

This sampling effort and report were made possible by the previous Greens Creek Mine Biological Monitoring Program efforts by staff from Kennecott Greens Creek Mining Company, USDA Forest Service, Alaska Department of Fish & Game, Alaska Department of Natural Resources, and the 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 USDA Forest Service, in cooperation with the U.S. Fish and Wildlife Service, began an aquatic biomonitoring program at Greens Creek Mine on Admiralty Island in southeast Alaska 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 Division, conducted the sampling in 2003 through 2007.

As part of the Kennecott Greens Creek Mining Company Fresh Water Monitoring Program, the Greens Creek Mine Biological Monitoring Program's purpose is to ensure the continued use of Greens Creek and Tributary Creek by fish and other aquatic species, and to document the continued health of all levels of the aquatic biological community: primary productivity, invertebrate communities, and fish. The intent is that the program will also detect changes in these aquatic communities over time that may result from changes in water quality associated with surface- or ground-water inputs to the streams. Elements of the biological monitoring program developed to meet the stated purpose include surveys of periphyton biomass, benthic macroinvertebrate density and community structure, juvenile fish abundance and distribution, and concentrations of selected heavy metals in fish tissues.

The two biomonitoring sites sampled on Greens Creek (Upper Greens Creek Site 48 above all facilities and Greens Creek Below Pond D Site 54 below all facilities) and one sampled on Tributary Creek (Tributary Creek Site 9 below the dry-stack tailings facility) continued to sustain functioning, diverse aquatic communities in 2007 although at a less abundant level compared to the previous six years of biomonitoring.

Periphyton biomass and community composition at the three sampled biomonitoring sites continue to appear robust, with a pronounced diatom component and a minimal green algae component. Chlorophyll *a* concentrations were significantly different between the two Greens Creek sites in 2007, and the mean chlorophyll *a* values at Tributary Creek Site 9 were more like those of Upper Greens Creek Site 48 than of those from Greens Creek Below Pond D Site 54. Periphyton biomass at Tributary Creek Site 9 was the lowest recorded in seven years of sampling at the site, and was significantly lower than the high chlorophyll *a* concentrations in 2003. The

community composition of periphyton at Tributary Creek continued to be similar to that at the Greens Creek sites.

The benthic macroinvertebrate communities at the three biomonitoring sites showed essentially the opposite trends of the periphyton communities. The mean rank scores for benthic macroinvertebrate abundance and taxonomic richness at the two Greens Creek sites in 2007 were the lowest of the years sampled and were not statistically different between sites. Tributary Creek Site 9 benthic macroinvertebrate abundance and taxonomic richness were well below those of the past six years, and significantly lower than the high densities of 2003. In contrast to most of the past six years of sampling, the number of common taxa in Tributary Creek Site 9 samples in 2007 was equal to or less than that found in Greens Creek samples. Distinctive differences in the benthic macroinvertebrate community between the two streams persisted. The percentage of the water quality-sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa in benthic macroinvertebrate samples remained high in all three sites sampled in 2007.

Dolly Varden (*Salvelinus malma*) populations in 2007 at each site were at or near the lowest documented in seven years of biomonitoring. Captures at Greens Creek sites had multiple size classes of fish present, although a shift to larger size classes was seen possibly to be a response to the higher stream flows at the time of sampling. Dolly Varden captures at Tributary Creek Site 9 in 2007 were as they had been in 2006, and no size classes typically associated with young-of-the-year Dolly Varden were captured at Tributary Creek Site 9 for the second year in a row. Coho salmon (*Oncorhynchus kisutch*) were not captured at Greens Creek Below Pond D Site 54, leading to concern about fish passage over the downstream falls area; no size classes associated with young-of-the-year coho salmon were captured at this site in 2006 or 2007. Coho salmon captures at Tributary Creek Site 9 rebounded from 2006's low to a moderate level for this site and higher than the regional average for this channel type. Total fish densities per square meter of wetted stream area among the three Greens Creek sites continued to be higher at Greens Creek Below Pond D Site 54 than at Upper Greens Creek Site 48, with Tributary Creek Site 9 having the highest densities in 2007 of the three sites.

The ranges of whole body concentrations of metals in juvenile Dolly Varden tissues in 2007 were generally similar to, or somewhat elevated from, those found in previous years' samples at each site. Tissue concentrations of cadmium, lead, and selenium tended to be higher downstream of mine facilities (sites 54 and 9), and concentrations of copper and zinc tended to be lower than in previous years' sampling. When median tissue concentrations were compared for each site over the seven years of biomonitoring sampling, the values from 2007 were the highest for cadmium and selenium at Greens Creek Below Pond D Site 54 and the highest for silver, cadmium, lead, and selenium at Tributary Creek Site 9. Also of note is that the median tissue concentrations of copper and zinc at Site 9 in 2007 were the lowest observed at that site seven years of sampling. Tissues of juvenile Dolly Varden from Tributary Creek Site 9 captured in 2007 continued to have different metals concentrations characteristics than did tissues from Dolly Varden from the two Greens Creek sites (48 and 54).

In general, the aquatic communities at Upper Greens Creek Site 48, Greens Creek Below Pond D Site 54, and Tributary Creek Site 9 have remained fairly diverse, robust, and moderately abundant during the seven years of biomonitoring sampling. Differences noted between years and between the streams (Greens Creek compared to Tributary Creek) have typically been of larger amplitude than have differences between the control and below-mining sites within Greens Creek or over time at the Tributary Creek site.

Although no trends of reduced productivity, community changes, or metals accumulation attributable to operations of the Greens Creek Mine have been noted, the 2007 biomonitoring results raise concerns that will need to be followed in future years of biomonitoring: low abundance of periphyton in Tributary Creek, lower density of benthic macroinvertebrates at all sites and low richness at sites 54 and 9, low density of Dolly Varden in Tributary Creek, lack of coho salmon at Greens Creek Below Pond D Site 54, and somewhat elevated levels of some metals in fish tissues at all sites.

INTRODUCTION

In 2000, an interagency regulatory team 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 U.S. Environmental Protection Agency (USEPA), the USDA Forest Service (USFS), and the U.S. Fish and Wildlife Service were invited by the Kennecott Greens Creek Mining Company (KGCMC) to conduct a third-party environmental audit of the Greens Creek Mine operations within Admiralty Island National Monument in southeast Alaska.

Based on findings of that review, the KGCMC Fresh Water Monitoring Program (FWMP) was updated (KGCMC 2000), including specifications for a biological monitoring program in areas adjacent to the KGCMC surface facilities associated with the mine, mill, tailings, and waste rock disposal.

This technical report presents results of the seventh year (2007) of the Greens Creek Mine Biological Monitoring Program as specified in the FWMP, and was conducted by the ADNR Office of Habitat Management and Permitting as successor to the ADF&G Habitat and Restoration Division. Results from previous years' biomonitoring can be found in Weber Scannell and Paustian (2002), Jacobs et al. (2003), Durst and Townsend (2004), Durst et al. (2005), and Durst and Jacobs (2006, 2007).

The intent of the Greens Creek Mine Biological Monitoring Program 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 periphyton, benthic macroinvertebrate, and fish communities (KGCMC 2000). Biomonitoring is designed to detect early changes in the aquatic communities that may result from changes in water chemistry through either surface- or ground-water inputs to the streams.

Results from biomonitoring are typically compared to baseline conditions, or to a reference site that is unaffected if baseline data are unavailable. Each of the Greens Creek Mine biomonitoring sites is evaluated individually to detect changes or trends over time, with consideration given to any previous monitoring (KGCMC 2000). Two sites on Greens Creek below mine facilities are also compared to a control site upstream of all mine facilities. All biomonitoring at the Greens

Creek Mine follows standard protocols acceptable to the 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 document 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 changes that may have occurred in aquatic communities.

The biological monitoring program for the Greens Creek mine was designed to address the following factors as specified in the Fresh Water Monitoring Program (KGCMC 2000):

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

LOCATION AND SCHEDULE OF MONITORING

Four of the FWMP sites were selected for the biomonitoring program. Upper Greens Creek Site 48 monitors Greens Creek upstream of all mine and mill facilities (some exploratory drilling has occurred upstream of this site); annual biomonitoring at Upper Greens Creek Site 48 serves as a control. Middle Greens Creek Site 6 monitors Greens Creek downstream of the mine portal and mill facilities but upstream of the production rock storage area; Site 6 was sampled in 2001 to provide baseline conditions (in this instance, baseline is meant to describe the conditions at the beginning of the biomonitoring program) and is sampled on a 5-year schedule to detect changes over time as a partial treatment site. Greens Creek Below Pond D Site 54 monitors Greens Creek downstream of the mine portal and mill facilities as well as the production rock storage area and its associated pond system; annual biomonitoring at Site 54 serves as a complete treatment site. Tributary Creek Site 9 monitors Tributary Creek downstream of the dry-stack tailings storage facility, which sits at the head of the drainage; biomonitoring occurs at Site 9 annually to detect any changes over time as a complete treatment site. KGCMC monitors the ambient water quality

[1] The toxicity testing component of the Greens Creek Biomonitoring Program was suspended after the 2003 sampling period (McGee and Marthaller 2004).

at these and other FWMP sites on a regular basis, and reports the results of that monitoring under separate cover. Figure 1 shows the location of the Greens Creek Mine and the biomonitoring sampling locations.

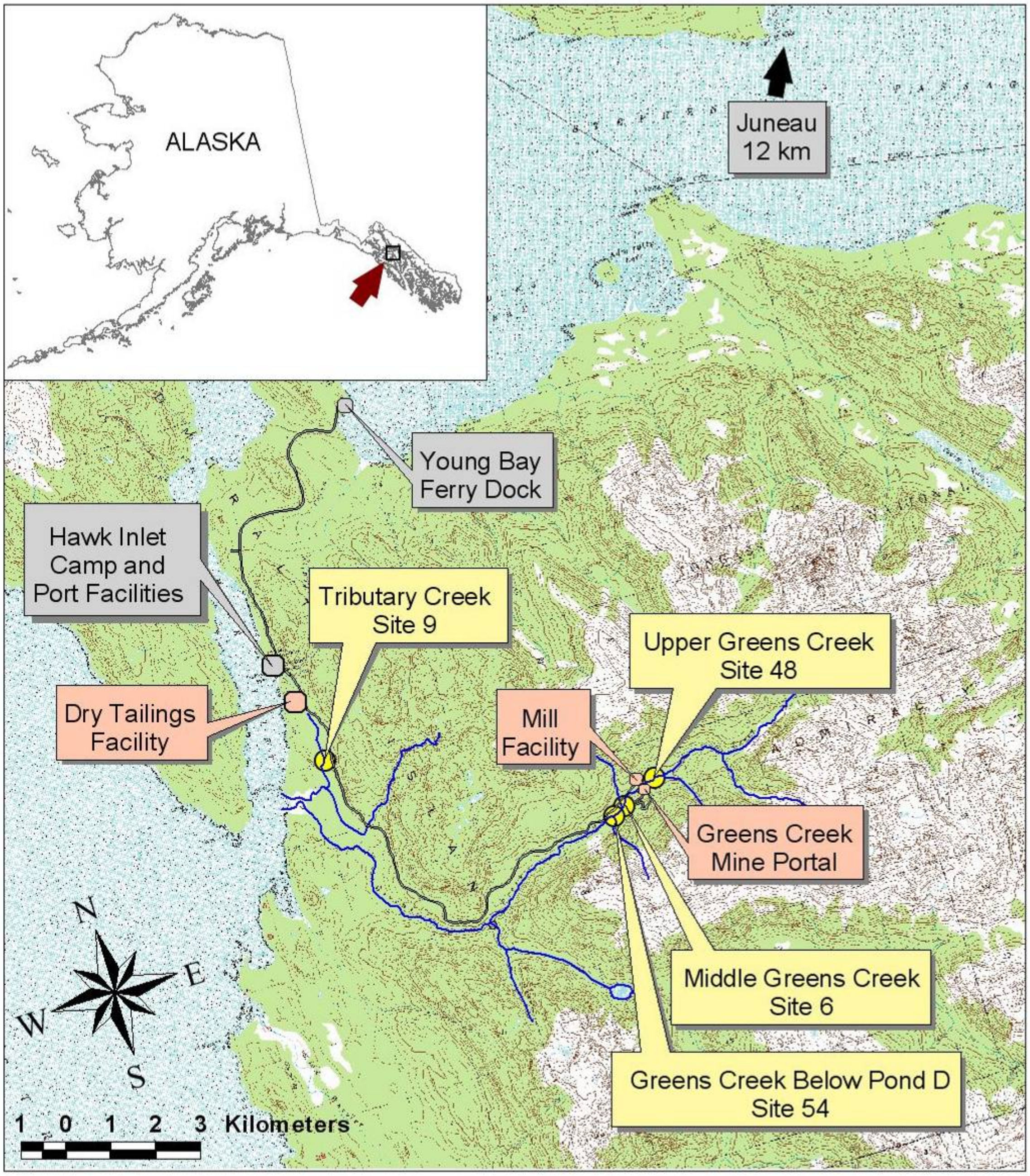

Figure 1. Location of the Greens Creek Mine operation and biomonitoring sampling sites on Admiralty Island in southeast Alaska, southwest of Juneau.

METHODS

Five to six hours are required at each site to gather the suite of raw data needed for biomonitoring sampling. 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, Durst and Townsend 2004, Durst et al. 2005, Durst and Jacobs 2006 and 2007). In addition to the procedures detailed below, field measurements included air and water temperatures, wetted widths, water velocities at benthic sample locations, and a quick survey for cross sectional area and discharge. Photographs were taken to document site conditions and sampling areas in each survey reach.

Data analyses were performed using hand calculators, Microsoft® Excel 2003, and Statistix® 9 (Analytical Software 2008). Kruskal-Wallis One-Way Analysis of Variance, a nonparametric alternative to a one-way analysis of variance (ANOVA), was used to test for differences between years and sites (H_0: All of the population distribution functions are identical). All-pairwise comparisons were conducted on the mean ranks for each group to test for homogeneity of rank means between pairs of years or sites when significant or substantial differences were found. Throughout this report, three levels of statistical differences are reported: ***significant differences*** required an $\alpha \leq 0.05$, ***substantial differences*** required an α value greater than 0.05 but less than or equal to 0.10 ($0.05 < \alpha \leq 0.10$), and groups reported as ***not statistically different*** were neither significantly different nor substantially different ($\alpha > 0.10$).

SAMPLE SITES

Upper Greens Creek Site 48

Upper Greens Creek Site 48 was selected as an upstream "control" reach for comparison to downstream "treatment" reaches of Greens Creek that are adjacent to and downstream from the KGCMC mine facilities. Site 48, at approximately 265 m elevation, is upstream of all mining facilities and activities except for exploratory drilling. Approximately 85 holes were drilled in the Big Sore Creek basin upstream of Site 48 in 1985-1986, and one additional hole per year was drilled upstream of Site 48 in 2004 and 2006, with an additional hole planned for in 2007 after biomonitoring sampling. The site lies approximately 0.8 km upstream of a concrete weir that blocks access to upper Greens Creek by anadromous fish. Because of this barrier, the only salmonid species at Site 48 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 at ordinary high water and a gradient of 2-4 percent. This is a typical stream for the middle portion of moderately sized basins in southeast Alaska (Paustian et al. 1992, Weber Scannell and Paustian 2002). Cobble is the dominant substrate and large woody debris has a key role in pool formation and fish habitat cover.

The periphyton and benthic macroinvertebrate sample reach is just downstream of the fish sample reach at this site. Both reaches are fairly homogeneous, with split- and single-channel areas, large woody debris, and a mix of pool and riffle habitats.

Water quality at Site 48 has been monitored monthly by KGCMC since 1995, and is reported annually under separate cover.

Middle Greens Creek Site 6

Middle Greens Creek Site 6, at approximately 235 m elevation, is located to detect potential effects on Greens Creek from activities in the KGCMC mine, mill, and shop areas but upstream of the production rock storage site and its associated treatment ponds. Access by anadromous fish to this stream reach was created by KGCMC in 1989 by installing a fish pass in a waterfall approximately 4.8 km downstream. Site 6 is near the upper limit of anadromous fish use and passage in Greens Creek, defined by a weir located approximately 0.8 km upstream. Both Dolly Varden and coho salmon (*Oncorhynchus kisutch*) have been captured in this reach during the biomonitoring program.

Middle Greens Creek Site 6 has a Moderate Width Mixed Control (MM2) channel type (Appendix 1), with an average channel width of 10 m at ordinary high water and a gradient of 2-4 percent. This is a typical stream for the middle portion of moderately sized basins in southeast Alaska (Paustian et al. 1992, Weber Scannell and Paustian 2002). Cobble is the dominant streambed material. Large woody debris is less abundant at this site than at the other two Greens Creek sites, but still integral to pool formation and fish habitat cover.

The periphyton and benthic macroinvertebrate sample reach is immediately upstream of the confluence of Bruin Creek with Greens Creek, while the fish sample reach is a short distance upstream above a large woody debris tangle. Both reaches are single-channel areas; the fish reach has both overhanging and pool-forming large woody debris.

Following the five-year pulsed sampling schedule presented in the FWMP, biomonitoring data were collected at Site 6 in 2001 for reference information (Weber Scannell and Paustian 2002) and again in 2006 (Durst and Jacobs 2007). The next biomonitoring sampling at this site is scheduled for 2011.

Water quality at Site 6 has been monitored monthly by the mine operator since 1978, and is reported annually under separate cover.

Greens Creek Below Pond D Site 54

Greens Creek Below Pond D Site 54 is located approximately 0.4 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. Site 54, at approximately 225 m elevation, was located to detect potential effects from the production rock storage area and treatment pond in addition to the facilities upstream of Middle Greens Creek Site 6. As such, Greens Creek Below Pond D Site 54 is downstream of all Greens Creek Mine facilities along Greens Creek except portions of the B Road. Anadromous fish access to Site 54 was created by KGCMC in 1989 when a fish pass was installed in a waterfall area approximately 4.4 km downstream. Coho salmon, Dolly Varden, and cutthroat trout (*Oncorhynchus clarki*) have been captured in this reach during the biomonitoring program.

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

The periphyton and benthic macroinvertebrate sample reach is a short distance upstream of the fish sample reach at this site, with Gallagher Creek entering at the upstream end of the fish sample reach. Both reaches have a single- or split-channel configuration depending on water level, with instream and overhanging large woody debris.

Water quality at Site 54 has been monitored monthly by KGCMC since 1995, and is reported annually under separate cover.

Tributary Creek Site 9

Tributary Creek is a small lowland stream with a dense canopy. Site 9, at approximately 25 m elevation, is included in the current biomonitoring program because it is located approximately 1.6 km downstream from the KGCMC dry-stack tailings facilities. As such, this is the closest free-flowing stream reach to the tailings facilities that is suitable for biomonitoring. Data from this site are analyzed for trends showing changes over time.

Tributary Creek provides habitat for a variety of fish populations including pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*O. keta*), coho salmon, cutthroat trout, rainbow trout (*O. mykiss*), Dolly Varden, and sculpin (*Cottus* sp.). 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. At Site 9, Tributary Creek averages 2-3 m wide with a stream gradient of one percent, has fine gravel as the dominant substrate (Paustian et al. 1992, Weber Scannell and Paustian 2002), and large woody debris is integral to substrate retention and pool formation.

The periphyton sampling area is within the upstream half of the fish sampling reach at this site, and the benthic macroinvertebrate reach is immediately downstream of the fish sampling reach. This low-energy stream is single channel, with moderately developed pools and riffles and a mixture of overhanging and embedded large woody debris.

Water quality on Tributary Creek was monitored downstream of Site 9 monthly from 1981 to 1993. Water quality monitoring at Site 9 was started by KGCMC in May 2006, occurs each May, July, and September, and is reported annually under separate cover.

Water Characteristics

Beginning in 2007, KGCMC personnel used field meters to characterize water quality at each site during biomonitoring sampling. An Oakton pH/Con 10 meter was used to measure temperature, pH, and conductivity, and a Hach 2100P turbidimeter was used to measure turbidity. Reported results are included in the sample site narratives of this report.

PERIPHYTON BIOMASS

Rationale

Periphyton, or attached algae, is sensitive to changes in water quality. An abundance of periphyton confirms that productivity is occurring at that specific location 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). The FWMP specifies that periphyton be sampled during a period of relatively stable flow, and not after scouring flow events. Ten rocks were collected from the nearshore area of the stream 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. Approximately 1 ml saturated $MgCO_3$ was added to the filter, after extracting as much water as possible, to prevent acidification and conversion of chlorophyll to phaeophytin. The glass filter was wrapped in a large paper filter (to absorb any additional water), and placed in a sealed labeled plastic bag with a desiccant. Filters were frozen on site in a lightproof container with desiccant, and then transported to Fairbanks where they were kept frozen until laboratory analyses were conducted by OHMP staff.

Methods for extraction and measurement of chlorophyll followed USEPA protocol (USEPA 1997). Filters for each rock sampled 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 refrigerator for 24 hours to extract the chlorophyll. 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). Chlorophyll *a* is predominant in all living plants, and is a useful indicator of biomass. Chlorophylls *b* and *c* are accessory pigments that can provide information on the types of periphyton present.

Periphyton biomass data are presented using Box and Whisker graphs (Velleman and Hoaglin 1981). The box shows the middle half of the data (the interquartile range), the line bisecting the box represents the median, and the vertical “whiskers” are the typical range of data in the sample. Whiskers always end at a data point that is within 1½ times the interquartile range. An asterisk represents possible outliers lying outside the box (interquartile range) by more than 1½ times the interquartile range, and ○ is used to represent probable outliers more than 3 times the interquartile range (Analytical Software 2008). We have no evidence to suggest that potential and probable outlier data values are other than part of the data set's actual distribution, so they were retained and used for data analysis.

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.

The sampler ring encompassed approximately 0.1 m^2 of substrate, and was pushed into the stream bottom to define the sample area. 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 80% denatured ethanol. Macroinvertebrate samples were later sorted from debris and identified to the lowest practical taxonomic level by a contracted taxonomist.

Analyses included comparisons of density, taxonomic richness, percent community composition, and percent dominant taxon. The latter is a metric intended to identify 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 mine surface 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). Fish were trapped using 6.4 mm (1/4 in) square mesh galvanized Gee's minnow traps baited with salmon roe that had been treated with a povidone-iodine (Betadine®) disinfectant solution. Approximately 25 minnow traps were deployed within each sample reach during each sampling event.

Sample reaches were identified by aluminum tree tags and flagging set by the USFS during previous years' sampling, and varied in length among sites because of the different availability of suitable habitat in which to set traps. At Upper Greens Creek Site 48, the 75 m reach sampled in 2001 was shortened to 50 m in 2002 and following years; at Greens Creek Below Pond D Site 54, the same 28 m long reach has been sampled each year of biomonitoring; and at Tributary Creek Site 9, the 44 m reach sampled in 2001 was extended to 50 m long for 2002 and following years. When Middle Greens Creek Site 6 was first sampled in 2001, a 135 m reach was used for trap placement. Habitat variations within such a long reach made population estimation difficult (Weber Scannell and Paustian 2002), and the authors recommended reducing the length of the trapped reach to 30 m to 40 m for subsequent sampling efforts. In 2006, USFS and OHMP staff established a 49 m reach for sampling within the upstream portion of the 135 m reach. The need for natural breaks in the channel to provide some closure to the population during depletion sampling necessitated a slightly longer sample reach at Site 6 than was recommended in 2002.

Traps were placed throughout each sample reach 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 and to provide cover for fish retained in the traps.

Where possible, natural features such as shallow riffles or small waterfalls over log steps were used to help define upper and lower sample reach boundaries to minimize fish movement into the sample section during sampling. To better meet the closure assumption of the three-pass removal method, traps were also set above and below each sample reach to serve as "blocks" by capturing potential migrants into the sample reach.

Minnow traps in each sample reach were set for about 1.5 hr, at which time all captured fish were transferred to perforated plastic buckets. Buckets were kept supplied with aerated water to reduce stress on captured fish. The traps were re-baited and reset for a second 1.5 hr period. While the second set was fishing, fish captured during the first set were counted, identified to species, 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. Block traps were left set in place for the entire 4.5 hr sampling period. Fish captured in block traps were counted and identified to species, but not included in further analyses.

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 reach 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 tributaries (Weber Scannell and Ott 2001). Should changes occur at the Greens Creek Mine that result in higher concentrations of metals in the biomonitored stream reaches, tissue sampling of juvenile fish living in those stream reaches should reflect such changes.

Sample Collection and Analysis

Six moderate-sized (target size range 95-125 mm fork length) juvenile Dolly Varden captured in baited minnow traps at each sample site were collected for whole body metals analysis[2]. Dolly Varden from Greens Creek Below Pond D Site 54 and Tributary Creek Site 9 potentially contained a mixture of resident and anadromous forms, although this would not be expected to alter metals accumulation levels in fish from the size range collected because anadromous forms would not have been through a marine cycle at this size and hence could be considered resident fish. 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.

[2] Six fish each were also collected from Greens Creek Below Pond D Site 54 and Tributary Creek Site 9 in 2000 during development of the protocols for this biomonitoring program. Data from these fish were not included in analyses in this report but are included in Appendix 5.

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, and correction made for the weight of the bag. The fish were submitted to a private analytical laboratory (Columbia Analytical Services, Inc. in Kelso, Washington), where they were digested, dried, and analyzed for silver (Ag), cadmium (Cd), copper (Cu), lead (Pb), selenium (Se), and zinc (Zn) on a dry-weight basis, with percent total solids also reported.

Samples were numbered following the convention established by ADF&G in 2001: Date/StreamCode/Site/SpeciesCode/AgeCode/SampleNumber. For example, one fish sample was labeled 072107GC48DVJ01 where 072107 represents July 21, 2007; GC48 represents Upper Greens Creek Site 48; DV represents Dolly Varden; J represents juvenile; and 01 represents sample replicate number 1.

Quality Control / Quality Assurance of Laboratory Analysis

Written chain of custody documentation was maintained on each fish collected for metals testing. 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.

RESULTS AND DISCUSSION

Water levels and stream discharges at the Greens Creek and Tributary Creek sites in 2007 were the highest seen during biomonitoring sampling, apparently due to a series of rainfall events in addition to continued runoff from a very heavy winter snowpack. Gage data from U.S. Geological Survey (USGS) Site 15101490, located near the mine portal between Upper Greens Creek Site 48 and Middle Greens Creek Site 6 (Table 1, Figure 2), indicate that the daily mean discharges for Greens Creek during biomonitoring sampling were notably higher in 2007 than in previous years. Field measurements taken during sampling of Tributary Creek Site 9 in 2007 show a similar pattern, although the record is not long enough to allow statistical analysis (Table 1).

Table 1. Greens Creek mean daily discharges (USGS Gage 15101490) and Tributary Creek field-measured discharges during biomonitoring sampling periods.

Water Year	Sampling Dates	Greens Cr. USGS Gage		Tributary Cr. Field Data	
		feet³/sec	meter³/sec	feet³/sec	meter³/sec
2001	July 23	72	2.04	- - -	- - -
	July 24	73	2.07	- - -	- - -
2002	July 23	51	1.44	- - -	- - -
	July 24	57	1.61	- - -	- - -
2003	July 22	16	0.45	- - -	- - -
	July 23	15	0.42	- - -	- - -
2004	July 21	25	0.70	0.1*	<0.01*
	July 22	22	0.62	- - -	- - -
2005	July 22	33	0.93	- - -	- - -
	July 23	29	0.82	2.7	0.08
2006	July 20	35	0.99	- - -	- - -
	July 21	59	1.67	3.4	0.10
2007	July 20	100	2.83	5.4	0.15
	July 21	98	2.78	- - -	- - -

*It is difficult to field measure low discharges in Tributary Creek because of the stream's relatively shallow channel and largely rectangular cross-section.

Previous versions of Table 1 (Durst and Townsend 2004, Durst et al. 2005, Durst and Jacobs 2006 and 2007) contained discharge data for Greens Creek that we believed to be correct at the time of reporting but that have been superseded. The Greens Creek discharges presented now in Table 1 are those approved for publication by the USGS.

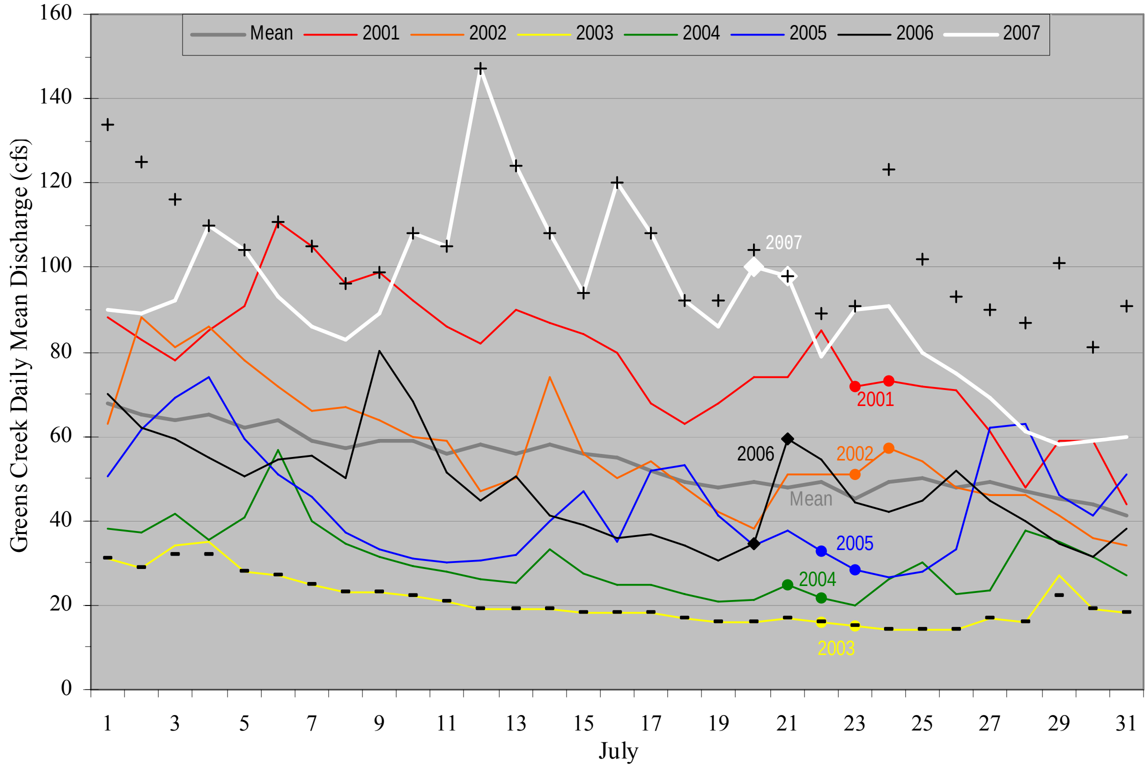

Figure 2. USGS Greens Creek daily mean discharge values for July for 2001 through 2007. Biomonitoring sampling dates are indicated by series markers. Mean of daily mean (gray line), maximum daily mean (+), and minimum daily mean (-) discharges were calculated from all 18 water years of record (1989 through 2007).

We noted no evidence of scouring flows during the biomonitoring sampling, and water levels were less than ordinary high water, but gage data show that Greens Creek flows during the three weeks prior to sampling in 2007 were at or near daily mean maxima for those dates (Figure 2), and were significantly higher than those of 2002 through 2006. This is in sharp contrast to 2003, when flows during the three weeks prior to sampling were at or near record minima for those dates. Biomonitoring sampling has now occurred over a very wide range of sampling conditions.

High stream flows can affect biomonitoring results in several ways. Fish habitat availability and distribution, and susceptibility to minnow trapping, can change as flows in main channel areas become too swift and fish move to lower velocity reaches and off-channel refugia. Flows fast enough to move gravel and larger bedload sediments can reduce periphyton and benthic macroinvertebrate densities through both physical scour and increased drift due to moving substrate.

The biomonitoring sample sites retained their essential character and habitat characteristics despite high flows, but each also showed evidence of a dynamic year for Greens Creek Mine area streams. We noted some changes between 2006 and 2007 sampling in the channel configuration and large woody debris distribution in all three sampling reaches. Some shifts in channel and bedload configurations were noted at each site, as were the presence of recently windthrown and bole-snapped trees and changes in large woody debris distribution. We suspect that many of these changes were initiated by the high water event in November 2005 and furthered by the elevated spring and summer discharges of Greens Creek in 2007 due to a heavy snowpack. In general, channel sinuosity increased, banks showed new erosion sites, and large woody debris pieces were either recruited or moved.

UPPER GREENS CREEK SITE 48

Upper Greens Creek Site 48 (Figure 3) was sampled in the morning of 21 July 2007. As sampling began, the weather was overcast skies with some breaks and some drizzle; the water temperature was 6°C and the air temperature 9.5°C. The weather dried and warmed during sampling. It had rained the previous day and night and water levels were high, although the stream stage fell slightly during sampling. Deep, fast water (4.5-5.0 feet per second in deep portions) prevented us from safely measuring average wetted width or a channel cross section and discharge estimate. Compared to the previous years of biomonitoring sampling, the mid-channel gravel bar in the upper portion of the sample reach was smaller, and the silted-in log tangle on the upper left bank had been mostly cleared of silt and had water flowing through it. The Greens Creek channel was more complex in 2007 than in 2006, with an increase in pools and backwaters. No major changes in large woody debris distribution were noted.

Figure 3. Upper Greens Creek Site 48, 21 July 2007.

During the first half of the sampling session, KGCMC staff measured Greens Creek at 6.5°C, with a pH of 7.33 units, a conductivity of 83.4 μS/cm, and a turbidity of 1.99 NTU. About two hours later, two transient turbidity events were seen, with Greens Creek becoming suddenly quite cloudy for a few minutes then clearing up. KGCMC staff observed the first of these sediment plumes coming from Big Sore Creek, a tributary to Greens Creek upstream of Site 48, and we suspect both came from bank sloughs along that stream. KGCMC staff measured Greens Creek as it was clearing from the first event, and reported a temperature of 7.1°C, pH of 7.32 units, conductivity of 84.5 μS/cm, and turbidity of 17.4 NTU.

Periphyton Biomass

Concentrations of chlorophyll *a*, an estimate of periphyton biomass, in Upper Greens Creek Site 48 were significantly different[3] between years when 2001 through 2007 were analyzed together. Multiple pairwise comparisons were then run, and values from 2007 were substantially different from 2001, but not significantly different from any prior year (Appendix 2). The Box and Whisker output plot from Statistix is shown in Figure 4.

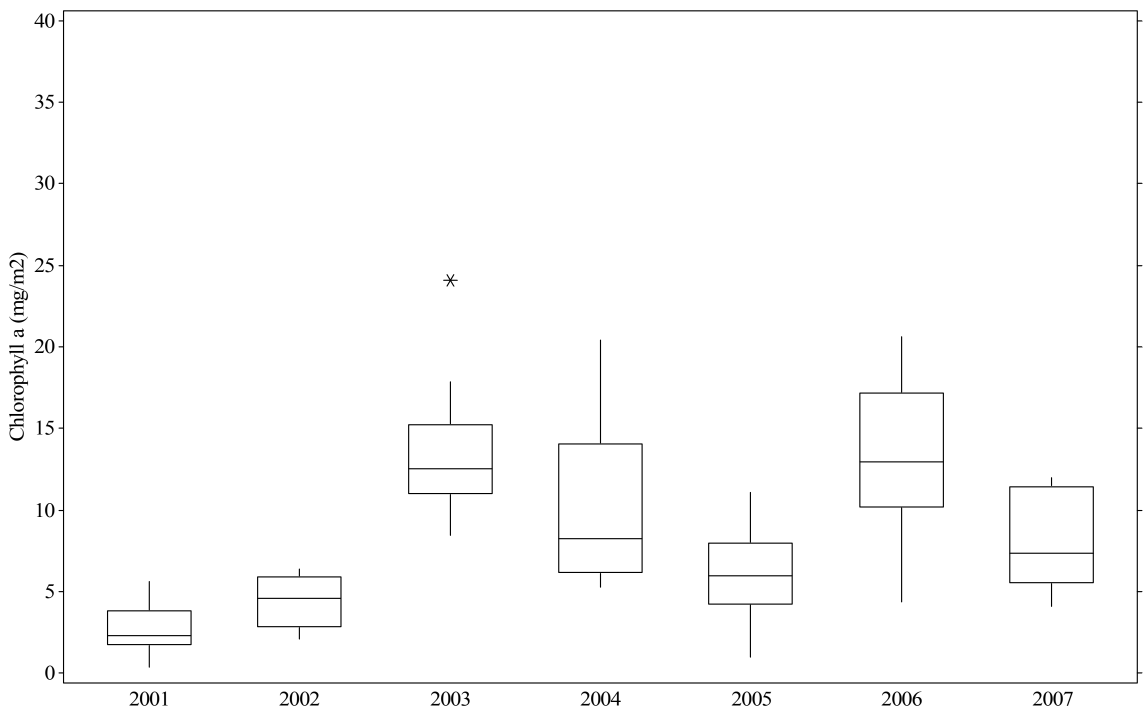

Figure 4. Estimated periphyton biomass densities at Upper Greens Creek Site 48 in 2001 through 2007 (n = 10 samples each year). Box encompasses middle half of data; horizontal line is median value. One possible statistical outlier value (*) was identified in the 2003 data set.

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[3] Throughout this report, ***significant differences*** required an $\alpha \leq 0.05$, ***substantial differences*** required an α value greater than 0.05 but less than or equal to 0.10 ($0.05 < \alpha \leq 0.10$), and groups ***not statistically different*** were neither significantly different nor substantially different ($\alpha > 0.10$).

The significantly higher proportions of chlorophyll *c* than chlorophyll *b* in all six years sampled (Figure 5) indicate that diatoms and/or dinoflagellates are a major component of the periphyton community at Upper Greens Creek Site 48, while the low to undetectable concentrations of chlorophyll *b* indicate low populations of green algae.

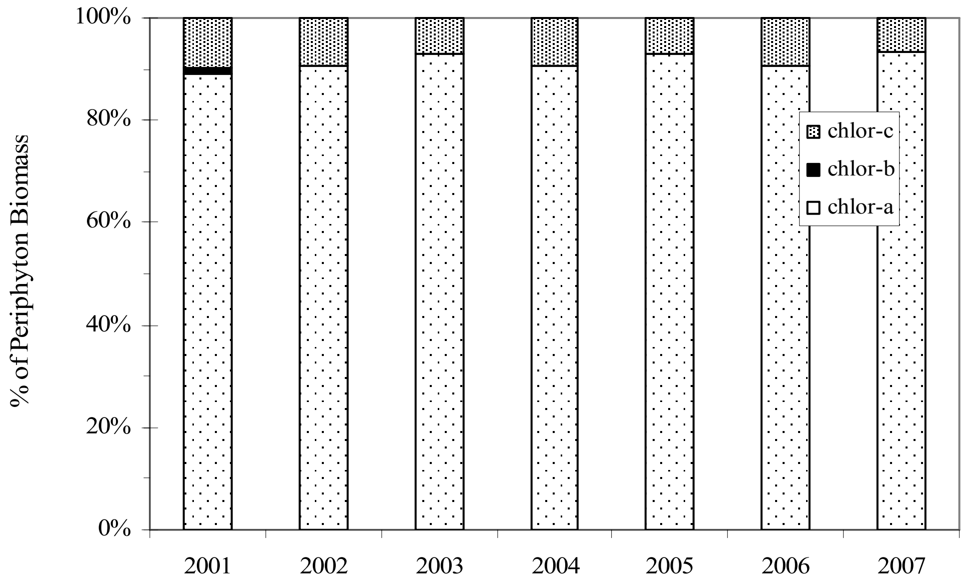

Figure 5. Proportions of mean chlorophyll *a*, *b*, and *c* concentrations in Upper Greens Creek Site 48 samples in 2001 through 2007.

Benthic Macroinvertebrates

The mean density of benthic macroinvertebrates in Upper Greens Creek Site 48 samples in 2007 was low relative to the range seen in the past six years of sampling at this site (Figure 6), but both taxonomic richness and the average taxa per sample had increased from those measured in 2006 (Table 2). The mean density of benthic macroinvertebrates in 2007 was significantly less than mean densities found in 2003, but similar to 2001, 2004, and 2005 (Appendix 3).

Table 2. Summary of benthic macroinvertebrate samples at Upper Greens Creek Site 48 in 2001 through 2007.

Year	Mean Density (aqua. 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
2005	2792	29	15.8
2006	1386	22	11.8
2007	1466	25	13.2

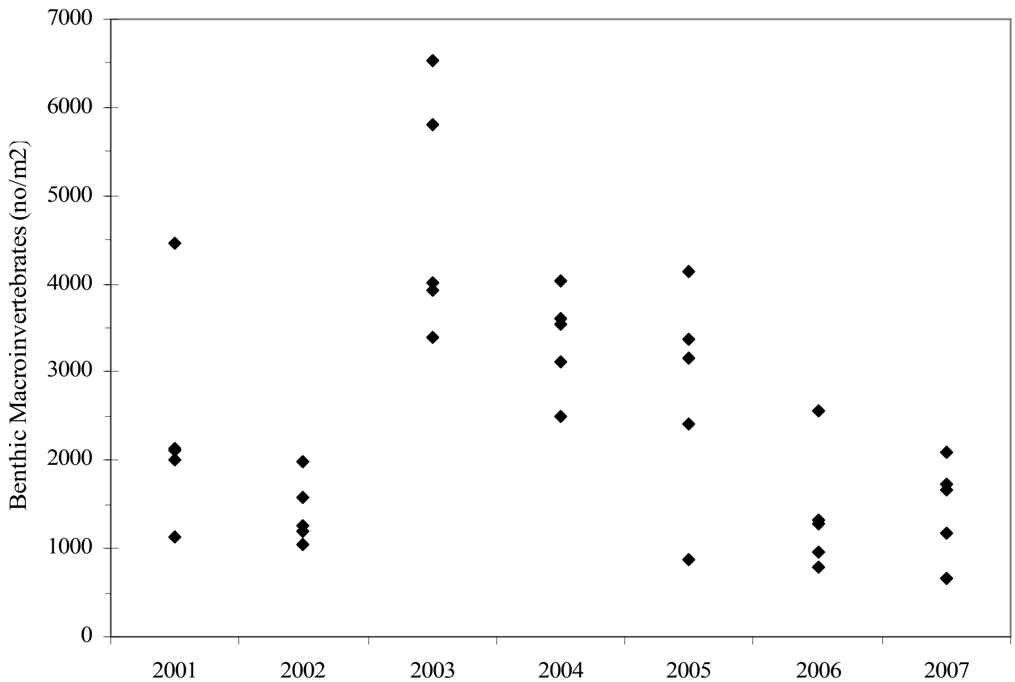

Figure 6. Density of benthic macroinvertebrates (n = 5 samples each year) at Upper Greens Creek Site 48 in 2001 through 2007.

Invertebrate communities were somewhat different among the seven years sampled, with relatively low proportions of Chironomidae occurring each year (Figure 7). The numbers of Chironomidae in 2007 samples were similar to those measured in 2002. The EPT taxa (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]) continued to be most prevalent (Figure 7). Given that most of the EPT taxa are sensitive to decreased water quality, especially metals, the high proportion found at this baseline site signifies clean or healthy water quality conditions for aquatic life.

At Upper Greens Creek Site 48, mayflies (Ephemeroptera) dominated the benthic macroinvertebrate samples (Figure 8, Table 3). Common taxa in the seven years sampled include the mayflies Baetidae: *Baetis*, Ephemerellidae: *Drunella*, and Heptgeniidae: *Epeorus* and *Rhithrogena*. *Baetis* are rated "moderately sensitive" to decreased water quality, *Drunella* are "very to extremely sensitive," *Epeorus* are "sensitive," and *Rhithrogena* are "very sensitive" (Barbour et al. 1999). In all seven years, pollution-sensitive taxa dominated the invertebrate community at Upper Greens Creek Site 48, and the many species of mayflies, stoneflies, caddisflies, and true flies represent a complex community. Appendix 3 lists the benthic macroinvertebrate taxa found at Upper Greens Creek Site 48 in 2001 through 2007.

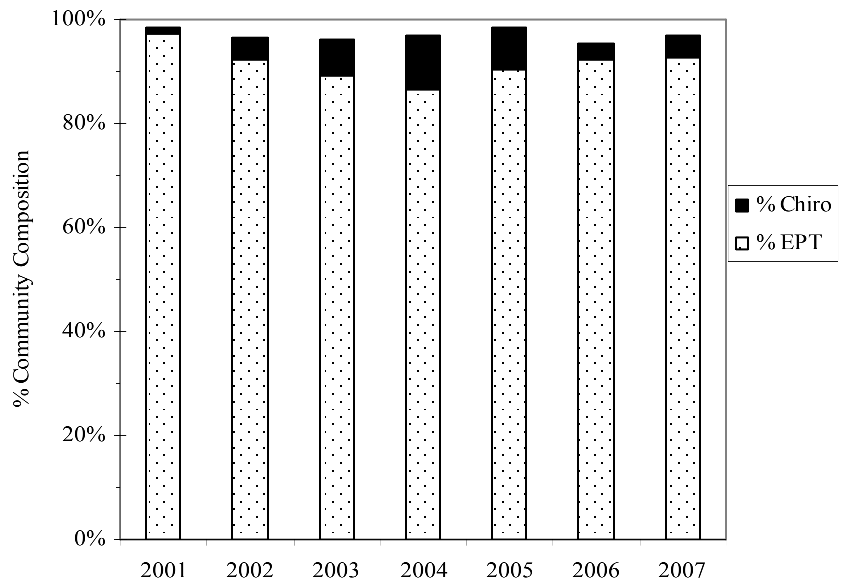

Figure 7. Proportions of EPT taxa and Chironomidae in Upper Greens Creek Site 48 samples in 2001 through 2007.

Table 3. Common taxa (>5.0% of benthic macroinvertebrates) found in Upper Greens Creek Site 48 samples in 2001 through 2007. The percent dominant taxon each year is bold.

Order	Family	Genus	2001	2002	2003	2004	2005	2006	2007
Ephemeroptera	Baetidae	*Baetis*	26%	22%	19%	23%	20%	19%	**28%**
	Ephemerellidae	*Drunella*	-	7%	**27%**	**24%**	26%	15%	-
	Heptageniidae	*Cinygmula*	8%	-	-	6%	6%	7%	12%
		Epeorus	**38%**	**27%**	16%	12%	**27%**	**35%**	8%
		Rhithrogena	16%	**27%**	12%	12%	5%	13%	23%
Diptera	Chironomidae		-	-	7%	11%	8%	-	-

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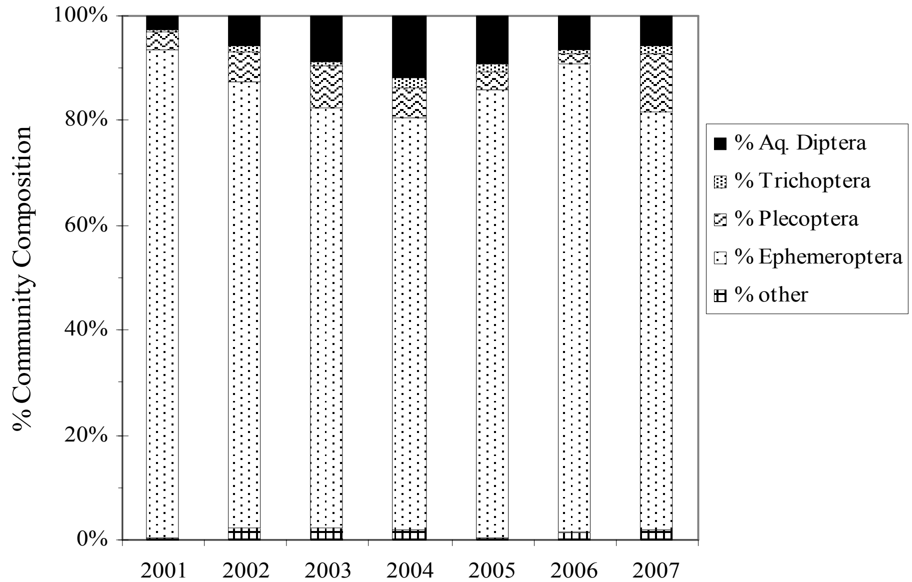

Figure 8. Community composition of benthic macroinvertebrates in Upper Greens Creek Site 48 samples in 2001 through 2007.

Juvenile Fish Populations

The 2007 juvenile fish survey captured 95 Dolly Varden in 26 minnow traps within the same 50-m reach at Upper Greens Creek Site 48 as sampled in 2002 through 2006. Three "block" traps were set downstream of this reach and two upstream; they captured one additional Dolly Varden that is not included in the reported results. The estimated 2007 population size for the reach, based on a three-pass removal, was 109 Dolly Varden with an approximate density of 0.2 fish/m² of wetted stream surface area. This was similar to the population estimate from 2001 and a significantly lower estimated population of fish than in 2002 through 2006 (Table 4, Appendix 4). The density estimates follow a similar trend, with the 2007 density being similar to that of 2001 and 2002, and considerably lower than the density values for 2003 through 2006.

Table 4. Juvenile fish population estimates for Upper Greens Creek Site 48 based on minnow trapping in 2001 through 2007.

Year Sampled	Fish Species	No. Fish Caught	FLength, mm	Popn Estimate, fish (95% CI)	Sample Reach, m	Density, fish/m^2
2001	DV	68	48-139	96 (68-124)	72	0.20
2002	DV	126	45-160*	145 (134-173)	50	0.23
2003	DV	285	54-180	333 (305-361)	50	0.9**
2004	DV	244	54-158	255 (246-264)	50	0.88
2005	DV	212	50-149	246 (222-264)	50	0.65
2006	DV	212	49-150	228 (215-241)	50	0.59
2007	DV	95	53-154	109 (95-123)	50	0.2**

* Forklengths recorded in 5mm intervals.
** Based on estimated wetted area value.

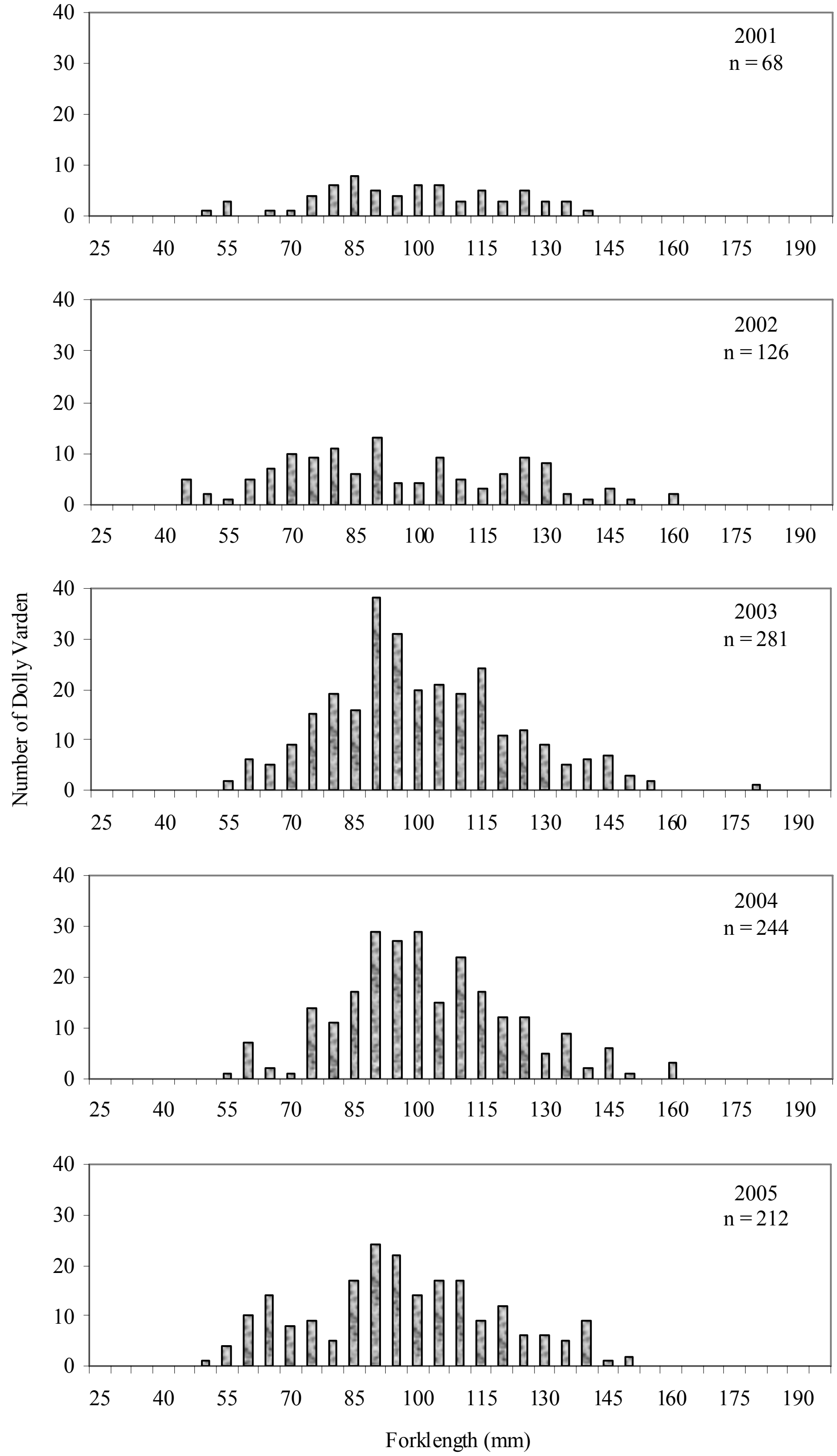

Figure 9. Length frequencies of Dolly Varden captured at Upper Greens Creek Site 48 in 2001 through 2007.

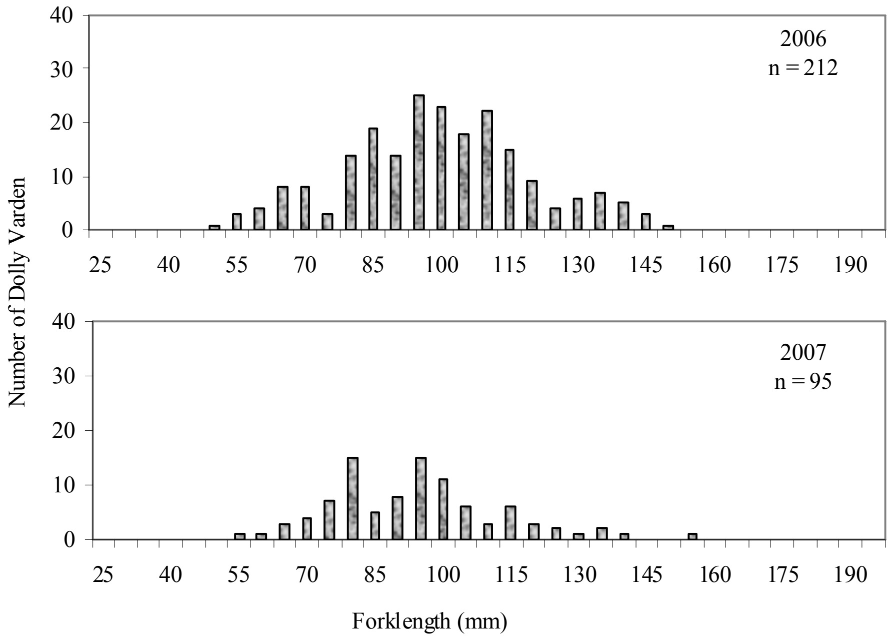

Figure 9. (Continued)

Fork lengths of captured Dolly Varden represent a wide range of fish sizes. Although we have no validation data to correlate fish lengths with age such as scale or otolith analyses, the ranges of fork lengths (Table 4) and length frequency plots (Figure 9) suggest that multiple age classes of Dolly Varden were captured in all seven years of biomonitoring. Young-of-the-year are not well represented in any of the years' sampling, but the numbers of larger fish the following years indicate that recruitment is occurring.

Metals Concentrations in Juvenile Fish

Median concentrations of metals in juvenile Dolly Varden tissues at Upper Greens Creek Site 48 in 2007 were generally similar to those of the previous six years of biomonitoring at this site, although medians for cadmium and zinc were second highest of the seven years of samples (Figure 10, Appendix 5). The mean rank for lead concentration in 2007 was significantly higher[4] than in 2003, that for cadmium was substantially higher in 2007 than in 2003, and the mean rank concentrations for silver, copper, selenium, and zinc were not statistically different from those of the previous six years of sampling at this site.

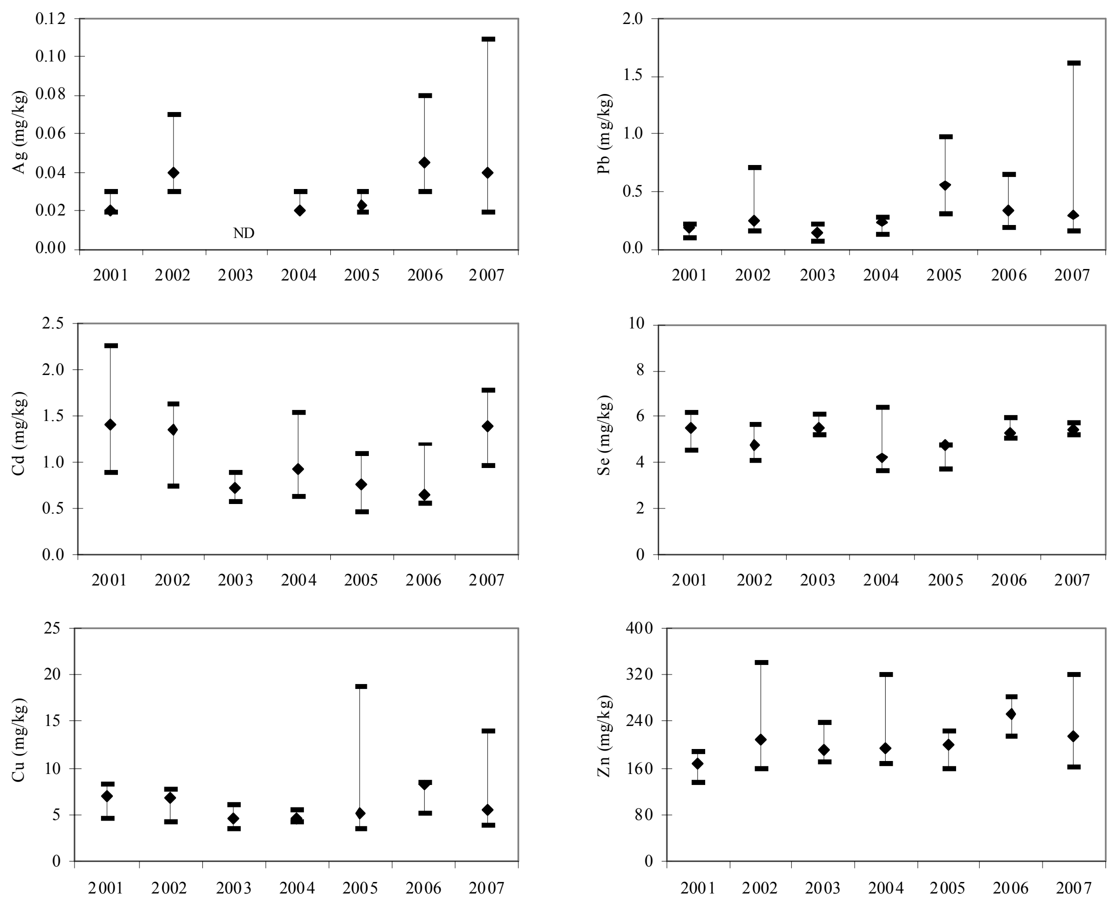

Figure 10. Whole body metals concentrations (medians and ranges) in Dolly Varden captured at Upper Greens Creek Site 48 in 2001 through 2007. ND = Not Detected at reporting limit for Ag of 0.02 mg/kg.

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[4] Throughout this report, groups reported as *not statistically different* were neither significantly different ($\alpha \leq 0.05$) nor substantially different ($0.05 < \alpha \leq 0.10$).

Summary

The Upper Greens Creek Site 48 sampling reach is just upstream of all KGCMC mine facilities and roads, so serves as a “control” site for biomonitoring. Any observed trends over time are anticipated to reflect changes in natural background conditions rather than effects from mine development and operation. In 2007, compared to previous years of sampling, this site exhibited moderate periphyton levels; relatively low benthic macroinvertebrate density and taxonomic richness; a lowered Dolly Varden population; higher juvenile fish tissue concentrations of lead; slightly higher tissue concentrations of cadmium; and tissue concentrations of silver, copper, selenium, and zinc similar to previous years. We have no evidence to suggest that these results are indicative of anything other than natural variability within this stream reach.

The benthic macroinvertebrate community remains dominated by disturbance-sensitive species, and the reductions noted may be at least partially attributed to the high stream flows of November 2005 and July 2008 that moved bedload and shifted large woody debris in the sampling reach. The Dolly Varden population density was at the low end of the typical range for this type of stream channel reach in southeast Alaska with a downstream barrier to anadromous fish, and the size distribution of captured fish shows a shift to larger sizes that is reasonable given the increased water velocities in the sampling reach in 2007. Upper Greens Creek Site 48 samples appear consistent with a functioning and apparently healthy aquatic community that is reestablishing after perturbations such as the previous high water events.

<u>GREENS CREEK BELOW POND D SITE 54</u>

Greens Creek Below Pond D Site 54 (Figure 11) was sampled in the afternoon of 20 July 2007. The weather was overcast skies with rain; the water temperature was 7°C and the air temperature was 11°C. The water level was high and rising. Deep, fast water (5.0-6.9 feet per second in deep portions) prevented us from safely measuring average wetted width. The channel cross section and discharge estimate were obtained from a large log crossing the channel; even so, the water was high enough that the log was touching the water surface on the right half of the channel. Compared to last year, the thalweg and side channel locations were closer to those noted before 2005's high water event. There continued to be a pulse of stream bed material moving through the sample reach, and the fish sampling area showed erosion on the left bank with concomitant increases and changes in large woody debris, particularly just downstream of the mouth of Gallagher Creek. We attribute these changes to the high discharge levels of spring and summer 2006 due to heavy snowpack.

During the sampling session, KGCMC staff measured Greens Creek at 7.2°C, with a pH of 7.48 units, a conductivity of 87.2 μS/cm, and a turbidity of 7.38 NTU.

Figure 11. Greens Creek Below Pond D Site 54, 20 July 2007.

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 data from 2001 through 2007 were analyzed together. When analyzed in an all-pairwise comparison, the difference between 2007 and 2006 values were significantly different with periphyton biomass being considerably lower in 2007 (Appendix 2). The Box and Whisker output plot from Statistix is shown in Figure 12.

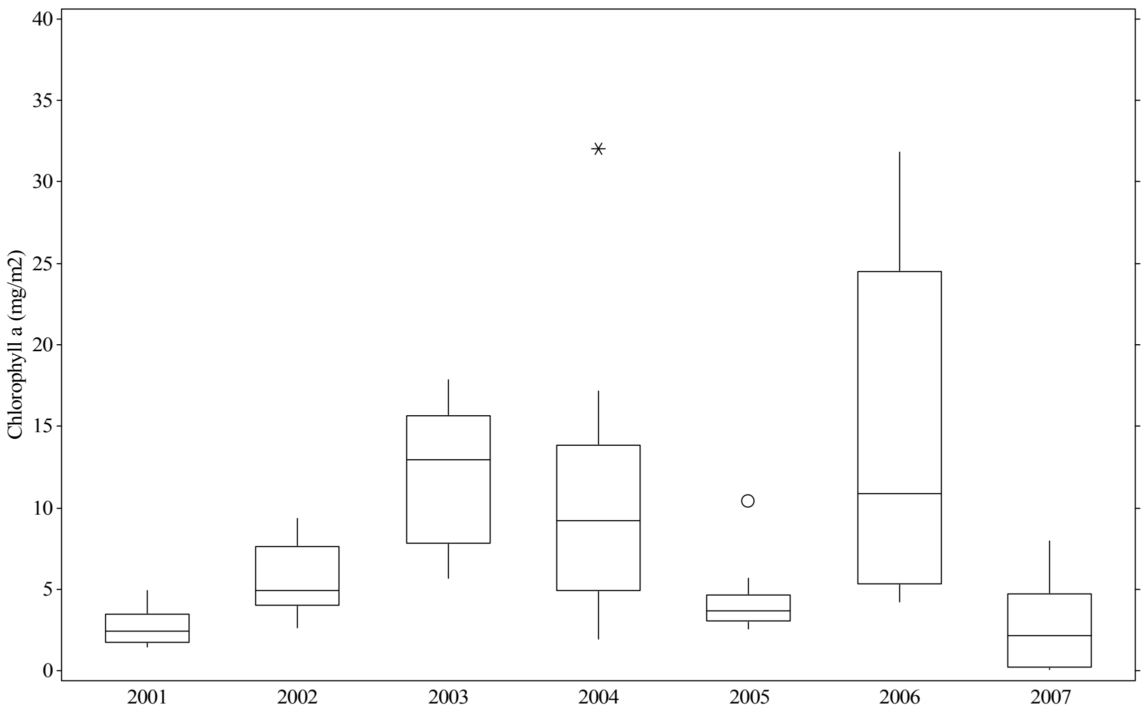

Figure 12. Estimated periphyton biomass densities at Greens Creek Below Pond D Site 54 in 2001 through 2007 (n = 10 samples each year). Box encompasses middle half of data; horizontal line is median value. One possible statistical outlier value (*) was identified in the 2004 data set, and one probable statistical outlier value (○) was identified in the 2005 data set.

The periphyton community at Greens Creek Below Pond D Site 54 had a higher proportion of chlorophyll *c* than chlorophyll *b* in all seven years sampled (Figure 13), indicating communities dominated by diatoms and/or dinoflagellates. Low to undetectable concentrations of chlorophyll *b* indicate low populations of green algae in the periphyton communities.

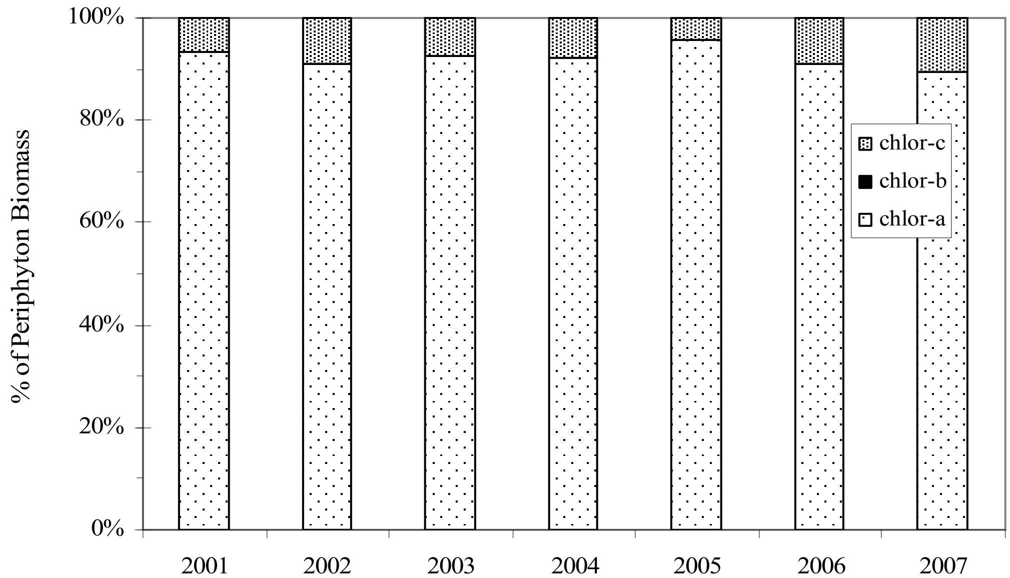

Figure 13. Proportions of mean chlorophyll *a*, *b*, and *c* concentrations in Greens Creek Below Pond D Site 54 samples in 2001 through 2007.

Benthic Macroinvertebrates

The average density of benthic macroinvertebrates (both median and mean) in 2007 Greens Creek Below Pond D Site 54 samples was the lowest of the seven years sampled at this site, and significantly lower than the high densities found in the 2003 and 2004 samples (Table 5, Figure 14, Appendix 3). Taxonomic richness followed a similar pattern, remaining low from the previous year.

Table 5. Summary of benthic macroinvertebrate samples at Greens Creek Below Pond D Site 54 in 2001 through 2007.

Year	Mean Density (aqua. 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
2005	2786	25	14.8
2006	1050	15	10.0
2007	650	15	8.2

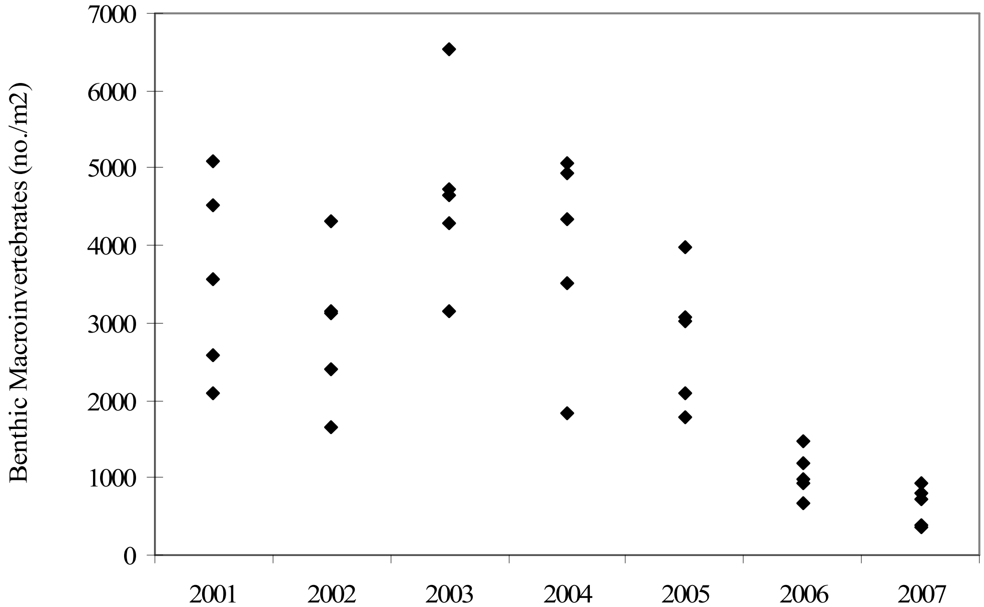

Figure 14. Density of benthic macroinvertebrates (n = 5 samples each year) in Greens Creek Below Pond D Site 54 samples in 2001 through 2007.

Invertebrate communities in Greens Creek Site 54 continued to be dominated by EPT taxa (Figure 15). In each of the seven years sampled, Ephemeroptera were the most commonly collected order (Figure 16). In 2007, the Ephemeroptera were dominated by Baetidae: *Baetis,* and Heptageniidae: *Cinygmula, Epeorus,* and *Rhithrogena. Baetis* are rated "moderately sensitive" to decreased water quality, *Epeorus* are "sensitive," and *Rhithrogena* are "very sensitive" (Barbour et al. 1999). The dominance of the benthic macroinvertebrate community by 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 productive aquatic community at this site.

Table 6. Common taxa (>5.0% of benthic macroinvertebrates) found in Greens Creek Below Pond D Site 54 samples in 2001 through 2007. The percent dominant taxon each year is bold.

Order	Family	Genus	2001	2002	2003	2004	2005	2006	2007
Ephemeroptera	Baetidae	*Baetis*	14%	15%	9%	15%	14%	20%	**27%**
	Ephemerellidae	*Drunella*	7%	19%	**38%**	**38%**	**39%**	11%	-
	Heptageniidae	*Cinygmula*	18%	5%	8%	6%	6%	13%	26%
		Epeorus	**53%**	**43%**	17%	12%	25%	**24%**	16%
		Rhithrogena	-	10%	13%	9%	-	22%	19%
Diptera	Chironomidae		-	-	6%	8%	-	-	-

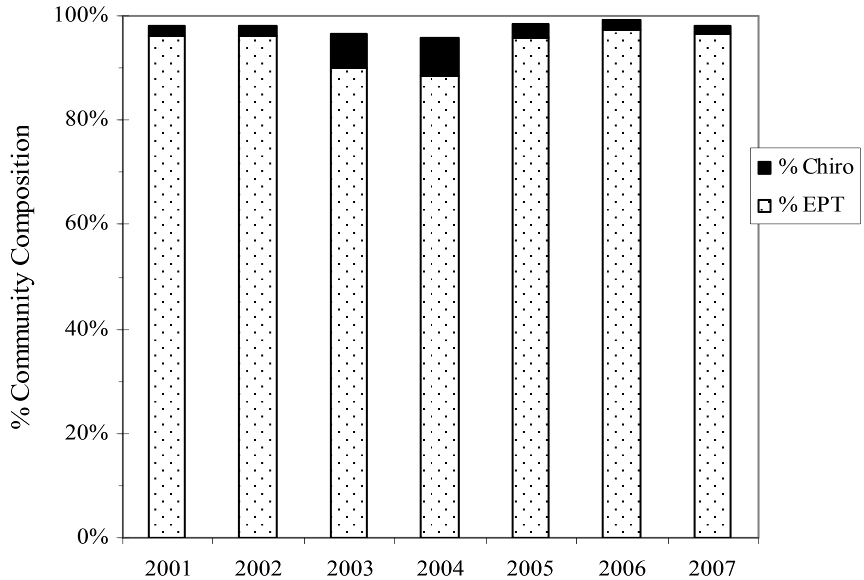

Figure 15. Proportions of EPT taxa and Chironomidae in Greens Creek Below Pond D Site 54 samples in 2001 through 2007.

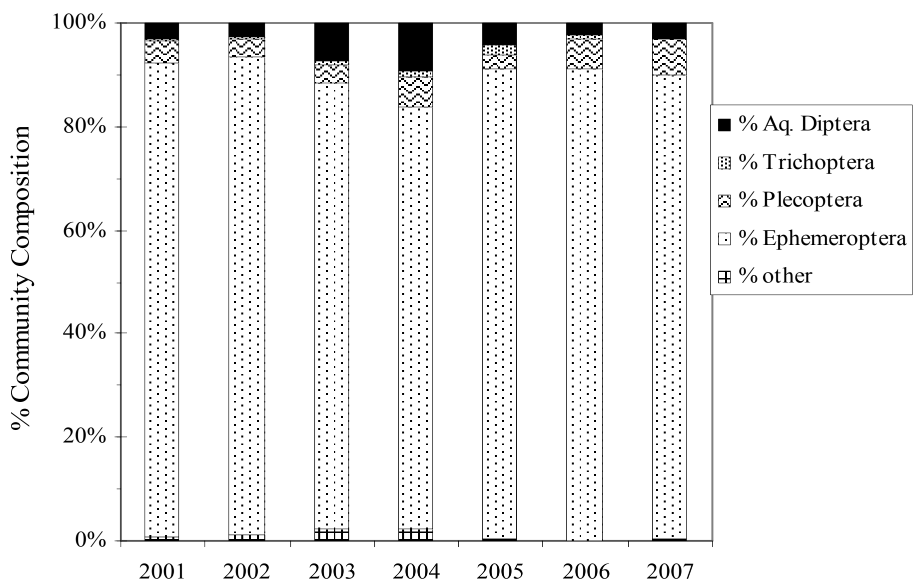

Figure 16. Community composition of benthic macroinvertebrates in Greens Creek Below Pond D Site 54 samples in 2001 through 2007.

Juvenile Fish Populations

The 2007 juvenile fish survey at Greens Creek Below Pond D Site 54 captured 107 Dolly Varden and 8 cutthroat trout in 19 minnow traps in the same 28-m reach as sampled in 2002 through 2006 (Table 7). No coho salmon were captured. Three "block" traps were used immediately downstream of the sample reach and three upstream; they captured an additional 4 Dolly Varden that are not included in the reported results. The estimated 2007 population sizes for the reach, based on a three-pass removal, were 122 Dolly Varden with an approximate density of 0.4 fish/m² and 10 cutthroat trout with an approximate density of 0.03 fish/m² of wetted stream area.

The estimated population of Dolly Varden in this sample reach in 2007 was significantly lower than the six previous biomonitoring estimates at this site. The estimated populations of juvenile coho salmon have been much smaller than those of Dolly Varden each of the previous six years of biomonitoring sampling at this site (Table 7, Appendix 4), but 2007 was the first biomonitoring sampling at this site to capture no coho salmon. It is interesting that 2007 was also the first reported capture of cutthroat trout in any of the three biomonitoring reaches along Greens Creek.

Table 7. Juvenile fish population estimates for Greens Creek Below Pond D Site 54 based on minnow trapping in 2001 through 2007.

Year Sampled	Fish Species	No. Fish Caught	FLength mm	Popn Estimate, fish (95% CI)	Sample Reach, m	Density, fish/m²
2001	DV	138	27-162	158 (141-175)	28	0.58
2002	DV	271	33-160	290 (276-304)	28	1.00
2003	DV	232	51-184	331 (275-387)	28	1.8*
2004	DV	201	52-161	234 (211-257)	28	1.57
2005	DV	213	52-146	255 (227-283)	28	1.17
2006	DV	217	49-158	254 (229-279)	28	1.22
2007	DV	107	50-145	122 (108-136)	28	0.4*
2001	CO	12	32-95	17 (8-26)	28	0.06
2002	CO	21	59-85	21 (21)	28	0.07
2003	CO	8	44-52	8 (8)	28	0.04*
2004	CO	24	70-95	31 (20-42)	28	0.21
2005	CO	61	66-93	67 (59-75)	28	0.31
2006	CO	7	62-88	7 (7)	28	0.03
2007	CO	0	---	0	28	0

* Based on estimated wetted area value.

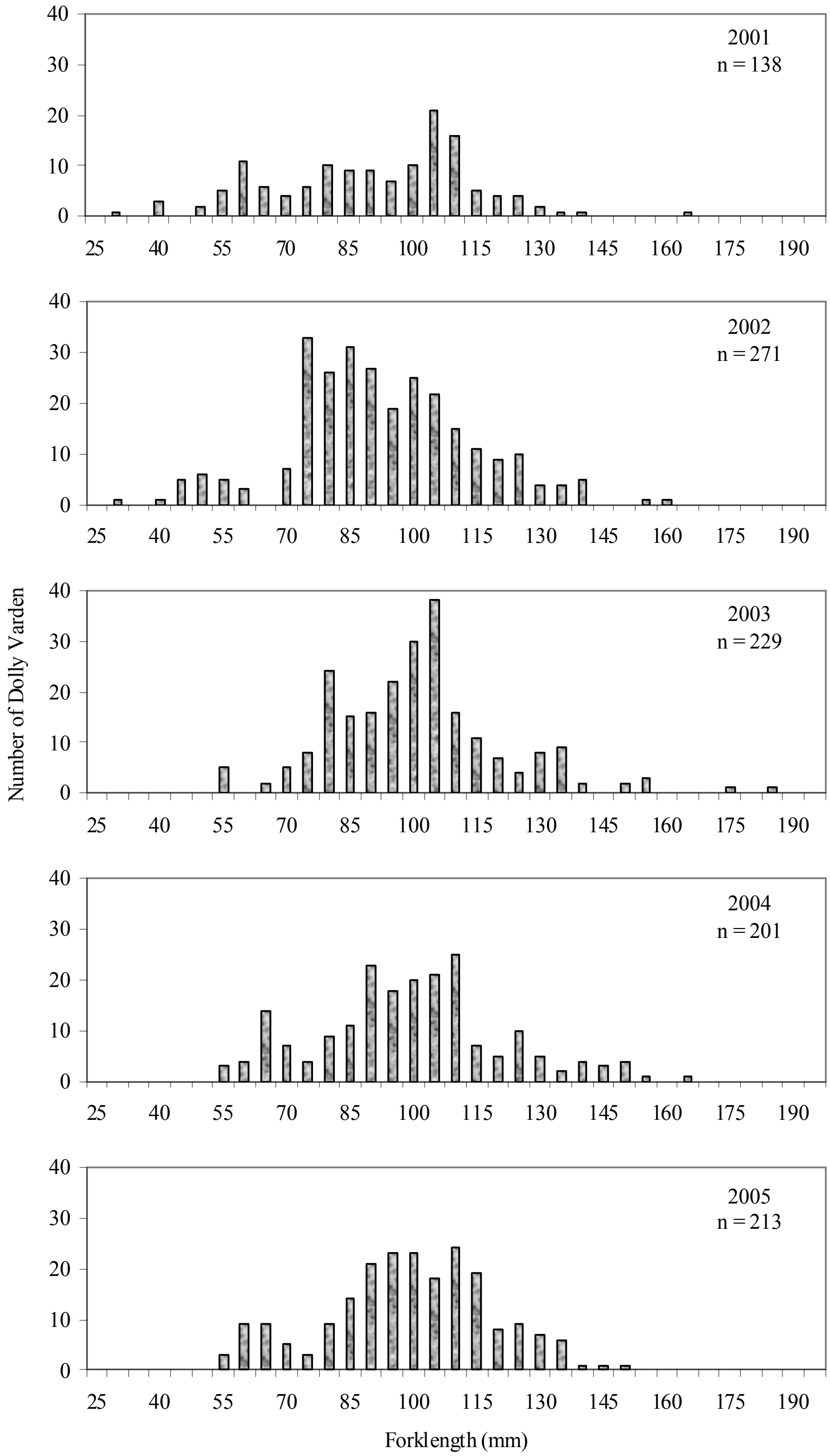

Figure 17. Length frequencies of Dolly Varden captured at Greens Creek Below Pond D Site 54 in 2001 through 2007.

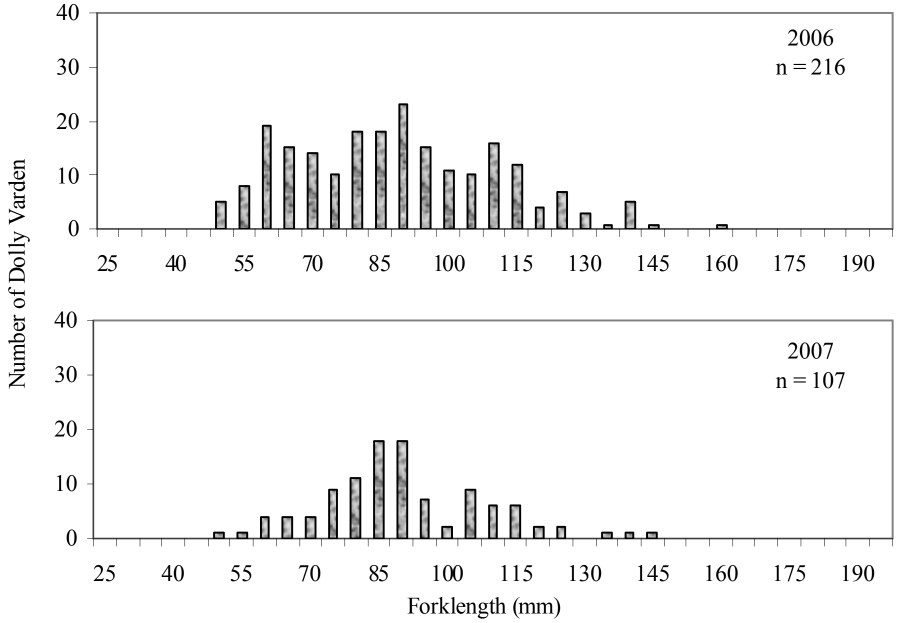

Figure 17. (Continued)

Fork lengths of captured Dolly Varden represent a wide range of fish sizes. Although we have no validation data to correlate fish lengths with age such as scale or otolith analyses, the length frequency plots (Figure 17) suggest that multiple age classes of Dolly Varden were captured in all seven years of biomonitoring. Young-of-the-year are not well represented in any year's sampling, but the numbers of larger fish the following years indicate that recruitment is occurring.

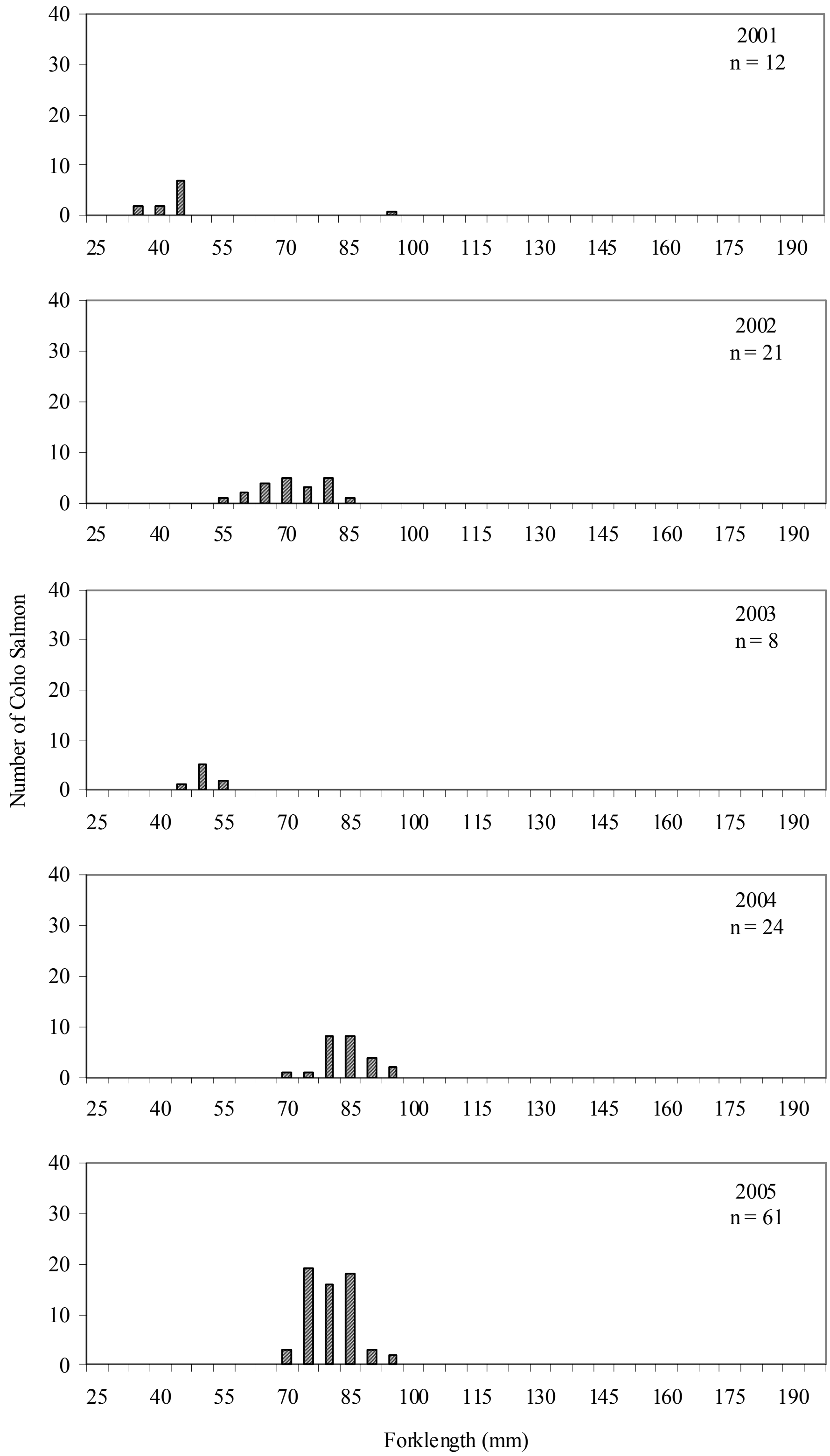

Figure 18. Length frequencies of juvenile coho salmon captured at Greens Creek Below Pond D Site 54 in 2001 through 2007.

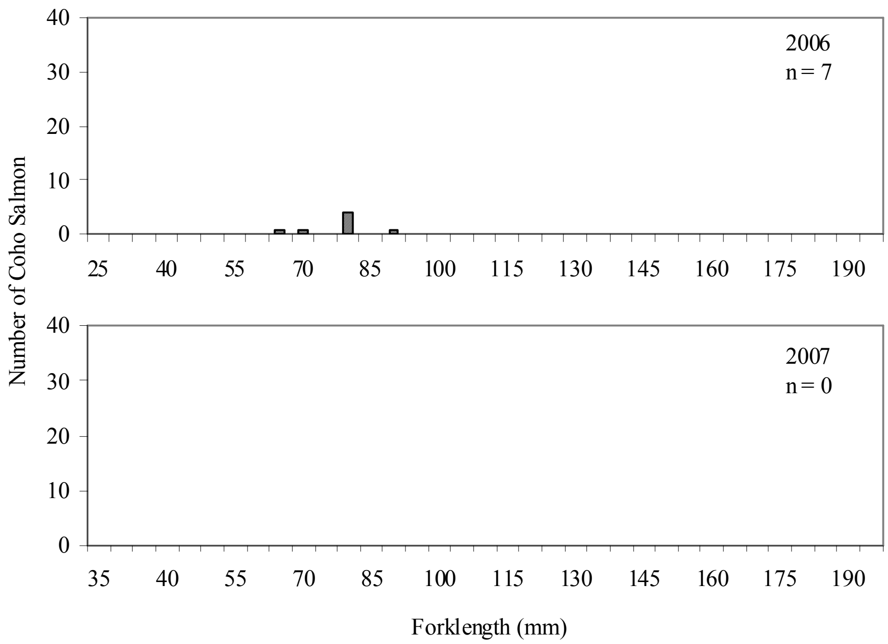

Figure 18. (Continued)

Metals Concentrations in Juvenile Fish

Median concentrations of metals in juvenile Dolly Varden tissues at Greens Creek Below Pond D Site 54 in 2007 were similar to or somewhat elevated from those found in the previous six years' samples at this site (Figure 19, Appendix 5). Mean rank scores for concentrations of selenium in 2007 samples were significantly higher than in 2002 and 2005, and those for lead were significantly higher than in 2005. The mean rank scores for whole body concentrations of silver, cadmium, copper, and zinc in 2007 were not statistically different from those of the previous six years of sampling at this site.

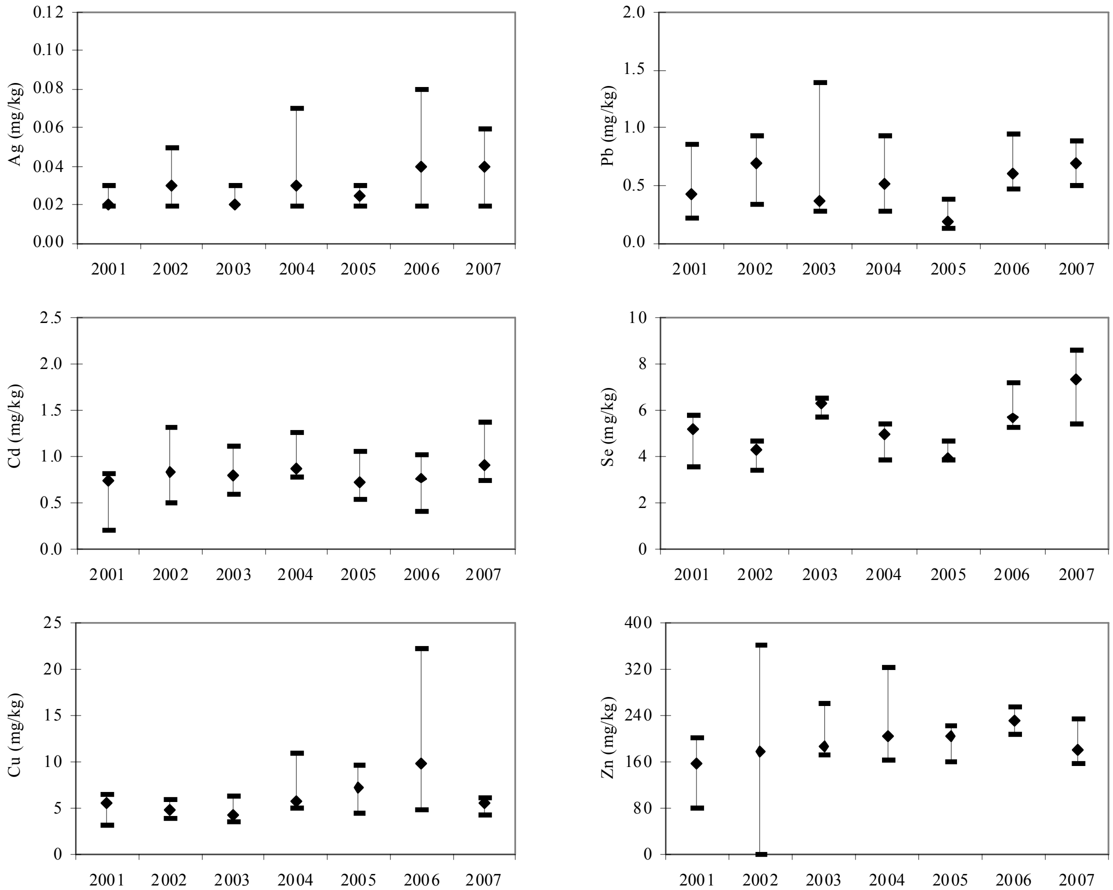

Figure 19. Whole body metals concentrations (medians and ranges) in Dolly Varden captured at Greens Creek Below Pond D Site 54 in 2001 through 2007.

Summary

Greens Creek Below Pond D Site 54 serves as a “treatment” site for biomonitoring sampling since the sampling reach is just downstream of all KGCMC mine, mill, and waste rock facilities along Greens Creek. Any trends over time that differ from those in Upper Greens Creek Site 48 could potentially result from mine development and operation. In 2007, Site 54 exhibited reduced periphyton levels; low benthic macroinvertebrate density and taxonomic richness; lower Dolly Varden abundance and density; no coho salmon presence; higher juvenile fish tissue concentrations of lead and selenium; and fish tissue concentrations of silver, cadmium, copper, and zinc similar to values in previous years.

The benthic macroinvertebrate community is still dominated by disturbance-sensitive species and the noted reductions may be at least partially attributed to two extreme mid-July high water events that moved much of the Greens Creek bedload and large woody debris in the sample reach. The Dolly Varden population density and size distribution is within expectations for this type of stream channel reach in southeast Alaska. The drop in coho salmon captures in 2006 and lack of captures in 2007 raise considerable concern for the continued presence of this species in this portion of Greens Creek. Except for the absence of coho salmon, Greens Creek Below Pond D Site 54 samples appear consistent with a functioning and apparently healthy aquatic community that is reestablishing after perturbations such as the two recent high water events.

TRIBUTARY CREEK SITE 9

Tributary Creek Site 9 (Figure 20) was sampled in the morning of 20 July 2007. The weather was low overcast with light rain; the water temperature was 11°C and the air temperature 13°C. Rain had fallen overnight and the water level was relatively high and rising. The water was humic-stained and had abundant small pieces of organic matter, and the clarity was typical of streams of this type at high flows. We had noted no major changes in channel, banks, or large woody debris at this site between 2001 and 2006; in 2007 we found that portions of the right bank in the upper half of the sample reach had eroded and that several pieces of large woody debris had transitioned from suspended over the water surface to within the water column. These features are changing the locations of some of the pools and riffles in the sample reach. Despite these changes, we noted no evidence of recent scouring flows or other major disturbance events.

During the sampling session, KGCMC staff measured Tributary Creek at 11.4°C, with a pH of 6.91 units, a conductivity of 69 μS/cm, and a turbidity of 7.71 NTU.

Figure 20. Tributary Creek Site 9, 20 July 2007.

Periphyton Biomass

Three out of ten periphyton samples could not be analyzed because they did not dry properly and resulted in heterogeneous lab samples. Concentrations of chlorophyll *a*, an estimate of periphyton biomass, at Tributary Creek Site 9 were not statistically different among the first five years sampled (2001 through 2005); however, the values from 2007 samples were significantly lower than the high values from 2003 samples. Median biomass in 2007 was less than the medians from 2001 through 2005, but slightly higher than the median of 2006 (Appendix 2). The Box and Whisker output plot from Statistix is shown in Figure 21.

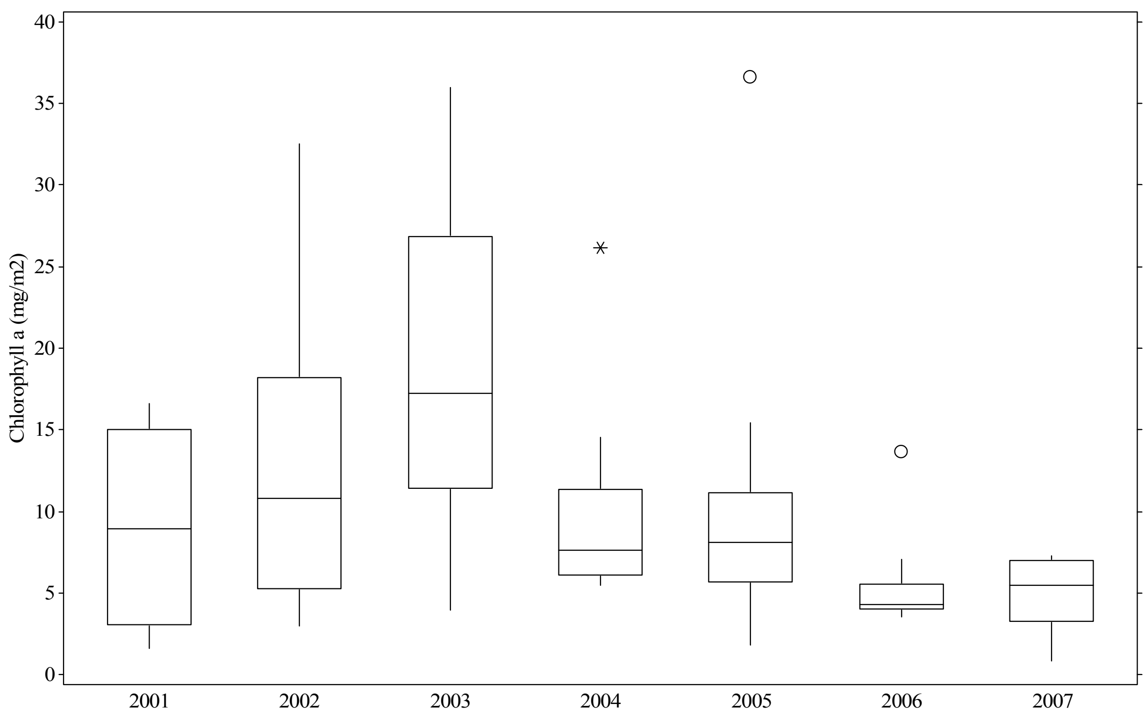

Figure 21. Estimated periphyton biomass densities at Tributary Creek Site 9 in 2001 through 2007 (n = 10 samples 2001-2006, n = 7 samples in 2007). Box encompasses middle half of data; horizontal line is median value. One possible statistical outlier value (*) was identified in the 2004 data set, and one probable statistical outlier value (○) was identified in each of the 2005 and 2006 data sets.

The periphyton community at Tributary Creek Site 9 in 2007 had a higher proportion of chlorophyll *c* than chlorophyll *b*, with the exception of proportions in 2002 (Figure 22). Higher concentrations of chlorophyll *b* compared to chlorophyll *c* indicate the presence of at least patchy populations of green algae (chlorophyll *b*) in addition the presence of diatoms and/or dinoflagellates (chlorophyll *c*).

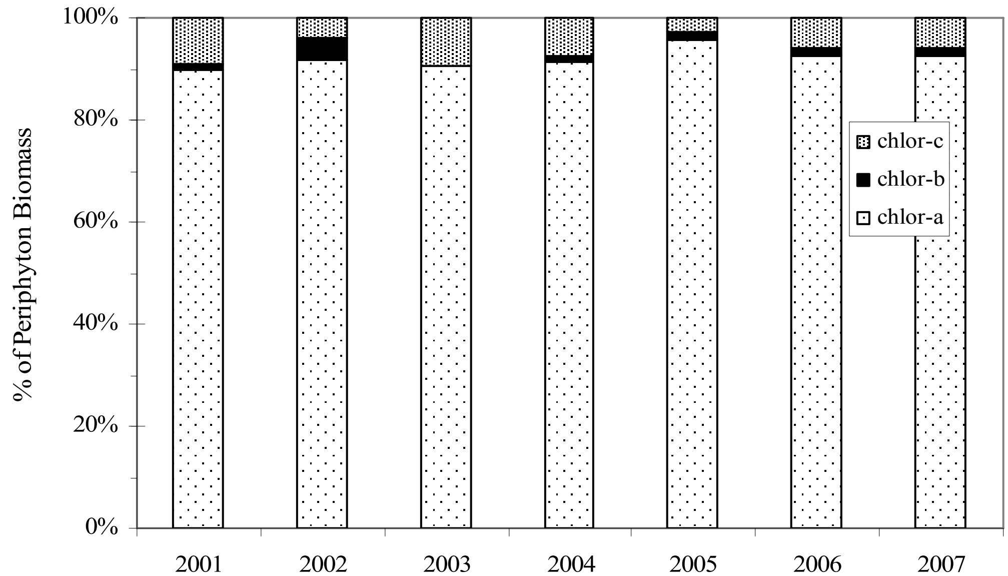

Figure 22. Proportions of mean chlorophyll *a*, *b*, and *c* concentrations in Tributary Creek Site 9 samples in 2001 through 2007.

Benthic Macroinvertebrates

The average density of benthic macroinvertebrates (both median and mean) in 2007 Tributary Creek Site 9 samples was moderate compared to previous years (Table 8, Figure 23), and substantially different from the higher densities of 2003. Taxonomic richness, as expressed by number of taxa in samples, was moderate over the whole site but lower per sample in 2007, and significantly lower than the many taxa in the 2003 samples.

Table 8. Summary of benthic macroinvertebrate samples at Tributary Creek Site 9 in 2001 through 2007.

Year	Mean Density (aqua. 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
2005	1056	30	14.2
2006	1250	26	12.4
2007	436	21	10.0

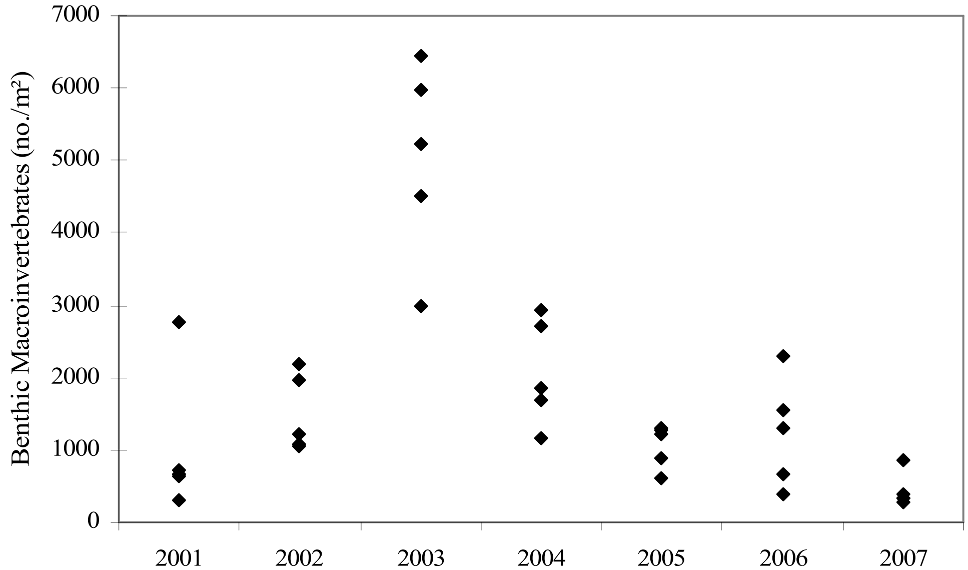

Figure 23. Density of benthic macroinvertebrates (n = 5 samples each year) in Tributary Creek Site 9 samples in 2001 through 2007.

The EPT taxa continued to be the majority component of the Tributary Creek Site 9 benthic macroinvertebrate community. Chironomidae remained a relatively small, stable component at the Tributary Creek site (Figure 24).

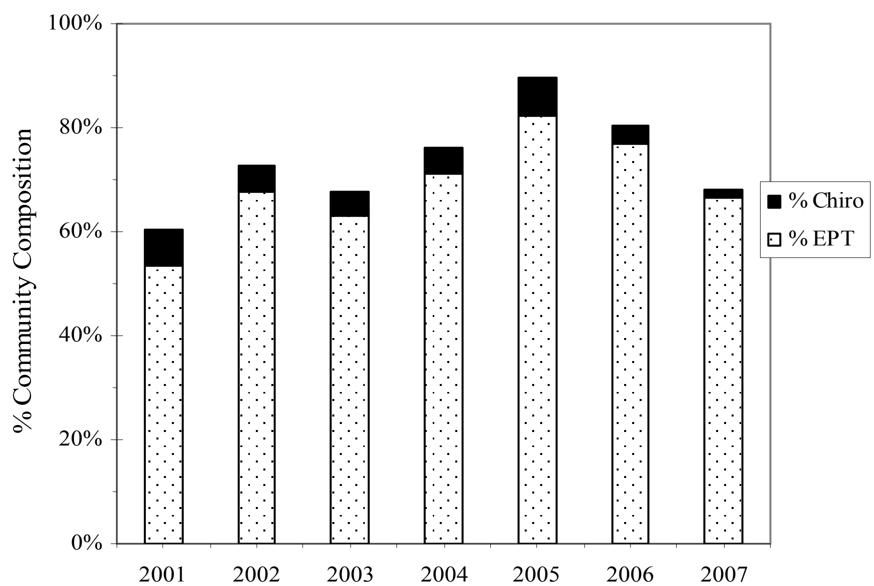

Figure 24. Proportions of EPT taxa and Chironomidae in Tributary Creek Site 9 samples in 2001 through 2007.

In the seven years of benthic macroinvertebrate community sampling at Tributary Creek Site 9, the community at this site has tended to be more complex than at the Greens Creek sites, with more taxa being common in the samples. The 2007 Tributary Creek Site 9 samples had more common taxa than those from 2002, 2004, 2005, and 2006; and were less diverse than in 2001 (Table 9).

Table 9. Common taxa (>5.0% of benthic macroinvertebrates) found in Tributary Creek Site 9 samples in 2001 through 2007. The dominant taxon each year is bold.

Order	Family	Genus	2001	2002	2003	2004	2005	2006	2007
Ephemeroptera	Baetidae	*Baetis*	8%	16%	6%	-	7%	-	-
	Ephemerellidae	*Ephemerella*	-	-	-	-	-	12%	-
	Heptageniidae	*Cinygma*	-	-	-	-	8%	-	-
		Cinygmula	17%	**24%**	**20%**	5%	-	20%	**20%**
	Leptophlebiidae	*Paraleptophlebia*	13%	13%	10%	**43%**	**36%**	**33%**	17%
	Ameletidae	*Ameletus*	-	-	-	-	-	5%	8%
Plecoptera	Chloroperlidae	*Suwallia*	7%	-	-	-	7%	-	-
		Sweltsa	-	6%	-	-	-	-	12%
		Neaviperla	-	-	7%	-	-	-	-
	Nemouridae	*Zapada*	-	-	15%	-	8%	-	-
Diptera	Chironomidae		7%	-	-	5%	8%	-	-
	Simuliidae	*Simulium*	8%	-	-	-	-	-	5%
Acarina			-	6%	-	-	-	-	-
Oligochaeta			8%	-	14%	11%	-	-	12%
Ostracoda			**18%**	-	8%	-	-	11%	8%
Isopoda	Gammaride	*Gammarus*	-	14%	-	-	-	-	-

Pollution-sensitive taxa, such as the mayflies *Cinygmula* and *Paraleptophlebia* were well represented at this site (Table 9, Figure 25). The presence of these taxa 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 includes both insects and non-insects such as springtails (Collembola), worms (Oligochaeta), mites (Acarina), and seed shrimp (Ostracoda) (Appendix 3).

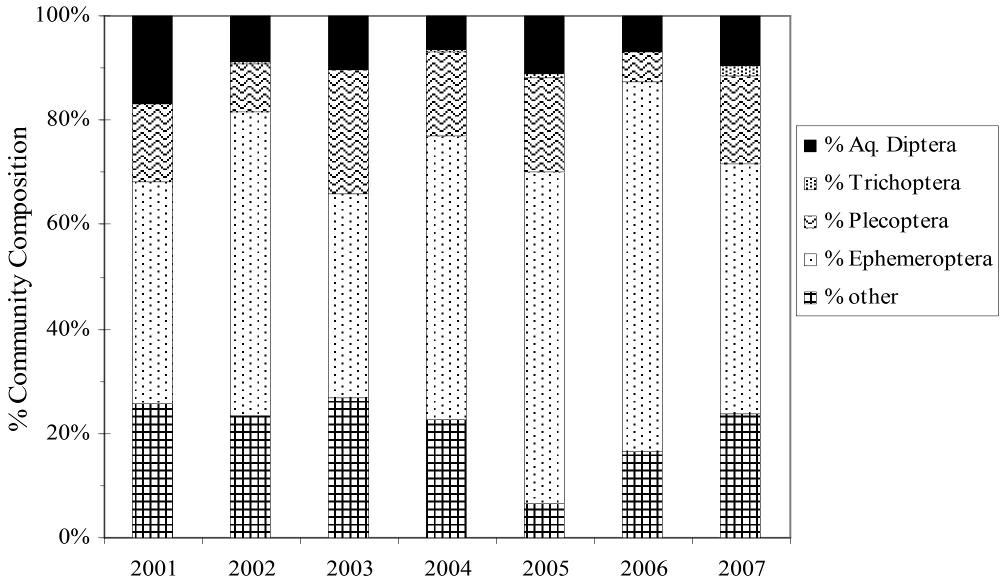

Figure 25. Community composition of benthic macroinvertebrates in Tributary Creek Site 9 samples in 2001 through 2007.

Juvenile Fish Populations

The 2007 juvenile fish survey in Tributary Creek Site 9 captured 12 Dolly Varden and 69 coho salmon in 25 minnow traps in the same 50-m sample reach as sampled in 2002 through 2006 (Table 10). Three "block" traps were set immediately downstream of the sample reach and two upstream; they captured an additional 3 Dolly Varden and 1 coho salmon that are not included in the reported results. Captured fish appeared in good condition. The estimated 2007 population sizes for the reach, based on a three-pass removal, was 12 Dolly Varden with an approximate density of 0.10 fish/m² and 71 coho salmon with an approximate density of 0.58 fish/m² of wetted stream surface area. Capture numbers and fish densities have been quite variable at this site during the seven years of biomonitoring sampling. The 2007 population estimate for Dolly Varden at this site was significantly higher than in 2006 and significantly lower than in 2001 through 2005 (Table 10, Appendix 4); the density of Dolly Varden in 2007 was approximately one-third the typical density for streams of this channel type in Southeast Alaska. For coho salmon, the population estimate for 2007 was significantly higher than in 2002 through 2006 and significantly lower than in 2001 and 2005; the density of coho salmon in 2007 was higher than typical for streams of this channel type in southeast Alaska.

Fork lengths of Dolly Varden captured at Tributary Creek Site 9 in 2001 through 2007 represented a wide range of fish sizes and suggest use by multiple age classes of both species

(Figure 26), but those of Dolly Varden captured in 2006 and 2007 suggest that the few fish present represented only older age classes, with no representation of young-of-the-year fish. Fork lengths of coho salmon (Figure 27) captured at this site in all years except 2006 suggest both recruitment and use by multiple age classes although we have no validation data to correlate fish lengths with age such as scale or otolith analyses.

Table 10. Juvenile fish population estimates for Tributary Creek Site 9 based on minnow trapping in 2001 through 2007. Captures of incidental species at this sampling site (cutthroat trout, rainbow trout, and sculpin) are not shown, but are reported in Appendix 4.

Year Sampled	Fish Species	No. Fish Caught	FLength, mm	Popn Estimate, fish (95% CI)	Sample Reach, m	Density, fish/m^2
2001	DV	81	58-110	81 (81)	44	0.92
2002	DV	51	38-147	56 (49-63)	50	0.46
2003	DV	19	54-114	20 (17-23)	50	0.3*
2004	DV	32	64-109	33 (31-35)	50	0.56
2005	DV	44	59-131	55 (41-69)	50	0.42
2006	DV	11	85-117	11 (11)	50	0.09
2007	DV	12	81-158	12 (12)	50	0.10
2001	CO	118	39-101	120 (117-123)	44	0.80
2002	CO	44	27-85	46 (42-50)	50	0.35
2003	CO	52	46-88	53 (51-55)	50	0.8*
2004	CO	27	40-94	27 (27)	50	0.46
2005	CO	139	39-103	150 (139-161)	50	1.15
2006	CO	10	69-108	10 (10)	50	0.08
2007	CO	69	38-104	71 (67-75)	50	0.58

* Based on estimated wetted area value.

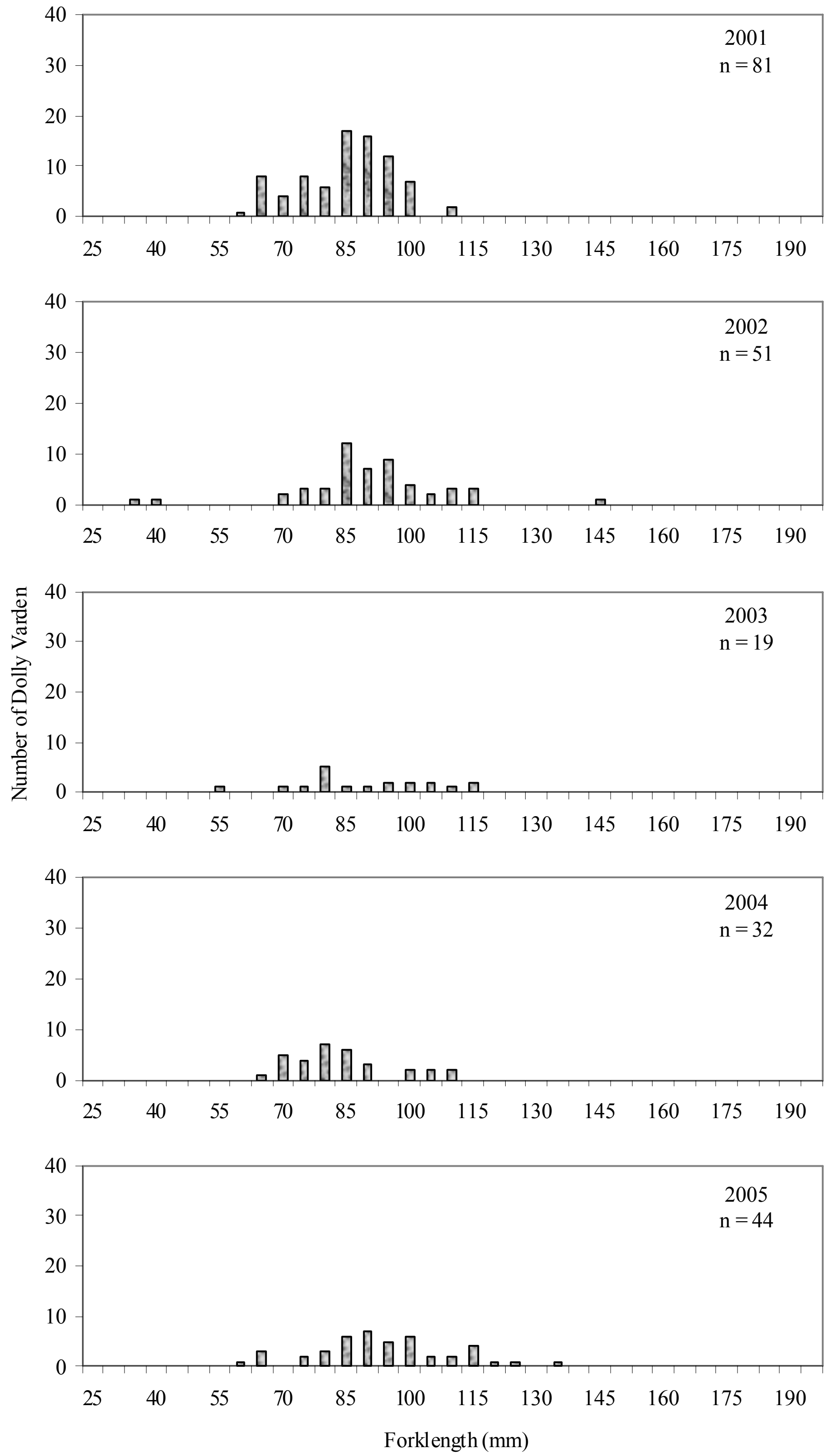

Figure 26. Length frequencies of Dolly Varden captured at Tributary Creek Site 9 in 2001 through 2007.

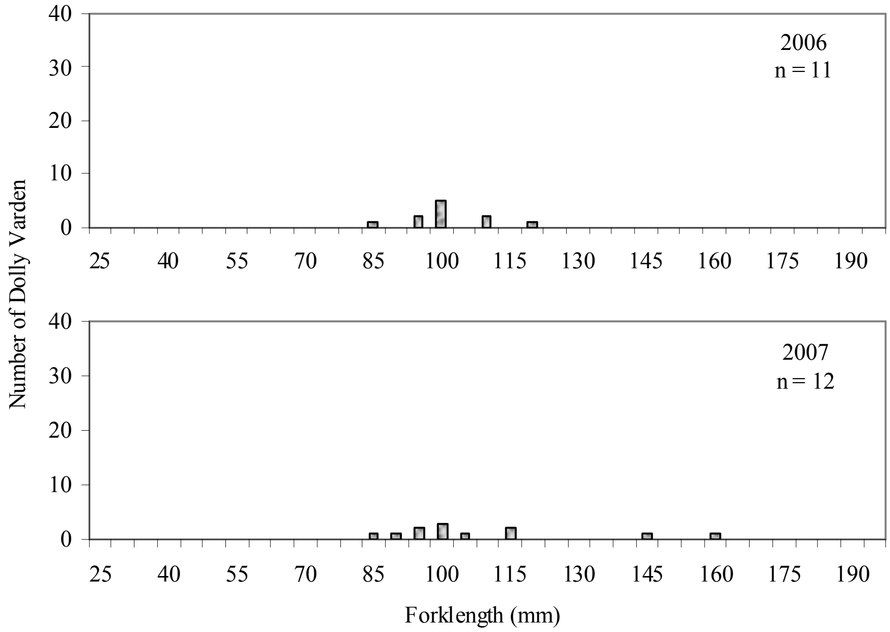

Figure 26. (Continued)

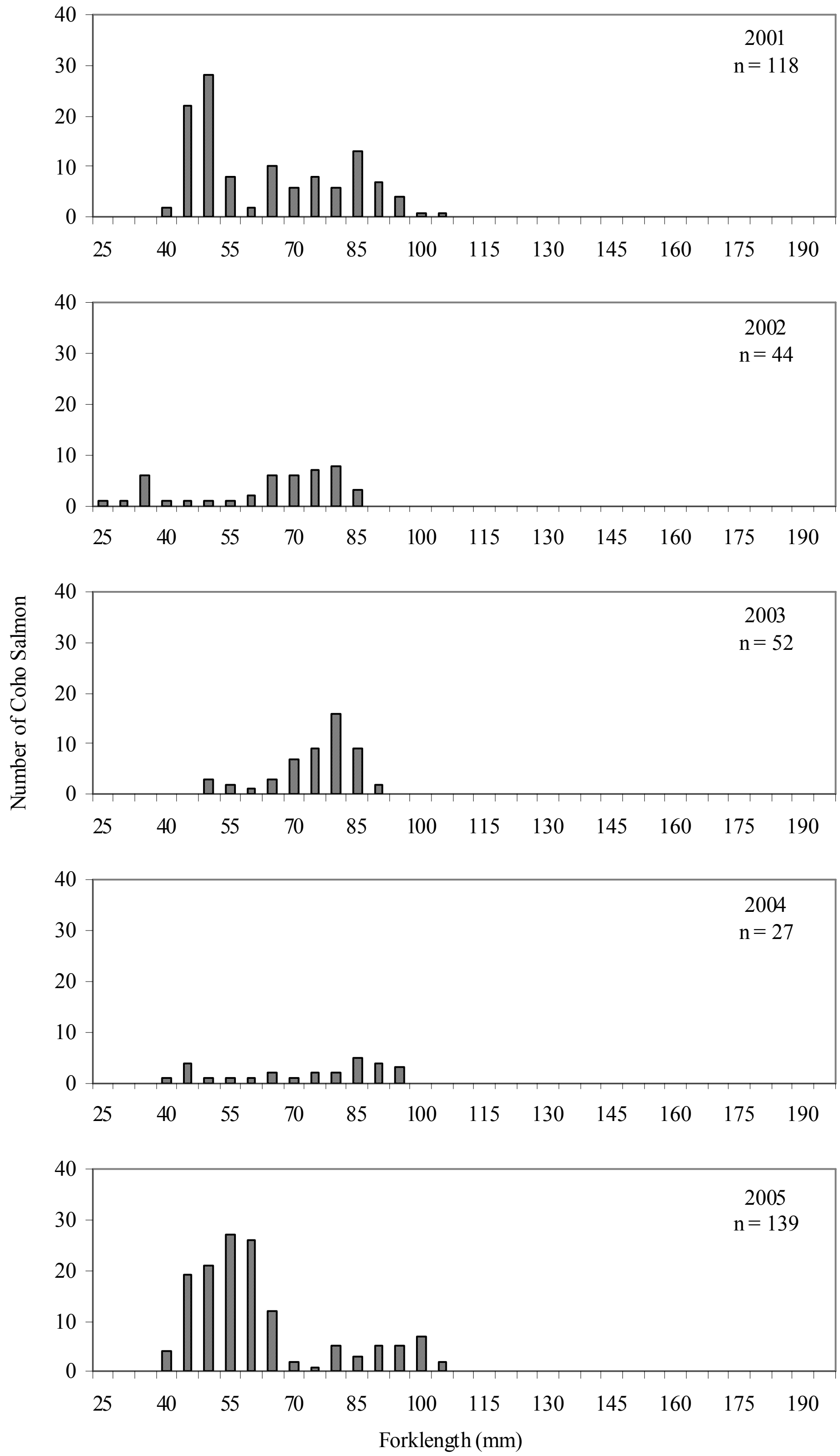

Figure 27. Length frequencies of juvenile coho salmon captured at Tributary Creek Site 9 in 2001 through 2007.

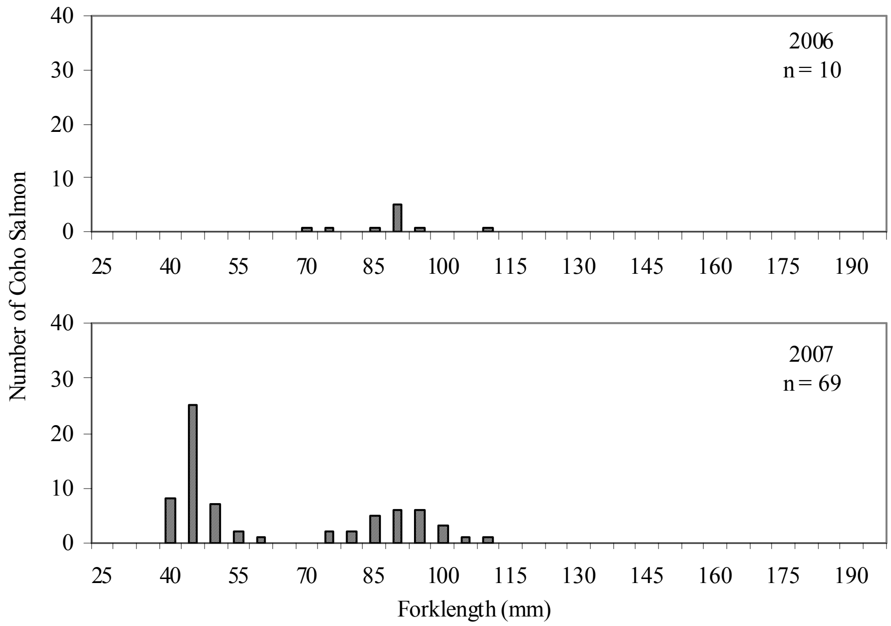

Figure 27. (Continued)

Metals Concentrations in Juvenile Fish

Median concentrations of metals in juvenile Dolly Varden tissues at Tributary Creek Site 9 in 2007 tended to be different than those from the previous six years of sampling (Figure 28, Appendix 5). In 2007 samples, the median tissue concentrations of silver, cadmium, lead, and selenium were the highest measured at this site, while the median tissue concentrations of copper and zinc were the lowest measured at this site when compared to the values from previous years. The mean ranks of tissue concentrations for cadmium and selenium were significantly higher in 2007 than in 2001 (Cd) or 2002 (Se), while the mean ranks for cadmium, selenium, and zinc were substantially higher than in 2003 (Cd, Se) or 2002 (Zn). The mean rank scores for whole body concentrations of silver, copper, and lead in 2007 were not statistically different from those of the six previous years of sampling at this site.

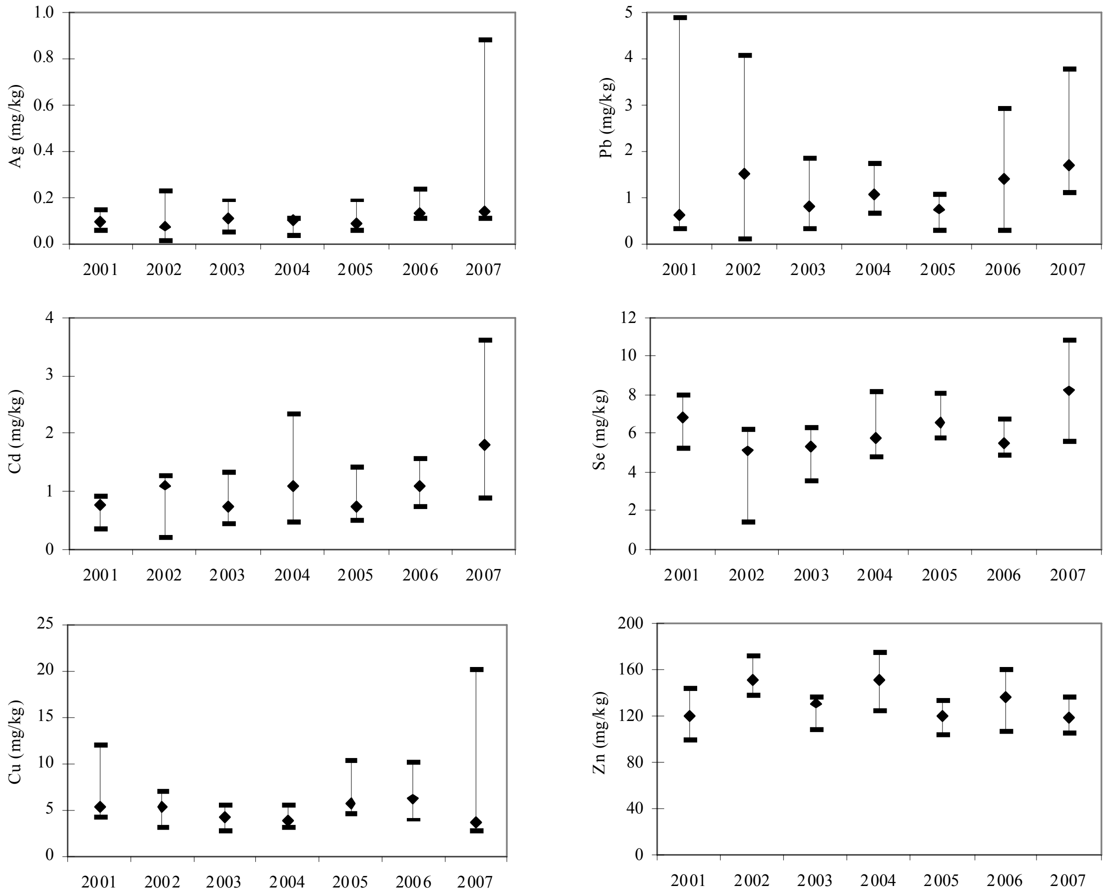

Figure 28. Whole body metals concentrations (medians and ranges) in Dolly Varden captured at Tributary Creek Site 9 in 2001 through 2007.

Summary

Tributary Creek Site 9 serves as a "treatment" site for biomonitoring sampling since it is downstream of the dry stack tailings facility. Any trends over time could potentially be attributed to effects on water quality from the tailings facility. In 2007, the Tributary Creek site exhibited low periphyton levels; low benthic macroinvertebrate density and taxonomic richness; very low Dolly Varden and moderate coho salmon populations and densities; higher juvenile fish tissue concentrations of silver, cadmium, lead, and selenium; and lower tissue concentrations of copper and zinc. The moderately abundant benthic macroinvertebrate community was dominated by disturbance-sensitive species although the taxonomic richness was somewhat lower at the scale of individual samples.

Although there was no evidence that the November 2005 high water event on Greens Creek also occurred on Tributary Creek, Site 9 showed marked changes in habitat between 2006 and 2007.

The Dolly Varden population was very small for the second year, with a noticeable lack of smaller size fish. The coho salmon population at this site showed good recruitment. Except for the Dolly Varden population level, Tributary Creek Site 9 samples appear consistent with a functioning aquatic community that has had perturbations.

COMPARISONS AMONG SITES

Periphyton Biomass

Periphyton biomass at the Greens Creek sites has shown a similar pattern over the seven years sampled, with lower values in 2001 and 2002 followed by a peak in 2003, decreases in 2004 and 2005, increase again in 2006, and down from that in 2007 (Figure 29). The pattern of periphyton biomass at the Tributary Creek site was generally similar to that at the Greens Creek sites in 2001 through 2004, but is typically more variable within each year, had less of a decline in 2005, further decline in 2006, and a slight increase in 2007.

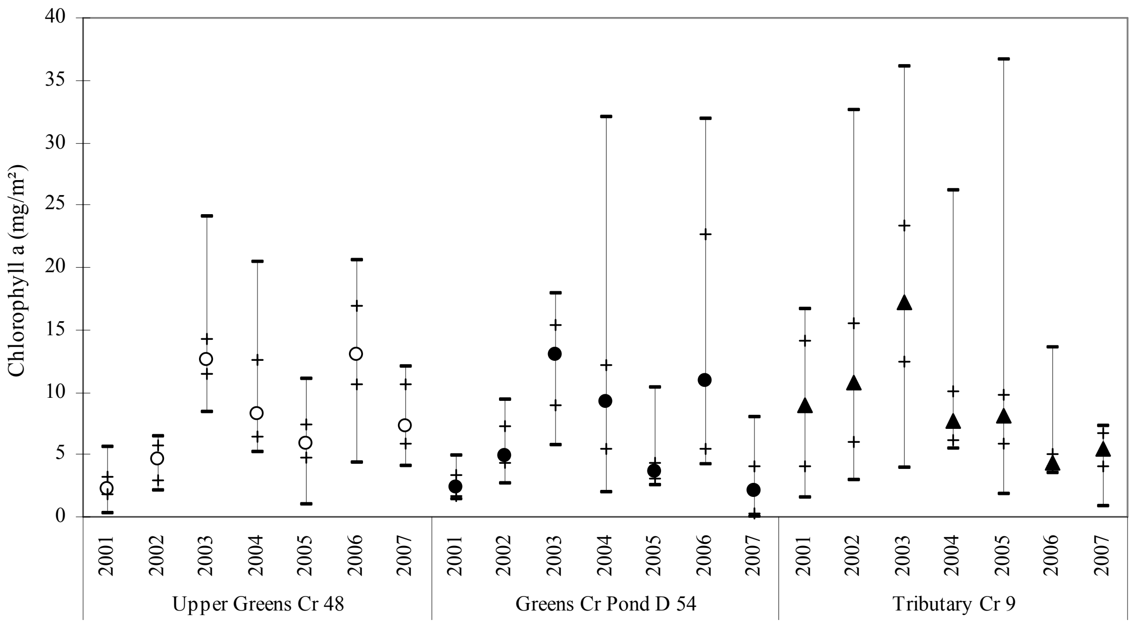

Figure 29. Comparison of estimated periphyton biomass (medians and ranges) among Greens Creek Mine biomonitoring sites sampled in 2001 through 2007 (n = 10 samples per site except n = 7 in 2007 Site 9). First and third quartiles are indicated by small ticks on vertical range line.

The difference between median community compositions of the periphyton sampled in 2007 at the two Greens Creek sites was statistically significant (Figure 30, Appendix 2)). Periphyton samples from Site 54 and 48 were primarily chlorophyll *a*, with approximately 10% chlorophyll *c* and no detectable chlorophyll *b*. There were marked statistical differences in chlorophyll *a*, but not between *b*, or *c* among the Greens Creek sites in 2007. Chlorophyll *a, b,* and *c* concentrations in 2007 from the Tributary Creek Site 9 samples were not significantly different than those from the Greens Creek sites, but were significantly lower than those from the high Tributary Creek Site 9 concentrations in 2003.

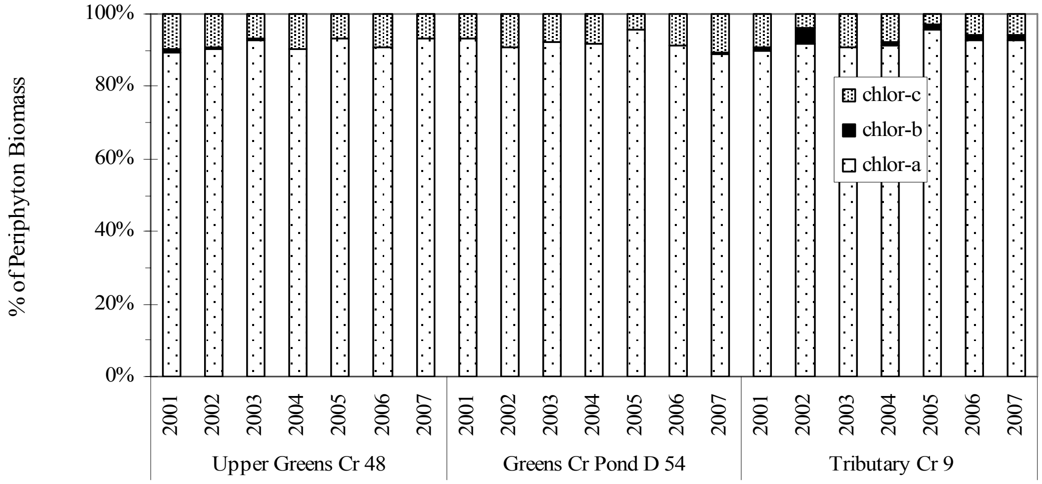

Figure 30. Comparison of proportions of mean chlorophyll *a*, *b*, and *c* concentrations among Greens Creek Mine biomonitoring sites in 2001 through 2007.

Chlorophyll *a* is a primary photosynthetic pigment, is present in all algae, and is a useful indicator of periphyton biomass and a healthy algal community (Wetzel 1983). Chlorophyll *b* is an accessory pigment found in combination with other photosynthetic pigments. When measured above detection limits in periphyton communities, 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 (includes diatoms) and dinoflagellates (Speer 1997). Diatoms play an important role in primary production in aquatic communities, and measurable quantities of chlorophyll *c* indicate the importance of diatoms in the community.

Some Upper Greens Creek Site 48 and Tributary Creek Site 9 biomonitoring samples over the years have had higher chlorophyll *b* concentrations than have other samples, suggesting that at the time of sampling there was a larger percentage of green algae or euglenophytes in the periphyton community (Wetzel 1983). Given the differences in channel morphology, flow regimes and streamside vegetation between streams and years, some differences in algal communities are not unexpected.

Benthic Macroinvertebrates

Benthic macroinvertebrate densities at Tributary Creek Site 9 and Greens Creek Site 54 sites in 2007 were the lowest values seen in the Greens Creek Biomonitoring program, and were not statistically different from one another (Figure 31). The benthic macroinvertebrate densities and taxa numbers from Tributary Creek Site 9 samples in 2007 were not statistically different than the 2007 samples from the sites on Greens Creek (Figures 31, 32).

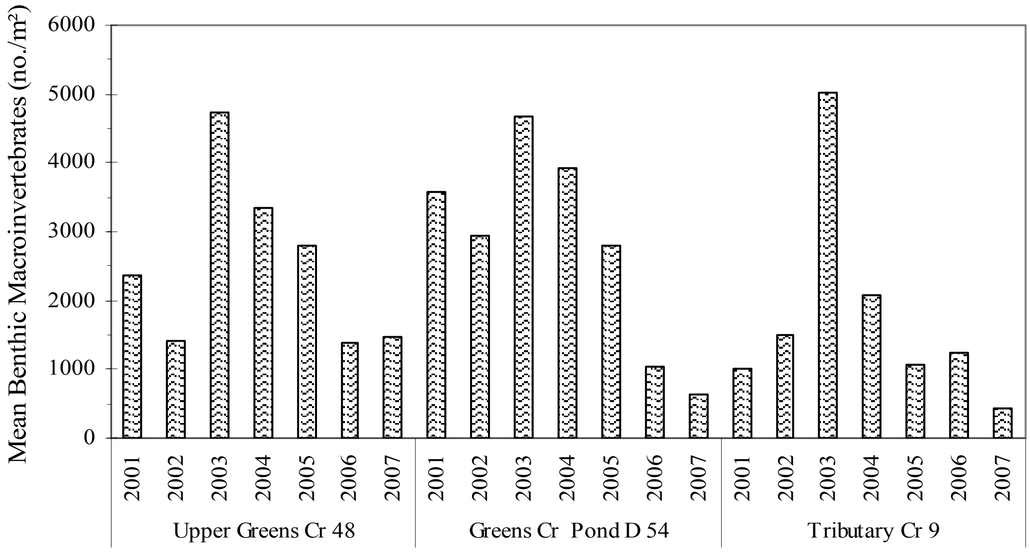

Figure 31. Comparison of benthic macroinvertebrate density among Greens Creek Mine biomonitoring sites in 2001 through 2007.

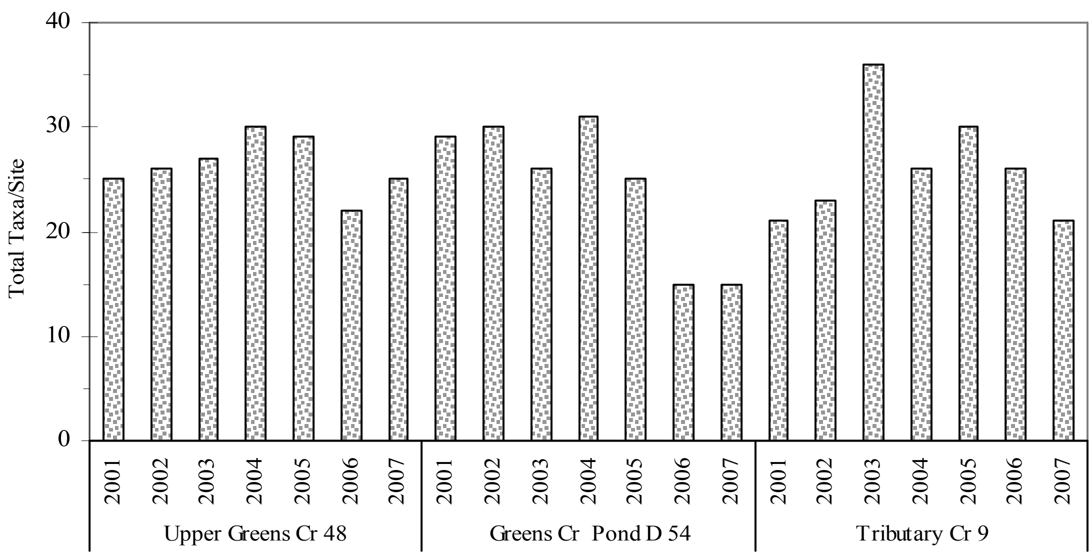

Figure 32. Comparison of benthic macroinvertebrate taxonomic richness among Greens Creek Mine biomonitoring sites in 2001 through 2007.

All three of the biomonitoring sites had complex invertebrate communities with abundant numbers of taxa (taxonomic richness) per sample. More than 50% of the invertebrates in samples from Upper Greens Creek Site 48 and Greens Creek Below Pond D Site 54 were from two dominant taxa, while four dominant taxa accounted for more than 50% of the invertebrates in samples from Tributary Creek Site 9 (Table 11). The number of taxa per site (richness) was among the lowest encountered in this biomonitoring project at the two Greens Creek sites and at Tributary Creek Site 9. Richness was not statistically different between sites in 2007.

For all sites taken together, benthic macroinvertebrate densities in 2006 and 2007 were significantly lower than in 2003 and 2004 and substantially lower than in 2001, and taxonomic richness per site was significantly lower in 2007 than in 2003 and 2004. The reasons for these marked declines are unclear. Noted 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 have communities that are more complex with many taxa present compared to more variable habitats such as the Greens Creek sites where fewer taxa typically dominate the communities (Hynes 1970). All three sites have likely been affected by the noted substrate movements and channel changes that occurred during the past two seasons.

Table 11. Common taxa (>5.0% of benthic macroinvertebrates) found in Greens Creek Mine biomonitoring samples in 2007. The percent dominant taxon percent for each site is bold.

Order	Family	Genus	Upper Grns Cr 48	Grns Cr Pond D 54	Trib Cr 9
Ephemeroptera	Baetidae	*Baetis*	**28%**	**27%**	-
	Ephemerellidae	*Drunella*	-	-	-
		Ephemerella	-	-	-
	Heptageniidae	*Cinygmula*	12%	26%	**20%**
		Epeorus	8%	16%	-
		Rhithrogena	23%	19%	-
	Leptophlebiidae	*Paraleptophlebia*	-	-	17%
	Ameletidae	*Ameletus*	-	-	8%
Diptera	Chironomidae		-	-	-
Ostracoda			-	-	8%

The percent EPT metric, based on the concept that many taxa within 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 years sampled (Figure 33). The percent of Chironomidae has been relatively constant at the Tributary Creek site but variable in the three Greens Creek sites.

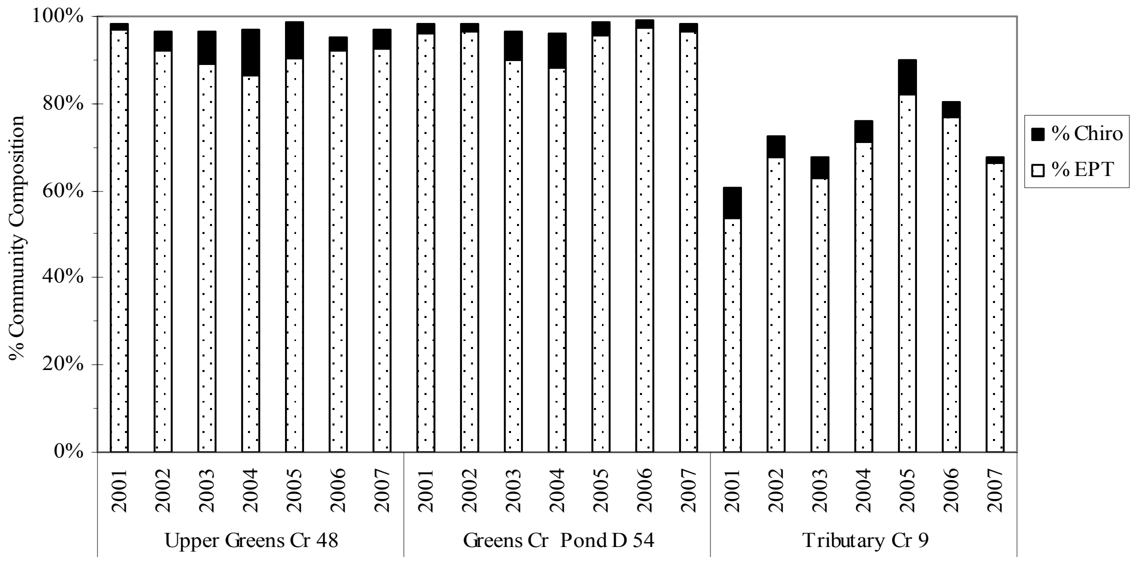

Figure 33. Comparison of proportions of EPT taxa and Chironomidae among Greens Creek Mine biomonitoring sites in 2001 through 2007.

Benthic macroinvertebrate community compositions at the Greens Creek sites continued to be similar to one another and somewhat different from that at the Tributary Creek site (Figure 34). The communities at the two Greens Creek sites were dominated by Ephemeroptera (mayflies), with small contributions by Plecoptera (stoneflies) and aquatic Diptera (primarily midge and blackfly larvae), while the Tributary Creek site community was somewhat less dominated by Ephemeroptera and more non-insect invertebrates were present. These differences in community composition are most likely due to the different physical characteristics of the streams.

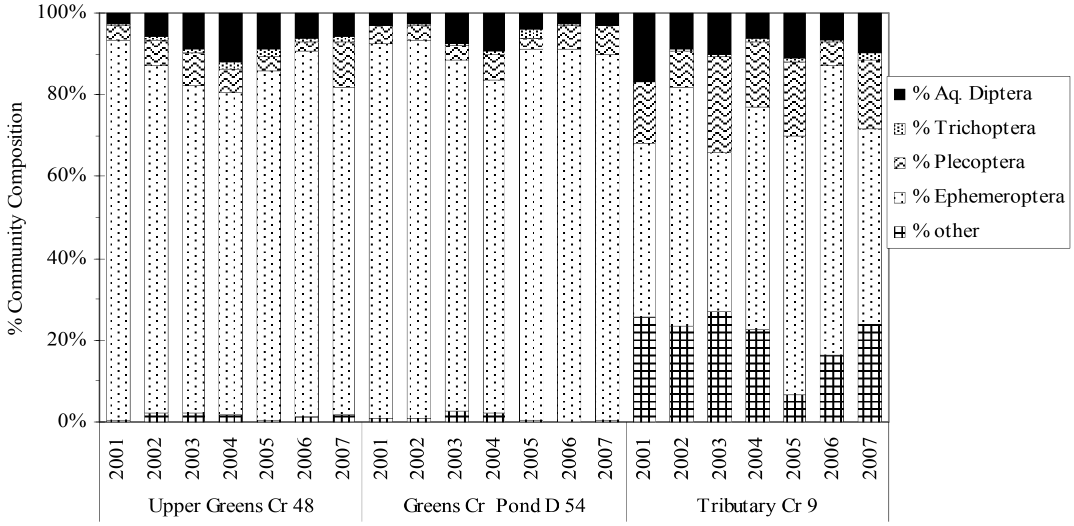

Figure 34. Comparison of community composition of benthic macroinvertebrates among Greens Creek Mine biomonitoring sites in 2001 through 2007.

Density and taxonomic richness metrics showed all three sites to have well-developed, complex communities similar in structure to previous years at the same sites. Abundance was fairly low at both Greens Creek sites in 2007, while Tributary Creek Site 9 had moderate 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 considered sensitive to pollution. Because all three communities continue to be dominated by pollution-sensitive species, we believe that any future perturbations by natural stressors or human-facilitated sources would likely cause detectable changes in abundance or richness.

Juvenile Fish Populations

For the fifth year in a row, the Dolly Varden density estimate at Greens Creek Below Pond D Site 54 was approximately twice the density estimate at Upper Greens Creek site 48 although the population estimates at the two sites were similar (Figure 35, Table 12). Murphy et al. (1986) and Bryant et al. (1991) provide average fish density values for various channel types on the Tongass National Forest based on captures, and Paustian et al. (1999) expanded these and other data to habitat capability estimations. In 2007, Dolly Varden densities were near the regional average at Greens Creek Below Pond D Site 54, and approximately one-half the regional average at Upper Greens Creek Site 48, for the Moderate Width Mixed Control channel type, while the density at Tributary Creek Site 9 was one-third the regional average for the Narrow Low Gradient Flood Plain channel type. The reduced Dolly Varden population the past two years at Tributary Creek Site 9 will need to be followed to see if it indicates a mining effect or natural variation.

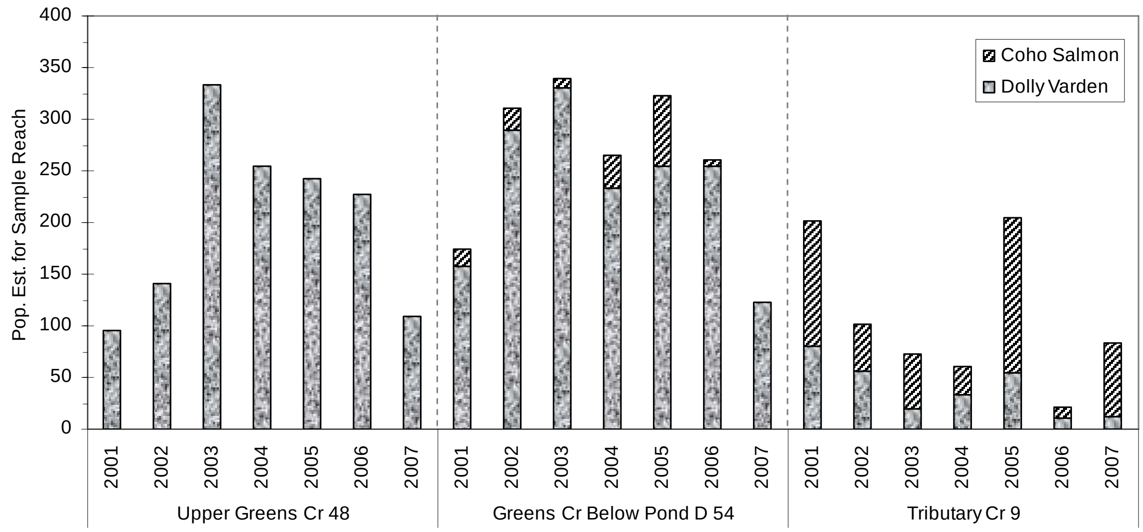

Figure 35. Comparison of population estimates for juvenile fish captured at Greens Creek Mine biomonitoring sites in 2001 through 2007.

Coho salmon population and density estimates at Tributary Creek Site 9 have ranged over one and one-half orders of magnitude during the seven years of biomonitoring sampling (Figure 35, Table 12, Appendix 4). Estimated coho salmon density in 2007 at Tributary Creek Site 9 was approximately twice the regional average densities for that channel type. The lack of coho salmon captures at Greens Creek Below Pond D Site 54 in 2007, following the poor capture rate in 2006 at the site, raises concerns about coho salmon access to this portion of Greens Creek, and will need to be addressed in a timely manner by the appropriate entities

Although comparisons among all sites must take into consideration the differences in size, channel type, and elevation between the Greens Creek and Tributary Creek sites, some generalizations can be made regarding the fish density values (population estimate per m^2 of wetted area in each sample reach) shown in Table 12. Using this metric, Upper Greens Creek Site 48 (upstream of mine facilities) has been less productive each year (both for total fish captured and for Dolly Varden only) than has Greens Creek Below Pond D Site 54 (downstream of mine facilities). The total fish density (and densities by fish species) at Tributary Creek Site 9 has varied greatly during the seven years of biomonitoring sampling, but it is not uncommon for it to be intermediate between the values for Upper Greens Creek Site 48 and those for Greens Creek Below Pond D Site 54, with generally lower densities of Dolly Varden and higher densities of coho salmon. In 2007, as in 2006, Tributary Creek Site 9 Dolly Varden productivity was lower than in either of the two Greens Creek sites.

A potential reason for at least some of these differences is the higher stream discharges noted the past two years. Ihlenfeldt (2005) found that the preferred spawning areas for resident Dolly Varden are the edges of pools in low velocity water with a gravel substrate size of 1-4 cm. Coho salmon, on the other hand, prefer to spawn in riffle areas (McPhail and Lindsey 1970). Based on comparisons of photos taken in 2005, 2006, and 2007, such areas in Greens Creek were substantially reworked during the November 2005 high water event and gravels in both streams were reworked between the 2006 and 2007 sampling events. This movement of gravels around eggs in redds may well have killed most or all of any incubating coho salmon eggs through physical jarring, sediment deposition, or physical flushing of the eggs out of the substrate. High water events can also reduce periphyton, benthic macroinvertebrates, and woody debris in streams. Murphy et al.. (1986) found that coho salmon young-of-the-year densities were directly related to periphyton biomass and benthic macroinvertebrate density, and that coho and Dolly Varden parr were directly related to pool and woody debris features.

High turbidity was noted in Tributary Creek Site 9 during biomonitoring sampling in 2006, but not during sampling at much higher flows in 2007. This reduction in turbidity at higher flows is believed to be related to upgrades in road maintenance and crossdrain culverts by KGCMC.

Table 12. Fish captures, population estimates, and densities in Greens Creek Mine biomonitoring sampling reaches during 2001 through 2007.

	Upper Greens Creek Site 48		Middle Greens Creek Site 6[1]		Greens Creek Below Pond D Site 54		Tributary Creek Site 9	
	Coho Salmon[2]	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden
2001								
Number of Fish Caught	---	68	3	131	12	138	118	81
Population Estimate	---	96	3	161	17	158	120	81
Sample Reach (m)	---	72	135	135	28	28	44	44
Density Est. (fish/m²)	---	0.20	<0.01	0.13	0.06	0.58	0.80	0.92
2002								
Number of Fish Caught	---	126	---	---	21	271	44	51
Population Estimate	---	141	---	---	21	290	46	56
Sample Reach (m)	---	50	---	---	28	28	50	50
Density Est. (fish/m²)	---	0.23	---	---	0.07	1.0	0.35	0.46
2003								
Number of Fish Caught	---	285	---	---	8	232	52	19
Population Estimate	---	333	---	---	8	331	53	20
Sample Reach (m)	---	50	---	---	28	28	50	50
Density Est. (fish/m²)	---	0.9[3]	---	---	0.04[3]	1.8[3]	0.8[3]	0.3[3]
2004								
Number of Fish Caught	---	244	---	---	24	201	27	32
Population Estimate	---	255	---	---	31	234	27	33
Sample Reach (m)	---	50	---	---	28	28	50	50
Density Est. (fish/m²)	---	0.88	---	---	0.21	1.57	0.46	0.56
2005								
Number of Fish Caught	---	212	---	---	61	213	139	44
Population Estimate	---	243	---	---	67	255	150	55
Sample Reach (m)	---	50	---	---	28	28	50	50
Density Est. (fish/m²)	---	0.65	---	---	0.31	1.17	1.15	0.42
2006								
Number of Fish Caught	---	212	1	97	7	217	10	11
Population Estimate	---	228	1	114	7	254	10	11
Sample Reach (m)	---	50	49	49	28	28	50	50
Density Est. (fish/m²)	---	0.59	<0.01	0.25	0.03	1.22	0.08	0.09
2007								
Number of Fish Caught	---	95	---	---	0	107	69	12
Population Estimate	---	109	---	---	0	122	71	12
Sample Reach (m)	---	50	---	---	28	28	50	50
Density Est. (fish/m²)	---	0.2[3]	---	---	0	0.4[3]	0.58	0.10

[1] Middle Greens Creek Site 6 is sampled on a five-year interval.
[2] Coho salmon are not present at Upper Greens Creek Site 48 because of a downstream barrier to anadromous fish.
[3] Based on approximate values for wetted area.

Metals Concentrations in Juvenile Fish

Compared to the "control" values from Upper Greens Creek Site 48, fish tissues values from "treatment" Greens Creek Below Pond D Site 54 had significantly higher selenium and significantly lower cadmium. Mean ranks for concentrations of silver, copper, lead, and zinc were not statistically different between the two Greens Creek sites in 2007 (Figure 36). Tissue concentrations of metals in juvenile Dolly Varden from the two Greens Creek sites (48 and 54) were generally more similar to each other in 2007 than they were to concentrations in Dolly Varden from Tributary Creek Site 9 (Figure 36). Tissues from Tributary Creek Site 9 fish contained significantly more silver than did tissues from Greens Creek fish, significantly more cadmium than did those from Site 54 fish, significantly more lead and selenium than did those from Site 48 fish, and significantly less zinc than did those from Greens Creek fish. There was no statistical differences between sites in 2007 for whole body concentrations of copper.

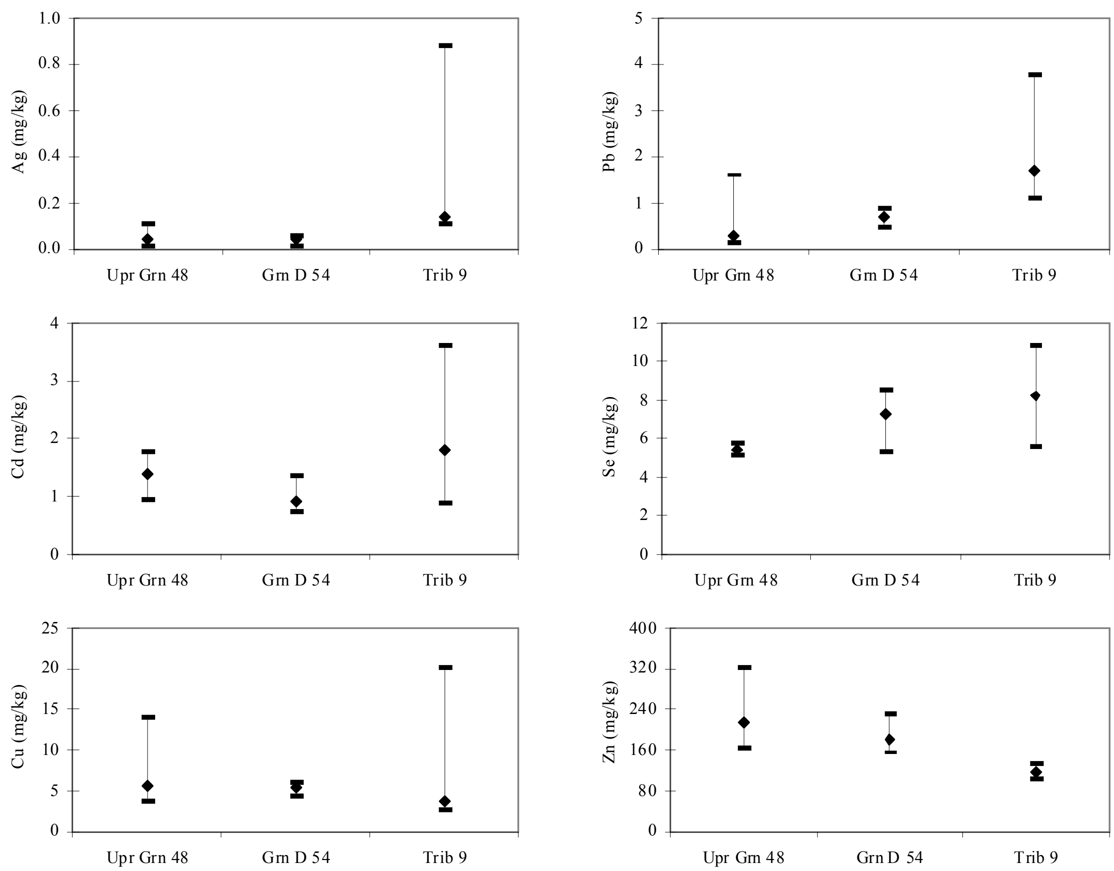

Figure 36. Comparison among sites of whole body metals concentrations (median, maximum, and minimum) in six Dolly Varden captured at each biomonitoring site in 2007.

Summary

Although not explicitly analyzed, it is apparent that appreciable portions of the variability noted between sites and within sites between years can be attributed both to differences in physical characteristics of the sampled stream reaches (including gradient, substrate, water velocity, elevation, and location in watershed) and to annual differences in discharge and weather patterns. Also not evaluated was the level of interaction effects between biotic components such as benthic macroinvertebrate consumption of periphyton or juvenile fish predation on benthic macroinvertebrates. The three Greens Creek Biomonitoring Program sites sampled in 2007 continue to be productive and diverse, although three areas warrant careful watch in future years: the lack of coho salmon captures at Greens Creek Below Pond D Site 54, the decline in Dolly Varden captures at Tributary Creek Site 9, and the general rising trend in some fish tissue metals concentrations in treatment sites.

CONCLUSIONS

The two biomonitoring sites sampled on Greens Creek (Upper Greens Creek Site 48 above all facilities and Greens Creek Below Pond D Site 54 below all facilities) and one sampled on Tributary Creek (Tributary Creek Site 9 below the dry-stack tailings facility) continued to sustain functioning, diverse aquatic communities in 2007 although at a less abundant level compared to the previous six years of biomonitoring.

Periphyton biomass and community composition at the three sampled biomonitoring sites continue to appear robust, with a pronounced diatom component and a minimal green algae component. Chlorophyll *a* concentrations were significantly different between the two Greens Creek sites in 2007, and the mean chlorophyll *a* values at Tributary Creek Site 9 were more like those of Upper Greens Creek Site 48 than of those from Greens Creek Below Pond D Site 54. Periphyton biomass at Tributary Creek Site 9 was the lowest recorded in seven years of sampling at the site, and was significantly lower than the high chlorophyll *a* concentrations in 2003. The community composition of periphyton at Tributary Creek continued to be similar to that at the Greens Creek sites.

The benthic macroinvertebrate communities at the three biomonitoring sites showed essentially the opposite trends of the periphyton communities. The mean rank scores for benthic macroinvertebrate abundance and taxonomic richness at the two Greens Creek sites in 2007 were the lowest of the years sampled and were not statistically different between sites. Tributary Creek Site 9 benthic macroinvertebrate abundance and taxonomic richness were well below those of the past six years, and significantly lower than the high densities of 2003. In contrast to most of the past six years of sampling, the number of common taxa in Tributary Creek Site 9 samples in 2007 was equal to or less than that found in Greens Creek samples. Distinctive differences in the benthic macroinvertebrate community between the two streams persisted. The percentage of the water quality-sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa in benthic macroinvertebrate samples remained high in all three sites sampled in 2007.

Dolly Varden (*Salvelinus malma*) populations in 2007 at each site were at or near the lowest documented in seven years of biomonitoring. Captures at Greens Creek sites had multiple size classes of fish present, although a shift to larger size classes was seen possibly to be a response to the higher stream flows at the time of sampling. Dolly Varden captures at Tributary Creek Site 9 in 2007 were as they had been in 2006, and no size classes typically associated with young-of-the-year Dolly Varden were captured at Tributary Creek Site 9 for the second year in a row. Coho salmon (*Oncorhynchus kisutch*) were not captured at Greens Creek Below Pond D Site 54, leading to concern about fish passage over the downstream falls area; no size classes associated with young-of-the-year coho salmon were captured at this site in 2006 or 2007. Coho salmon captures at Tributary Creek Site 9 rebounded from 2006's low to a moderate level for this site and higher than the regional average for this channel type. Total fish densities per square meter of wetted stream area among the three Greens Creek sites continued to be higher at Greens Creek Below Pond D Site 54 than at Upper Greens Creek Site 48, with Tributary Creek Site 9 having the highest densities in 2007 of the three sites.

The ranges of whole body concentrations of metals in juvenile Dolly Varden tissues in 2007 were generally similar to, or somewhat elevated from, those found in previous years' samples at each site. Tissue concentrations of cadmium, lead, and selenium tended to be higher downstream of mine facilities (sites 54 and 9), and concentrations of copper and zinc tended to be lower than in previous years' sampling. When median tissue concentrations were compared for each site over the seven years of biomonitoring sampling, the values from 2007 were the highest for cadmium and selenium at Greens Creek Below Pond D Site 54 and the highest for silver, cadmium, lead, and selenium at Tributary Creek Site 9. Also of note is that the median tissue concentrations of copper and zinc at Site 9 in 2007 were the lowest observed at that site seven years of sampling. Tissues of juvenile Dolly Varden from Tributary Creek Site 9 captured in 2007 continued to have different metals concentrations characteristics than did tissues from Dolly Varden from the two Greens Creek sites (48 and 54).

In general, the aquatic communities at Upper Greens Creek Site 48, Greens Creek Below Pond D Site 54, and Tributary Creek Site 9 have remained fairly diverse, robust, and moderately abundant during the seven years of biomonitoring sampling. Differences noted between years and between the streams (Greens Creek compared to Tributary Creek) have typically been of larger amplitude than have differences between the control and below-mining sites within Greens Creek or over time at the Tributary Creek site.

Although no trends of reduced productivity, community changes, or metals accumulation attributable to operations of the Greens Creek Mine have been noted, the 2007 biomonitoring results raise concerns that will need to be followed in future years of biomonitoring: low abundance of periphyton in Tributary Creek, lower density of benthic macroinvertebrates at all sites and low richness at sites 54 and 9, low density of Dolly Varden in Tributary Creek, lack of coho salmon at Greens Creek Below Pond D Site 54, and somewhat elevated levels of some metals in fish tissues at all sites.

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APPENDIX 1. USFS CHANNEL TYPE DESCRIPTIONS

From: A Channel Type User Guide for the Tongass National Forest (Paustian et al. 1992)

MM2 – Moderate Width Mixed Control Channel Type (Greens Creek sites 6, 48, and 54): MM2 channels are 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. The riparian plant communities for the MM2 channel type are dominated by the Sitka spruce series and the western hemlock series.

MM2 channels function as sediment transport systems. These channels have moderate stream energy. Fine sediment is rapidly moved through the MM2 channels, Large woody debris accumulations are extensive and help retain coarse gravels, portion of which will be mobilized during high flow events. Significant stream bank erosion and lateral channel migration can occur during high flow events.

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.

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.

FP3 – Narrow Low Gradient Flood Plain Channel Type (Tributary Creek Site 9): 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.

FP3 channels function as sediment deposition systems. Sediment routed from high and moderate gradient sediment transport channels is temporarily stored in this channel type and on the adjacent flood plain. Sand and fine gravel deposits in point bars and pools are dominant stream bed features. Large woody debris accumulations are frequent and retain significant volumes of fine sediment. Stream power is low, allowing for massive mobilization of sediment only during peak flow events.

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, with the exception of Chinook salmon. FP3 channels have a large amount of available rearing area and are used extensively by coho, Dolly Varden, and steelhead. Thirty-seven percent of the active water in pools has an average depth of 0.31 m, which provides good overwintering habitat. Woody debris and beaver dams enhance these pools as overwintering areas.

Stream banks are composed of coarse to fine textured alluvium, which, due to low stream flow volume and relatively low stream power, are only moderately sensitive to disturbance.

APPENDIX 2. PERIPHYTON BIOMASS DATA

Estimates of periphyton biomass as represented by chlorophyll concentrations (mg/m²) at Greens Creek Mine biomonitoring sampling sites from 2001through 2007.

	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 2. (Continued)

	2005			2006			2007		
mg/m²	chlor-a	chlor-b	chlor-c	chlor-a	chlor-b	chlor-c	chlor-a	chlor-b	chlor-c
Upper Greens Creek Site 48									
	0.9719	0.0000	0.0086	8.5030	0.0000	0.7988	6.638	0.000	0.162
	4.6992	0.0000	0.5099	11.5900	0.0000	0.7103	5.639	0.000	0.228
	6.6216	0.0000	0.2741	10.7417	0.0000	1.2532	7.595	0.000	0.330
	6.1944	0.0000	0.5062	20.6036	0.0000	2.0380	11.692	0.000	1.391
	11.1072	0.0000	0.9152	10.6005	0.0000	0.9790	7.038	0.000	0.471
	5.6604	0.0000	0.5118	14.3454	0.0000	1.7241	11.401	0.000	0.541
	7.6896	0.0000	0.5330	17.2710	0.0000	1.7606	11.995	0.012	0.603
	5.1264	0.0000	0.2909	15.8082	0.0000	1.7423	4.941	0.000	0.291
	2.4564	0.0153	0.2755	17.2649	0.0000	1.7302	8.259	0.000	1.096
	9.0780	0.0000	0.6302	4.3364	0.0000	0.5366	4.112	0.000	0.435
median	5.9274	0.0000	0.5081	12.9677	0.0000	1.4887	7.316	0.000	0.453
max	11.1072	0.0153	0.9152	20.6036	0.0000	2.0380	11.995	0.012	1.391
min	0.9719	0.0000	0.0086	4.3364	0.0000	0.5366	4.112	0.000	0.162
Middle Greens Creek Site 6									
	-	-	-	27.3154	0.0000	2.7825	-	-	-
	-	-	-	19.3208	0.0000	2.0456	-	-	-
	-	-	-	17.5776	0.0000	1.7884	-	-	-
	-	-	-	33.9456	0.0000	3.3068	-	-	-
	-	-	-	47.5520	0.0000	4.9348	-	-	-
	-	-	-	16.1184	0.0000	1.5892	-	-	-
	-	-	-	8.9573	0.0000	1.0331	-	-	-
	-	-	-	11.8417	0.0000	1.1067	-	-	-
	-	-	-	8.6446	0.0000	0.9749	-	-	-
	-	-	-	29.1943	0.0000	3.0873	-	-	-
median	-	-	-	18.4492	0.0000	1.9170	-	-	-
max	-	-	-	47.5520	0.0000	4.9348	-	-	-
min	-	-	-	8.6446	0.0000	0.9749	-	-	-
Greens Creek Below Pond D Site 54									
	10.3596	0.0000	0.5350	19.8594	0.0000	1.6172	0.407	0.036	0.045
	2.5632	0.0000	0.2555	5.6248	0.0000	0.7556	0.183	0.000	0.000
	3.3108	0.0000	0.1688	12.7421	0.0000	1.1864	1.365	0.042	0.114
	2.8836	0.0000	0.1173	23.5686	0.0000	2.6259	4.248	0.000	0.482
	5.6604	0.0000	0.3834	4.6147	0.0000	0.4661	0.130	0.092	0.017
	2.9904	0.0000	0.1346	27.6712	0.0000	2.2151	3.285	0.000	0.382
	4.2720	0.0000	0.1775	4.2484	0.0000	0.3842	7.934	0.000	0.977
	4.3788	0.0000	0.3098	8.9576	0.0000	0.9350	0.047	0.000	0.000
	4.0584	0.0000	0.1604	31.8454	0.0000	3.1710	2.966	0.000	0.392
	3.0972	0.0000	0.1583	5.4829	0.0000	0.6776	6.434	0.000	0.815
median	3.6846	0.0000	0.1732	10.8498	0.0000	1.0607	2.165	0.000	0.248
max	10.3596	0.0000	0.5350	31.8454	0.0000	3.1710	7.934	0.092	0.977
min	2.5632	0.0000	0.1173	4.2484	0.0000	0.3842	0.047	0.000	0.000
Tributary Creek Site 9									
	6.4294	0.0000	0.2502	3.5384	0.2492	0.1902	5.447	0.079	0.228
	8.0100	1.2833	0.1830	4.2115	0.3962	0.2018	7.262	0.005	0.544
	1.8156	0.1313	0.0746	7.0732	0.0000	0.4036	0.854	0.164	0.107
	9.8256	0.0595	0.2907	4.0118	0.0108	0.3195	6.408	0.055	0.244
	5.6818	0.0000	0.1025	4.2010	0.0000	0.3909	7.049	0.236	0.649
	5.3827	0.0000	0.1225	4.7449	0.0000	0.2872	5.020	0.000	0.258
	8.1809	0.0000	0.2028	13.6349	0.0000	0.5726	3.204	0.000	0.234
	15.4326	0.0000	0.4551	4.3786	0.0052	0.2053	-	-	-
	36.6004	0.0989	1.1198	5.1579	0.0000	0.5586	-	-	-
	9.4518	0.0000	0.2629	3.7563	0.3717	0.2617	-	-	-
median	8.0954	0.0000	0.2265	4.2951	0.0026	0.3034	5.447	0.055	0.244
max	36.6004	1.2833	1.1198	13.6349	0.3962	0.5726	7.262	0.236	0.649
min	1.8156	0.0000	0.0746	3.5384	0.0000	0.1902	0.854	0.000	0.107

APPENDIX 3. BENTHIC MACROINVERTEBRATE DATA

Appendix 3.1. Numbers of benthic macroinvertebrates identified in Upper Greens Creek Site 48 biomonitoring samples from 2001 through 2007.

Order	Family	Genus	2001	2002	2003	2004	2005	2006	2007
Ephemeroptera	unidentified		-	-	-	-	-	3	38
	Baetidae	*Acentrella*	309	152	445	390	279	130	206
	Ephemerellidae	*Caudatella*	2	-	-	-	-	-	-
		Ephemerella	-	-	10	23	15	1	4
		Drunella	47	49	650	406	369	102	16
	Heptageniidae	*Cinygmula*	99	20	117	99	89	48	91
		Epeorus	444	190	384	209	371	240	61
		Rhithrogena	193	187	287	196	71	88	165
	Leptophlebiidae	*Paraleptophlebia*	-	1	-	-	-	-	-
	Ameletidae	*Ameletus*	-	-	4	-	-	-	3
Plecoptera	unidentified		-	-	-	-	9	7	1
	Capniidae	*Capnia*	-	-	82	-	-	-	-
		Eucapnopsis	-	-	-	-	1	-	-
	Chloroperlidae	unidentified	-	-	-	-	2	-	6
		Alloperla	1	1	-	1	-	-	-
		Kathroperla	-	-	2	3	-	2	-
		Neaviperla	-	-	70	6	3	-	11
		Paraperla	-	-	-	6	-	-	-
		Plumiperla	5	-	-	5	-	-	-
		Suwallia	8	1	-	-	5	-	-
		Sweltsa	1	4	-	-	-	-	-
	Leuctridae	*Despaxia*	-	2	-	-	-	-	-
		Paraleuctra	4	3	6	65	-	3	10
		Perlomyia	-	12	-	-	-	-	-
	Nemouridae	*Podmosta*	7	5	-	2	-	-	-
		Zapada	23	4	30	7	14	5	50
	Perlodidae	*Isoperla*	-	-	-	1	9	-	4
		Megarcys	-	-	1	-	-	1	-
		Skwala	-	9	-	-	4	-	-
Trichoptera	unidentified		-	-	-	-	-	3	-
	Apataniidae	*Apatania*	-	1	-	-	-	-	-
	Glossosomatidae	*Glossosoma*	-	-	2	16	14	-	-
	Hydropsychidae	*Arctopsyche*	2	-	-	-	-	-	-
		Hydropsyche	-	-	1	-	1	-	-
	Limnephilidae	*Onocosmoecus*	-	-	1	-	-	-	-
	Rhyacophilidae	*Rhyacophila*	5	8	16	15	7	6	11
Coleoptera	Elmidae	*Narpus*	-	-	-	1	-	-	-
	Staphylinidae		1	-	6	-	-	-	-
Diptera	Ceratopogonidae	*Dasyhelea*	-	1	-	-	-	-	-
		Probezzia	-	-	-	-	-	16	-
	Chironomidae		14	30	172	177	112	22	31
	Deuterophlebiidae	*Deuterophlebia*	2	-	-	1	1	1	-
	Empididae	unidentified	-	-	-	-	1	-	-
		Chelifera	1	2	5	1	-	-	-
		Hemerodromia	-	-	-	-	5	-	-
		Oreogeton	3	2	22	11	-	-	6
	Psychodidae	*Psychoda*	1	-	-	-	-	-	-

Appendix 3.1. (Continued)

Order	Family	Genus	2001	2002	2003	2004	2005	2006	2007
Diptera	Simuliidae	*Parasimulium*			-	-	-	-	-
(cont.)			2	-					
		Prosimulium	2	-	-	2	-	-	-
		Simulium	6	4	-	1	3	1	2
	Tipulidae	*Antocha*	-	-	2	-	-	-	-
		Dicranota	-	-	3	-	2	-	-
		Rhabdomastix	-	-	-	-	1	-	2
		Tipula	-	-	2	6	1	4	-
Collembola	unidentified		-	-	-	-	-	1	1
	Onychiuridae	*Onychiurus*	-	1	-	-	-	-	-
	Sminthuridae	*Dicyrtoma*	2	-	-	-	-	-	-
Copepoda	Cyclopoida		-	-	-	1	-	-	1
Acarina			-	2	20	10	3	6	5
Oligochaeta			-	5	20	8	3	1	1
Gastropoda	Pelecypoda		-	-	-	1	-	-	1
Ostracoda			-	8	7	9	1	2	4

Appendix 3.2. Numbers of benthic macroinvertebrates identified in Middle Greens Creek Site 6 biomonitoring samples in 2001 and 2006.

Order	Family	Genus	2001	2006
Ephemeroptera	Baetidae	*Acentrella*	153	30
	Ephemerellidae	*Ephemerella*	-	2
		Drunella	52	48
	Heptageniidae	*Cinygmula*	303	28
		Epeorus	408	107
		Rhithrogena	-	40
Plecoptera	unidentified		-	12
	Chloroperlidae	unidentified	-	6
		Suwallia	2	-
	Leuctridae	*Paraleuctra*	7	-
	Nemouridae	*Zapada*	16	3
	Perlodidae	*Isoperla*	7	-
Trichoptera	Rhyacophilidae	*Rhyacophila*	1	1
Coleoptera	Staphylinidae		1	-
Diptera	Chironomidae		19	28
	Deuterophlebiidae	*Deuterophlebia*	1	-
	Dolichopodidae		1	-
	Empididae	*Chelifera*	1	-
		Oreogeton	3	-
	Tipulidae	*Dicranota*	-	1
Arachnida			1	-
Acarina			4	-
Oligochaeta			15	1
Ostracoda			3	-

Appendix 3.3. Numbers of benthic macroinvertebrates identified in Greens Creek Below Pond D Site 54 biomonitoring samples from 2001 through 2007.

Order	Family	Genus	2001	2002	2003	2004	2005	2006	2007
Ephemeroptera	unidentified		-	-	-	-	-	6	-
	Baetidae	*Acentrella*	248	225	220	299	198	107	87
	Ephemerellidae	*Ephemerella*	2	6	6	47	22	-	-
		Drunella	118	280	894	742	543	56	1
	Heptageniidae	*Cinygmula*	319	75	176	112	90	68	82
		Epeorus	935	626	408	228	341	124	52
		Rhithrogena	-	140	306	173	66	116	62
	Leptophlebiidae	*Paraleptophlebia*	1	-	1	-	4	-	2
	Ameletidae	*Ameletus*	4	-	-	-	1	-	-
Plecoptera	unidentified		-	-	-	-	-	7	-
	Capniidae	*Capnia*	-	-	5	-	1	-	-
		Eucapnopsis	-	-	-	-	8	-	-
	Chloroperlidae	*Alloperla*	3	-	-	1	-	-	-
		Kathroperla	-	-	2	2	-	-	2
		Neaviperla	-	14	22	26	5	13	-
		Paraperla	-	-	5	4	-	-	-
		Plumiperla	2	-	-	5	3	-	-
		Suwallia	-	-	-	2	-	-	11
		Sweltsa	6	-	-	-	-	-	-
	Leuctridae	*Despaxia*	-	-	-	15	-	-	8
		Paraleuctra	-	4	-	18	-	1	-
		Perlomyia	13	3	19	33	-	-	-
	Nemouridae	*Podmosta*	-	7	-	-	-	-	-
		Zapada	52	22	14	11	15	9	-
	Perlodidae	*Diura*	1	-	-	-	-	-	-
		Isoperla	3	-	-	-	3	-	1
		Skwala	-	3	15	-	2	-	-
		Rickera	-	1	-	-	-	-	-
Trichoptera	Glossosomatidae	*Glossosoma*	-	-	-	12	1	-	-
	Hydropsychidae	*Arctopsyche*	-	1	-	1	-	-	-
		Hydropsyche	-	-	-	-	-	1	-
	Limnephilidae	unidentified	-	-	-	-	2	-	-
		Psychoglypha	1	-	-	-	-	-	-
	Rhyacophilidae	*Rhyacophila*	6	5	12	6	27	3	-
Coleoptera	Elmidae	*Narpus*	-	-	-	3	-	-	-
	Staphylinidae		1	1	-	-	-	-	-
Diptera	Chironomidae		33	27	149	148	42	9	5
	Deuterophlebiidae	*Deuterophlebia*	-	1	1	-	-	-	-
	Dolichopodidae		2	-	-	-	-	-	-
	Empididae	unidentified	-	-	-	-	2	-	-
		Chelifera	2	-	-	1	-	-	-
		Hemerodromia	-	-	-	-	8	-	-
		Oreogeton	10	4	15	25	-	-	-
	Simuliidae	*Prosimulium*	-	1	-	5	-	-	-
		Simulium	3	3	-	-	2	-	2

Appendix 3.3. (Continued)

Order	Family	Genus	2001	2002	2003	2004	2005	2006	2007
Diptera (cont.)	Tipulidae	*Antocha*	1	-	3	2	-	-	-
		Dicranota	2	1	-	-	-	-	-
		Hesperoconopa	-	1	1	-	-	-	-
		Pilaria	-	-	1	-	-	-	-
		Rhabdomastix	-	-	3	2	3	-	2
		Tipula	-	1	-	1	-	4	-
Collembola	unidentified		-	-	-	-	-	1	1
	Onychiuridae	*Onychiurus*	-	1	-	-	-	-	-
	Sminthuridae	*Dicyrtoma*	-	1	-	-	-	-	-
		Sminthurus	-	-	-	2	-	-	-
Copepoda	Cyclopoida		-	-	1	1	-	-	-
Acarina			9	3	6	11	2	-	-
Oligochaeta			3	7	49	18	2	-	-
Gastropoda	Valvatidae		1	1	-	-	-	-	-
Ostracoda			1	1	1	11	-	-	-

Appendix 3.4. Numbers of benthic macroinvertebrates identified in Tributary Creek Site 9 biomonitoring samples from 2001 through 2007.

Order	Family	Genus	2001	2002	2003	2004	2005	2006	2007
Ephemeroptera	unidentified		-	-	-	-	-	1	-
	Baetidae	*Acentrella*	41	123	160	21	38	1	3
		Procloeon	5	-	-	-	-	-	-
	Ephemerellidae	*Caudatella*	3	-	-	-	-	-	-
		Ephemerella	-	14	7	4	1	74	-
		Drunella	-	3	10	-	8	3	-
	Heptageniidae	*Cinygma*	1	-	-	-	43	-	-
		Cinygmula	89	177	507	49	24	127	43
		Epeorus	-	8	1	-	2	-	-
		Rhithrogena	-	-	1	-	2	1	-
	Leptophlebiidae	*Paraleptophlebia*	66	96	249	442	191	204	38
	Ameletidae	*Ameletus*	-	15	46	46	25	33	18
Plecoptera	unidentified		-	-	-	-	-	21	-
	Chloroperlidae	unidentified	-	-	-	-	1	-	8
		Neaviperla	-	-	174	24	-	-	-
		Paraperla	-	11	-	-	-	-	-
		Plumiperla	-	-	-	38	-	-	-
		Suwallia	34	-	24	20	36	-	-
		Sweltsa	-	42	-	-	12	-	26
	Leuctridae	*Despaxia*	3	-	6	5	3	1	3
		Paraleuctra	7	-	1	-	-	-	-
		Perlomyia	-	3	-	-	-	-	-
	Nemouridae	*Podmosta*	-	1	-	-	-	-	-
		Zapada	23	12	388	41	43	13	-
	Perlodidae	*Isoperla*	1	-	-	38	-	-	-
Trichoptera	unidentified		-	-	-	-	-	1	-
	Apataniidae	*Apatania*	-	1	-	-	-	-	-
	Brachycentridae	*Brachycentrus*	-	-	1	-	-	-	-
	Lepidostomatidae	*Lepidostoma*	-	-	-	1	1	1	1
	Limnephilidae	unidentified	-	-	-	-	1	-	-
		Ecclisomyia	-	-	1	-	1	-	3
		Onocosmoecus	-	-	-	1	-	-	-
	Rhycophilidae	*Rhycophila*	-	1	5	3	1	-	-
Coleoptera	Elmidae	*Narpus*	2	6	32	14	1	8	3
	Dytiscidae	*Megadytes*	-	-	2	-	-	-	-
Diptera	unidentified		-	-	-	-	-	1	-
	Ceratopogonidae	*Bezzia*	-	-	1	-	-	-	-
		Dasyhelea	3	-	-	-	-	-	
		Probezzia	-	-	9	-	-	1	-
	Chironomidae		35	36	125	52	40	22	3
	Empididae	*Chelifera*	-	1	-	-	-	-	-
		Hemerodromia	-	-	1	-	1	-	-
		Oreogeton	4	2	24	8	1	-	-
	Simuliidae	*Simulium*	40	22	81	4	14	8	10
	Tipulidae	*Antocha*	-	-	10	-	-	-	-
		Dicranota	-	-	2	-	2	6	2
		Pilaria	-	-	2	-	-	-	-
		Rhabdomastix	-	-	1	-	1	-	-
		Tipula	4	5	-	2	-	4	5
		Limonia	-	-	-	-	1	-	1

Appendix 3.4. (Continued)

Order	Family	Genus	2001	2002	2003	2004	2005	2006	2007
Branchiopoda	Chydoridae		-	-	2	-	-	-	-
Collembola	unidentified		-	-	-	-	-	1	2
	Sminthuridae	*Dicyrtoma*	-	2	-	-	-	-	-
		Sminthurus	-	-	3	34	1	2	-
Copepoda	unidentified		-	-	-	-	-	1	-
	Cyclopoida		-	-	6	5	-	-	-
	Harpacticoida		-	-	5	-	-	-	-
Acarina			15	20	72	39	2	-	2
Oligochaeta			40	45	349	111	23	21	27
Gastropoda			1	-	1	2	-	1	1
Isopoda	Gammaridae	*Gammarus*	-	-	-	1	-	-	-
Ostracoda			92	102	207	27	8	68	17

APPENDIX 4. JUVENILE FISH CAPTURE DATA

Sampling Site	Fish Species[1]	Number of Fish Captured Set 1	Set 2	Set 3	Total	MLE[2] Pop. Est.	Standard Error	95% Conf. Interval
2001[3]								
Upper Greens Cr 48	DV	30	16	22	68	96	13.80	68 - 124
Middle Greens Cr 6	DV	80	8	43	131	161	12.14	137 - 185
	CO	1	0	2	3	3	0.00	3 - 3
Greens Cr Below D 54	DV	70	49	19	138	158	8.44	141 - 175
	CO	2	6	4	12	17	4.46	8 - 26
Tributary Cr 9	DV	70	4	7	81	81	0.00	81 - 81
	CO	89	18	11	118	120	1.69	117 - 123
	CT	1	0	0	1	1	---	---
	Sc	3	1	0	4	4	0.00	4 - 4
2002[3]								
Upper Greens Cr 48	DV	74	29	23	126	141	6.87	127 - 155
Greens Cr Below D 54	DV	168	72	31	271	290	6.81	276 - 304
	CO	14	6	1	21	21	0.00	21 - 21
Tributary Cr 9	DV	29	14	8	51	56	3.63	49 - 63
	CO	29	9	6	44	46	1.92	42 - 50
	CT	0	0	1	1	1	0.00	1 - 1
	Sc	0	1	1	2	2	0.00	2 - 2
2003								
Upper Greens Cr 48	DV	157	72	56	285	333	14.04	305 - 361
Greens 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	0.00	1 - 1
2004								
Upper Greens Cr 48	DV	168	48	28	244	255	4.70	246 - 264
Greens 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	0.00	4 - 4
	Sc	1	1	0	2	2	0.00	2 - 2
2005								
Upper Greens Cr 48	DV	118	56	38	212	243	10.70	222 - 264
Greens Cr Below D 54	DV	111	59	43	213	255	14.13	227 - 283
	CO	33	20	8	61	67	3.97	59 - 75
Tributary Cr 9	DV	21	12	11	44	55	7.16	41 - 69
	CO	82	42	15	139	150	5.31	139 - 161
	CT	1	1	0	2	2	0.00	2 - 2
	Sc	2	0	0	2	2	---	---
2006								
Upper Greens Cr 48	DV	138	40	34	212	228	6.34	215 - 241
Middle Greens Cr 6	DV	44	41	12	97	114	8.24	98 - 130
	CO	1	0	0	1	1	---	---
Greens Cr Below D 54	DV	116	61	40	217	254	12.34	229 - 279
	CO	6	0	1	7	7	0.00	7 - 7
Tributary Cr 9	DV	7	3	1	11	11	0.00	11 - 11
	CO	5	4	1	10	10	0.00	10 - 10
	CT	0	0	0	0	---	---	---
	Sc	0	0	0	0	---	---	---
2007								
Upper Greens Cr 48	DV	50	29	16	95	103	7.01	95 - 123
Greens Cr Below D 54	DV	64	19	24	107	122	7.22	108 - 136
	CO	0	0	0	0	0	---	---
Tributary Cr 9	DV	7	5	0	12	12	0.00	12 - 12
	CO	50	10	9	69	71	1.80	67 - 75
	CT	0	0	1	1	1	0.00	1 - 1
	Sc	0	0	0	0	0	---	---

[1] Species: DV = Dolly Varden, CO = coho salmon, CT = cutthroat trout, RT = rainbow trout / steelhead, Sc = sculpin species.

[2] Maximum Likelihood Estimate of fish population in the sample reach (Lockwood and Schneider 2000).

[3] Capture data for 2001 and 2002 from USDA Forest Service.

APPENDIX 5. METALS IN JUVENILE FISH DATA

Appendix 5.1. Information on fish collected in 2000 through 2007 for whole body analysis of metals. Sample Number contains codes for date, water body, site, fish species, age, and replicate.

Collector	Date Collected	Location	Site	Fish Sp	FLength (mm)	Mass (g)	Solids (%)	Sample Number
ADF&G / FS	23-Jul-2001	Upper Greens Creek	Site 48	DV	131	26.0	21.6	072301GC48DVJ01
ADF&G / FS	23-Jul-2001	Upper Greens Creek	Site 48	DV	137	28.8	23.7	072301GC48DVJ02
ADF&G / FS	23-Jul-2001	Upper Greens Creek	Site 48	DV	119	18.8	20.7	072301GC48DVJ03
ADF&G / FS	23-Jul-2001	Upper Greens Creek	Site 48	DV	121	21.1	22.8	072301GC48DVJ04
ADF&G / FS	23-Jul-2001	Upper Greens Creek	Site 48	DV	111	13.7	21.8	072301GC48DVJ05
ADF&G / FS	23-Jul-2001	Upper Greens Creek	Site 48	DV	121	21.1	20.3	072301GC48DVJ06
ADF&G	24-Jul-2002	Upper Greens Creek	Site 48	DV	133	23.2	24.3	072402GC48DVJ01
ADF&G	24-Jul-2002	Upper Greens Creek	Site 48	DV	120	15.0	19.2	072402GC48DVJ02
ADF&G	24-Jul-2002	Upper Greens Creek	Site 48	DV	122	17.5	22.1	072402GC48DVJ03
ADF&G	24-Jul-2002	Upper Greens Creek	Site 48	DV	127	20.8	21.2	072402GC48DVJ04
ADF&G	24-Jul-2002	Upper Greens Creek	Site 48	DV	134	24.8	21.5	072402GC48DVJ05
ADF&G	24-Jul-2002	Upper Greens Creek	Site 48	DV	128	21.7	20.9	072402GC48DVJ06
ADNR	22-Jul-2003	Upper Greens Creek	Site 48	DV	90	8.9	23.8	072203GC48DVJ01
ADNR	22-Jul-2003	Upper Greens Creek	Site 48	DV	98	9.9	23.6	072203GC48DVJ02
ADNR	22-Jul-2003	Upper Greens Creek	Site 48	DV	103	12.1	23.7	072203GC48DVJ03
ADNR	22-Jul-2003	Upper Greens Creek	Site 48	DV	112	12.5	23.5	072203GC48DVJ04
ADNR	22-Jul-2003	Upper Greens Creek	Site 48	DV	108	11.9	23.8	072203GC48DVJ05
ADNR	22-Jul-2003	Upper Greens Creek	Site 48	DV	100	10.5	24.2	072203GC48DVJ06
ADNR	22-Jul-2004	Upper Greens Creek	Site 48	DV	96	8.6	23.7	072204GC48DVJ01
ADNR	22-Jul-2004	Upper Greens Creek	Site 48	DV	88	6.8	23.4	072204GC48DVJ02
ADNR	22-Jul-2004	Upper Greens Creek	Site 48	DV	101	11.5	23.5	072204GC48DVJ03
ADNR	22-Jul-2004	Upper Greens Creek	Site 48	DV	98	9.3	23.8	072204GC48DVJ04
ADNR	22-Jul-2004	Upper Greens Creek	Site 48	DV	93	7.6	21.4	072204GC48DVJ05
ADNR	22-Jul-2004	Upper Greens Creek	Site 48	DV	91	7.5	23.9	072204GC48DVJ06
ADNR	22-Jul-2005	Upper Greens Creek	Site 48	DV	103	19.7	24.8	072205GC48DVJ01
ADNR	22-Jul-2005	Upper Greens Creek	Site 48	DV	96	13.1	23.6	072205GC48DVJ02
ADNR	22-Jul-2005	Upper Greens Creek	Site 48	DV	119	15.6	23.2	072205GC48DVJ03
ADNR	22-Jul-2005	Upper Greens Creek	Site 48	DV	114	17.1	23.5	072205GC48DVJ04
ADNR	22-Jul-2005	Upper Greens Creek	Site 48	DV	111	15.3	24.9	072205GC48DVJ05
ADNR	22-Jul-2005	Upper Greens Creek	Site 48	DV	125	16.9	23.7	072205GC48DVJ06
ADNR	20-Jul-2006	Upper Greens Creek	Site 48	DV	110	15.8	21.2	072006GC48DVJ01
ADNR	20-Jul-2006	Upper Greens Creek	Site 48	DV	110	15.4	21.4	072006GC48DVJ02
ADNR	20-Jul-2006	Upper Greens Creek	Site 48	DV	113	16.1	23.3	072006GC48DVJ03
ADNR	20-Jul-2006	Upper Greens Creek	Site 48	DV	132	25.0	22.9	072006GC48DVJ04
ADNR	20-Jul-2006	Upper Greens Creek	Site 48	DV	104	12.8	21.0	072006GC48DVJ05
ADNR	20-Jul-2006	Upper Greens Creek	Site 48	DV	114	16.7	20.9	072006GC48DVJ06
ADNR	21-Jul-2007	Upper Greens Creek	Site 48	DV	122	17.91	22.30	072107GC48DVJ01
ADNR	21-Jul-2007	Upper Greens Creek	Site 48	DV	95	10.35	24.70	072107GC48DVJ02
ADNR	21-Jul-2007	Upper Greens Creek	Site 48	DV	135	22.79	24.40	072107GC48DVJ03
ADNR	21-Jul-2007	Upper Greens Creek	Site 48	DV	98	9.88	21.50	072107GC48DVJ04
ADNR	21-Jul-2007	Upper Greens Creek	Site 48	DV	105	13.19	20.70	072107GC48DVJ05
ADNR	21-Jul-2007	Upper Greens Creek	Site 48	DV	99	10.03	22.00	072107GC48DVJ06
ADF&G / FS	23-Jul-2001	Middle Greens Creek	Site 6	DV	139	28.4	20.8	072301GC06DVJ01
ADF&G / FS	23-Jul-2001	Middle Greens Creek	Site 6	DV	140	30.5	22.8	072301GC06DVJ02
ADF&G / FS	23-Jul-2001	Middle Greens Creek	Site 6	DV	167	43.9	21.7	072301GC06DVJ03
ADF&G / FS	23-Jul-2001	Middle Greens Creek	Site 6	DV	155	34.8	21.6	072301GC06DVJ04
ADF&G / FS	23-Jul-2001	Middle Greens Creek	Site 6	DV	109	15.7	22.2	072301GC06DVJ05
ADF&G / FS	23-Jul-2001	Middle Greens Creek	Site 6	DV	168	49.1	21.9	072301GC06DVJ06
ADNR	21-Jul-2006	Middle Greens Creek	Site 6	DV	103	12.6	21.7	072106GC06DVJ01
ADNR	21-Jul-2006	Middle Greens Creek	Site 6	DV	106	13.5	21.3	072106GC06DVJ02
ADNR	21-Jul-2006	Middle Greens Creek	Site 6	DV	96	11.8	21.0	072106GC06DVJ03
ADNR	21-Jul-2006	Middle Greens Creek	Site 6	DV	110	12.0	20.6	072106GC06DVJ04
ADNR	21-Jul-2006	Middle Greens Creek	Site 6	DV	128	23.2	22.0	072106GC06DVJ05
ADNR	21-Jul-2006	Middle Greens Creek	Site 6	DV	102	11.5	20.1	072106GC06DVJ06

Appendix 5.1. (Continued)

Collector	Date Collected	Location	Site	Fish Sp	FLength (mm)	Mass (g)	Solids (%)	Sample Number
USFS	21-Jun-2000	Greens Cr Below Pond D	Site 54	CO	72	4.4	20.5	062100GCCOJ01
USFS	21-Jun-2000	Greens Cr Below Pond D	Site 54	CO	82	6.1	20.2	062100GCCOJ02
USFS	21-Jun-2000	Greens Cr Below Pond D	Site 54	CO	73	4.9	20.4	062100GCCOJ03
USFS	21-Jun-2000	Greens Cr Below Pond D	Site 54	CO	68	3.4	21.4	062100GCCOJ04
USFS	21-Jun-2000	Greens Cr Below Pond D	Site 54	CO	73	5.9	20.7	062100GCCOJ05
USFS	21-Jun-2000	Greens Cr Below Pond D	Site 54	CO	75	6.0	20.2	062100GCCOJ06
ADF&G / FS	23-Jul-2001	Greens Cr Below Pond D	Site 54	DV	121	21.5	22.6	072301GC54DVJ01
ADF&G / FS	23-Jul-2001	Greens Cr Below Pond D	Site 54	DV	119	19.3	26.1	072301GC54DVJ02
ADF&G / FS	23-Jul-2001	Greens Cr Below Pond D	Site 54	DV	107	15.7	23.5	072301GC54DVJ03
ADF&G / FS	23-Jul-2001	Greens Cr Below Pond D	Site 54	DV	109	13.6	21.1	072301GC54DVJ04
ADF&G / FS	23-Jul-2001	Greens Cr Below Pond D	Site 54	DV	105	13.5	22.8	072301GC54DVJ05
ADF&G / FS	23-Jul-2001	Greens Cr Below Pond D	Site 54	DV	138	27.5	22.1	072301GC54DVJ06
ADF&G	24-Jul-2002	Greens Cr Below Pond D	Site 54	DV	118	18.0	21.2	072402GC54DVJ01
ADF&G	24-Jul-2002	Greens Cr Below Pond D	Site 54	DV	128	22.3	23.2	072402GC54DVJ02
ADF&G	24-Jul-2002	Greens Cr Below Pond D	Site 54	DV	115	17.7	21.9	072402GC54DVJ03
ADF&G	24-Jul-2002	Greens Cr Below Pond D	Site 54	DV	115	18.9	21.3	072402GC54DVJ04
ADF&G	24-Jul-2002	Greens Cr Below Pond D	Site 54	DV	124	21.1	21.4	072402GC54DVJ05
ADF&G	24-Jul-2002	Greens Cr Below Pond D	Site 54	DV	123	20.9	20.9	072402GC54DVJ06
ADNR	22-Jul-2003	Greens Cr Below Pond D	Site 54	DV	123	21.1	25.1	072203GC54DVJ01
ADNR	22-Jul-2003	Greens Cr Below Pond D	Site 54	DV	101	10.6	22.9	072203GC54DVJ02
ADNR	22-Jul-2003	Greens Cr Below Pond D	Site 54	DV	88	9.2	22.8	072203GC54DVJ03
ADNR	22-Jul-2003	Greens Cr Below Pond D	Site 54	DV	109	14.8	24.0	072203GC54DVJ04
ADNR	22-Jul-2003	Greens Cr Below Pond D	Site 54	DV	95	10.6	23.9	072203GC54DVJ05
ADNR	22-Jul-2003	Greens Cr Below Pond D	Site 54	DV	92	9.7	23.8	072203GC54DVJ06
ADNR	21-Jul-2004	Greens Cr Below Pond D	Site 54	DV	103	9.9	23.8	072104GC54DVJ01
ADNR	21-Jul-2004	Greens Cr Below Pond D	Site 54	DV	104	10.0	22.6	072104GC54DVJ02
ADNR	21-Jul-2004	Greens Cr Below Pond D	Site 54	DV	86	6.6	23.7	072104GC54DVJ03
ADNR	21-Jul-2004	Greens Cr Below Pond D	Site 54	DV	96	9.3	22.9	072104GC54DVJ04
ADNR	21-Jul-2004	Greens Cr Below Pond D	Site 54	DV	93	9.9	22.1	072104GC54DVJ05
ADNR	21-Jul-2004	Greens Cr Below Pond D	Site 54	DV	104	12.9	21.4	072104GC54DVJ06
ADNR	22-Jul-2005	Greens Cr Below Pond D	Site 54	DV	120	12.3	23.1	072205GC54DVJ01
ADNR	22-Jul-2005	Greens Cr Below Pond D	Site 54	DV	106	12.1	22.6	072205GC54DVJ02
ADNR	22-Jul-2005	Greens Cr Below Pond D	Site 54	DV	113	20.8	23.1	072205GC54DVJ03
ADNR	22-Jul-2005	Greens Cr Below Pond D	Site 54	DV	114	17.9	22.3	072205GC54DVJ04
ADNR	22-Jul-2005	Greens Cr Below Pond D	Site 54	DV	112	16.1	23.0	072205GC54DVJ05
ADNR	22-Jul-2005	Greens Cr Below Pond D	Site 54	DV	118	22.3	22.4	072205GC54DVJ06
ADNR	20-Jul-2006	Greens Cr Below Pond D	Site 54	DV	137	27.3	24.6	072006GC54DVJ01
ADNR	20-Jul-2006	Greens Cr Below Pond D	Site 54	DV	112	14.9	21.7	072006GC54DVJ02
ADNR	20-Jul-2006	Greens Cr Below Pond D	Site 54	DV	102	12.0	19.2	072006GC54DVJ03
ADNR	20-Jul-2006	Greens Cr Below Pond D	Site 54	DV	114	19.6	21.8	072006GC54DVJ04
ADNR	20-Jul-2006	Greens Cr Below Pond D	Site 54	DV	98	12.3	20.8	072006GC54DVJ05
ADNR	20-Jul-2006	Greens Cr Below Pond D	Site 54	DV	115	16.9	21.7	072006GC54DVJ06
ADNR	20-Jul-2007	Greens Cr Below Pond D	Site 54	DV	102	11.81	24.30	072007GC54DVJ01
ADNR	20-Jul-2007	Greens Cr Below Pond D	Site 54	DV	125	21.06	21.60	072007GC54DVJ02
ADNR	20-Jul-2007	Greens Cr Below Pond D	Site 54	DV	97	10.69	22.30	072007GC54DVJ03
ADNR	20-Jul-2007	Greens Cr Below Pond D	Site 54	DV	123	19.74	22.80	072007GC54DVJ04
ADNR	20-Jul-2007	Greens Cr Below Pond D	Site 54	DV	104	12.46	22.60	072007GC54DVJ05
ADNR	20-Jul-2007	Greens Cr Below Pond D	Site 54	DV	110	15.08	21.60	072007GC54DVJ06

Appendix 5.1. (Continued)

Collector	Date Collected	Location	Site	Fish Sp	FLength (mm)	Mass (g)	Solids (%)	Sample Number
USFS	21-Jun-2000	Tributary Creek	Site 9	CO	102	9.7	22.9	062100TRCOJ01
USFS	21-Jun-2000	Tributary Creek	Site 9	CO	75	5.3	22.5	062100TRCOJ02
USFS	21-Jun-2000	Tributary Creek	Site 9	DV	112	12.8	23.1	062100TRCOJ03
USFS	21-Jun-2000	Tributary Creek	Site 9	DV	105	13.8	22.2	062100TRDVJ04
USFS	21-Jun-2000	Tributary Creek	Site 9	DV	105	13.4	22.1	062100TRDVJ05
USFS	21-Jun-2000	Tributary Creek	Site 9	DV	100	11.3	23.0	062100TRDVJ06
ADF&G / FS	23-Jul-2001	Tributary Creek	Site 9	DV	97	9.1	22.1	072301TR09DVJ01
ADF&G / FS	23-Jul-2001	Tributary Creek	Site 9	DV	97	9.7	21.3	072301TR09DVJ02
ADF&G / FS	23-Jul-2001	Tributary Creek	Site 9	DV	97	9.5	22.2	072301TR09DVJ03
ADF&G / FS	23-Jul-2001	Tributary Creek	Site 9	DV	98	10.4	22.6	072301TR09DVJ04
ADF&G / FS	23-Jul-2001	Tributary Creek	Site 9	DV	86	6.4	22.2	072301TR09DVJ05
ADF&G / FS	23-Jul-2001	Tributary Creek	Site 9	DV	93	7.8	20.6	072301TR09DVJ06
ADF&G	24-Jul-2002	Tributary Creek	Site 9	DV	103	10.8	20.9	072402TR09DVJ01
ADF&G	24-Jul-2002	Tributary Creek	Site 9	DV	97	10.4	22.8	072402TR09DVJ02
ADF&G	24-Jul-2002	Tributary Creek	Site 9	DV	100	11.2	23.2	072402TR09DVJ03
ADF&G	24-Jul-2002	Tributary Creek	Site 9	DV	90	7.9	23.1	072402TR09DVJ04
ADF&G	24-Jul-2002	Tributary Creek	Site 9	DV	90	9.2	23.0	072402TR09DVJ05
ADF&G	24-Jul-2002	Tributary Creek	Site 9	DV	100	9.3	17.8	072402TR09DVJ06
ADNR	23-Jul-2003	Tributary Creek	Site 9	DV	106	10.7	21.9	072304TR09DVJ01
ADNR	23-Jul-2003	Tributary Creek	Site 9	DV	89	6.8	22.8	072304TR09DVJ02
ADNR	23-Jul-2003	Tributary Creek	Site 9	DV	112	17.4	24.3	072304TR09DVJ03
ADNR	23-Jul-2003	Tributary Creek	Site 9	DV	95	11.6	22.5	072304TR09DVJ04
ADNR	23-Jul-2003	Tributary Creek	Site 9	DV	91	9.5	22.2	072304TR09DVJ05
ADNR	23-Jul-2003	Tributary Creek	Site 9	DV	84	8.4	23.2	072304TR09DVJ06
ADNR	21-Jul-2004	Tributary Creek	Site 9	DV	84	5.5	23.0	072104TR09DVJ01
ADNR	21-Jul-2004	Tributary Creek	Site 9	DV	96	8.5	23.0	072104TR09DVJ02
ADNR	21-Jul-2004	Tributary Creek	Site 9	DV	105	14.1	23.3	072104TR09DVJ03
ADNR	21-Jul-2004	Tributary Creek	Site 9	DV	85	5.8	22.6	072104TR09DVJ04
ADNR	21-Jul-2004	Tributary Creek	Site 9	DV	81	6.4	24.0	072104TR09DVJ05
ADNR	21-Jul-2004	Tributary Creek	Site 9	DV	86	10.4	17.6	072104TR09DVJ06
ADNR	23-Jul-2005	Tributary Creek	Site 9	DV	97	11.1	25.8	072305TR09DVJ01
ADNR	23-Jul-2005	Tributary Creek	Site 9	DV	113	16.8	26.7	072305TR09DVJ02
ADNR	23-Jul-2005	Tributary Creek	Site 9	DV	115	18.8	26.2	072305TR09DVJ03
ADNR	23-Jul-2005	Tributary Creek	Site 9	DV	117	20.5	26.1	072305TR09DVJ04
ADNR	23-Jul-2005	Tributary Creek	Site 9	DV	101	11.7	27.4	072305TR09DVJ05
ADNR	23-Jul-2005	Tributary Creek	Site 9	DV	107	13.7	25.9	072305TR09DVJ06
ADNR	21-Jul-2006	Tributary Creek	Site 9	DV	99	12.9	22.6	072106TR09DVJ01
ADNR	21-Jul-2006	Tributary Creek	Site 9	DV	96	11.6	24.0	072106TR09DVJ02
ADNR	21-Jul-2006	Tributary Creek	Site 9	DV	94	10.9	24.5	072106TR09DVJ03
ADNR	21-Jul-2006	Tributary Creek	Site 9	DV	100	10.9	21.8	072106TR09DVJ04
ADNR	21-Jul-2006	Tributary Creek	Site 9	DV	97	11.7	23.3	072106TR09DVJ05
ADNR	21-Jul-2006	Tributary Creek	Site 9	DV	117	20.8	23.7	072106TR09DVJ06
ADNR	20-Jul-2007	Tributary Creek	Site 9	DV	98	12.40	26.40	072007TR09DVJ01
ADNR	20-Jul-2007	Tributary Creek	Site 9	DV	89	8.88	25.80	072007TR09DVJ02
ADNR	20-Jul-2007	Tributary Creek	Site 9	DV	114	14.06	25.50	072007TR09DVJ03
ADNR	20-Jul-2007	Tributary Creek	Site 9	DV	81	7.08	26.80	072007TR09DVJ04
ADNR	20-Jul-2007	Tributary Creek	Site 9	DV	114	14.60	27.50	072007TR09DVJ05
ADNR	20-Jul-2007	Tributary Creek	Site 9	DV	93	10.60	26.80	072007TR09DVJ06

Appendix 5.2. Whole body concentrations of selected metals in fish collected in 2000-2007

Date Collected	Site	Fish Sp	Analyte Basis	Ag mg/kg	Cd mg/kg	Cu mg/kg	Pb mg/kg	Se mg/kg	Zn mg/kg	Sample Number
23-Jul-2001	Site 48	DV	dry wt	0.02	1.76	8.3	0.20	6.1	180	072301GC48DVJ01
23-Jul-2001	Site 48	DV	dry wt	0.03	0.89	7.2	0.17	4.6	146	072301GC48DVJ02
23-Jul-2001	Site 48	DV	dry wt	0.02	2.27	5.7	0.20	6.2	189	072301GC48DVJ03
23-Jul-2001	Site 48	DV	dry wt	0.02	1.56	6.9	0.17	5.2	182	072301GC48DVJ04
23-Jul-2001	Site 48	DV	dry wt	0.03	0.89	4.7	0.23	5.4	138	072301GC48DVJ05
23-Jul-2001	Site 48	DV	dry wt	0.02	1.26	7.4	0.10	5.6	157	072301GC48DVJ06
24-Jul-2002	Site 48	DV	dry wt	0.03	1.64	6.8	0.72	4.8	239	072402GC48DVJ01
24-Jul-2002	Site 48	DV	dry wt	0.07	0.85	7.0	0.28	4.1	210	072402GC48DVJ02
24-Jul-2002	Site 48	DV	dry wt	0.03	0.74	4.3	0.17	4.9	162	072402GC48DVJ03
24-Jul-2002	Site 48	DV	dry wt	0.04	1.40	6.1	0.16	4.7	185	072402GC48DVJ04
24-Jul-2002	Site 48	DV	dry wt	0.05	1.30	7.9	0.46	4.3	208	072402GC48DVJ05
24-Jul-2002	Site 48	DV	dry wt	0.04	1.56	6.8	0.22	5.7	343	072402GC48DVJ06
22-Jul-2003	Site 48	DV	dry wt	ND	0.65	4.2	0.14	5.6	191	072203GC48DVJ01
22-Jul-2003	Site 48	DV	dry wt	ND	0.90	5.1	0.22	5.5	180	072203GC48DVJ02
22-Jul-2003	Site 48	DV	dry wt	ND	0.82	5.6	0.16	5.4	241	072203GC48DVJ03
22-Jul-2003	Site 48	DV	dry wt	ND	0.78	6.1	0.11	6.1	192	072203GC48DVJ04
22-Jul-2003	Site 48	DV	dry wt	ND	0.63	3.9	0.14	5.2	174	072203GC48DVJ05
22-Jul-2003	Site 48	DV	dry wt	ND	0.58	3.7	0.08	5.5	218	072203GC48DVJ06
22-Jul-2004	Site 48	DV	dry wt	ND	0.63	4.7	0.15	4.3	206	072204GC48DVJ01
22-Jul-2004	Site 48	DV	dry wt	ND	0.83	5.6	0.26	4.0	175	072204GC48DVJ02
22-Jul-2004	Site 48	DV	dry wt	ND	1.54	4.6	0.21	4.1	183	072204GC48DVJ03
22-Jul-2004	Site 48	DV	dry wt	ND	0.80	5.2	0.28	3.7	168	072204GC48DVJ04
22-Jul-2004	Site 48	DV	dry wt	ND	1.25	4.4	0.14	6.4	220	072204GC48DVJ05
22-Jul-2004	Site 48	DV	dry wt	0.03	1.01	4.5	0.29	5.6	323	072204GC48DVJ06
22-Jul-2005	Site 48	DV	dry wt	0.02	0.66	4.4	0.44	4.2	183	072205GC48DVJ01
22-Jul-2005	Site 48	DV	dry wt	ND	0.84	14.5	0.98	4.8	220	072205GC48DVJ02
22-Jul-2005	Site 48	DV	dry wt	ND	0.89	4.3	0.66	4.8	226	072205GC48DVJ03
22-Jul-2005	Site 48	DV	dry wt	0.02	0.59	6.0	0.32	4.8	178	072205GC48DVJ04
22-Jul-2005	Site 48	DV	dry wt	0.03	1.10	18.8	0.79	4.6	217	072205GC48DVJ05
22-Jul-2005	Site 48	DV	dry wt	0.03	0.47	3.6	0.36	3.8	160	072205GC48DVJ06
20-Jul-2006	Site 48	DV	dry wt	0.04	0.56	8.5	0.37	5.4	244	072006GC48DVJ01
20-Jul-2006	Site 48	DV	dry wt	0.05	1.20	8.3	0.31	6.0	217	072006GC48DVJ02
20-Jul-2006	Site 48	DV	dry wt	0.04	0.65	6.3	0.24	5.4	264	072006GC48DVJ03
20-Jul-2006	Site 48	DV	dry wt	0.06	0.63	8.1	0.66	5.2	232	072006GC48DVJ04
20-Jul-2006	Site 48	DV	dry wt	0.08	0.96	8.5	0.37	5.1	283	072006GC48DVJ05
20-Jul-2006	Site 48	DV	dry wt	0.03	0.63	5.3	0.20	5.1	270	072006GC48DVJ06
21-Jul-2007	Site 48	DV	dry wt	0.03	1.16	5.5	0.17	5.5	221	072107GC48DVJ01
21-Jul-2007	Site 48	DV	dry wt	0.02	1.42	3.9	0.29	5.8	165	072107GC48DVJ02
21-Jul-2007	Site 48	DV	dry wt	0.08	1.34	14.1	1.37	5.3	166	072107GC48DVJ03
21-Jul-2007	Site 48	DV	dry wt	0.03	0.96	5.7	0.27	5.2	269	072107GC48DVJ04
21-Jul-2007	Site 48	DV	dry wt	0.11	1.79	11.4	1.62	5.4	323	072107GC48DVJ05
21-Jul-2007	Site 48	DV	dry wt	0.04	1.43	5.2	0.31	5.7	208	072107GC48DVJ06
23-Jul-2001	Site 6	DV	dry wt	0.04	1.94	16.7	1.24	5.0	173	072301GC06DVJ01
23-Jul-2001	Site 6	DV	dry wt	0.03	0.84	4.6	1.00	4.5	167	072301GC06DVJ02
23-Jul-2001	Site 6	DV	dry wt	0.03	0.82	5.3	1.94	4.3	171	072301GC06DVJ03
23-Jul-2001	Site 6	DV	dry wt	0.03	1.52	5.4	1.78	4.5	215	072301GC06DVJ04
23-Jul-2001	Site 6	DV	dry wt	0.02	0.89	11.1	0.33	5.3	126	072301GC06DVJ05
23-Jul-2001	Site 6	DV	dry wt	0.04	0.73	8.0	1.96	4.6	169	072301GC06DVJ06
21-Jul-2006	Site 6	DV	dry wt	0.03	0.71	8.0	0.70	5.2	183	072106GC06DVJ01
21-Jul-2006	Site 6	DV	dry wt	0.04	0.81	12.0	0.62	5.6	271	072106GC06DVJ02
21-Jul-2006	Site 6	DV	dry wt	0.03	0.56	12.7	0.97	4.5	215	072106GC06DVJ03
21-Jul-2006	Site 6	DV	dry wt	0.03	0.56	7.7	0.92	5.9	223	072106GC06DVJ04
21-Jul-2006	Site 6	DV	dry wt	0.03	0.95	5.4	1.31	4.4	221	072106GC06DVJ05
21-Jul-2006	Site 6	DV	dry wt	0.02	0.63	6.5	0.86	4.5	302	072106GC06DVJ06

Appendix 5.2. (Continued)

Date Collected	Site	Fish Sp	Analyte Basis	Ag mg/kg	Cd mg/kg	Cu mg/kg	Pb mg/kg	Se mg/kg	Zn mg/kg	Sample Number
21-Jun-2000	Site 54	CO	dry wt	0.04	0.95	15.3	1.40	4.9	251	062100GCCOJ01
21-Jun-2000	Site 54	CO	dry wt	0.09	0.66	11.7	1.21	4.7	224	062100GCCOJ02
21-Jun-2000	Site 54	CO	dry wt	0.22	1.07	24.2	1.40	3.4	206	062100GCCOJ03
21-Jun-2000	Site 54	CO	dry wt	0.10	0.97	24.0	1.12	3.5	181	062100GCCOJ04
21-Jun-2000	Site 54	CO	dry wt	0.05	0.96	44.0	1.53	4.9	304	062100GCCOJ05
21-Jun-2000	Site 54	CO	dry wt	0.08	1.47	36.1	5.02	4.7	340	062100GCCOJ06
23-Jul-2001	Site 54	DV	dry wt	0.03	0.46	4.3	0.33	5.7	126	072301GC54DVJ01
23-Jul-2001	Site 54	DV	dry wt	0.02	0.21	3.2	0.22	3.6	82	072301GC54DVJ02
23-Jul-2001	Site 54	DV	dry wt	0.03	0.73	6.3	0.59	4.7	144	072301GC54DVJ03
23-Jul-2001	Site 54	DV	dry wt	0.02	0.82	5.4	0.86	4.9	172	072301GC54DVJ04
23-Jul-2001	Site 54	DV	dry wt	0.02	0.79	6.5	0.45	5.8	203	072301GC54DVJ05
23-Jul-2001	Site 54	DV	dry wt	0.02	0.74	5.8	0.40	5.4	171	072301GC54DVJ06
24-Jul-2002	Site 54	DV	dry wt	0.03	0.50	4.4	0.94	3.4	363	072402GC54DVJ01
24-Jul-2002	Site 54	DV	dry wt	0.03	0.52	4.5	0.35	4.7	150	072402GC54DVJ02
24-Jul-2002	Site 54	DV	dry wt	0.05	0.95	6.0	0.66	4.4	161	072402GC54DVJ03
24-Jul-2002	Site 54	DV	dry wt	0.03	1.03	5.2	0.66	4.2	216	072402GC54DVJ04
24-Jul-2002	Site 54	DV	dry wt	0.05	1.32	5.2	0.74	3.9	2	072402GC54DVJ05
24-Jul-2002	Site 54	DV	dry wt	0.02	0.70	3.9	0.78	4.4	195	072402GC54DVJ06
22-Jul-2003	Site 54	DV	dry wt	0.03	0.85	6.4	1.40	6.1	188	072203GC54DVJ01
22-Jul-2003	Site 54	DV	dry wt	ND	0.67	4.2	0.32	6.4	174	072203GC54DVJ02
22-Jul-2003	Site 54	DV	dry wt	ND	0.75	4.3	0.35	6.5	186	072203GC54DVJ03
22-Jul-2003	Site 54	DV	dry wt	ND	1.11	5.8	0.38	5.7	188	072203GC54DVJ04
22-Jul-2003	Site 54	DV	dry wt	ND	0.59	3.5	0.29	5.7	174	072203GC54DVJ05
22-Jul-2003	Site 54	DV	dry wt	ND	0.91	4.1	0.43	6.5	263	072203GC54DVJ06
21-Jul-2004	Site 54	DV	dry wt	0.02	0.79	11.0	0.57	4.6	232	072104GC54DVJ01
21-Jul-2004	Site 54	DV	dry wt	ND	0.88	5.5	0.54	5.0	206	072104GC54DVJ02
21-Jul-2004	Site 54	DV	dry wt	ND	1.26	5.1	0.36	5.3	164	072104GC54DVJ03
21-Jul-2004	Site 54	DV	dry wt	0.03	0.79	5.9	0.28	5.4	191	072104GC54DVJ04
21-Jul-2004	Site 54	DV	dry wt	ND	0.83	5.0	0.48	3.9	202	072104GC54DVJ05
21-Jul-2004	Site 54	DV	dry wt	0.07	1.12	7.0	0.93	4.9	216	072104GC54DVJ06
22-Jul-2005	Site 54	DV	dry wt	0.03	0.72	5.0	0.27	4.0	160	072205GC54DVJ01
22-Jul-2005	Site 54	DV	dry wt	0.02	0.63	4.5	0.13	3.9	200	072205GC54DVJ02
22-Jul-2005	Site 54	DV	dry wt	ND	0.73	8.8	0.17	4.7	223	072205GC54DVJ03
22-Jul-2005	Site 54	DV	dry wt	ND	0.82	9.7	0.17	3.9	222	072205GC54DVJ04
22-Jul-2005	Site 54	DV	dry wt	0.03	1.06	8.8	0.22	4.4	209	072205GC54DVJ05
22-Jul-2005	Site 54	DV	dry wt	0.02	0.55	5.5	0.39	3.9	185	072205GC54DVJ06
20-Jul-2006	Site 54	DV	dry wt	0.06	0.42	4.8	0.50	5.7	208	072006GC54DVJ01
20-Jul-2006	Site 54	DV	dry wt	0.04	0.75	16.0	0.95	7.2	223	072006GC54DVJ02
20-Jul-2006	Site 54	DV	dry wt	0.02	0.93	22.2	0.52	6.3	239	072006GC54DVJ03
20-Jul-2006	Site 54	DV	dry wt	0.04	1.03	7.6	0.85	5.3	252	072006GC54DVJ04
20-Jul-2006	Site 54	DV	dry wt	0.08	0.54	10.9	0.48	5.4	223	072006GC54DVJ05
20-Jul-2006	Site 54	DV	dry wt	0.04	0.78	8.6	0.68	5.6	257	072006GC54DVJ06
20-Jul-2007	Site 54	DV	dry wt	0.04	0.88	5.3	0.54	5.6	157	072007GC54DVJ01
20-Jul-2007	Site 54	DV	dry wt	0.03	0.97	5.2	0.83	7.5	234	072007GC54DVJ02
20-Jul-2007	Site 54	DV	dry wt	0.06	0.81	5.7	0.89	8.6	185	072007GC54DVJ03
20-Jul-2007	Site 54	DV	dry wt	0.02	0.75	4.4	0.50	7.1	175	072007GC54DVJ04
20-Jul-2007	Site 54	DV	dry wt	0.03	0.92	5.6	0.57	7.8	174	072007GC54DVJ05
20-Jul-2007	Site 54	DV	dry wt	0.04	1.38	6.2	0.82	5.4	191	072007GC54DVJ06

Appendix 5.2. (Continued)

Date Collected	Site	Fish Sp	Analyte Basis	Ag mg/kg	Cd mg/kg	Cu mg/kg	Pb mg/kg	Se mg/kg	Zn mg/kg	Sample Number
21-Jun-2000	Site 9	CO	dry wt	0.04	0.42	16.2	1.03	3.2	213	062100TRCOJ01
21-Jun-2000	Site 9	CO	dry wt	0.07	0.50	16.5	2.01	3.7	220	062100TRCOJ02
21-Jun-2000	Site 9	DV	dry wt	0.12	0.75	11.2	1.63	3.8	194	062100TRCOJ03
21-Jun-2000	Site 9	DV	dry wt	0.07	0.56	10.6	1.53	3.6	88	062100TRDVJ04
21-Jun-2000	Site 9	DV	dry wt	0.06	0.58	12.8	1.59	3.5	204	062100TRDVJ05
21-Jun-2000	Site 9	DV	dry wt	0.05	0.45	32.8	1.57	5.0	213	062100TRDVJ06
23-Jul-2001	Site 9	DV	dry wt	0.09	0.35	4.3	0.56	6.8	127	072301TR09DVJ01
23-Jul-2001	Site 9	DV	dry wt	0.10	0.77	5.2	0.67	8.0	118	072301TR09DVJ02
23-Jul-2001	Site 9	DV	dry wt	0.15	0.92	5.4	4.88	5.3	144	072301TR09DVJ03
23-Jul-2001	Site 9	DV	dry wt	0.15	0.86	6.7	2.19	--	99	072301TR09DVJ04
23-Jul-2001	Site 9	DV	dry wt	0.08	0.76	4.9	0.33	6.2	106	072301TR09DVJ05
23-Jul-2001	Site 9	DV	dry wt	0.06	0.37	12.0	0.38	6.8	122	072301TR09DVJ06
24-Jul-2002	Site 9	DV	dry wt	0.02	0.22	3.7	0.12	1.4	144	072402TR09DVJ01
24-Jul-2002	Site 9	DV	dry wt	0.07	1.20	5.5	1.66	3.3	172	072402TR09DVJ02
24-Jul-2002	Site 9	DV	dry wt	0.13	1.06	6.1	3.40	5.0	138	072402TR09DVJ03
24-Jul-2002	Site 9	DV	dry wt	0.23	1.29	7.1	4.08	5.2	168	072402TR09DVJ04
24-Jul-2002	Site 9	DV	dry wt	0.08	1.15	5.2	1.39	6.2	150	072402TR09DVJ05
24-Jul-2002	Site 9	DV	dry wt	0.04	0.84	3.2	0.33	5.4	152	072402TR09DVJ06
23-Jul-2003	Site 9	DV	dry wt	0.06	0.46	2.8	0.34	6.3	134	072304TR09DVJ01
23-Jul-2003	Site 9	DV	dry wt	0.10	1.01	4.0	0.82	6.0	131	072304TR09DVJ02
23-Jul-2003	Site 9	DV	dry wt	0.16	1.35	4.4	1.85	5.7	108	072304TR09DVJ03
23-Jul-2003	Site 9	DV	dry wt	0.19	0.69	5.6	1.30	3.6	136	072304TR09DVJ04
23-Jul-2003	Site 9	DV	dry wt	0.05	0.72	4.4	0.56	4.9	131	072304TR09DVJ05
23-Jul-2003	Site 9	DV	dry wt	0.12	0.76	3.9	0.78	4.7	125	072304TR09DVJ06
21-Jul-2004	Site 9	DV	dry wt	0.10	0.96	3.2	1.19	5.4	169	072104TR09DVJ01
21-Jul-2004	Site 9	DV	dry wt	0.10	1.24	3.8	0.67	5.9	138	072104TR09DVJ02
21-Jul-2004	Site 9	DV	dry wt	0.10	2.02	4.0	1.75	5.7	125	072104TR09DVJ03
21-Jul-2004	Site 9	DV	dry wt	0.04	0.47	3.7	0.93	4.8	175	072104TR09DVJ04
21-Jul-2004	Site 9	DV	dry wt	0.09	2.34	4.3	1.44	8.2	140	072104TR09DVJ05
21-Jul-2004	Site 9	DV	dry wt	0.11	0.83	5.5	0.97	5.8	161	072104TR09DVJ06
23-Jul-2005	Site 9	DV	dry wt	0.06	0.70	10.4	0.29	6.4	104	072305TR09DVJ01
23-Jul-2005	Site 9	DV	dry wt	0.10	0.63	4.7	0.97	6.1	122	072305TR09DVJ02
23-Jul-2005	Site 9	DV	dry wt	0.07	0.52	6.3	0.53	5.8	109	072305TR09DVJ03
23-Jul-2005	Site 9	DV	dry wt	0.19	0.79	9.9	1.07	6.7	117	072305TR09DVJ04
23-Jul-2005	Site 9	DV	dry wt	0.07	1.44	5.2	1.00	8.1	130	072305TR09DVJ05
23-Jul-2005	Site 9	DV	dry wt	0.10	1.29	4.6	0.46	8.0	134	072305TR09DVJ06
21-Jul-2006	Site 9	DV	dry wt	0.12	0.74	4.0	0.32	6.3	120	072106TR09DVJ01
21-Jul-2006	Site 9	DV	dry wt	0.12	0.76	7.7	1.32	6.8	157	072106TR09DVJ02
21-Jul-2006	Site 9	DV	dry wt	0.18	1.59	10.3	2.48	4.9	160	072106TR09DVJ03
21-Jul-2006	Site 9	DV	dry wt	0.11	1.34	8.5	1.46	5.2	142	072106TR09DVJ04
21-Jul-2006	Site 9	DV	dry wt	0.14	0.88	4.6	0.96	5.2	107	072106TR09DVJ05
21-Jul-2006	Site 9	DV	dry wt	0.24	1.29	4.3	2.92	5.9	129	072106TR09DVJ06
20-Jul-2007	Site 9	DV	dry wt	0.11	0.91	2.7	1.10	7.7	106	072007TR09DVJ01
20-Jul-2007	Site 9	DV	dry wt	0.12	1.72	3.3	1.80	5.6	136	072007TR09DVJ02
20-Jul-2007	Site 9	DV	dry wt	0.15	2.76	3.4	1.28	8.7	122	072007TR09DVJ03
20-Jul-2007	Site 9	DV	dry wt	0.14	1.90	4.2	2.03	7.0	114	072007TR09DVJ04
20-Jul-2007	Site 9	DV	dry wt	0.88	3.63	3.9	1.56	10.9	131	072007TR09DVJ05
20-Jul-2007	Site 9	DV	dry wt	0.14	1.50	20.3	3.80	9.4	107	072007TR09DVJ06