Bioassessment of Silviculture Best Management Practices in Arkansas

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Executive Summary

Silviculture is a major land use in Arkansas. Approximately 7.3 million hectares, representing 55 percent of the state's land, are covered in commercial forest. Arkansas is 4th in the nation in softwood lumber production and ranks first among southern states. The total economic value of forest industries in Arkansas exceeds $12 billion per year and employs approximately 100,000 workers.

Such a large-scale dedicated land-use requires an assessment of sustainable practices and environmental impacts. In the 1950s through the 1970s, studies of clear-cut logging frequently demonstrated impairment of stream ecosystems lying adjacent to harvest areas. The Clean Water Act directed states to develop silviculture best management practices (BMPs) to address this problem, and Arkansas has recently (2002) updated their BMP implementation guidelines. These guidelines are designed to reduce the impact of timber harvesting by minimizing the effects of logging on soil and water. This is achieved by specifying the location and construction of access roads and skid trails, following special precautions on steeper slopes, implementing a stream-side management zone and harvesting during periods of dry weather to reduce sediment loss from harvest areas and into adjacent streams.

This study was designed to examine the effectiveness of Arkansas' silviculture BMPs in protecting the water quality and biological integrity of streams adjacent to harvest areas. Bioassessment using benthic macroinvertebrate assemblages were the primary means by which potential environmental degradation was evaluated. Harvest sites to be sampled were selected based on meeting most of a previously established list of criteria. These criteria included 1) an adjacent lower order stream of sufficiently high water and habitat quality that it supported benthic macroinvertebrate assemblages that were mostly intolerant of elevated sediment conditions; 2) minimal or no equipment traffic crossing the stream during logging and BMP implementation; 3) sites in the highland regions that had upstream and downstream riffles and pools that were of reasonably similar width and depth; total area of timber harvest within the range of 30 to 80 ha; 4) sites without ephemeral streams or major tributaries; and 5) upstream reference and downstream treated sites were within the same stream reach and had comparable habitat characteristics.

After pre-harvest samples were collected in spring 2003, standard Arkansas silviculture methods for harvesting and BMPs were implemented by the timber

companies managing each site. The study sites were mechanically harvested.. Post-harvest site preparation typically consisted of ripping (leaving plowed furrows to replant into) at drier upland sites, (Arkansas Valley, Ouachita, and Ozark highland ecoregion sites) and hipping (leaving mounds to replant into) at the Southern Coastal Plains sites, where the water table was closer to the surface. No aerial herbicide applications were performed.

Streamside management zones (SMZ), or undisturbed strips of land adjacent to streams within harvested sites, varied with the slope of the land but were 11.5 m wide at a minimum. Placement of a road inside SMZs was avoided, and roads were perpendicular to the stream when stream crossings were necessary. Engineering controls used to minimize erosion from logging roads were rolling dips on steep slopes, and broad-based dips on level ground. Additionally, permanent logging roads were surfaced with wash rock or gravel to minimize soil transport to nearby streams. Inactive logging roads were blocked to prevent traffic, and were left to naturally revegetate or were reseeded if necessary. AFC personnel inspected each site after completion of BMPs to determine the degree (percent) to which they met the standards established by Arkansas. All selected sites scored as high or higher than the Arkansas statewide average of 88 % ..

Winter and spring water physico-chemical evaluations and bioassessments of benthic macroinvertebrates were conducted upstream and downstream of timber harvests for one year prior to, and two years after, logging at seven locations in four Arkansas ecoregions—the Arkansas Valley, the Ouachita and Ozark highlands, and the Southern Coastal Plains.

Water quality characteristics, measured at each station during each survey period, included water temperature, dissolved oxygen concentration, conductivity, pH, turbidity, nitrate and ortho-phosphate and total suspended solids. Discharge was measured using a water current velocity meter. Water depths and current velocities were used to calculate the discharge rate at the station at the time of each biological survey.

For bioassessment three replicate samples were collected by kick net at each of three stations within each of the seven study sites during all surveys. A sample consisted of six pooled "kicks" in the predominant habitat types within each station of each study stream. Habitats were sampled in the proportion of area that they occupied in the sample reach. A total of 378 macroinvertebrate samples were collected during the course of this study. Benthic macroinvertebrates were identified in the laboratory to the lowest practical taxonomic classification, generally genus or species for insects, genus for crustaceans; and family level for most other non-insect taxa (annelids, mollusks, etc.). Chironomids (non-biting midges) were mounted on microscope slides prior to identification.

Bioassessment data were used to calculate 16 community metrics. The six core metrics used for the Arkansas Macroinvertebrate Index for Small Watersheds (AMISW) were determined:. 1) total taxa richness, 2) EPT (Ephemeroptera, Plecoptera and Trichoptera) index (= richness), 3) relative abundance of the dominant taxon, 4) relative abundance of Diptera, 5) Hilsenhoff Biotic Index, and 6) relative abundance of the collector functional feeding group. Additionally, temporal and spatial patterns were examined for the following invertebrate community metrics: relative abundance of EPT organisms and the relative abundances of each component order of this group, relative abundances of Chironomidae and non-insects, and the relative abundances of the shredder, filterer, scraper and predator functional feeding groups.

Differences over time (before and after logging and BMP implementation), season (winter, spring) and space (upstream and downstream of the harvest) in the water quality measurements and 16 community variables listed above were tested using multiple factor analysis of variance with the following model:

$$X_{ijk} = \mu + \alpha_i + \tau_{k(i)} + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

where μ was the overall mean,
α_i was the effect of period (i = before or after silviculture activity),
$\tau_{k(i)}$ was the effect of season (k = winter or spring)
β_j was the effect of location (j = above or below silviculture site),
$(\alpha\beta)_{ij}$ was the interaction between period (before or after) and location (above or below), and ε_{ijk} represented the remaining error (variation) for each data point X_{ijk}.

Additionally, examinations of compositional similarity for period, season, and location were performed using a similarity index (Euclidian distance) and an ordination analysis (principal components analysis).

Analysis of variance revealed few significant differences in either water quality or biological variables that could be associated with silviculture impacts. Differences between upstream and downstream sites, when noted, were present before as well as after the timber harvest. In contrast, seasonal variation in macroinvertebrate assemblage structure was frequently evident using analysis of variance and principal components analysis. Total taxa richness was consistently higher in the spring, whereas differences in relative abundance variables (e.g., percent EPT) were typically location-specific and appeared unrelated to silviculture activities. Annual differences in assemblage characteristics were also noted, particularly in temporary streams. We conclude that the current Best Management Practices implemented after timber harvest are effective in protecting the water quality and biological integrity of Arkansas' streams.

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1.0 INTRODUCTION

Silviculture is a major land use in Arkansas; a total of 7.3 million hectares (ha), which comprise approximately 55 % of the state's land cover, is commercial forest (AFC 2002). hectares, representing 55 percent of the state's land, are covered in commercial forest. Arkansas is 4th in the nation in softwood lumber production and ranks first among southern states. The total economic value of forest industries in Arkansas exceeds $12 billion per year and employs approximately 100,000 workers (Pelkki 2002).

Such a large-scale dedicated land-use requires an assessment of sustainable practices and environmental impacts. Numerous studies have demonstrated the negative impact of timber harvesting activities when no consideration was given to the adjacent ecosystems (Tebo 1955; Brown 1970; Hansmann and Phinney 1973; Lee and Samuel 1976; Swift 1983). Gibbons and Salo (1973) summarized the mechanisms by which logging activities may impair adjacent stream quality as: 1) introduction of sediment and logging debris, 2) altered flow and water temperature, 3) increased nutrient concentrations, 4) altered form and amount of organic detritus, and 5) altered rates of aquatic primary production. However, more recent researchers have described two general categories of impact—1) the alteration of the energy source that results from canopy removal, and 2) habitat degradation that follows increased soil erosion into the stream. Canopy removal has been associated with increased stream temperature and magnitude of temperature fluctuation (Gray and Edington 1969; Brown and Krygier 1970; Burton and Likens 1973), reduced inputs of coarse particulate organic matter (Gurtz 1981; Noel et al. 1986), and shifts in algal community structure (Hansmann and Phinney, 1973; Martin et al. 1981). Erosional effects have been reported as increased sediment deposition in streams (Haupt and Kidd 1965; Miller et al. 1988; Ralph et al. 1994; Christie and Fletcher 1999), increased nutrient concentrations (Gurtz 1981; Noel et al. 1986; O'Brien 1995) and increased flow regime or magnitude of high flow events (Hornbeck et al. 1970; Borman and Likens 1979).

Effects of timber harvests on stream macroinvertebrate communities have also been demonstrated, although the range of experimental conditions has been large (low-impact selective cut to clear-cut), and biological responses have been varied. Martin et al.

(1981), Hawkins et al. (1982) and Silsbee and Larson (1983) noted greater macroinvertebrate density and biomass in logged streams as opposed to unlogged streams, although they did not address any changes in community structure. Newbold et al. (1980), Noel et al. (1986) and Stone and Wallace (1998), however, did observe compositional shifts in the benthic community with reduced presence of shredders and increased abundances of scrapers and collectors. The latter authors suggested that the results fit the conditions predicted by the river continuum concept (Vannote et al. 1980), i.e., removal of the canopy would alter the stream energy base from primarily heterotrophic origin (allochthonous coarse particulate organic matter [CPOM] utilized by shredders) to primarily autotrophic origin (algal production elevated by the increased insolation, and utilized by scrapers and collectors).

Some studies conducted to address potential silviculture impacts have been undertaken in Arkansas. Williams et al. (2002) studied the combined effects of year, drainage basin characteristics and presence or absence of logging. They reported logging-associated effects on water quality and physical variables, but not on fish or invertebrate assemblages. However, sampling for this study was conducted only after logging was completed. Additionally, the logging practices were not large-scale clear-cut harvests. Brown et al. (1997) examined the effect of a variety of logging practices on invertebrate communities of small pools. Their results did not indicate degradation of invertebrate communities by any harvest type from clear cutting to single-tree selection (the method of least disturbance). However, the isopod-dominated communities noted in their study were very simple—56 total taxa for the study, of which 42 were represented by less than 10 individuals—and extremely variable with regard to composition. Hlass et al. (1998) surveyed habitat characteristics and fish communities in four Ouachita streams, two of which were adjacent to differing types of timber harvests, and reported a significantly lower Index of Biotic Integrity (IBI) score for the stream next to the even-age timber harvest as opposed to the reference streams or the stream next to the uneven-age timber harvest. None of the habitat variables they measured was significantly associated with IBI score. As with the previous study, the assemblages surveyed may have been too simple (18 total species for the four streams) to be suitable for IBI calculation. The above studies, even in combination, were not adequate to directly address the question of whether silviculture best management practices (BMPs) were effective in protecting stream water quality in Arkansas.

The Federal Water Pollution Control Act of 1972, also referred to as the Clean Water Act (CWA), directed the states to develop water quality management plans that identify BMPs to reduce water pollution from each non point-source (NPS) category, one of which is silviculture (Corbett et al. 1978). Some states have already conducted studies assessing the effectiveness of forestry BMPs (Adams et al. 1995; Wynn et al. 2000; Vowell and Frydenborg 2004). In the first of these studies, the effectiveness of silvicultural BMP protocols was evaluated in South Carolina. Assessments of habitat quality and macroinvertebrate community quality indicated that when BMPs were properly implemented, they were sufficient to protect the water quality of associated streams (Adams et al. 1995). Likewise, no significant changes between reference (no silviculture activity) and test (silviculture with BMPs implemented) conditions were observed in a Florida study (Vowell and Frydenborg 2004). Results of a Virginia study indicated increased sediment and nutrient inputs during storm events when BMPs were

not implemented (Wynn et al. 2000). Additionally, an unpublished study conducted in the sand-clay hills region of Mississippi indicated that when streamside buffer zones, a common component of silvicultural BMPs, were left unharvested, stream habitat quality and biological integrity were not impaired (Schoenholtz et al. 2002).

In Arkansas, the agency responsible for monitoring non-point source pollution is the Arkansas Department of Environmental Quality (ADEQ). As per section 208(c) of the Clean Water Act, a water quality management plan was developed for Arkansas, and ADEQ delegated responsibilities for various NPS activities to other agencies (D. Eagle, pers. comm.). The agency delegated with the responsibility for silvicultural activities was the Arkansas Forestry Commission (AFC). The AFC submits data to the Arkansas Soil and Water Conservation Commission, which is in charge of compiling all NPS information and providing it to ADEQ. The ADEQ then submits the information to the Environmental Protection Agency (EPA). Prior to 1996, the AFC simply monitored soil erosion loss utilizing the Universal Soil Loss Equation method (D. Eagle, pers. comm.). Subsequently, AFC used BMP methodology recommended by the Southeastern Group of State Foresters, whose protocols were primarily developed by United States Fish and Wildlife Service and EPA representatives (D. Eagle, pers. comm.). General objectives include the following: 1) establishing forested buffers, termed streamside management zones, along the stream; 2) plan and operate active logging roads to minimize water quality impacts, e.g., minimizing stream crossings and placing the road near ridges rather than streams; 3) stabilize and revegetate inactive logging roads; and 4) design the harvest site and operation to minimize the area of disturbed ground and reduce erosion (AFC 2002). The current BMP compliance monitoring process used by the AFC does not include biological monitoring or other methods of risk assessment, nor has the AFC monitored BMP effectiveness in protecting stream quality to determine whether adjustments are necessary for current BMPs. Because previous studies in Arkansas did not directly address the question of BMP effectiveness, a biomonitoring study similar to the ones completed or ongoing in other southeastern states would be helpful in evaluating the effectiveness of silvicultural BMPs in the state.

Biological monitoring may be defined as "the systematic use of biological responses to evaluate changes in the environment with the intent to use this information in a quality control program...." (Matthews et al. 1982). A common use of biological monitoring is that of surveillance, which can be utilized to determine the impact of an activity or to determine whether resource management techniques are effective (McBride 1985). Several biological assemblages have been used for this purpose, including phytoplankton, zooplankton, benthic macroinvertebrates and fish. The advantages of using benthic macroinvertebrate communities in biomonitoring studies include the following: 1) they are ubiquitous and, therefore, may be affected by environmental disturbances in many different types of aquatic systems (Lenat et al. 1980); 2) the large number of species comprising the assemblage offers a variety of responses to environmental stresses (Hellawell 1986); 3) they are more sedentary than fish, which allows effective spatial examinations of disturbance effects (Abel 1989); and 4) they have relatively long life cycles, which allows examination of temporal changes caused by disturbances (Wiederholm 1980). Benthic macroinvertebrate communities can, therefore, be effective indicators of environmental quality of aquatic systems. They are continuous monitors of the waters they inhabit and are sensitive to the effects of episodic and cumulative

pollution in addition to physical habitat alteration (Rosenberg and Resh 1993). Benthic macroinvertebrate communities have been used to test the effects of silviculture activities on stream ecosystems for at least 30 years (Erman et al. 1977; Herlihy et al. 2005).

Study Goal and Objectives

The general goal of this study was to determine whether silviculture activities, using properly implemented current BMP protocols for Arkansas, impair water quality in adjacent stream systems. We used the benthic macroinvertebrate community structure of the stream as the primary indicator of water quality. The community "quality" refers to its unimpaired or minimally impaired state, with characteristic levels of taxonomic richness and relative compositions of major sub-groups. These characteristics naturally vary from one stream to another, but should remain relatively stable at a particular stream. Null hypotheses tested in this study were:

1. There was no change in community quality before and after the timber harvest (with BMP implementation) at locations upstream of the harvested area;

2. There was no change in community quality before and after the timber harvest at locations downstream of the harvested area;

3. There was no difference in community quality between locations upstream and downstream of the harvested area prior to timber harvest; and
4. There was no change in the difference in community quality between locations upstream and downstream of the harvested area before and after the timber harvest (i.e., there was no interaction between period [before or after harvest] and location)..

We rejected the null hypotheses if macroinvertebrate communities were of significantly reduced quality (i.e., reduced taxonomic richness or diversity, or increased presence of pollution-tolerant taxa) at locations downstream of the harvest site after silviculture activities were performed. Also, substantial changes in the relative compositions of functional feeding groups (e.g., collectors) were interpreted to indicate reduced quality, particularly if reduced abundance of shredders, and correspondingly increased abundances of collectors, scrapers, and filterers were observed. However, if macroinvertebrate community quality was not significantly lower in downstream stations relative to upstream stations, or was not significantly lower in post-timber harvest samples than in those collected prior to harvest, we retained the null hypotheses. Although efforts were made to avoid these conditions, macroinvertebrate assemblages frequently vary between upstream and downstream stations in the absence of silvicultural activities. If differences between upstream and downstream locations were evident prior to timber harvest, we expected these differences to remain after the harvest. Since the seven study sites essentially represented separate experiments, some or all the null hypotheses could be retained at some sites and rejected at others. Even so, we expected the null hypothesis to be rejected or retained at a clear majority of study sites to indicate whether BMPs were generally effective (if retained) or not effective (if rejected) in Arkansas.

2.0 STUDY SITES

Study sites were selected using the following criteria as guidelines, but realizing that it was unlikely that many of the potential sites would meet all conditions:

1. Sites were located adjacent to a perennial, or long-term intermittent, second or third order stream representative of the slope and soil erodibility conditions associated with silvicultural treatments used in that ecoregion.
2. Sites were located on streams of sufficient high water quality and habitat quality to support benthic macroinvertebrate assemblages that are mostly intolerant of elevated sediment conditions.
3. Sites had minimal or no equipment traffic crossing the stream during logging and BMP implementation.
4. Sites in the highland regions had upstream and downstream riffles and pools that are of reasonably similar width and depth.
5. Sites were in areas where the total area of timber harvest is within the range of 30 to 80 ha, which is typical of commercial silviculture in Arkansas.
6. Sites containing ephemeral streams within the harvest area were avoided where possible.
7. Sites with major tributaries entering the main stream between the upstream and downstream sampling stations were avoided where possible.
8. Control and impact sites were in the same stream reach and had comparable habitat characteristics.

Seven streams from four Arkansas Level III ecoregions were selected for this study (Figure 1). An eighth site was originally planned for the study, but was later dropped because the silviculture activities were not performed as planned. Two streams in each of the Ouachita Highlands (Caney Creek and Harris Creek), Ozark Highlands (Bailey Creek and Thompson Creek) and Southern Coastal Plains (Lloyds Creek and an unnamed tributary of the Saline River) and one in the Arkansas Valley ecoregion (Big Creek) were surveyed. The four streams in the Ouachita and Ozark highlands ecoregions were high gradient (> 10 m/km) low order (3° or less) streams draining areas of less than 2500 ha (Table 1). Big Creek and Lloyds Creek were the two largest streams in the study, each draining over 7000 ha. Both permanent and temporary streams were sampled in three of the four ecoregions.

Three stations on each stream, two immediately upstream of the proposed timber harvest and one immediately downstream of the harvest, were monitored (Figure 2). The two upstream stations were typically adjacent to each other, and were considered references, against which the downstream "treatment" station could be compared. The two upstream references were used as replicates to capture some of the spatial variability inherent in benthic macroinvertebrate population distributions, and in case one of the stations was found to be unsuitable for unforeseen reasons. In contrast, an additional downstream station would not have served the same function. It would have been a different distance downstream of the potential treatment effect (in this case the silviculture activities), and thus would theoretically be expected to differ in its

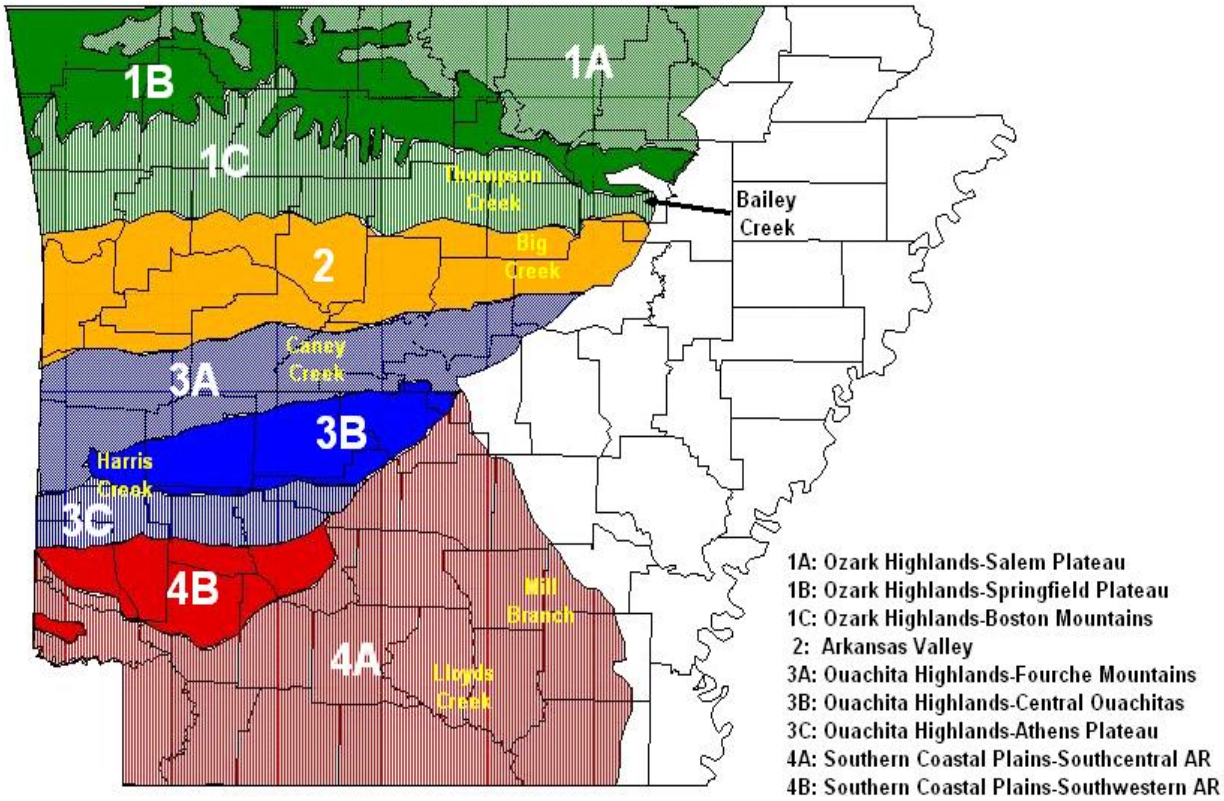

Figure 1. Arkansas ecoregions and study stream locations.

response to the treatment from the initial downstream station, precluding its use as a downstream replicate. Stations consisted of three successive riffle and run/pool sequences, and were therefore not equal in terms of linear distance. In most cases station length was between 100 and 150 m (Table 2). In contrast to the other streams, Lloyds Creek was a slow moving, sand bottomed lowland stream with no riffle habitat. Stations were shorter at this study site due to the homogeneity of habitat. Mean width and mean depths of riffles and run/pool areas did not appear to vary as a longitudinal function, i.e., increasing as one moved downstream. At most streams, all three stations were located within a relatively small geographic area, and were separated by less than 2.4 km. The exception was Big Creek, where the downstream station was approximately 5.6 km from the upstream stations.

Habitat attributes at all stations were assessed in the spring of each study year, using a modification combining the USEPA RBP habitat assessment (Barbour et al. 1999) and the Ohio EPA qualitative habitat evaluation index (OEPA 1989). This index summarizes substrate composition, instream cover abundance, sinuosity, channelization, riffle/pool development and riparian/floodplain characteristics.
The total habitat score for a station may theoretically range from 0 (extremely poor habitat quality) to 100 (outstanding habitat quality).

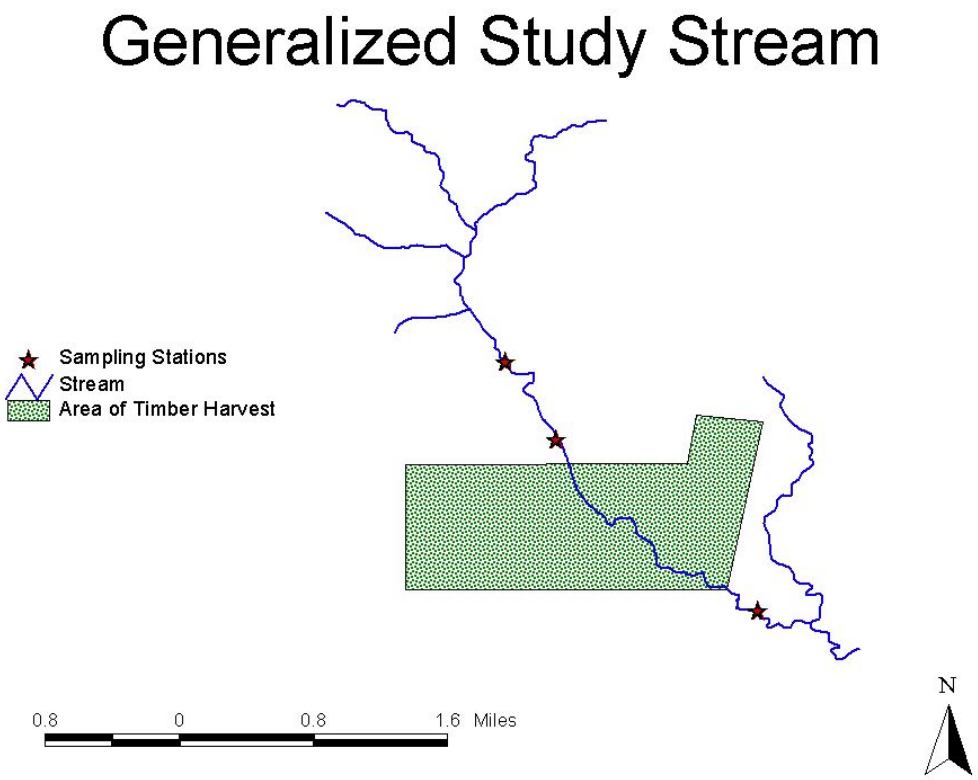

Figure 2. Generalized study stream showing stations relative to harvest area.

Categories of habitat characteristics that were directly measured, and the highest potential scores for each category, are as follows:

- Dominant substrate types (20 points);
- Amount of in-stream habitat (20);
- Degree of siltation (10);
- Channel morphology (10);
- Riffle/pool quality (10);
- Bank stability (10);
- Vegetative protection of the stream bank (10); and
- Width of the riparian area (10).

Habitat characteristics varied widely between study streams, but were generally comparable among the three stations at each stream (Table 2). Big Creek was also the exception to this trend, as the mean habitat score was substantially higher at the downstream station than at either of the two upstream stations. This reflected differences in riparian characteristics; upstream stations were buffered by much

Table 1. General characteristics of the seven study sites. Latitude and longitude are for the middle (#2) sampling station. Order, gradient, elevation, and drainage area information were obtained from USGS 1:24,000 topographic maps.

Stream/Ecoregion	County	Order	Temporary or permanent	Gradient (m/km)	Drained area (ha)	Max. elevation (m above) msl)	GPS Latitude	Longitude
Bailey Creek (BLC) Ozark Highlands	Independence	2	Temporary	10.1	2233	105	35.552467	-91.51015
Big Creek (BGC) Arkansas Valley	Cleburne	4	Permanent	4.3	8951	184	35.403933	-92.003133
Caney Creek (CNC) Ouachita Highlands	Perry	1-2*	Temporary	16.7	684	276	34.805683	-93.226283
Harris Creek (HRC) Ouachita Highlands	Howard	3	Permanent	12.2	2424	308	34.350367	-94.07325
Lloyds Creek (LDC) S .Coastal Plains	Calhoun	3	Permanent	1.1	7318	30	33.381867	-92.424383
Mill Branch (MBR) S. Coastal Plains	Cleveland	2	Temporary	3.0	764	46	33.804367	-92.058417
Thompson Crk (TMC) Ozark Highlands	Van Buren	2	Permanent	15.8	1028	197	35.585317	-92.339233

*Stream order changes between sampling Stations 2 and 3 due to intermittent tributary

Table 2. Selected physical characteristics measured at the three sampling stations at each study stream, January 2003 to March 2005. Stations 1 and 2 were upstream and Station 3 was downstream of the harvest area.

Stream	Station	Length of reach (~m)	Mean width (m) N = 5	Mean riffle depth (cm) n = 10	Mean run/pool depth (cm) n = 10	Mean habitat score n = 3	Mean canopy cover (%) n = 12
Bailey Creek	1	125	12.0	18.2	49.1	82.5	59.8
	2	116	9.2	17.0	51.5	83.2	63.6
	3	105	9.6	17.1	37.3	82.3	65.7
Big Creek	1	111	17.3	15.2	54.1	64.8	47.2
	2	125	9.9	16.5	50.8	64.8	45.2
	3	114	8.5	21.3	52.3	79.8	60.7
Caney Creek	1	128	4.5	10.0	29.1	71.3	75.8
	2	92	7.4	9.3	37.1	71.2	63.6
	3	110	5.7	9.5	42.4	73.3	49.3
Harris Creek	1	144	9.2	18.8	70.4	80.8	53.0
	2	142	8.6	20.4	53.2	80.8	46.9
	3	174	8.3	20.7	50.9	78.2	53.3
Lloyds Creek	1	40	11.3	--	76.0	48.8	63.0
	2	35	15.7	--	84.8	48.0	44.3
	3	50	9.9	--	52.9	48.5	80.8
Mill Branch	1	205	5.4	8.7	41.8	57.7	82.1
	2	162	6.1	8.4	41.6	54.2	81.4
	3	135	7.3	10.2	38.5	55.2	83.5
Thompson Creek	1	97	6.8	15.2	48.6	76.2	71.2
	2	144	7.2	14.7	60.8	77.5	63.6
	3	110	12.3	13.7	42.2	80.5	69.6

thinner forested strips than the downstream stations, even after the timber harvest. Percent canopy cover was estimated using a concave forest densiometer. Canopy cover varied between study streams and among stations within each stream, but did not conform to an upstream vs. downstream pattern before or after the harvest.

Timber Harvest

After pre-harvest samples were collected in spring 2003, standard Arkansas silviculture methods for harvesting and BMPs were implemented by the timber companies managing each site. The study sites were mechanically harvested with feller bunchers and moved to landing areas with rubber-tired or tracked skidders (D. Eagle, AFC, pers. comm.). Tree limbs and tops were left in piles at skidder landings and/or distributed over skidder trails. Site preparation typically consisted of ripping (leaving plowed furrows to replant into) at drier upland sites, such as the Arkansas Valley ecoregion, and Ouachita and Ozark highland ecoregion sites and hipping (leaving mounds to replant into) at the Southern Coastal Plains sites, where the water table was closer to the surface (D. Eagle, AFC, pers. comm.). No aerial herbicide applications were performed.

BMP Implementation

Streamside management zones (SMZ), or undisturbed strips of land adjacent to streams within harvested sites, varied with the slope of the land but were 11.5 m wide at a minimum (AFC 2002.). Placement of a road inside the SMZ was avoided, and the road was perpendicular when stream crossings were necessary. Engineering controls used to minimize erosion from logging roads were rolling dips on steep slopes, and broad-based dips on level ground. Additionally, permanent logging roads were surfaced with wash rock or gravel to minimize soil transport to nearby streams. Inactive logging roads were blocked to prevent traffic, and were left to naturally re-vegetate or were reseeded if necessary. AFC personnel inspected each site after completion of BMPs to determine the degree to which they met the standards established by Arkansas. BMP implementation scores for each of the seven sites are given in Table 3. All selected sites scored as high or higher than the Arkansas statewide average of 88 % (D. Eagle, AFC, pers. comm.).

Table 3. BMP implementation score assessed by Arkansas Forestry Commission to harvest sites adjacent to each study stream.

Stream	County	Score
Bailey Creek	Independence	92
Big Creek	Cleburne	88
Caney Creek	Perry	98
Harris Creek	Howard	96
Lloyds Creek	Calhoun	100
Mill Branch	Cleveland	90
Thompson Creek	Van Buren	89

3.0 STUDY METHODS

Field Surveys

Sampling was performed twice per year, once in early winter (December 15 through January 15) and once in early spring (March 15 through April 15). Surveys were performed one year prior to the timber harvest (2003) and for two years following the harvest (2004-2005). Early spring was considered the primary survey period because samples collected then often contain the greatest variety of organisms, because numerous taxa are about to emerge as winged adults (Butler 1984; Ward 1992). The winter sampling served as an additional survey period, enabling us to examine seasonal variation in the invertebrate communities. Each survey consisted of benthic macroinvertebrate and water quality sampling. Benthic macroinvertebrates were collected using a 46-cm by 23-cm long-handled kick net with 500 µm mesh, one gear type recommended for stream surveys in the USEPA's rapid bioassessment protocols (RBPs)(Barbour et al. 1999).

Three replicate samples were collected at each of the three stations within each of the seven study sites during all surveys. A sample consisted of six pooled "kicks" in the predominant habitat types within each station of each study stream (Barbour et al. 1999). Habitats were sampled in the proportion of area that they occupied in the sample reach. For example, if there was approximately twice as much riffle habitat as pool habitat, four kicks were obtained from the riffle and two from the pool. A single kick represented the disturbance of an approximately 0.75 m^2 area. This was most often done in a riffle, run or pool area, by placing the net downstream of the sampling position, disturbing the substrate for several seconds and capturing the displaced organisms in the net. Riffles and runs, which consisted of flowing water over predominantly cobble and gravel substrates, comprised the majority of the available habitat in the Ouachita and Ozark study streams. Pools were areas of no flow over mostly sand and gravel substrates; these were the predominant habitat in the Southern Coastal Plain study streams. When boulders were numerous in a sampling area, an approximate 0.75 m^2 area of boulder surface was disturbed with a stiff-bristled brush as a substitute for a riffle kick. The goal was to sample approximately 4.5 m^2 of area from multiple habitats within each station for each replicate. Combining samples from separate habitat types allowed comparisons of stream reach assemblages between stations and time periods, while reducing the number of samples that underwent laboratory processing. A total of 378 macroinvertebrate samples (three replicates x three stations x seven study sites x six survey periods) was collected during the course of this study. Organisms and debris were preserved in 7 percent formalin and transported to the ASU Biomonitoring Laboratory for processing and identification. Juvenile unionid mollusks that were infrequently encountered during surveys were identified to family and immediately returned to the stream. No large unionids were collected.

In addition to invertebrate sampling, water quality characteristics were measured at each station during each survey period. Discharge was measured using a Marsh-McBirney Flo-Mate 2000 water current velocity meter. Water depths and current velocities were measured at 0.5 m or shorter intervals across a transect of the stream from left bank to right bank, and these data were used to calculate the discharge rate at the station at the time of each biological survey.

Discharge was calculated as:

$$Q = W \times D \times V$$

where W = width of the interval in m,
D = depth at the midpoint of the interval in dm,
V = velocity reading from the flow meter in m/sec, and
Q = discharge, in m^3/sec, of the transect.

Flow values for all intervals were summed to obtain the discharge measurement for the entire stream transect. Water temperature (^oC) and dissolved oxygen concentration (mg/L) were measured using a YSI Model 55 DO meter. Grab samples were collected in 500 mL polyethylene containers and kept at approximately 4° C in a cooler for subsequent measurement of conductivity, pH, turbidity, nitrate and ortho-phosphate. These variables were measured on the evening of the day in which the grab sample was collected, using a Hach conductivity meter, an Orion 230A pH meter, a LaMotte 2020 turbidimeter, and a Hach DR/850 colorimeter, respectively. Finally, grab samples were collected for measurement of total suspended solids (TSS). These samples were collected in two 1L polyethylene containers and were also kept on ice in a cooler until returning to the laboratory. TSS measurements were performed using the standard method (APHA 1995) recommended by the ASU Ecotoxicology Research Facility. Specifically, the value was obtained by filtering a known volume of the sample through a dried glass fiber filter of known weight, then drying the filter along with the sample residue, then re-weighing the filter and subtracting the original weight. A total of 126 water quality samples (three stations x seven sites x six survey periods) were collected during the course of the study.

Laboratory

Benthic macroinvertebrate samples were returned to the laboratory where they were logged in prior to processing. Sub-sampling was necessary due to the large number of samples and large sample volumes, which would make analysis of the entire sample both time- and cost-prohibitive. Samples were initially "picked" for debris to reduce sample volume. This entailed rinsing and removal of large objects (rocks, sticks, leaves) that would obstruct a sub-sampling device. The sample was then placed into a 583 µm mesh sieve to obtain a sub-sample. The sample was thoroughly mixed, and a portion of the sample was randomly selected using two coin tosses. The sieve was divided into quadrants. The first toss determined whether the sub-sample was collected from an upper or lower quadrant of the sieve. The second toss determined whether the sub-sample was collected from the left or the right quadrant. Thus, the sub-sample was collected from one-fourth of the original sample. The objective was to obtain a sub-sample of 100 organisms from each sample. A smaller number may not sufficiently represent the invertebrate community composition in the sample (Courtemanch 1996; Sovell and Vondracek 1999), whereas a larger number would be time/cost prohibitive (Plafkin et al. 1989). Additionally, this is the target number used by ADEQ for stream macroinvertebrate samples (ADEQ 2002). Organisms were sorted into two vials. The first contained taxa that had to be mounted on microscope slides for identification (i.e.,

chironomids and oligochaetes), whereas the second contained all other taxa. Insect taxa were identified to the lowest practical taxonomic classification, generally genus or species. Ephemeroptera (mayflies) were identified using Allen and Edmunds (1965), McCafferty (1975), Pescador and Berner (1981), Kondratieff and Voshell (1984), Provonsha (1990), Funk and Sweeney (1994), Edmunds and Waltz (1996). Odonates (damselflies and dragonflies) were identified using Westfall and May (1996) and Westfall and Tennessen (1996). Plecoptera (stoneflies) were identified using Stewart and Stark (1988), Poulton and Stewart (1991) and Stewart and Harper (1996). Aquatic hemiptera (true bugs) were identified using Polhemus (1996). Trichoptera (caddisflies) were identified using Flint (1984), Floyd (1995), Glover (1996), Moulton and Stewart (1996) and Wiggins (1998). Aquatic coleoptera (beetles) were identified using White and Brigham (1996). Aquatic diptera (true flies) other than Chironomidae were identified using Byers (1996), Courtney et al. (1996) and Peterson (1996). Chironomids (non-biting midges) were mounted on microscope slides and were identified primarily using Coffman and Ferrington (1996), Maschwitz and Cook (2000) and Epler (2001), but a variety of additional keys to selected chironomid genera were used. Crustaceans were identified to genus level, and most other non-insect taxa (annelids, mollusks, etc.) were generally identified to the family level using Pennak (1989), Kathman and Brinkhurst (1998) and keys in Thorp and Covich (1991).

A reference collection was prepared and maintained for this project. At least one specimen of each taxon reported was included in this collection. The reference collection was stored in the Arkansas State University Museum of Zoology (ASUMZ), and is available for examination by any interested party. Additionally, the samples themselves were saved and donated to the ASUMZ.

Data Analyses

Water quality data were summarized and compared by year, season, and location upstream or downstream of the timber harvest. Macroinvertebrate data were summarized using taxa lists comparing assemblages before and after harvest, by station and by season. Three general categories of analyses were performed: 1) comparison of community characteristics upstream and downstream of the timber harvest, 2) analysis of variance testing differences in biological variables over time and space, and 3) examinations of compositional similarity using a similarity index and an ordination analysis.

Simple comparisons of mean values of invertebrate community variables were made on three bases: before timber harvest vs. after harvest, upstream vs. downstream of harvest area, and season of collection. The primary characteristics of interest were those calculated for a stream condition index developed by Arkansas Department of Environmental Quality (ADEQ 2002). Specifically, six core metrics are used for the Arkansas Macroinvertebrate Index for Small Watersheds (AMISW). These are: 1) total taxa richness, 2) EPT (Ephemeroptera, Plecoptera and Trichoptera) index (= richness), 3) relative abundance of the dominant taxon, 4) relative abundance of Diptera, 5) Hilsenhoff Biotic Index (Hilsenhoff 1987), and 6) relative abundance of the collector functional feeding group. Additionally, temporal and spatial patterns were examined for the following invertebrate community characteristics, which have been utilized in past invertebrate community monitoring programs (Kerans et al. 1992; DeShon 1995; Merritt

and Cummins 1996; Lenat and Resh 2001): relative abundance of EPT organisms and the relative abundances of each component order of this group, relative abundances of Chironomidae and non-insects, and the relative abundances of the shredder, filterer, scraper and predator functional feeding groups. Some of the variables listed above—total richness, EPT richness, Percent EPT organisms were chosen because they represent characteristics of healthy, stable aquatic macroinvertebrate communities, i.e., they decrease in response to environmental impairment. In contrast, Hilsenhoff Biotic Index, Percent Chironomidae and Percent Non-insects typically increase with increasing disturbance to the system. The remaining variables do not necessarily increase or decrease with increased impairment, but represent important subsets of macroinvertebrate communities with regard to abundance and trophic balance.

Differences over time (before and after logging and BMP implementation) and space (upstream and downstream of the harvest) in the 16 community variables listed above were tested using multiple factor analysis of variance with the following model:

$$X_{ijk} = \mu + \alpha_i + \tau_{k(i)} + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

where μ was the overall mean,
α_i was the effect of period (i = before or after silviculture activity),
$\tau_{k(i)}$ was the effect of season (k = winter or spring)
β_j was the effect of location (j = above or below silviculture site),
$(\alpha\beta)_{ij}$ was the interaction between period (before or after) and location (above or below),
and ε_{ijk} represented the remaining error (variation) for each data point X_{ijk}.

The interaction variable was included to evaluate whether upstream vs. downstream patterns changed after the harvest, i.e., did the BMPs, as implemented, protect community quality. Minitab (Version 13.1) software was used to perform the analyses of variance using the General Linear Model procedure. For each test, the assumptions of normality and equal variance were checked. If only the normality assumption was violated, the data were transformed using the recommendation of a Box-Cox transformation analysis (Kutner et al. 2005). If the equal variance assumption was violated, the non-parametric Kruskal-Wallis test was substituted for the analysis of variance and only the main effects (season, location, before/after) were analyzed.

The next statistical approach involved comparisons of samples that represent overall community composition. Minitab (Version 13.1) software was also used to perform these analyses. The first of these comparisons was a similarity (or dissimilarity) index, which was used to examine variation in community structure. Specifically, harvested sites were compared with unharvested—either prior to harvest, or upstream of harvest—sites. Comparisons of sample pairs were made on the following bases: Station 1 vs. Station 2 (reference vs. reference); Station 1 vs. Station 3 (reference vs. logged); and Station 2 vs. Station 3 (reference vs. logged). The Euclidean distance similarity index was used, which has been previously utilized to measure the degree of difference between invertebrate communities in studies of logging effects (Newbold et al. 1980; Noel et al. 1986). The

Euclidean distance (D_{jk}) between each pair of samples (j and k) was calculated using the formula:

$$D_{jk} = [\Sigma_i (X_{ij} - X_{ik})^2]^{1/2}$$

where X_{ij} and X_{ik} are the mean number of organisms in the ith taxon collected from stations j and k, respectively.

Principal components analysis (PCA) was used to compare compositional similarities among macroinvertebrate samples. This reduced the dimensionality of the data matrix from 100+ axes, i.e., one for each taxon in the samples, to a few axes that accounted for the majority of the variation in the dataset. Sample scores on the first two axes generated by PCA were plotted against each other. The resulting scatterplot was examined for clustering, and evaluated whether clusters were most segregated, if at all, by location, season, or survey year. Additionally, we examined the loadings, or correlations, of each taxon to the first two principal components axes to determine the taxa whose abundances most corresponded to sample placement.

We also attempted to test whether macroinvertebrate assemblage patterns were particular to certain study sites, as opposed to present at most or all sites. For this examination, we examined the same 16 community structure variables listed above, again using Minitab software to perform the analyses of variance using the General Linear Model procedure. For each test, the assumptions of normality and equal variance paired t-tests for the main effects (season, location above or below the harvest, and study year before or after the harvest) were checked on all aforementioned assemblage variables. In this analysis, replicates were mean values of a group of samples from one season at one location in study years before or after the silviculture activities at each of the seven study sites. The number of samples within groups varied from 3 (winter or spring, downstream, before the harvest) to 12 (winter or spring, upstream, after the harvest). A significant difference noted for any variable would suggest that its pattern was consistent for most of the state of Arkansas, rather than present only sporadically.

Lastly, Pearson's Product Moment Correlation analysis was used to test whether there was a relationship between the degree of BMP implementation, as measured by the site score by the Arkansas Forestry Commission's BMP forester, and changes in macroinvertebrate community structure, as measured by the change in total richness at stations downstream of silviculture activities at each site. Specifically, these values were obtained by subtracting the mean total richness before silviculture activities from the value after silviculture activities. This evaluation was used to determine whether the level at which BMPs were implemented was correlated with the most sensitive community metric—taxa richness. A significant correlation would suggest that the BMPs had not been implemented to a degree that ostensibly should not cause a change in this community metric, thus disallowing inferences on the stated goal of this study.

4.0 RESULTS

4.1 BAILEY CREEK (INDEPENDENCE COUNTY)

Water Quality

With the exception of temperature, water quality variables did not differ substantially between seasons, study years, or locations (Table 4). Water temperature was greater, and dissolved oxygen concentration lower, in the spring. Values of pH were always within the range of 6.4 to 6.9. Conductivity levels were atypically high during the winter 2003 survey period and low during the spring 2003 period. Discharge was greater in winter samples of 2003 and 2004, but comparable between seasons in 2005. Variables did not clearly or consistently differ between areas upstream and downstream of the timber harvest either before or after the harvest. Water temperature means were slightly lower at the station downstream of the cut in both winter and spring; but this was probably because the downstream station was always sampled first. Differences in dissolved oxygen concentrations were small (less than 1 mg/L) between upstream and downstream stations and did not consistently vary spatially either pre- or post-harvest. Likewise, pH and conductivity levels were similar among stations during all six sampling periods. The low values for these variables, always below 7 for pH and generally below 40 mS/cm for conductivity, were characteristic of a softwater/headwater stream. Stream discharge generally ranged between 0.05 and 0.31 cm, and was always slightly higher at the downstream station..

Table 4. Water quality measurements at Bailey Creek sampling stations before (2003) and after harvest (2004, 2005) during each of the six survey periods.

Variable	Station	Winter 2003	Spring 2003	Winter 2004	Spring 2004	Winter 2005	Spring 2005
Temperature	1 (Up)	5.3	10.7	8.1	11.7	3.5	14.3
(^{o}C)	2 (Up)	4.6	10.7	8.0	10.6	2.7	12.6
	3 (Down)	3.9	10.5	7.8	10.3	3.1	10.2
Dissolved	1 (Up)	11.34	11.40	11.18	10.54	12.99	10.91
Oxygen	2 (Up)	11.93	11.34	11.29	10.77	12.86	11.67
(mg/L)	3 (Down)	12.17	11.06	11.47	10.44	13.43	11.78
pH	1 (Up)	6.47	6.87	6.65	6.40	6.44	6.60
	2 (Up)	6.62	6.55	6.80	6.51	6.61	6.70
	3 (Down)	6.65	6.64	6.57	6.53	6.49	6.69
Conductivity	1 (Up)	119	13.8	38.7	28.7	33.0	33.5
(mS/cm)	2 (Up)	123	14.2	40.6	29.5	30.7	32.5
	3 (Down)	134	14.8	15.2	29.6	30.8	32.2
Discharge	1 (Up)	0.172	0.116	0.107	0.058	0.052	0.072
(m^3/sec)	2 (Up)	0.257	0.117	0.125	0.058	0.074	0.061
	3 (Down)	0.313	0.180	0.191	0.066	0.096	0.101

Three of the four variables potentially associated with sediment inputs were similar at upstream and downstream stations before and after the timber harvest (Figures 3 and 4). Turbidity levels were always low (< 1.5 NTU), were similar between stations prior to the harvest, and were slightly higher at the downstream station in winter 2004 and winter 2005. Total suspended solids were likewise low (< 1.5 mg/L) during all sampling events. When spatial differences were evident, TSS levels were higher at one or both of the upstream stations (Figure 3). Nitrate and orthophosphate concentrations at the downstream station were generally less than or approximately equal to those of the upstream stations in both pre- and post-harvest surveys (Figure 4).

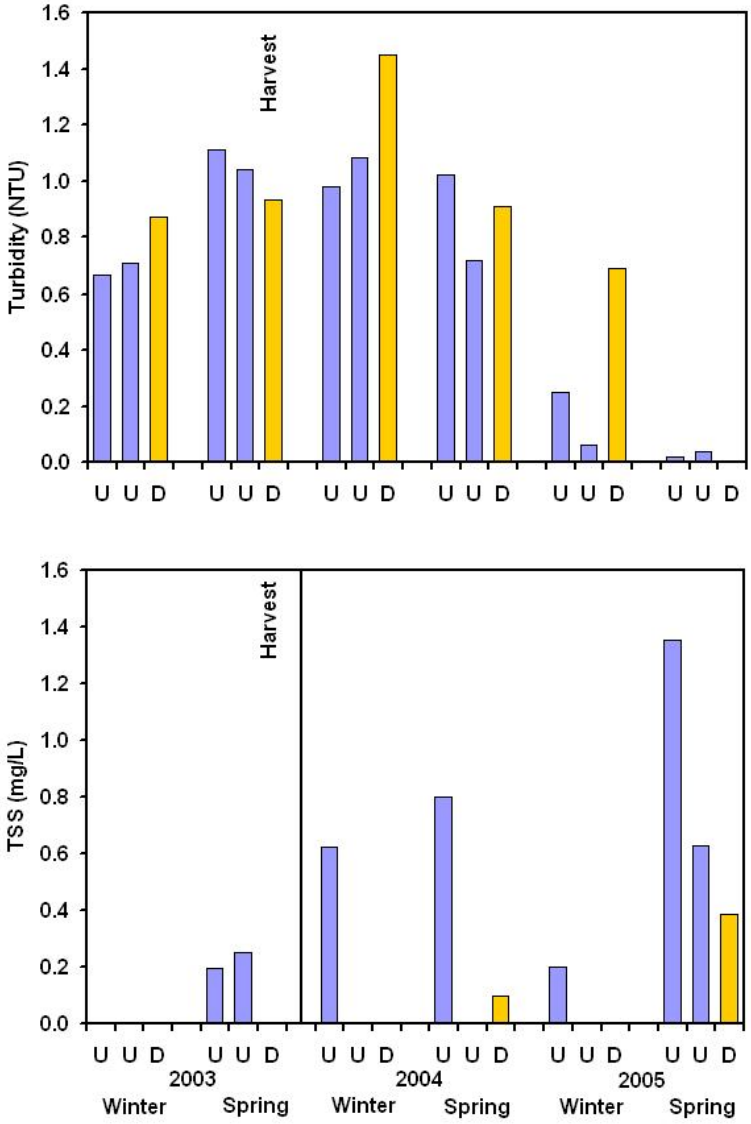

Figure 3. Turbidity and total suspended solids (TSS) concentration at Bailey Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

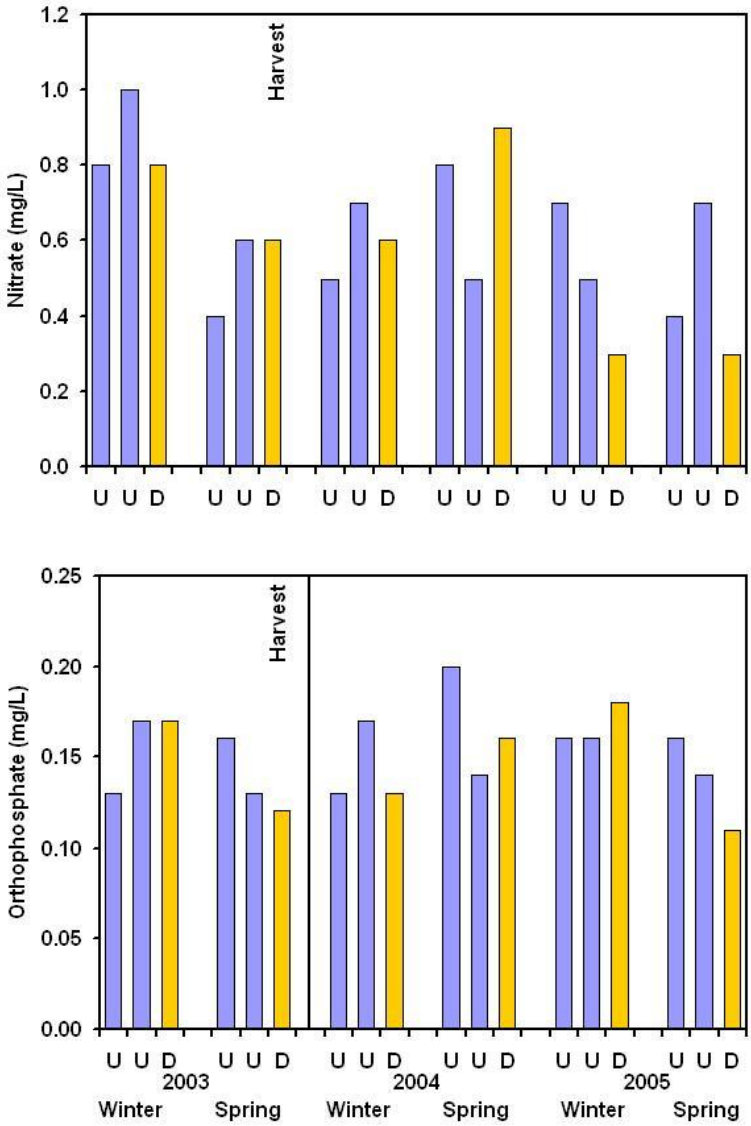

Figure 4. Nitrate and orthophosphate concentrations at Bailey Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

A one-way analysis of variance testing whether values differed between the three stations, using study years as replicates, did not reveal significant differences ($\alpha = 0.05$) in any water quality parameter in either spring or winter samples.

Macroinvertebrates

Total richness of macroinvertebrate assemblages of Bailey Creek did not differ significantly by year, season, or location upstream or downstream of the harvest (Table 5). EPT richness was greater in the spring than in the fall, but did not statistically differ by location or year. Hilsenhoff Biotic Index (HBI) was significantly greater in the winter, but likewise did not differ between locations or years. Relative abundance of

EPT organisms was greater in the spring than the winter, reflecting increased abundances of mayflies (primarily *Acentrella/Plauditus* spp. and *Leucrocuta* sp.), stoneflies (*Amphinemura* sp. and *Isoperla* sp.), and caddisflies (*Dibusa angata* and *Rhyacophila kiamichi*) (Appendix A). Each of this metric's component orders was also significantly more numerous in the spring. Mayflies were more numerous before the timber harvest; otherwise the abundances of the three orders did not differ between years or locations.

Table 5. Mean ± standard error for macroinvertebrate assemblage characteristics at Bailey Creek by season, by location upstream or downstream of the timber harvest, and by study year before or after the harvest. * indicates $p < 0.05$; ** indicates $p < 0.01$. Variables with KW superscript were tested with non-parametric Kruskal-Wallis test instead of GLM ANOVA, due to violation of equal variance assumption.

	Season		Location		Harvest	
	Winter n = 27	Spring n = 27	Upstream n = 36	Downstream n = 18	Before n = 18	After n = 36
Total richness	25 ± 1.1	26.1 ± 0.7	24.8 ± 0.9	26.4 ± 1.0	26.0 ± 1.0	25.0 ± 0.9
EPT richness^{KW}	9.0 ± 0.8	12.3 ± 0.4**	10.4 ± 0.6	11.3 ± 0.9	11.3 ± 0.4	10.4 ± 0.7
Hilsenhoff Biotic Index^{KW}	5.3 ± 0.3**	3.8 ± 0.1	4.5 ± 0.2	4.5 ± 0.3	4.2 ± 0.2	4.7 ± 0.2*
% EPT^{KW}	44 ± 4	65 ± 2**	55 ± 3	52 ± 4	57 ± 2	53 ± 3
% Ephemeroptera	14 ± 2	17 ± 1*	16 ± 1	14 ± 2	22 ± 2**	13 ± 1
% Plecoptera	21 ± 2	33 ± 1*	28 ± 2	26 ± 2	25 ± 2	28 ± 2
% Trichoptera	9 ± 1	14 ± 1**	11 ± 1	13 ± 2	10 ± 2	12 ± 1
% Dominant Taxon^{KW}	27 ± 3**	15 ± 1	21 ± 2	23 ± 3	17 ± 1	23 ± 2*
% Diptera	17 ± 2	25 ± 2**	21 ± 2	21 ± 9	26 ± 2*	19 ± 2
% Chironomidae	7 ± 1	17 ± 1**	13 ± 2	10 ± 2	13 ± 2	11 ± 2
% Non-insects^{KW}	38 ± 5**	9 ± 6	22 ± 4	25 ± 5	16 ± 2	27 ± 4*
Functional Feeding Groups						
% Collectors^{KW}	49 ± 4**	29 ± 1	39 ± 3	39 ± 4	33 ± 1	42 ± 4
% Filterers	7 ± 1	6 ± 1	6 ± 1	8 ± 2	11 ± 2**	5 ± 1
% Predators^{KW}	14 ± 2	25 ± 1**	21 ± 2*	15 ± 2	19 ± 2	19 ± 2
% Scrapers^{KW}	15 ± 2	16 ± 1	15 ± 1	16 ± 2	24 ± 1**	11 ± 1
% Shredders	16 ± 1	24 ± 2**	19 ± 1	22 ± 2*	14 ± 1	23 ± 1**

The relative abundance of the dominant taxon, while consistently low (< 25 percent) was significantly greater in the winter than the spring, but did not differ by year or location relative to the cut. The relative abundances of Diptera and its major constituent group, Chironomidae, were significantly greater in the spring. The seasonal difference was largely attributable to different taxa in each year, *Eukiefferiella claripennis* gp. in 2003, *Cricotopus* spp. in 2004, and *Polypedilum aviceps* in 2005 (Appendix A). Additionally, *Parametriocnemus* sp. was consistently more abundant in the spring. Percent Diptera and Percent Chironomidae were the only variables tested that exhibited a significant interaction effect (Table 6).

Table 6. Mean ± standard error for macroinvertebrate assemblage characteristics at Bailey Creek by the interaction between study year and location upstream or downstream of the timber harvest. Variables with an asterisk had significant ($p < 0.05$) interaction effects.

	Before Harvest		After Harvest	
	Upstream	Downstream	Upstream	Downstream
	n = 12	n = 6	n = 24	n = 12
Total richness	26.7 ± 1.4	24.7 ± 1.3	23.8 ± 1.0	27.3 ± 1.3
EPT richness	10.9 ± 0.5	12.0 ± 0.8	10.1 ± 0.9	11.0 ± 1.4
Hilsenhoff Biotic Index	4.42 ± 0.30	3.77 ± 0.21	4.59 ± 0.28	4.85 ± 0.40
% EPT	55 ± 2	61 ± 3	55 ± 4	48 ± 6
% Ephemeroptera	23 ± 2	20 ± 3	13 ± 1	11 ± 2
% Plecoptera	25 ± 3	26 ± 3	30 ± 2	25 ± 3
% Trichoptera	8 ± 2	15 ± 3	12 ± 1	12 ± 1
% Dominant Taxon	17 ± 1	18 ± 2	23 ± 3	25 ± 5
% Diptera*	29 ± 3	21 ± 4	17 ± 2	21 ± 2
% Chironomidae*	15 ± 2	8 ± 1	11 ± 2	12 ± 2
% Non-insects	15 ± 2	17 ± 3	26 ± 5	29 ± 8
Functional Feeding Groups				
% Collectors	33 ± 1	33 ± 2	42 ± 4	42 ± 6
% Filterers	11 ± 2	10 ± 3	4 ± 1	7 ± 2
% Predators	21 ± 2	15 ± 2	21 ± 2	15 ± 2
% Scrapers	23 ± 1	24 ± 2	10 ± 1	12 ± 2
% Shredders	12 ± 1	18 ± 2	22 ± 2	24 ± 2

Percent Diptera decreased significantly after the harvest at upstream locations, but not at downstream locations. *Tipula* sp. was the primary dipteran taxon that was more abundant at upstream locations prior to the timber harvest. For Chironomidae, relative abundance decreased upstream of the cut but increased downstream of the cut following the harvest. The downstream increase was attributable to several taxa, primarily *Polypedilum aviceps*, whereas *Eukiefferiella claripennis* gp. was the only taxon whose abundance decreased markedly in upstream areas after the cut. Non-insects were much more abundant in the winter than the spring, principally reflecting higher numbers of the isopod *Lirceus* sp., the amphipod *Synurella bifurca*, and various oligochaetes.

Differences in the relative abundances of functional feeding groups were noted between seasons, years and locations (Table 5). Collectors were significantly more abundant in the winter, a pattern driven by the same non-insect taxa mentioned above, but did not differ between locations or survey years. Filterers were more abundant prior to the harvest, reflecting greater collection of the blackfly *Prosimulium* sp. and the Chironomid *Microtendipes pedellus* gp. Relative abundances of filterers were similar between seasons and between locations. In contrast, the relative abundance of predators differed statistically between seasons and between locations, due to increased collection of the stoneflies *Clioperla clio* and *Isoperla* sp. in spring and at locations upstream of the cut (Appendix A). The relative abundance of scrapers did not differ between seasons or locations, but was significantly greater prior to the harvest, reflecting high numbers of the mayfly *Stenonema femoratum*. Percent shredders differed significantly between seasons, locations and years (Table 5). Shredders were more abundant in the spring, a pattern attributable to greater numbers of *Amphinemura* sp. (all years), *Cricotopus* spp. (2004) and *Polypedilum aviceps* (2005). Greater abundance of shredders in locations downstream of the cut mostly reflected differential collection of the stonefly *Strophopteryx* sp. Finally, the higher abundance of shredders in years following the timber harvest was associated with the stonefly *Allocapnia* spp., and the chironomids *Cricotopus* spp. and *Polypedilum aviceps*.

Evaluation of Euclidean distance did not indicate that macroinvertebrate community composition differed on an upstream/downstream basis. Distances were typically comparable between locations, and during three periods—winter and spring 2003 and winter 2004—the distance was shortest between one of the upstream stations and the downstream station (Table 7). Distances were shortest between the two upstream in spring 2004 and thereafter, but never by wide margins (always < 60). By contrast, the Euclidean distance between samples from the same station (1) in winter 2003 and spring 2003 was 258, and between samples from that station in winter 2003 and winter 2004 was 526.

Table 7. Euclidean distance between benthic macroinvertebrate samples from Bailey Creek stations upstream and downstream of timber harvest during each of six survey periods, 2003-2005

Winter		Spring	
Stream station	Euclidean Distance	Stream station	Euclidean Distance
2003		2003	
Upstream 1 - Upstream 2	239	Upstream 1 - Upstream 2	133
Upstream 2 - Downstream	113	Upstream 2 - Downstream	104
Upstream 1 - Downstream	280	Upstream 1 - Downstream	165
2004		2004	
Upstream 1 - Upstream 2	187	Upstream 1 - Upstream 2	83
Upstream 2 - Downstream	176	Upstream 2 - Downstream	94
Upstream 1 - Downstream	73	Upstream 1 - Downstream	121
2005		2005	
Upstream 1 - Upstream 2	103	Upstream 1 - Upstream 2	79
Upstream 2 - Downstream	143	Upstream 2 - Downstream	118
Upstream 1 - Downstream	160	Upstream 1 - Downstream	126

Results of the PCA were summarized by plotting the 54 sample scores along Axis 1 against the scores along Axis 2 (Figure 5). The first two axes had the highest eigenvalues and accounted for 50 % and 18 % of the variance in the data set, respectively. Axis 1 was positively correlated with the abundances of *Lirceus* sp. and *Allocapnia* spp., and negatively correlated with the abundance of *Isoperla* sp. This pattern reflected annual and seasonal differences in abundance. *Lirceus* sp., the taxon most strongly correlated with Axis 1, was always more numerous in the winter, but was particularly so in winter 2004 (Appendix A). Samples from spring in each of the three survey years were clustered in the lower left corner of the graph. Some sample segregation along Axis 2 was evident, although much less than that for Axis 1. Axis 2 was positively correlated to the abundances of *Stenonema femoratum* and *Tipula* sp., and negatively correlated to the abundances of *Amphinemura* sp. and *Isoperla* sp. The first two taxa were most numerous in both seasons of 2003 whereas each of the stoneflies were highly abundant in the spring of all three study years. Thus, sample placement along this axis appeared to also reflect both annual and seasonal variation in the composition of macroinvertebrate assemblages at Bailey Creek. No clustering on the basis of location upstream or downstream of the timber harvest was indicated.

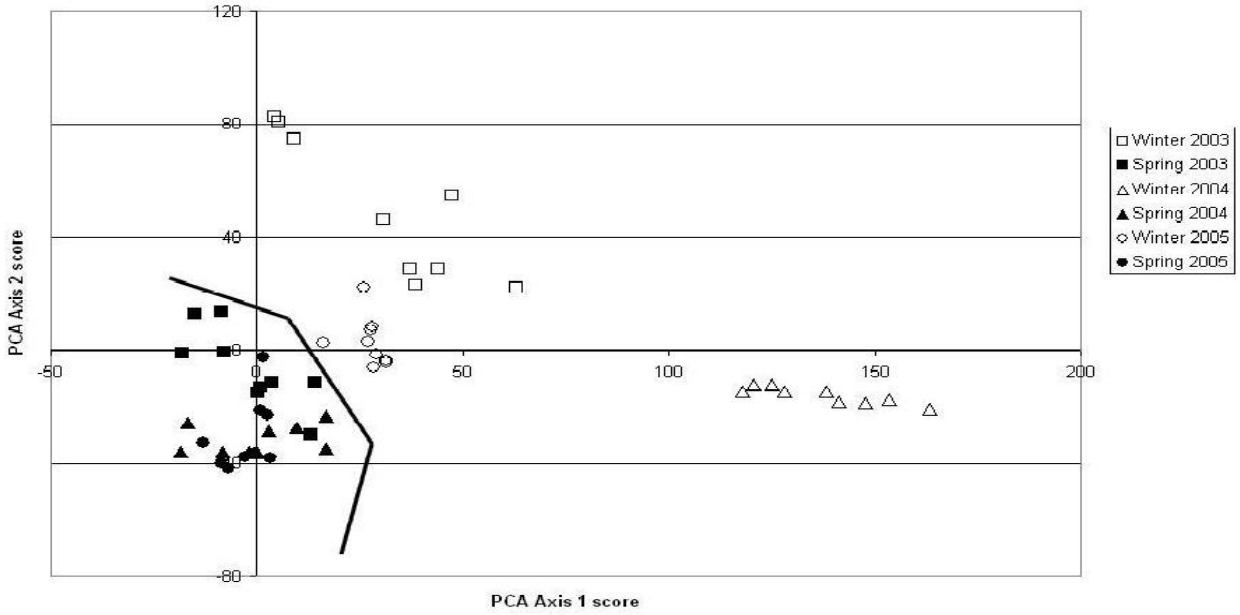

Figure 5. Plot of Bailey Creek benthic macroinvertebrate sample scores on PCA axes 1 and 2.

4.2 BIG CREEK (CLEBURNE COUNTY)

Water Quality

Water quality variables at Big Creek did not consistently differ between areas upstream and downstream of the timber harvest either before or after the harvest (Table 8). Water temperature means were slightly lower at the station downstream of the cut in both winter and spring. Differences in dissolved oxygen concentrations were small (less than 1 mg/L) between upstream and downstream stations and did not consistently vary pre- or post-harvest. Likewise, pH and conductivity levels were similar among stations during all six sampling periods. The low values for these variables, always below 7 for pH and below 40 mS/cm for conductivity, were characteristic of a softwater stream. Stream discharge generally ranged between 0.3 and 0.8 cms, except in spring 2005, when considerably higher flows were encountered (Table 8).

Table 8. Water quality measurements at Big Creek sampling stations during each of the six survey periods before (2003) and after harvest (20004, 2005).

Variable	Station	Winter 2003	Spring 2003	Winter 2004	Spring 2004	Winter 2005	Spring 2005
Temperature	1 (Up)	3.2	9.6	4.8	15.1	7.8	14.5
(^{o}C)	2 (Up)	3.0	9.8	4.7	14.4	7.6	14.1
	3 (Down)	4.4	11.6	4.2	12.0	5.5	14.5
Dissolved	1 (Up)	12.95	10.79	12.23	10.52	12.11	11.14
Oxygen	2 (Up)	13.08	10.82	12.52	10.73	12.53	11.09
(mg/L)	3 (Down)	12.81	11.48	12.51	10.32	12.71	10.43
pH	1 (Up)	6.79	6.80	6.64	6.51	6.38	6.67
	2 (Up)	6.91	6.63	6.63	6.65	6.39	6.75
	3 (Down)	6.81	6.76	6.82	6.70	6.53	6.81
Conductivity	1 (Up)	21.8	9.3	28.8	23.7	29.8	25.0
(mS/cm)	2 (Up)	19.1	10.0	31.2	23.8	26.6	24.6
	3 (Down)	21.2	10.3	37.2	23.7	26.7	24.3
Discharge	1 (Up)	0.303	0.546	0.396	0.341	0.443	1.293
(m^3/sec)	2 (Up)	0.258	0.459	0.329	0.430	0.470	1.409
	3 (Down)	0.398	0.736	0.687	0.732	0.785	2.377

Variables potentially associated with sediment inputs were nearly always similar at upstream and downstream stations before and after the timber harvest (Figures 6 and 7). Turbidity levels were higher at the most upstream station in spring 2005, but otherwise were nearly equal between stations. Total suspended solids were similar at all stations during each sampling period. As noted for turbidity, TSS levels were markedly greater in spring 2005. These patterns were likely attributable to the greater stream discharge that was present during this period. Nitrate and orthophosphate concentrations at the downstream station were generally less than or approximately equal to those of the upstream stations in both pre- and post-harvest surveys. Two exceptions to this pattern were the slightly higher (0.1 mg/L) nitrate level downstream in spring 2003 and the higher orthophosphate level at the downstream station in spring 2004. A one-way analysis of variance testing whether values differed between stations, using study years as replicates, did not indicate significant differences in any water quality variable in either spring or winter samples.

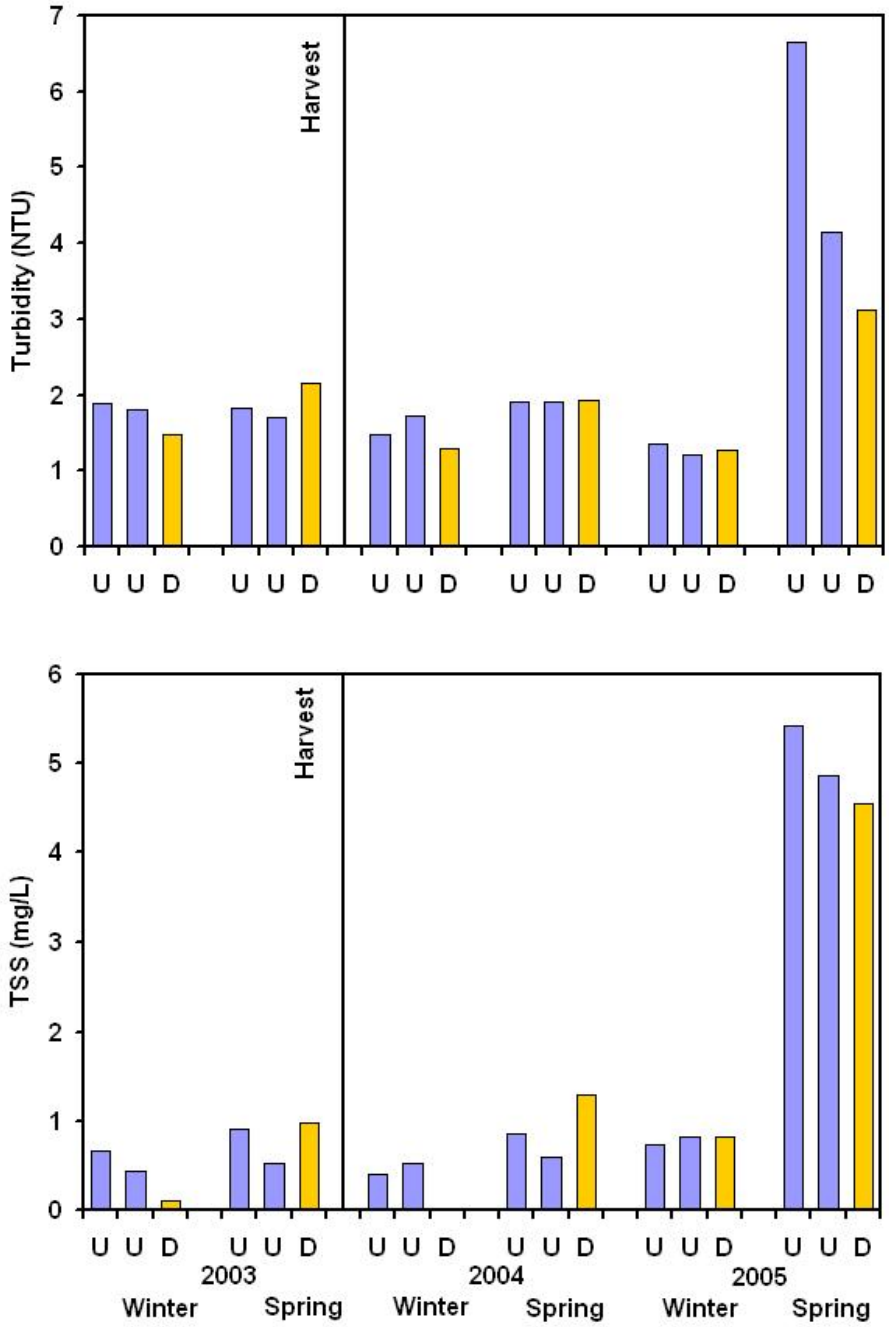

Figure 6. Turbidity and total suspended solids (TSS) concentration at Big Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

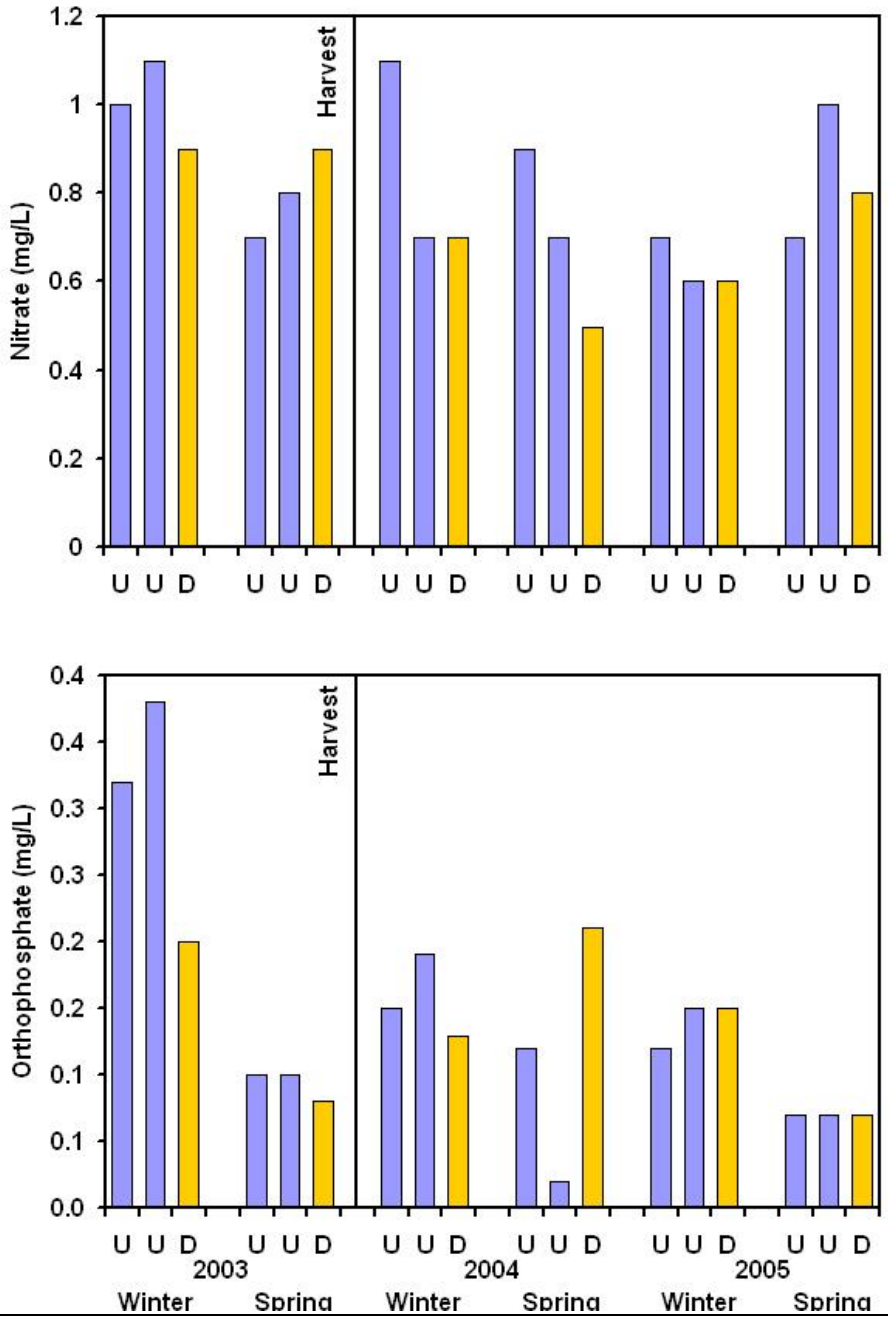

Figure 7. Nitrate and orthophosphate concentrations at Big Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

Macroinvertebrates

Total richness of macroinvertebrate assemblages was significantly greater in the spring (pooled locations and years) than in the winter ($p < 0.01$), and greater after the cut (pooled seasons and locations) than before ($p < 0.05$) but did not differ between locations

(Table 9). EPT richness did not statistically differ by season, location or year. Hilsenhoff Biotic Index (HBI) was significantly greater in the winter, in study years after the timber harvest, and upstream of the harvest area. Relative abundance of EPT organisms was greater in the winter than the spring, reflecting increased abundances of mayflies (primarily *Isonychia* sp. and *Stenonema femoratum*) and to a lesser extent caddisflies, particularly *Chimarra* sp. (Appendix B). Mayflies were also more numerous in years after the cut, whereas the reverse was the case for caddisflies. The relative abundance of the dominant taxon, while consistently low (< 25 percent) was greater upstream of the cut ($p < 0.05$). The relative abundances of Diptera and its major component, Chironomidae, were significantly greater in the spring. This largely reflected the increased collection of *Polypedilum aviceps* in the spring. Differences in the relative abundances of functional feeding groups were also mostly seasonal (Table 9).

Table 9. Mean ± standard error for macroinvertebrate assemblage characteristics at Big Creek by season, location upstream or downstream of the timber harvest, and by study year before and after the harvest. Asterisks indicate significant difference from other factor. * indicates $p < 0.05$, ** indicates $p < 0.01$. Variables with KW superscript were tested with non-parametric Kruskal-Wallis test instead of GLM ANOVA, due to violation of equal variance assumption.

	Season		Location		Harvest	
	Winter n = 27	Spring n = 27	Upstream n = 36	Downstream n = 18	Before n = 18	After n = 36
Total richness	27.3 ± 1.0	30.4 ± 3.6**	27.8 ± 0.7	31.1 ± 1.3	27.5 ± 1.1	29.6 ± 0.8*
EPT richness	13.9 ± 0.5	14.7 ± 2.3	13.8 ± 0.4	15.4 ± 0.7	14.2 ± 0.6	14.4 ± 0.4
Hilsenhoff Biotic Index	4.7 ± 0.1*	4.4 ± 0.3	4.7 ± 0.1*	4.4 ± 0.1	4.2 ± 0.1	4.7 ± 0.1**
% EPT	69 ± 2**	52 ± 10	59 ± 2	63 ± 2	60 ± 2	61 ± 2
% Ephemeroptera	42 ± 2**	29 ± 7	36 ± 2	36 ± 2	30 ± 2	39 ± 2
% Plecoptera^{KW}	10 ± 1	11 ± 5	10 ± 1	12 ± 1	13 ± 1	10 ± 1
% Trichoptera	16 ± 2**	11 ± 6	13 ± 1	15 ± 2	16 ± 2*	12 ± 1
% Dominant Taxon	22 ± 1	18 ± 7	21 ± 1*	17 ± 1	19 ± 2	21 ± 1
% Diptera^{KW}	21 ± 2	33 ± 12**	29 ± 2	24 ± 2	29 ± 2	26 ± 2
% Chironomidae^{KW}	9 ± 1	22 ± 11**	16 ± 2	15 ± 2	12 ± 1	17 ± 2
% Non-insects	4 ± 1	3 ± 2	4 ± 1	3 ± 1	4 ± 1	4 ± 1
Functional Feeding Groups						
% Collectors	13 ± 1	16 ± 5*	15 ± 1	13 ± 1	14 ± 1	14 ± 1
% Filterers^{KW}	35 ± 2**	15 ± 4	26 ± 2	24 ± 3	27 ± 4	24 ± 2
% Predators	8 ± 1	18 ± 4**	13 ± 1	14 ± 2	12 ± 2	14 ± 1*
% Scrapers	34 ± 2	33 ± 9	33 ± 2	35 ± 2	36 ± 2	32 ± 1
% Shredders^{KW}	11 ± 1	18 ± 10**	14 ± 2	15 ± 1	12 ± 1	16 ± 2

Filterers were more abundant in the winter ($p < 0.01$), reflecting greater numbers of *Isonychia* sp. and the blackfly *Prosimulium* sp. (Appendix B). In contrast, the relative abundances of collectors, predators and shredders were all significantly higher in the spring. Predators were slightly, but significantly, more numerous in years after the timber harvest. No functional feeding group differed in abundance between upstream and downstream locations.

The interaction between survey year, i.e., before or after the timber harvest, and location upstream or downstream of the harvest was not a significant factor for any of the 16 variables tested (Table 10). Total and EPT richness were slightly higher at the downstream location after the harvest. HBI increased after the harvest at both upstream and downstream stations. The one variable that shifted moderately (but not significantly) only at the downstream station after the timber harvest was Percent Trichoptera, which decreased. This pattern seemed attributable to the combination of two factors: a) abundance of *Agapetus* sp. decreased at all stations after the harvest, and b) increased numbers of *Cheumatopsyche* sp. and *Chimarra* sp. offset the decrease at the upstream stations (Appendix B).

Table 10. Mean ± standard error for macroinvertebrate assemblage characteristics at Big Creek by the interaction between study year and location upstream or downstream of the timber harvest. Asterisks indicate significant difference from other factors. * indicates $p < 0.05$; ** indicates $p < 0.01$.

	Before Harvest		After Harvest	
	Upstream n = 12	Downstream n = 6	Upstream n = 24	Downstream n = 12
Total richness	27.4 ± 1.4	27.7 ± 2.0	28.0 ± 0.7	32.8 ± 1.6
EPT richness	14.3 ± 0.7	14.0 ± 1.0	13.5 ± 0.4	16.1 ± 0.8
Hilsenhoff Biotic Index	4.32 ± 0.12	3.98 ± 0.15	4.82 ± 0.09	4.53 ± 0.09
% EPT	57 ± 2	65 ± 2	60 ± 3	63 ± 3
% Ephemeroptera	30 ± 2	31 ± 1	39 ± 3	39 ± 2
% Plecoptera	13 ± 1	13 ± 1	8 ± 1	12 ± 2
% Trichoptera	14 ± 2	21 ± 2	13 ± 2	12 ± 2
% Dominant Taxon	20 ± 2	17 ± 2	22 ± 1	17 ± 2
% Diptera	31 ± 2	25 ± 3	28 ± 3	23 ± 2
% Chironomidae	12 ± 1	14 ± 1	18 ± 3	15 ± 3
% Non-insects	3 ± 1	4 ± 1	4 ± 1	3 ± 1
Functional Feeding Groups				
% Collectors	15 ± 2	12 ± 1	14 ± 1	14 ± 2
% Filterers	26 ± 4	28 ± 7	25 ± 2	22 ± 3
% Predators	12 ± 2	11 ± 4	13 ± 1	15 ± 2
% Scrapers	36 ± 2	36 ± 4	31 ± 2	34 ± 2
% Shredders	11 ± 2	13 ± 1	16 ± 2	16 ± 2

In both winter and spring sampling periods in 2003 and 2005, Euclidean distance was shortest between the two stations upstreams of the cut (Table 11). In 2004, however, Euclidean distance was shortest between the lower upstream station (Station 2) and the station downstream of the cut. The macroinvertebrate assemblage structure appeared to be more similar between the two upstream stations than between either upstream station and the downstream station prior to the timber harvest.

Table 11. Euclidean distance between benthic macroinvertebrate samples from Big Creek stations upstream and downstream of timber harvest during each of six survey periods, 2003-2005.

Winter		Spring	
Stream station	Euclidean Distance	Stream station	Euclidean Distance
2003		2003	
Upstream 1 - Upstream 2	83	Upstream 1 - Upstream 2	94
Upstream 2 - Downstream	109	Upstream 2 - Downstream	98
Upstream 1 - Downstream	160	Upstream 1 - Downstream	111
2004		2004	
Upstream 1 - Upstream 2	206	Upstream 1 - Upstream 2	97
Upstream 2 - Downstream	85	Upstream 2 - Downstream	86
Upstream 1 - Downstream	180	Upstream 1 - Downstream	159
2005		2005	
Upstream 1 - Upstream 2	92	Upstream 1 - Upstream 2	82
Upstream 2 - Downstream	180	Upstream 2 - Downstream	115
Upstream 1 - Downstream	121	Upstream 1 - Downstream	100

Results of the PCA were summarized by plotting the 54 sample scores along Axis 1 against the scores along Axis 2 (Figure 8). The first two axes had the highest eigenvalues and accounted for 33 % and 21 % of the variance in the data set, respectively. Axis 1 was positively correlated to the abundances of *Acentrella/Plauditus* spp., *Stenelmis* sp. and *Polypedilum aviceps*, and negatively correlated to the abundances of *Isonychia* sp., *Stenonema femoratum*, *Allocapnia* sp., *Chimarra* sp. and *Prosimulium* sp. This pattern largely reflected seasonal differences in abundance; each of the taxa positively correlated with Axis 1 were more numerous in the spring and those negatively correlated were most abundant in the winter. Samples segregated along Axis 1, with spring samples from 2004 and 2005 forming a cluster to the right of 0, and winter samples from all three years forming a cluster to the left of 0. A small cluster containing samples from spring 2003 is located between the two larger clusters. Axis 2 was positively correlated to the abundances of *Prosimulium* sp. and *Agapetus* sp., and negatively correlated to the abundances of *Isonychia* sp., *Chimarra* sp., *Polypedilum aviceps* and *Stenonema*

pulchellum/terminatum. The pattern along this axis primarily reflected annual differences in abundance, i.e., taxa that were positively correlated with Axis 2 were more abundant in 2003 and those that were negatively correlated were more abundant in 2004 and 2005. Sample separation along Axis 2 was not as evident as that along the first axis. No clustering related to location upstream or downstream of the timber harvest was evident.

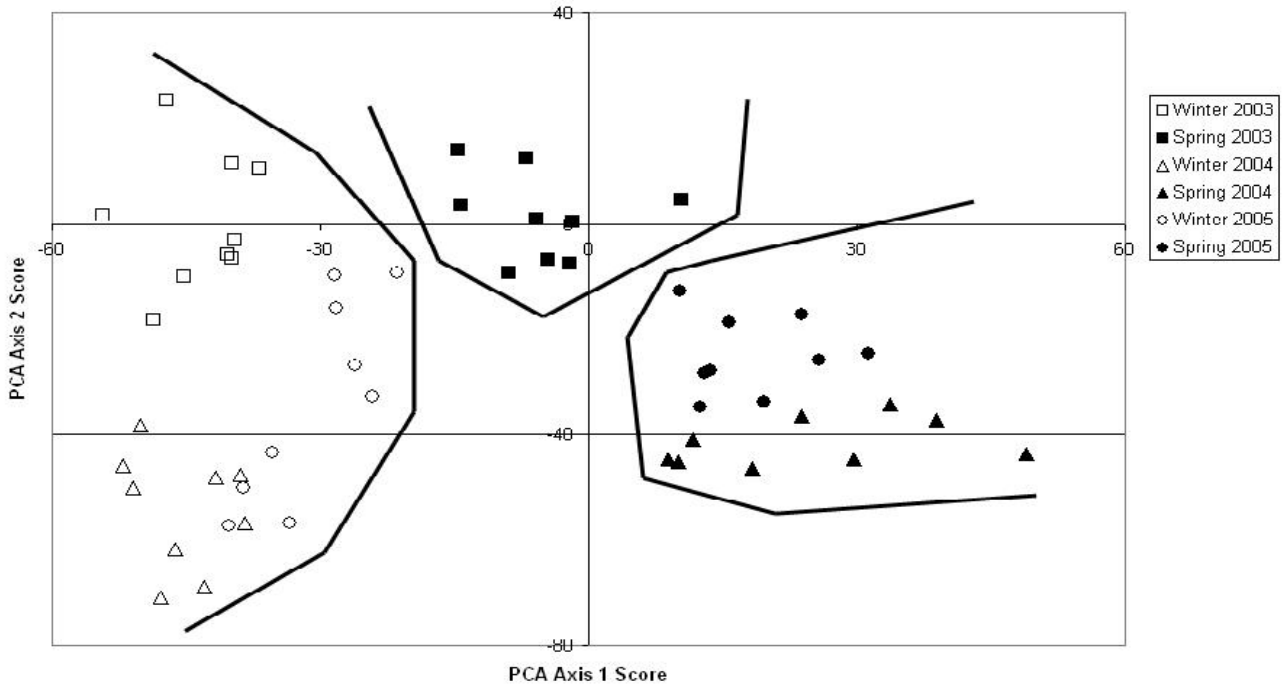

Figure 8. Plot of Big Creek benthic macroinvertebrate sample scores on PCA axes 1 and 2.

4.3 CANEY CREEK (PERRY COUNTY)

Water Quality

As expected, stream temperature varied on a seasonal basis, and discharge varied on an upstream/downstream basis (Table 12). Otherwise, water quality variables did not differ substantially between seasons, study years, or locations. Water temperature was greater, and dissolved oxygen concentration slightly lower, in the spring. Values of pH ranged between 6.2 and 6.9, but did not exhibit clear patterns. Conductivity levels were markedly higher during the winter 2003 survey period and lower during the winter 2004 period, but generally remained within a narrow range otherwise. The low values for these variables, always below 7 for pH and generally below 50 mS/cm for conductivity, were characteristic of a softwater/headwater stream. Discharge was greatest in the winter samples of 2004, but did not follow a clear seasonal or annual pattern in this study. Discharge was always highest at the downstream station; a difference most likely attributable to the entrance of a tributary into Caney Creek between Stations 2 and 3.

Table 12. Water quality measurements at Caney Creek sampling stations during each of the six survey periods.

Variable	Station	Winter 2003	Spring 2003	Winter 2004	Spring 2004	Winter 2005	Spring 2005
Temperature	1 (Up)	3.3	15.2	13.0	12.7	6.2	11.5
(^{o}C)	2 (Up)	3.7	15.7	12.8	10.6	4.5	7.9
	3 (Down)	4.3	15.1	12.9	9.2	4.2	9.1
Dissolved	1 (Up)	10.70	9.72	10.21	10.26	12.16	10.94
Oxygen	2 (Up)	11.58	9.32	10.34	11.04	12.38	12.05
(mg/L)	3 (Down)	11.18	9.39	10.29	10.71	12.30	11.27
pH	1 (Up)	6.40	6.85	6.85	6.67	6.51	6.82
	2 (Up)	6.19	6.86	6.85	6.82	6.48	6.70
	3 (Down)	6.28	6.71	6.73	6.67	6.46	6.68
Conductivity	1 (Up)	71.8	36.0	12.2	39.3	39.8	44
(mS/cm)	2 (Up)	70.7	39.4	12.3	46.3	34.2	45
	3 (Down)	36.6	36.4	13.0	35.5	35.3	62
Discharge	1 (Up)	0.0002	0.0099	0.0187	0.0176	0.0063	0.0000
(m^3/sec)	2 (Up)	0.0004	0.0114	0.0283	0.0027	0.0030	0.0009
	3 (Down)	0.0028	0.0276	0.0564	0.0260	0.0110	0.0051

Turbidity was at least 2 NTU higher at the downstream station than at either of the two upstream stations in five of the six survey periods, including the spring (2003) preceding the timber harvest (Figure 9). Total suspended solids (TSS) were similar between stations, or were lower at the downstream station in all 2003 and 2004 surveys. In 2005,

downstream TSS exceeded that of the upstream sites in both winter (markedly) and spring (slightly). However, TSS levels were relatively low (< 2 mg/L) during all sampling events.

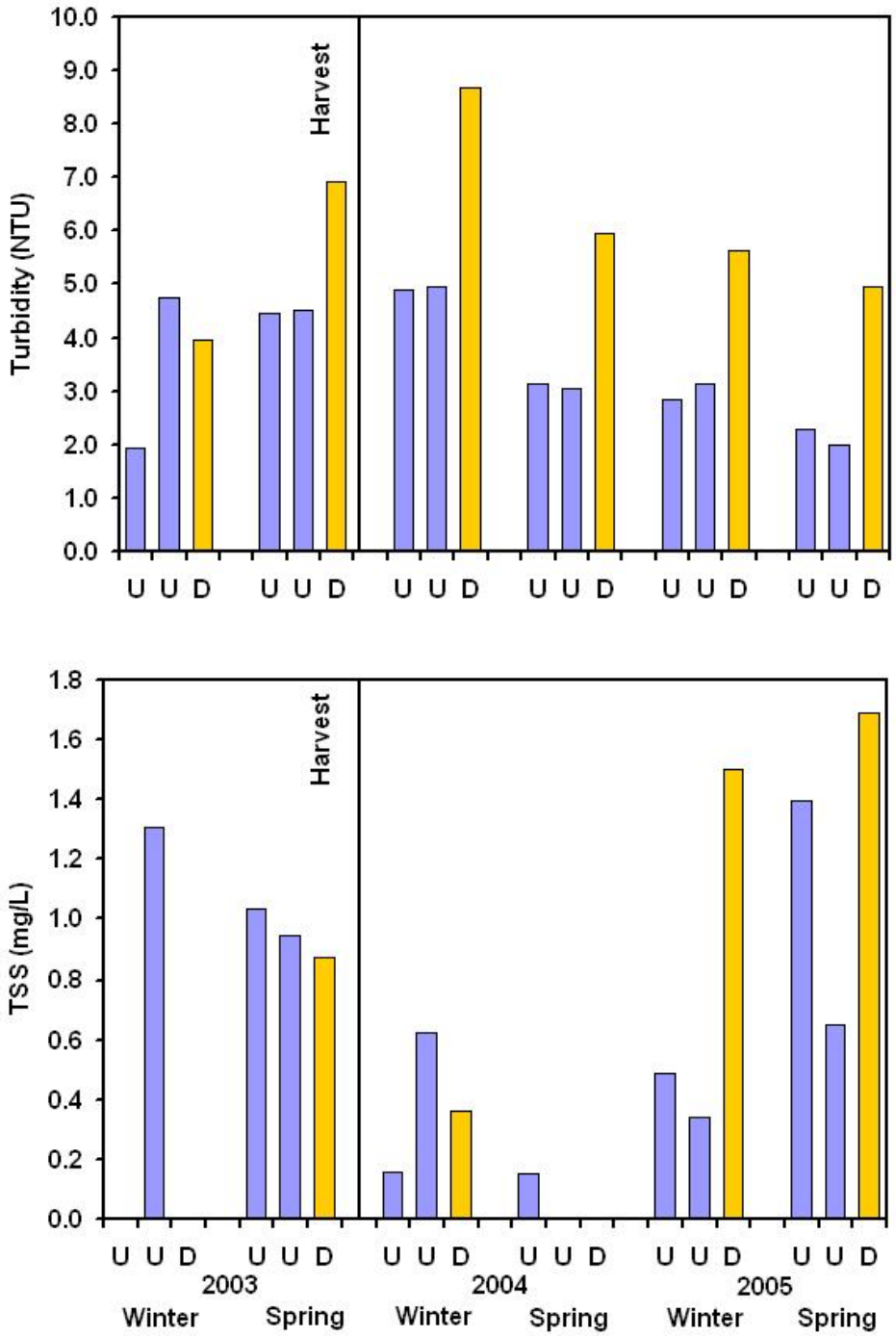

Figure 9. Turbidity and total suspended solids (TSS) concentration at Caney Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

Nitrate and orthophosphate concentrations at the downstream station were generally less than or approximately equal to those of the upstream stations in both pre- and post-harvest surveys (Figure 10). Neither seasonal nor annual trends in the concentrations of these nutrients were evident. No water quality variables differed statistically between areas upstream and downstream of the timber harvest in either winter or spring surveys (one-way ANOVA, n = 3, α = 0.05).

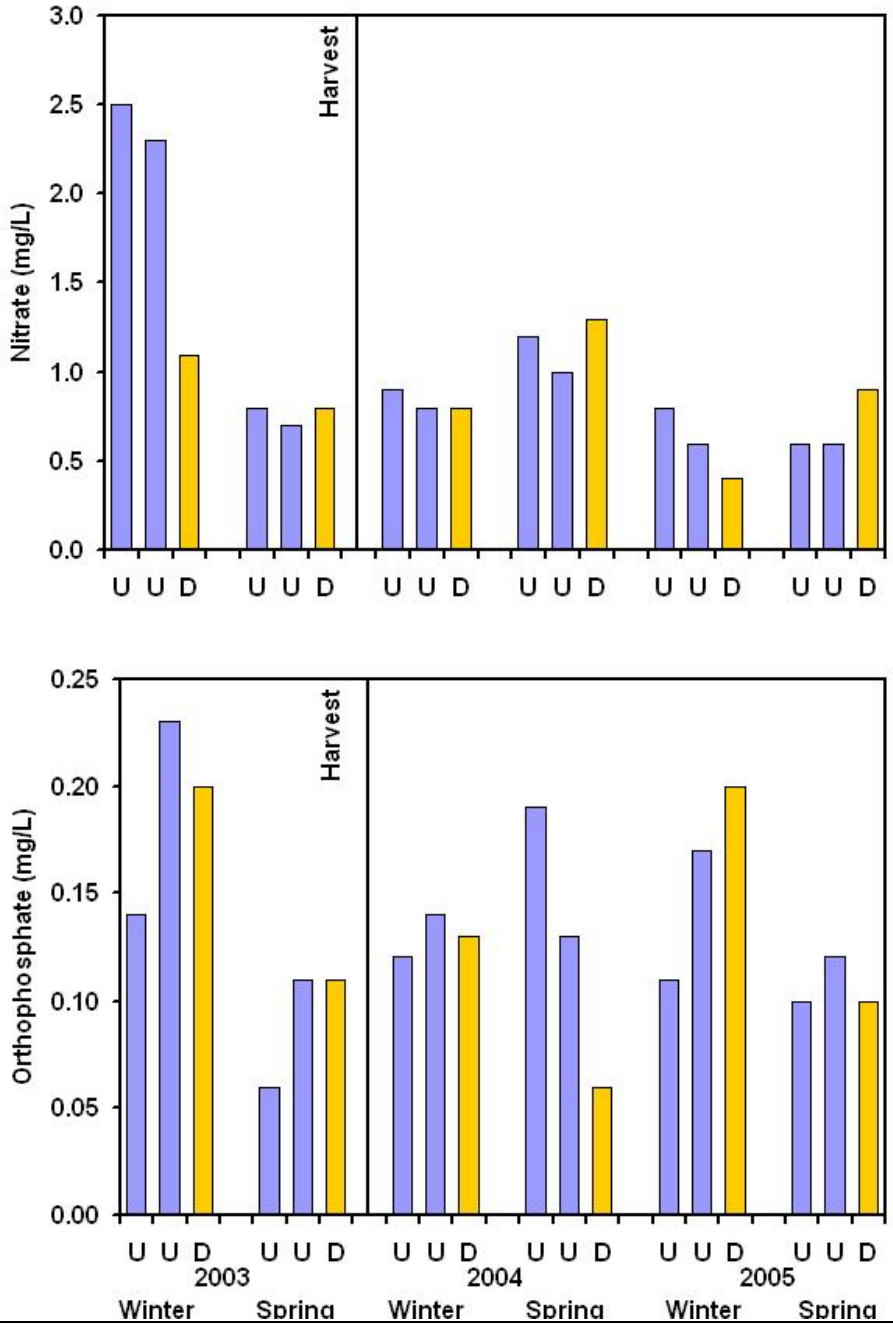

Figure 10. Nitrate and orthophosphate concentrations at Caney Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

Macroinvertebrates

Macroinvertebrate assemblage characteristics at Caney Creek primarily differed between seasons. However, total richness and EPT richness did not differ significantly by season, or location upstream or downstream of the timber harvest, but were greater after the harvest (Table 13). HBI was significantly higher in the winter, but did not differ between locations or years. Relative abundances of EPT organisms, and of two of the metric's three component orders, were significantly greater in the spring than the winter, reflecting increased abundances of mayflies (primarily *Leucrocuta* sp. and *Paraleptophlebia* sp.), and stoneflies (*Amphinemura* sp., *Isoperla* sp., and early instar Chloroperlidae) (Appendix C). Stoneflies were significantly more numerous at the station downstream of the cut, due to the greater collection of *Amphinemura* sp., *Isoperla* sp., and *Strophopteryx* spp.

Table 13. Mean ± standard error for macroinvertebrate assemblage characteristics at Caney Creek by season, by location upstream or downstream of the timber harvest, and by study year before or after the harvest. Asterisks indicate significant difference from other factor. One asterisk indicates $p < 0.05$; two indicate $p < 0.01$. Variables with KW superscript were tested with non-parametric Kruskal-Wallis Test instead of GLM ANOVA, due to violation of equal variance assumption.

	Season		Location		Harvest	
	Winter n = 27	Spring n = 27	Upstream n = 36	Downstream n = 18	Before n = 18	After n = 36
Total richness^{KW}	21.2 ± 1.2	22.0 ± 0.7	21.3 ± 0.8	22.2 ± 1.4	18.1 ± 0.7	23.3 ± 0.9**
EPT richness^{KW}	9.0 ± 0.8	9.5 ± 0.4	9.2 ± 0.5	9.3 ± 0.8	6.9 ± 0.5	10.4 ± 0.5**
Hilsenhoff Biotic Index^{KW}	6.05 ± 0.27**	3.45 ± 0.14	5.03 ± 0.32	4.19 ± 0.26	4.60 ± 0.22	4.82 ± 0.23
% EPT^{KW}	35 ± 3	68 ± 2**	50 ± 4	55 ± 4	51 ± 7	52 ± 3
% Ephemeroptera^{KW}	11 ± 1	36 ± 2**	27 ± 3	18 ± 3	23 ± 4	24 ± 3
% Plecoptera^{KW}	19 ± 3	27 ± 3*	18 ± 2	33 ± 3**	24 ± 4	23 ± 2
% Trichoptera	4 ± 1	6 ± 1	5 ± 1	5 ± 1	4 ± 1	6 ± 1
% Dominant Taxon^{KW}	41 ± 3**	27 ± 1	36 ± 3	31 ± 3	45 ± 4**	29 ± 2
% Diptera^{KW}	19 ± 3	14 ± 1	15 ± 1	21 ± 4	17 ± 4	17 ± 1
% Chironomidae	8 ± 1	10 ± 1	10 ± 1	9 ± 1	7 ± 1	10 ± 1*
% Non-insects^{KW}	44 ± 4**	15 ± 2	34 ± 4*	21 ± 4	31 ± 7	29 ± 3
Functional Feeding Groups						
% Collectors	56 ± 4**	31 ± 2	49 ± 4**	34 ± 3	45 ± 8	43 ± 2
% Filterers^{KW}	6 ± 3	4 ± 1	3 ± 0.4	10 ± 4**	10 ± 4	3 ± 0.4
% Predators	11 ± 2	20 ± 1**	15 ± 1	16 ± 2	11 ± 1	17 ± 2**
% Scrapers^{KW}	8 ± 1	29 ± 2**	20 ± 2	16 ± 3	16 ± 4	20 ± 2
% Shredders^{KW}	19 ± 2	16 ± 2	14 ± 2	24 ± 3**	19 ± 3	17 ± 2

Differences in the relative abundances of functional feeding groups were most frequently noted between seasons and locations (Table 13). Percent Collectors followed much the same patterns as those noted for Percent Non-insects, i.e., higher in winter, higher upstream of the timber harvest, and decreasing upstream while increasing downstream after the harvest. This most reflected that *Caecidotea* sp. was the major taxon in both groups at Caney Creek. Filterers were not usually one of the major functional feeding groups in samples at this stream, but were very numerous at the downstream station in the winter prior to the cut. This occurrence seemed most attributable to the significant difference between locations, and reflected the high abundance of *Prosimulium* sp. Percent Predators differed statistically between seasons and years, due to increased collection of the stoneflies Chloroperlidae and *Isoperla* sp. in spring samples, and of *Clioperla clio* after the cut. Percent Scrapers was significantly greater in the spring due to the increased abundance of *Leucrocuta* sp., but did not differ between locations or years. Percent Shredders differed significantly between locations, but not between seasons or years (Table 13). This pattern was most attributable to greater downstream collection of *Amphinemura* sp. and *Strophopteryx* sp.

The relative abundance of the dominant taxon was greater in the winter than the spring and greater prior to the timber harvest, but did not differ by location relative to the cut. The relative abundance of Diptera did not differ between any of the three main effects, but an effect due to the interaction between year and location was indicated. Specifically, dipteran abundance increased somewhat at upstream stations after the cut, but decreased substantially at the downstream station (Table 14). The taxa accounting for these patterns were the crane fly *Tipula* sp. (upstream) and the blackfly *Prosimulium* sp. (downstream). This pattern could not be tested statistically because the equal variance assumption was violated. The relative abundance of Chironomidae was significantly higher before the timber harvest, although *Corynoneura* sp. was the only major taxon that was clearly more abundant in 2003. Percent Chironomidae did not differ between seasons or between locations. Non-insects were statistically more abundant in the winter than the spring, principally reflecting higher numbers of the isopod *Caecidotea*, and to a lesser extent, the amphipod *Synurella bifurca* (Appendix C). Percent Non-insects, principally *Caecidotea*, was also significantly greater upstream of the harvest. An interaction effect between year and location may have been present, but could not be statistically tested because the equal variance assumption was not met. Abundances of non-insects decreased at upstream stations after the cut, but increased at downstream stations over the same period. These trends were also largely driven by differential collection of *Caecidotea*.

Table 14. Mean ± standard error for macroinvertebrate assemblage characteristics at Caney Creek by the interaction of study year and location upstream or downstream of the timber harvest. Variables with an asterisk had significant ($p < 0.05$) interaction effects. Variables with X superscript had significant interaction effect indicated by GLM ANOVA, but treatment groups did not have equal variances

	Before Harvest		After Harvest	
	Upstream n = 12	Downstream n = 6	Upstream n = 24	Downstream n = 12
Total richness	18.2 ± 0.9	18.0 ± 1.1	22.8 ± 1.0	24.3 ± 1.8
EPT richness	6.9 ± 0.7	7.0 ± 0.9	10.4 ± 0.6	10.4 ± 1.0
Hilsenhoff Biotic Index	5.16 ± 0.74	3.50 ± 0.44	4.97 ± 0.31	4.53 ± 0.29
% EPT	48 ± 9	55 ± 12	51 ± 4	55 ± 3
% Ephemeroptera	28 ± 5	15 ± 6	26 ± 3	19 ± 4
% Plecoptera	18 ± 4	36 ± 6	19 ± 2	31 ± 3
% Trichoptera	3 ± 1	5 ± 1	6 ± 1	5 ± 1
% Dominant Taxon	47 ± 5	40 ± 4	31 ± 3	26 ± 3
% Diptera^{X}	11 ± 1	29 ± 10	17 ± 1	17 ± 2
% Chironomidae	8 ± 1	6 ± 1	11 ± 1	10 ± 2
% Non-insects^{X}	39 ± 9	15 ± 6	31 ± 3	25 ± 4
Functional Feeding Groups				
% Collectors*	55 ± 10	23 ± 5	45 ± 2	39 ± 3
% Filterers^{X}	3 ± 1	23 ± 9	2 ± 0.5	3 ± 1
% Predators	10 ± 2	12 ± 2	17 ± 1	18 ± 3
% Scrapers	17 ± 5	15 ± 5	21 ± 2	17 ± 3
% Shredders	14 ± 3	27 ± 5	14 ± 2	23 ± 4

Euclidean distance did not indicate that macroinvertebrate community composition clearly differed on an upstream/downstream basis. Distances were generally comparable among locations, and during three periods—spring 2003 and winter and spring 2005—the distance was shortest between one of the upstream stations and the downstream station (Table 15). Distances were shortest between the two upstream stations in both 2003 survey periods and in winter 2004, but were much shorter than any upstream/downstream Euclidean distance only in the winters of 2003 and 2004.

Table 15. Euclidean distance between benthic macroinvertebrate samples from Caney Creek stations upstream and downstream of timber harvest during each of six survey periods.

Winter		Spring	
Stream station	Euclidean Distance	Stream station	Euclidean Distance
2003		2003	
Upstream 1 - Upstream 2	59	Upstream 1 - Upstream 2	106
Upstream 2 - Downstream	466	Upstream 2 - Downstream	194
Upstream 1 - Downstream	483	Upstream 1 - Downstream	130
2004		2004	
Upstream 1 - Upstream 2	98	Upstream 1 - Upstream 2	220
Upstream 2 - Downstream	244	Upstream 2 - Downstream	309
Upstream 1 - Downstream	219	Upstream 1 - Downstream	206
2005		2005	
Upstream 1 - Upstream 2	141	Upstream 1 - Upstream 2	139
Upstream 2 - Downstream	161	Upstream 2 - Downstream	160
Upstream 1 - Downstream	97	Upstream 1 - Downstream	110

Results of the PCA were summarized by plotting the 54 sample scores along Axis 1 against the scores along Axis 2 (Figure 11). The first two axes had the highest eigenvalues, and accounted for 55 % and 15 % of the variance in the data set, respectively. Axis 1 was positively correlated to the abundances of *Caecidotea* sp. and *Allocapnia* spp., and negatively correlated to the abundances of *Leucrocuta* sp., *Amphinemura* sp. and *Isoperla* sp. This pattern most reflected seasonal differences in abundance. *Caecidotea* sp., the taxon most strongly correlated with Axis 1 was always more numerous in the winter, whereas the latter three taxa listed above were most abundant in the spring (Appendix C). Samples from spring in each of the three survey years were clustered in the lower left corner of the graph. Some sample segregation along Axis 2 was evident, although less than that for Axis 1. Axis 2 appeared to most reflect the interaction of upstream vs. downstream and before/after harvest variation, and was positively correlated to the abundances of *Clioperla clio, Strophopteryx* spp. and *Prosimulium* sp., each of which was dramatically more abundant in downstream samples prior to the timber harvest. Axis 2 was negatively correlated to the abundances of *Caecidotea* sp., *Leucrocuta* sp., and *Paraleptophlebia* sp.; these taxa were each more abundant in upstream samples before the cut. No clustering on the basis of location upstream or downstream of the timber harvest, and after the harvest, was observed.

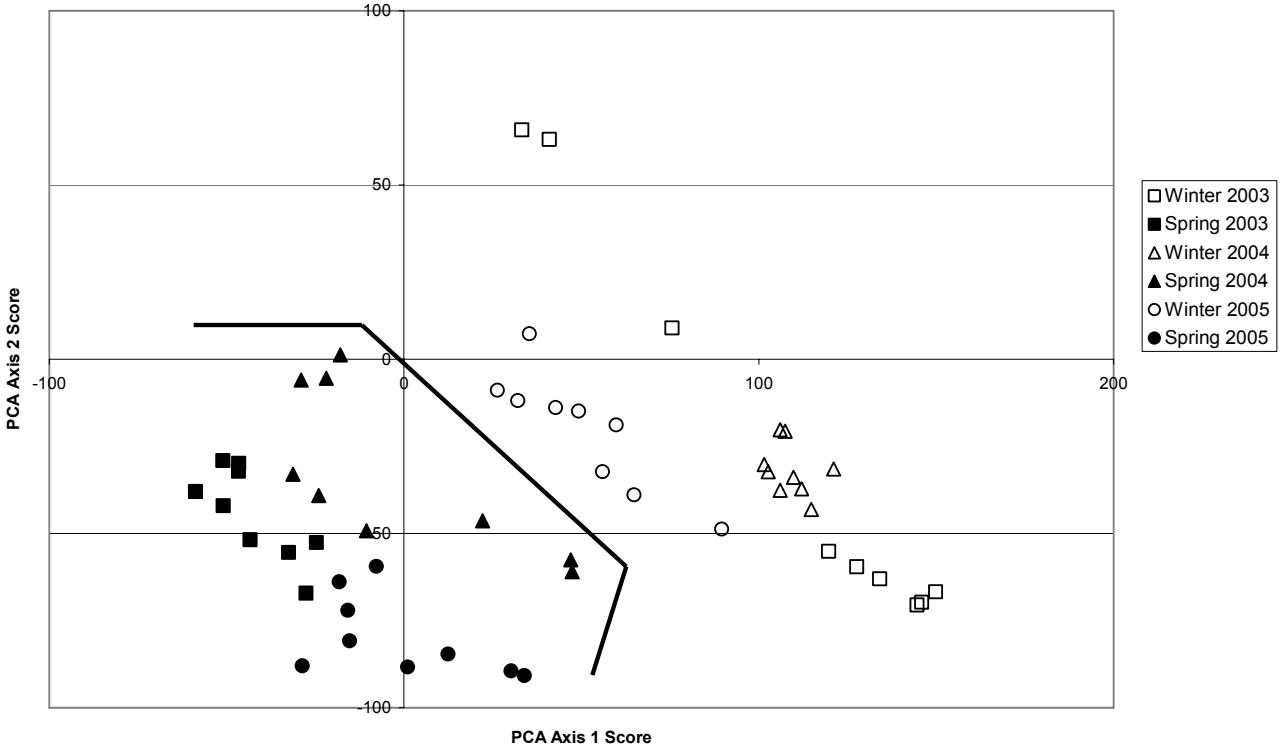

Figure 11. Plot of Caney Creek benthic macroinvertebrate sample scores on PCA axes 1 and 2.

4.4 HARRIS CREEK (HOWARD COUNTY)

Water Quality

Water quality variables at Harris Creek did not consistently differ between areas upstream and downstream of the timber harvest either before or after the harvest (Table 16). Water temperature means were slightly lower at the station downstream of the cut in both winter and spring, probably because measurements were always made earliest in the day at this location. Dissolved oxygen concentrations were often highest at the downstream station, although the differences were typically small (less than 1 mg/L). Neither temperature nor dissolved oxygen appeared to vary between pre- and post-harvest survey years. Likewise, pH levels were similar among stations during all six sampling periods. Conductivity varied widely (12 to 130 mS/cm) over the course of the study, but did not exhibit any clear annual, seasonal or spatial trend. Stream discharge was always greatest at the downstream station, but did not consistently differ between seasons. Highest flows were present in winter 2004, but flow did not appear to generally increase after the timber harvest (Table 16).

Table 16. Water quality measurements at Harris Creek sampling stations during each of the six survey periods.

Variable	Station	Winter 2003	Spring 2003	Winter 2004	Spring 2004	Winter 2005	Spring 2005
Temperature	1 (Up)	1.2	13.6	7.8	16.1	6.3	7.7
(^{o}C)	2 (Up)	1.4	12.8	7.9	12.3	5.8	7.4
	3 (Down)	0.4	11.8	8.1	9.2	4.8	7.1
Dissolved	1 (Up)	12.95	10.18	11.11	10.14	12.28	11.93
Oxygen	2 (Up)	13.02	10.49	11.20	11.28	12.25	11.83
(mg/L)	3 (Down)	14.30	10.59	11.14	11.39	12.63	11.77
pH	1 (Up)	7.02	7.12	6.88	6.87	6.29	7.22
	2 (Up)	7.13	7.09	6.93	6.87	6.54	7.24
	3 (Down)	6.62	7.00	6.86	6.88	6.59	7.20
Conductivity	1 (Up)	70.4	22.4	12.4	23.2	40.6	130.0
(mS/cm)	2 (Up)	49.6	21.8	12.0	17.8	38.2	77.0
	3 (Down)	47.4	21.4	11.9	25.2	35.1	75.0
Discharge	1 (Up)	0.036	0.087	0.124	0.085	0.049	0.036
(m^3/sec)	2 (Up)	0.025	0.087	0.132	0.084	0.064	0.046
	3 (Down)	0.057	0.159	0.158	0.149	0.099	0.060

Variables associated with sediment inputs did not indicate an effect resulting from the timber harvest. Turbidity levels were higher at the downstream station both before and after the harvest, and were highest in winter 2004 when stream flow was also highest (Figure 12). Additionally, turbidity decreased at all stations in each consecutive survey

after the harvest. Unlike turbidity, total suspended solids did not appear to be correlated with flow conditions. Levels were always low (< 1 mg/L) and were near or below detection limits (0.5 mg/L) until spring 2004, when the downstream TSS concentrations far exceeded the upstream levels.

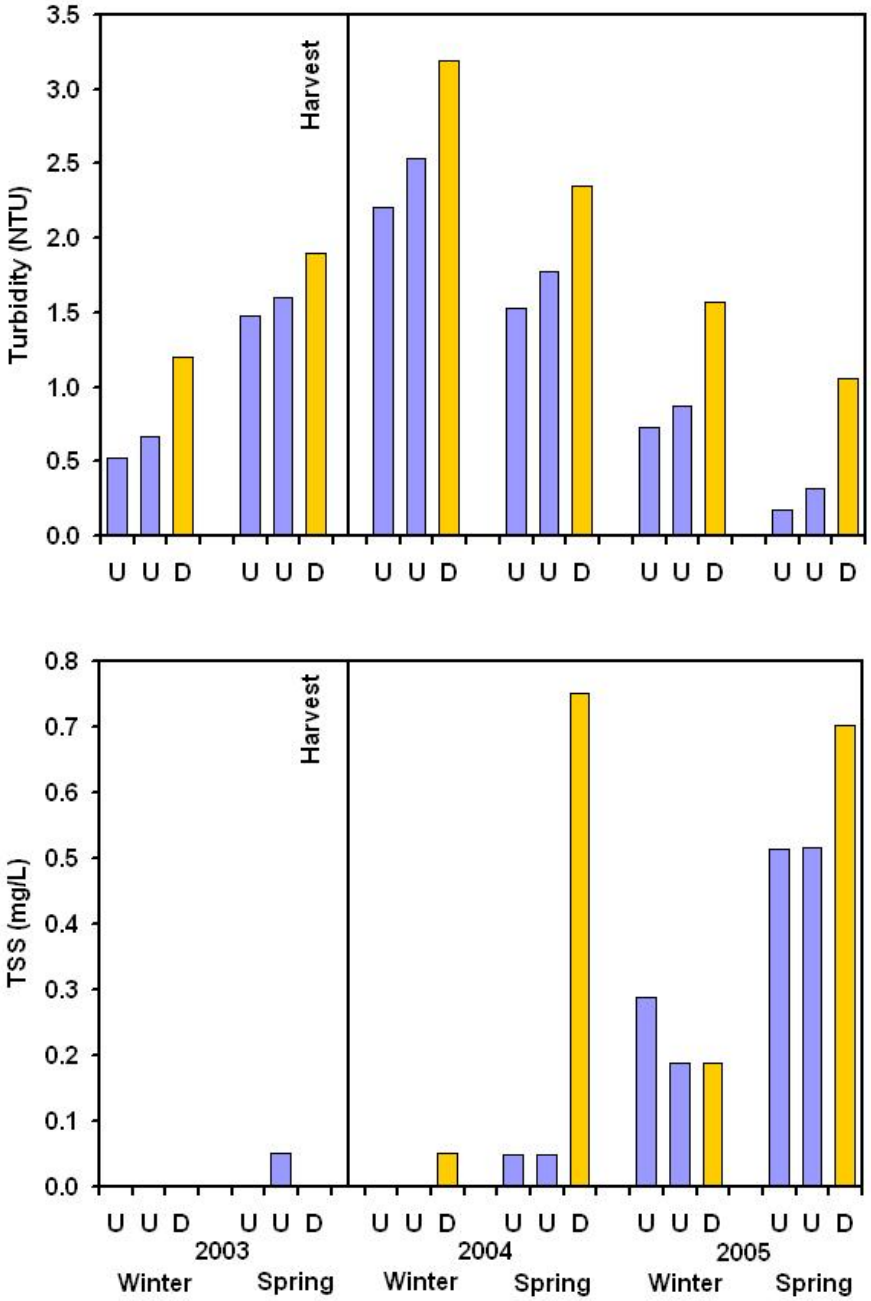

Figure 12. Turbidity and total suspended solids (TSS) concentration at Harris Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

This pattern was not repeated in winter 2005, but was evident to a lesser extent in spring 2005, when downstream TSS was approximately 0.2 mg/L higher than upstream levels.

Nitrate and orthophosphate concentrations at the downstream station were generally less than or approximately equal to those of the upstream stations in both pre- and post-harvest surveys (Figure 13). The exception to this pattern was the slightly higher (~0.1 mg/L) orthophosphate level downstream in spring 2004. Nutrient levels did not conform to clear annual or seasonal patterns. A one-way analysis of variance testing whether values differed between stations, using study years as replicates, did not indicate significant differences ($\alpha = 0.05$) in water quality variables in either spring or winter.

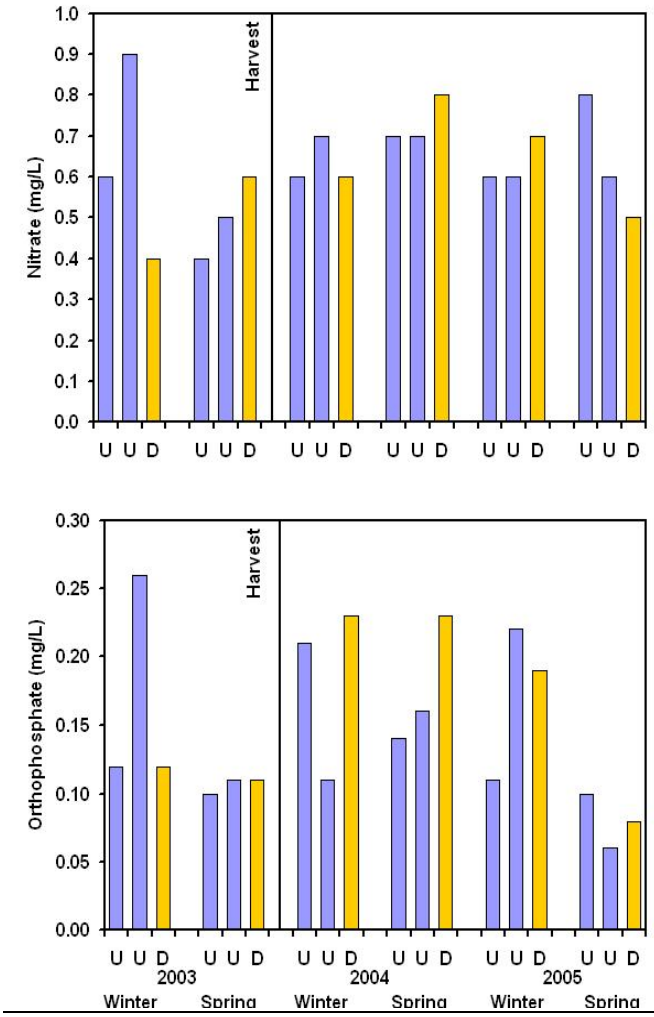

Figure 13. Nitrate and orthophosphate concentrations at Harris Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

Macroinvertebrates

Total richness of macroinvertebrate assemblages was significantly greater in the spring (pooled locations and years) than in the winter ($p < 0.01$), and greater after the cut (pooled seasons and locations) than before ($p < 0.05$) (Table 17). EPT richness did not statistically differ by season, but was also significantly greater after the timber harvest.

Neither total richness nor EPT richness differed between locations. Hilsenhoff Biotic Index (HBI) did not differ by season, location or survey year. Relative abundance of EPT organisms was greater in the winter than the spring, reflecting increased abundances of certain winter stoneflies (*Allocapnia* spp. and *Taeniopteryx* sp.) and caddisflies (*Cheumatopsyche* sp. and *Chimarra* sp.) (Appendix D). Percent EPT was also slightly but significantly higher after the harvest. The pattern seemed most associated with greater post-harvest collection of the mayflies *Diphetor* sp., *Leucrocuta* sp., *Paraleptophlebia* sp. and *Stenacron* sp. However, percent Ephemeroptera did not differ within any of the three main effects.

Table 17. Mean ± standard error for macroinvertebrate assemblage characteristics at Harris Creek by season, by location upstream or downstream of the timber harvest, and by study year before or after the harvest. Asterisks indicate significant difference from other factor. One asterisk indicates $p < 0.05$; two indicate $p < 0.01$.

	Season		Location		Harvest	
	Winter n = 27	Spring n = 27	Upstream n = 36	Downstream n = 18	Before n = 18	After n = 36
Total richness	29.9 ± 0.9	34.1 ± 0.6**	32.1 ± 0.8	31.7 ± 1.1	29.7 ± 1.3	33.1 ± 0.6*
EPT richness	18.6 ± 0.7	18.6 ± 0.4	18.4 ± 0.5	18.8 ± 0.6	16.6 ± 0.7	19.6 ± 0.4**
Hilsenhoff Biotic Index	3.91 ± 0.06	3.86 ± 0.07	3.89 ± 0.06	3.88 ± 0.63	3.87 ± 0.11	3.90 ± 0.05
% EPT	78 ± 2**	71 ± 1	74 ± 1	76 ± 2	72 ± 2	76 ± 2*
% Ephemeroptera	49 ± 2	47 ± 1	47 ± 1	50 ± 2	46 ± 2	49 ± 1
% Plecoptera	14 ± 1	14 ± 1	13 ± 1	16 ± 1*	13 ± 1	14 ± 1
% Trichoptera	16 ± 1**	9 ± 1	14 ± 1*	10 ± 1	12 ± 1	13 ± 1
% Dominant Taxon	15 ± 1*	13 ± 1	14 ± 1	13 ± 1	15 ± 1*	13 ± 1
% Diptera	13 ± 1	18 ± 1**	15 ± 1	15 ± 1	15 ± 1	15 ± 1
% Chironomidae	6 ± 1	13 ± 1**	9 ± 1	9 ± 2	7 ± 1	11 ± 1*
% Non-insects	1 ± 0.2	3 ± 0.3**	2 ± 0.3	2 ± 0.4	2 ± 0.4	2 ± 0.2
Functional Feeding Groups						
% Collectors	18 ± 1	24 ± 1**	20 ± 1	23 ± 2	19 ± 1	23 ± 1**
% Filterers	29 ± 2**	16 ± 2	23 ± 2	22 ± 2	26 ± 2**	21 ± 2
% Predators	9 ± 1	19 ± 1**	14 ± 1	14 ± 2	14 ± 1	14 ± 1
% Scrapers	32 ± 1	33 ± 1	34 ± 1*	30 ± 1	34 ± 2	32 ± 1
% Shredders	12 ± 1*	8 ± 1	9 ± 1	11 ± 1	8 ± 1	11 ± 1*

The relative abundance of the dominant taxon, while consistently low (overall mean = 14; individual values never exceeded 21 %) was greater in the winter, and upstream of

the cut. The relative abundances of Diptera and its major component, Chironomidae, were significantly greater in the spring. This largely reflected the increased collection of *Polypedilum aviceps* and *Trissopelopia ogemawi* in the spring (Appendix D). Percent Chironomidae was also higher after the timber harvest, a trend that also reflected the differential collection of these two taxa. Percent Non-insects was consistently low, with an overall mean of 2 and levels never exceeding 6 %. Nevertheless, non-insects were significantly more abundant in the spring, a trend that reflected differential collection of *Elimia* sp. and *Orconectes* sp.

Differences in the relative abundances of functional feeding groups were mostly seasonal (Table 17). Collectors were more abundant in the spring and after the harvest (both $p < 0.01$), reflecting greater numbers of the mayflies *Diphetor* sp., *Eurylophella* sp. and *Paraleptophlebia* sp. In contrast, the relative abundance of filterers was higher in the winter, due to greater numbers of *Cheumatopsyche* sp., *Chimarra* sp., and the blackfly *Prosimulium* sp. (Appendix D). The abundance of filterers was also higher before the timber harvest. Predators, primarily *Isoperla* sp., were more frequently collected in the spring. Percent Scrapers did not differ between seasons or study years, but was significantly greater upstream of the cut. This pattern appeared to reflect the differential abundance of *Agapetus* sp. and the aquatic beetles *Optioservus* sp. and *Psephenus herricki*. The relative abundance of shredders was greater in the winter, due to increased collection of *Allocapnia* sp. and *Taeniopteryx* sp., and greater after the timber harvest, reflecting higher numbers of *Allocapnia* sp and *Polypedilum aviceps*.

Percent Plecoptera was statistically greater at the downstream station after the harvest, resulting in a significant interaction effect between location and study year (Table 18). It was difficult to determine which taxa were associated with this trend; numerically dominant stoneflies did not exhibit a clear pattern. Only early instar Chloroperlidae and *Paracapnia angulata* were substantially more abundant at the downstream location after the cut. Percent Trichoptera was greater in the winter, due to the increased collection of *Cheumatopsyche* sp. and *Chimarra* sp., and greater upstream of the cut. The three most abundant caddisfly taxa—*Agapetus* sp., *Cheumatopsyche* sp. and *Chimarra* sp.—were each more frequently collected at upstream stations.

Table 18. Mean ± standard error for macroinvertebrate assemblage characteristics at Harris Creek by the interaction of study year and location upstream or downstream of the timber harvest. Variables with an asterisk had significant ($p < 0.05$) interaction effects.

	Before Harvest		After Harvest	
	Upstream n = 12	Downstream n = 6	Upstream n = 24	Downstream n = 12
Total richness	29.5 ± 1.5	30.2 ± 2.5	33.4 ± 0.7	32.5 ± 1.1
EPT richness	16.5 ± 0.9	16.8 ± 1.2	19.4 ± 0.6	19.8 ± 0.5
Hilsenhoff Biotic Index	3.86 ± 0.11	3.89 ± 0.08	3.91 ± 0.06	3.87 ± 0.09
% EPT	71 ± 2	73 ± 2	75 ± 2	78 ± 3
% Ephemeroptera	45 ± 2	49 ± 3	48 ± 2	51 ± 2
% Plecoptera*	13 ± 1	13 ± 1	13 ± 1	17 ± 1
% Trichoptera	13 ± 1	11 ± 2	14 ± 1	10 ± 2
% Dominant Taxon	15 ± 1	15 ± 1	13 ± 1	12 ± 1
% Diptera	15 ± 2	15 ± 1	16 ± 2	14 ± 2
% Chironomidae	6 ± 1	7 ± 2	11 ± 1	11 ± 2
% Non-insects	2 ± 1	2 ± 1	2 ± 0.3	2 ± 0.4
Functional Feeding Groups				
% Collectors	18 ± 1	20 ± 2	22 ± 1	25 ± 2
% Filterers	25 ± 3	27 ± 4	21 ± 2	19 ± 2
% Predators	15 ± 1	13 ± 2	13 ± 1	15 ± 3
% Scrapers	35 ± 2	31 ± 3	33 ± 1	29 ± 1
% Shredders	7 ± 1	9 ± 1	10 ± 1	13 ± 2

Euclidean distance calculations did not indicate that macroinvertebrate assemblage composition differed substantially between locations upstream and downstream of the cut. Distances were generally similar between locations (Table 19). In four of the six survey periods, the distance was shortest between one of the upstream stations and the downstream stations.

Table 19. Euclidean distance between benthic macroinvertebrate samples from Harris Creek stations upstream and downstream of timber harvest during each of six . survey periods, 2003-2005.

Winter		**Spring**	
Stream station	Euclidean Distance	Stream station	Euclidean Distance
2003		2003	
Upstream 1 - Upstream 2	74	Upstream 1 - Upstream 2	100
Upstream 2 - Downstream	63	Upstream 2 - Downstream	100
Upstream 1 - Downstream	94	Upstream 1 - Downstream	80
2004		2004	
Upstream 1 - Upstream 2	79	Upstream 1 - Upstream 2	57
Upstream 2 - Downstream	82	Upstream 2 - Downstream	89
Upstream 1 - Downstream	105	Upstream 1 - Downstream	80
2005		2005	
Upstream 1 - Upstream 2	96	Upstream 1 - Upstream 2	97
Upstream 2 - Downstream	93	Upstream 2 - Downstream	39
Upstream 1 - Downstream	87	Upstream 1 - Downstream	109

Results of the PCA were summarized by plotting the 54 sample scores along Axis 1 against the scores along Axis 2 (Figure 14). The first two axes had the highest eigenvalues and accounted for 37 % and 11 % of the variance in the data set, respectively. Axis 1 was positively correlated to the abundances of *Leucrocuta* sp., *Amphinemura* sp., *Isoperla* sp. and *Psephenus herricki*, and negatively correlated to the abundances of *Isonychia* sp., *Stenonema mediopunctatum*, *Allocapnia* sp., *Taeniopteryx* sp., *Cheumatopsyche* sp., *Chimarra* sp. and *Prosimulium* sp. This pattern largely reflected seasonal differences in abundance; each of the taxa positively correlated with Axis 1 were more numerous in the spring and those negatively correlated were most abundant in the winter. Samples segregated distinctly along Axis 1 with spring samples from all years forming a cluster to the left of -20, and winter samples from all years forming a cluster to the right of -10. Axis 2 was positively correlated to the abundances of *Isonychia* sp. and *Stenonema mediopunctatum*, and negatively correlated to the abundances of *Stenonema femoratum* and *Cheumatopsyche* sp. The pattern along this axis did not clearly reflect annual, seasonal or locational differences, and sample separation was not as evident along Axis 2 as it was along the first axis.

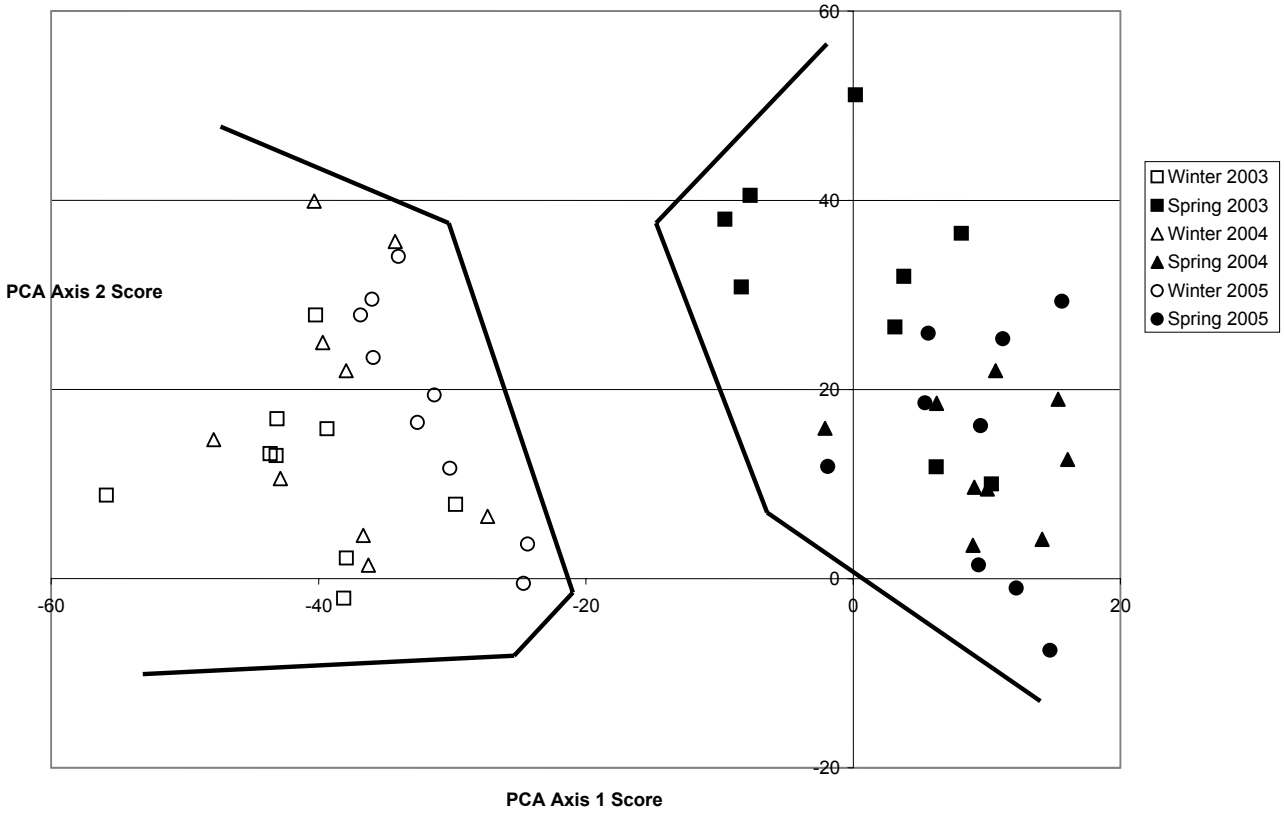

Figure 14. Plot of Harris Creek benthic macroinvertebrate sample scores on PCA axes 1 and 2.

4.5 LLOYDS CREEK (CALHOUN COUNTY)

Water Quality

Water quality variables at Lloyds Creek were similar between locations upstream and downstream of the timber harvest, and did not appear to differ between study years before and after the harvest. Stream temperature was greater in the spring (Table 20). Dissolved oxygen concentrations were frequently less than 5 mg/L, but did not exhibit clear annual, seasonal, or spatial variation. Mean pH was similar among locations in all surveys. Conductivity levels were markedly higher during the winter 2003 survey period, but otherwise did not conform to clear patterns of variation. Discharge was greater in the

spring samples of 2003 and 2004, but greater in the winter of 2005, and differed only slightly between upstream and downstream stations.

Table 20. Water quality measurements at Lloyd's Creek at each of the six sampling stations.

Variable	Station	Winter 2003	Spring 2003	Winter 2004	Spring 2004	Winter 2005	Spring 2005
Temperature (^oC)	1 (Up)	5.2	15.2	5.9	16.1	5.6	11.9
	2 (Up)	5.6	15.3	5.9	16.0	5.0	12.6
	3 (Down)	6.1	14.8	4.1	15.8	5.4	11.7
Dissolved Oxygen (mg/L)	1 (Up)	4.64	3.80	1.37	3.61	5.24	4.46
	2 (Up)	4.49	3.41	1.62	3.41	5.75	4.15
	3 (Down)	4.38	4.16	2.15	3.53	6.24	5.00
pH	1 (Up)	5.28	5.92	5.85	5.13	5.31	5.44
	2 (Up)	5.51	5.55	5.85	5.32	5.36	5.55
	3 (Down)	5.65	5.40	5.81	5.49	5.39	5.58
Conductivity (mS/cm)	1 (Up)	573	43.4	22.3	60.8	36.3	66.2
	2 (Up)	525	44.1	21.3	58.6	34.2	58.5
	3 (Down)	628	44.3	20.5	58.5	33.7	57.2
Discharge (m^3/sec)	1 (Up)	0.039	0.061	0.000	0.237	0.121	0.014
	2 (Up)						
	3 (Down)	0.049	0.059	0.036	0.219	0.182	0.013

Variables associated with sediment inputs were generally similar at upstream and downstream stations before and after the timber harvest (Figure 15). Turbidity was greatest in spring 2005. Similarly, total suspended solids (TSS) levels were highest in spring 2005, and nearly as high in spring 2003. These trends did not correspond to increased stream flow. To the contrary, survey periods when discharges were greatest, spring 2004 and winter 2005, had much lower turbidity and TSS levels.

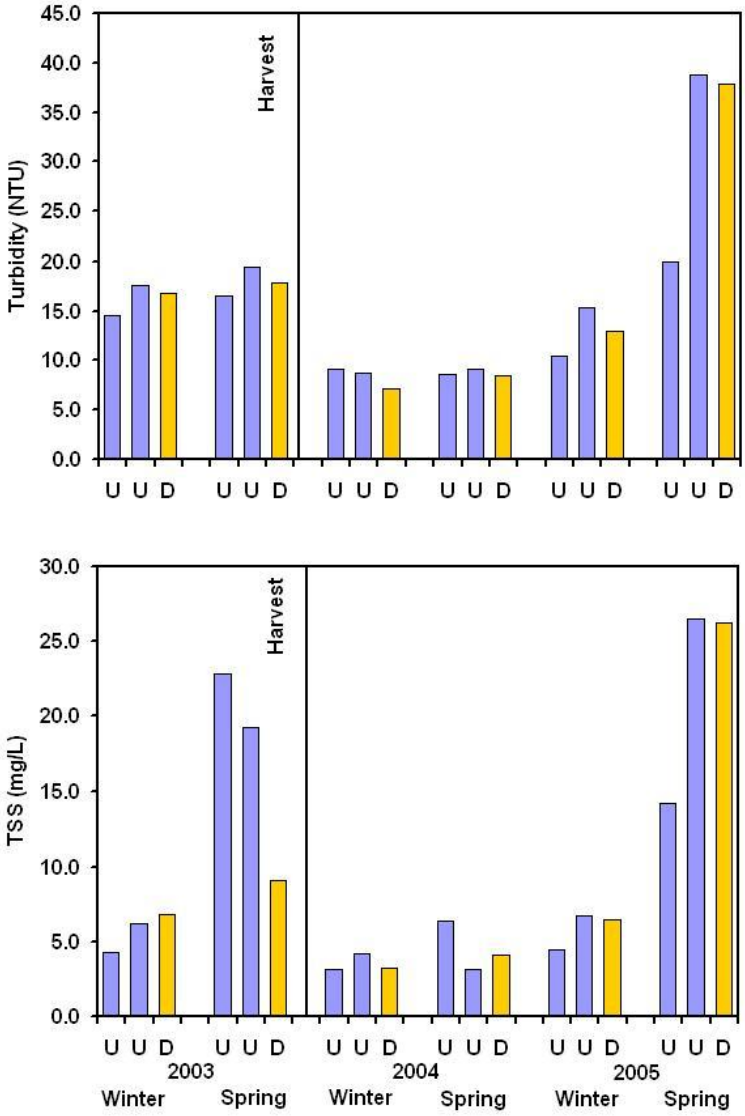

Figure 15. Turbidity and total suspended solids (TSS) concentration at Lloyds Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods

Nitrate concentrations did not obviously differ between seasons, locations or study years (Figure 16). Orthophosphate concentrations at the downstream station were generally less than or approximately equal to those of the upstream stations in both pre- and post-harvest surveys. No water quality variables differed statistically between areas upstream and downstream of the timber harvest in either spring or fall surveys (one-way ANOVA, $n = 3$, $\alpha = 0.05$).

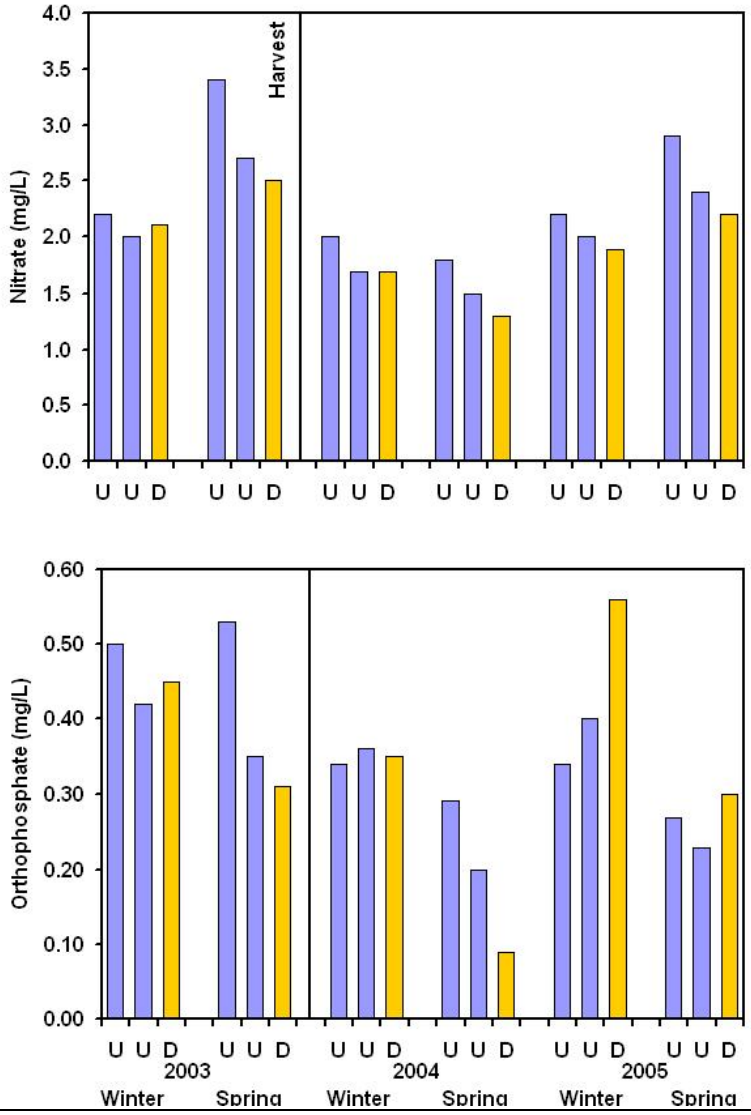

Figure 16. Nitrate and orthophosphate concentrations at Lloyds Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

Macroinvertebrates

Macroinvertebrate assemblages at Lloyds Creek were numerically dominated by silt-tolerant organisms such as chironomids, notably *Hydrobaenus* sp., *Kiefferulus* sp., *Omisus* sp., *Procladius* spp. and *Zavrelimyia* sp., and other dipterans (*Chaoborus punctipennis*) as well as by non-insects (Appendix A). Major non-insect taxa in this stream were the isopods *Caecidotea* sp. and *Lirceus* sp., the amphipods *Crangonyx* sp. and *Hyalella azteca*, and tubificid oligochaetes. There were few representative taxa of

the Ephemeroptera, Plecoptera and Trichoptera orders, and only two—the mayfly *Callibaetis* sp. and the caddisfly *Ptilostomis* sp.—were collected with any frequency. Other insect taxa that were common at Lloyds Creek included the damselflies *Enallagma* sp. and *Ischnura* sp., the dragonfly *Pachydiplax longipennis*, and the predaceous diving beetle *Hydroporus* sp. Total richness was significantly greater in spring surveys ($p < 0.05$), and at locations upstream of the timber harvest ($p < 0.01$), but did not differ between surveys before and after the harvest (Table 21). EPT Richness was always low (mean < 2), but was statistically higher upstream of the cut. This variable did not differ between seasons or study years. The HBI was significantly higher in the winter, higher downstream of the harvest, and higher in the survey year before the harvest. Relative abundance of EPT organisms was slightly, but significantly, greater in the winter. Otherwise, this group and its constituent orders did not differ between years, seasons, or locations.

The relative abundance of the dominant taxon was greater in winter samples, but did not differ by the other two main effects. Percent Diptera and Percent Chironomidae, which was the major contributor to Percent Diptera, were both significantly greater in the winter. This pattern was attributable to the increased collection of the *Hydrobaenus* sp., and to a lesser extent, *Chaoborus punctipennis*. Percent Chironomidae was also higher before the timber harvest, due to the greater pre-harvest abundances of *Hydrobaenus* sp., *Dicrotendipes modestus*, and *Procladius* spp. Percent Non-insects, primarily represented by *Crangonyx* sp., *Palaemonetes kadiakensis*, and the naidid oligochaete *Nais* sp., was significantly greater in the winter. The relative abundance of non-insects was also greater at the station downstream of the timber harvest, due to increased collection of *Caecidotea* sp. and tubificid oligochaetes.

Collectors and predators were the major functional feeding groups in the macroinvertebrate assemblage at Lloyds Creek. Percent Collectors was significantly greater in the winter due to the increased abundance of *Hydrobaenus* sp., and greater downstream of the timber harvest, reflecting higher numbers of *Caecidotea* sp. and tubificid oligochaetes, but did not differ between survey years. Percent Filterers, although this group was never abundant, was statistically greater in survey years following the timber harvest. The relative abundance of predators was greater in the spring—due to increased collection of *Hydroporus* sp. and *Zavrelimyia* sp—and upstream of the cut, resulting from higher numbers of a variety of odonates. Percent Scrapers and Percent Shredders did not differ between seasons, years, or locations

Only one of the 16 assemblage characteristics measured indicated an effect of the interaction between location and survey year. Percent collectors decreased after the cut at locations upstream of the harvest, but stayed approximately the same at the downstream location (Table 22). The taxon whose abundance was most attributable for this pattern was *Hydrobaenus* sp. (Appendix E).

Table 21. Mean ± standard error for macroinvertebrate assemblage characteristics at Lloyds Creek by season, by location upstream or downstream of the timber harvest, and by study year before or after the harvest. Asterisks indicate significant difference from other factor. * indicates $p < 0.05$; ** indicates $p < 0.01$. Variables with KW superscript were tested with non-parametric Kruskal-Wallis test instead of GLM ANOVA, due to violation of equal variance assumption.

	Season		Location		Harvest	
	Winter n = 27	Spring n = 27	Upstream n = 36	Downstream n = 18	Before n = 18	After n = 36
Total richness	28.2 ± 1.2	31.1 ± 1.3*	32.3 ± 0.8**	24.4 ± 1.5	28.2 ± 1.5	30.4 ± 1.1
EPT richness	1.3 ± 0.1	1.2 ± 0.1	1.4 ± 0.1*	0.9 ± 0.2	1.2 ± 0.2	1.3 ± 0.1
Hilsenhoff Biotic Index	8.7 ± 0.1**	8.3 ± 0.1	8.4 ± 0.1	8.6 ± 0.1*	8.6 ± 0.1*	8.4 ± 0.1
% EPT^{KW}	4 ± 1*	2 ± 0.3	3 ± 0.4	3 ± 1	2 ± 0.4	3 ± 1
% Ephemeroptera	1 ± 0.2	1 ± 0.2	1 ± 0.2	1 ± 0.1	0.3 ± 0.1	1 ± 0.2
% Plecoptera	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
% Trichoptera^{KW}	3 ± 1	1 ± 0.3	2 ± 0.4	2 ± 1	2 ± 0.4	2 ± 1
% Dominant Taxon^{KW}	30 ± 3**	15 ± 1	20 ± 2	28 ± 4	28 ± 4	20 ± 2
% Diptera^{KW}	47 ± 4**	29 ± 2	41 ± 3	32 ± 5	44 ± 4	35 ± 3
% Chironomidae^{KW}	42 ± 4**	26 ± 2	36 ± 3	29 ± 5	41 ± 4**	30 ± 3
% Non-insects^{KW}	39 ± 3	53 ± 3**	41 ± 2	54 ± 5*	43 ± 3	47 ± 3
Functional Feeding Groups						
% Collectors	70 ± 2**	62 ± 2	63 ± 2	72 ± 2**	70 ± 2	64 ± 2
% Filterers	1 ± 0.2	2 ± 0.3	1 ± 0.2	1 ± 0.4	0.7 ± 0.2	2 ± 0.2*
% Predators	20 ± 1	28 ± 2**	27 ± 1**	18 ± 2	22 ± 2	25 ± 2
% Scrapers	0.4 ± 0.1	1 ± 0.3	1 ± 0.2	1 ± 0.2	1 ± 0.3	1 ± 0.2
% Shredders^{KW}	5 ± 1	3 ± 0.4	4 ± 1	3 ± 1	3 ± 1	4 ± 1

Table 22. Mean ± standard error for macroinvertebrate assemblage characteristics at Lloyds Creek by the interaction of study year and location upstream or downstream of the timber harvest. Variables with an asterisk had significant ($p < 0.05$) interaction effects.

	Before Harvest		**After Harvest**	
	Upstream n = 12	Downstream n = 6	Upstream n = 24	Downstream n = 12
Total richness	31.2 ± 1.5	22.2 ± 1.1	32.9 ± 1.0	25.5 ± 2.1
EPT richness	1.3 ± 0.3	1.0 ± 0.4	1.5 ± 0.1	0.9 ± 0.2
Hilsenhoff Biotic Index	8.52 ± 0.14	8.74 ± 0.17	8.37 ± 0.06	8.53 ± 0.07
% EPT	2 ± 0.4	2 ± 1	4 ± 1	3 ± 1
% Ephemeroptera	0.5 ± 0.2	0 ± 0	2 ± 0.2	0.2 ± 0.1
% Plecoptera	0 ± 0	0 ± 0	0 ± 0	0 ± 0
% Trichoptera	2 ± 0.4	2 ± 1	2 ± 1	3 ± 1
% Dominant Taxon	25 ± 4	33 ± 7	18 ± 2	25 ± 4
% Diptera	44 ± 4	43 ± 10	40 ± 3	26 ± 6
% Chironomidae	41 ± 4	42 ± 10	34 ± 3	23 ± 6
% Non-insects	43 ± 3	44 ± 8	41 ± 3	60 ± 6
Functional Feeding Groups				
% Collectors*	69 ± 2	72 ± 4	60 ± 2	73 ± 3
% Filterers	1 ± 0.3	1 ± 0.2	2 ± 0.2	2 ± 1
% Predators	24 ± 2	19 ± 4	29 ± 2	17 ± 2
% Scrapers	1 ± 0.4	1 ± 1	1 ± 0.2	1 ± 0.2
% Shredders	3 ± 1	3 ± 1	4 ± 1	4 ± 1

Euclidean distances were shorter between the two upstream stations than between either upstream station and the downstream station in five of the six surveys. This indicated that macroinvertebrate community composition indeed differed on an upstream/downstream basis (Table 23). Distances were shortest between the two upstream stations in spring 2003 and in all 2004 and 2005 survey periods.

Table 23. Euclidean distance between benthic macroinvertebrate samples from Lloyds Creek stations upstream and downstream of timber harvest during each of six survey periods, 2003-2005.

Winter		Spring	
Stream station	Euclidean Distance	Stream station	Euclidean Distance
2003		2003	
Upstream 1 - Upstream 2	62	Upstream 1 - Upstream 2	43
Upstream 2 - Downstream	34	Upstream 2 - Downstream	72
Upstream 1 - Downstream	70	Upstream 1 - Downstream	59
2004		2004	
Upstream 1 - Upstream 2	44	Upstream 1 - Upstream 2	41
Upstream 2 - Downstream	129	Upstream 2 - Downstream	113
Upstream 1 - Downstream	104	Upstream 1 - Downstream	105
2005		2005	
Upstream 1 - Upstream 2	26	Upstream 1 - Upstream 2	38
Upstream 2 - Downstream	71	Upstream 2 - Downstream	62
Upstream 1 - Downstream	58	Upstream 1 - Downstream	53

Results of the PCA were summarized by plotting the 54 sample scores along Axis 1 against the scores along Axis 2 (Figure 17). The first two axes had the highest eigenvalues and accounted for 50 % and 20 % of the variance in the data set, respectively. Axis 1 was positively correlated to the abundances of *Hydrobaenus* sp., and negatively correlated to the abundances of *Caecidotea* sp., *Hyalella azteca* and *Crangonyx* sp. Axis 2 was positively correlated to the abundances of *Caecidotea* sp., tubificid oligochaetes and *Hydrobaenus* sp., and was negatively correlated to the abundance of *Hyalella azteca, Palaemonetes kadiakensis,* and *Guttipelopia guttipennis*. Some sample clustering was evident, with winter samples of the 2003 and 2005 study years grouped closely along Axis 2, and to the right of 0 on Axis 1. Spring samples from all years and winter samples from 2004 tightly clustered on Axis 1, but were moderately separated along Axis 2 from –5 to 50. Samples were not segregated exclusively by any of the three main effects—year, season, or location.

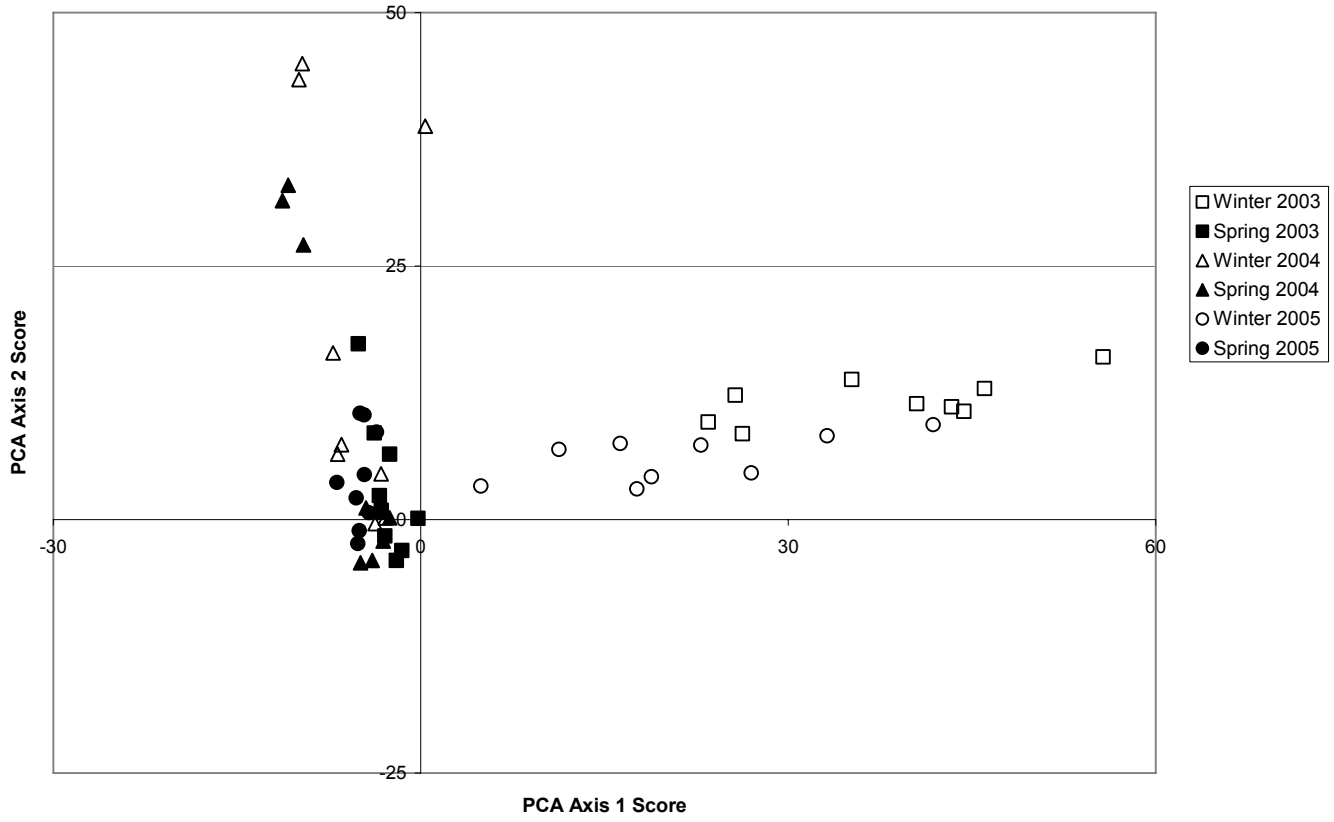

Figure 17. Plot of Lloyds Creek benthic macroinvertebrate sample scores on PCA axes 1 and 2.

4.6 MILL BRANCH (CLEVELAND COUNTY)

Water Quality

Water quality variables at Mill Branch differed on a seasonal basis, when they varied at all. The tributary ceased flowing in the winter of 2004, and stations consisted only of isolated pools. This strongly affected the levels of several variables. Mean stream temperature was consistently greater in the spring, although by a small margin in 2005 (Table 24). Conversely, dissolved oxygen concentration was slightly higher in the winter in 2003 and 2005, but markedly lower in winter 2004 due to the cessation of flow. These two variables also exhibited a weak spatial pattern of lower temperature and higher DO concentration at the downstream station, probably reflecting the timing of collection during the day. Values of pH ranged between 5.1 and 6.2, but did not exhibit clear annual, seasonal, or spatial patterns. Conductivity levels were markedly higher during the winter 2003 survey period and lower during the spring 2003 period, but otherwise did not conform to clear patterns of variation. Discharge was greater in the spring samples of

2003 and 2004, but greater in the winter of 2005. Discharge was always highest at the downstream station.

Table 24. Water quality measurements at Mill Branch sampling stations during each of the six survey periods.

Variable	Station	Winter 2003	Spring 2003	Winter 2004	Spring 2004	Winter 2005	Spring 2005
Temperature	1 (Up)	8.8	14.3	4.9	16.6	9.5	10.7
(^{o}C)	2 (Up)	8.5	14.1	7.7	16.6	9.0	9.8
	3 (Down)	7.7	13.2	4.4	16.6	8.9	9.7
Dissolved	1 (Up)	10.58	9.44	1.56	8.59	10.44	10.47
Oxygen	2 (Up)	10.96	9.49	1.92	8.57	10.32	9.04
(mg/L)	3 (Down)	11.24	10.09	2.13	9.29	10.84	10.36
pH	1 (Up)	5.25	5.17	6.22	5.13	5.51	5.28
	2 (Up)	5.42	5.10	5.44	5.19	5.35	5.32
	3 (Down)	5.38	5.23	5.67	5.35	5.60	5.09
Conductivity	1 (Up)	438	21	138	186	198	258
(mS/cm)	2 (Up)	407	22	110	141	180	242
	3 (Down)	453	22	96	161	169	211
Discharge	1 (Up)	0.016	0.060	0.000	0.065	0.035	0.010
(m^3/sec)	2 (Up)	0.014	0.062	0.000	0.056	0.038	0.005
	3 (Down)	0.014	0.071	0.000	0.080	0.047	0.010

Variables associated with sediment inputs were typically similar at upstream and downstream stations before and after the timber harvest (Figure 18). Turbidity was at or below 3 NTU except in winter 2004, when greater levels were found at all locations. Similarly, total suspended solids (TSS) were similar between stations and sampling periods with the exception again occurring in the winter 2004 survey. Atypically high values and high variability of turbidity and TSS in winter 2004 reflected the ceased flow in this period. Samples were collected from isolated pools of various volumes. Pools at Station 1, the most upstream site, were the smallest and thus suspended materials may have been most concentrated.

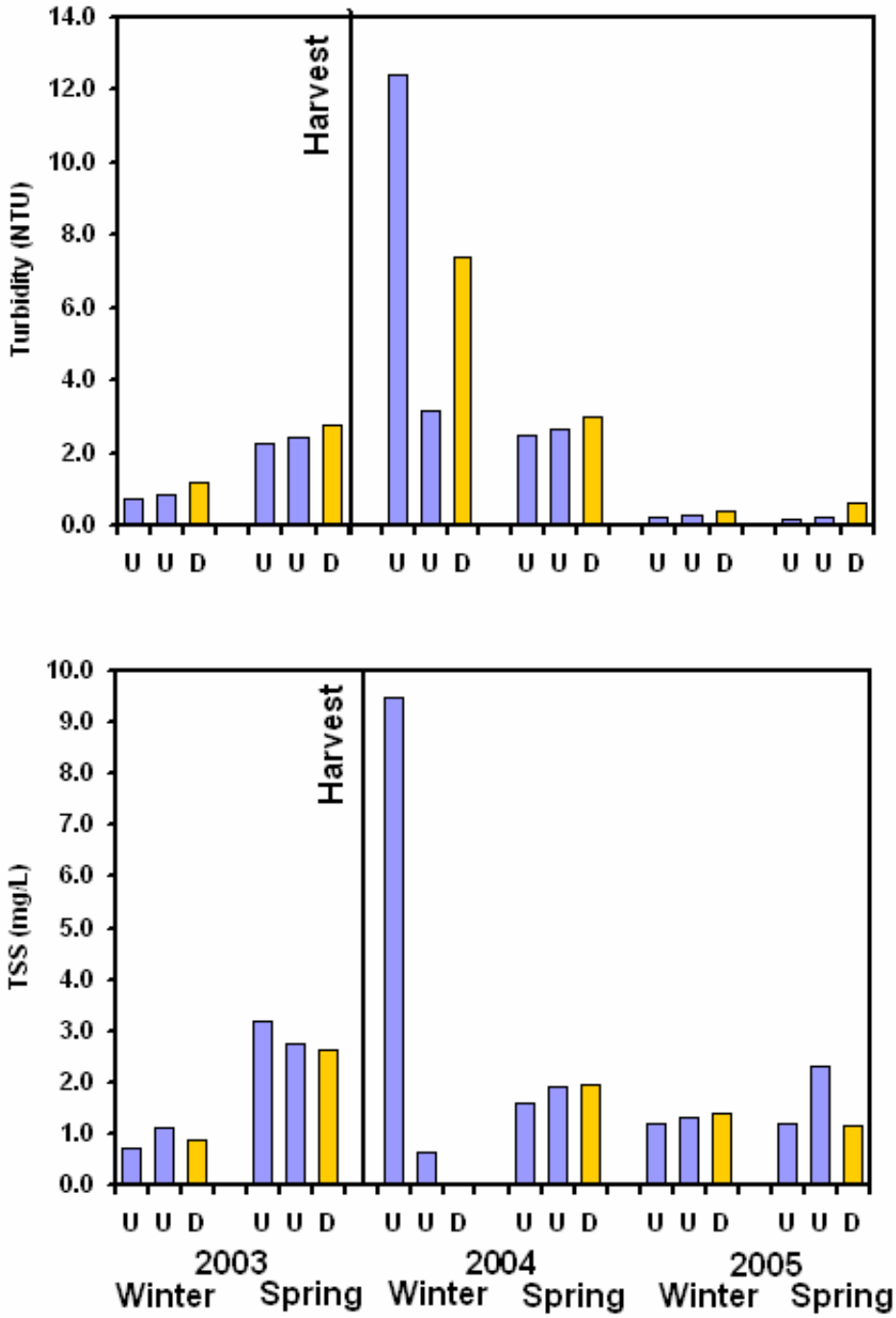

Figure 18. Turbidity and total suspended solids (TSS) concentration at Mill Branch stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

Nitrate concentrations were higher at the downstream station in the winter and spring preceding the timber harvest, and substantially higher in the survey immediately following the harvest (Figure 19). Afterward, nitrate levels at the downstream station

were less than those of upstream stations. Orthophosphate concentrations at the downstream station were generally less than or approximately equal to those of the upstream stations in both pre- and post-harvest surveys. Neither seasonal nor annual trends in the concentrations of these nutrients were evident. No water quality variables differed statistically between areas upstream and downstream of the timber harvest in either spring or fall surveys (one-way ANOVA, $n = 3$, $\alpha = 0.05$).

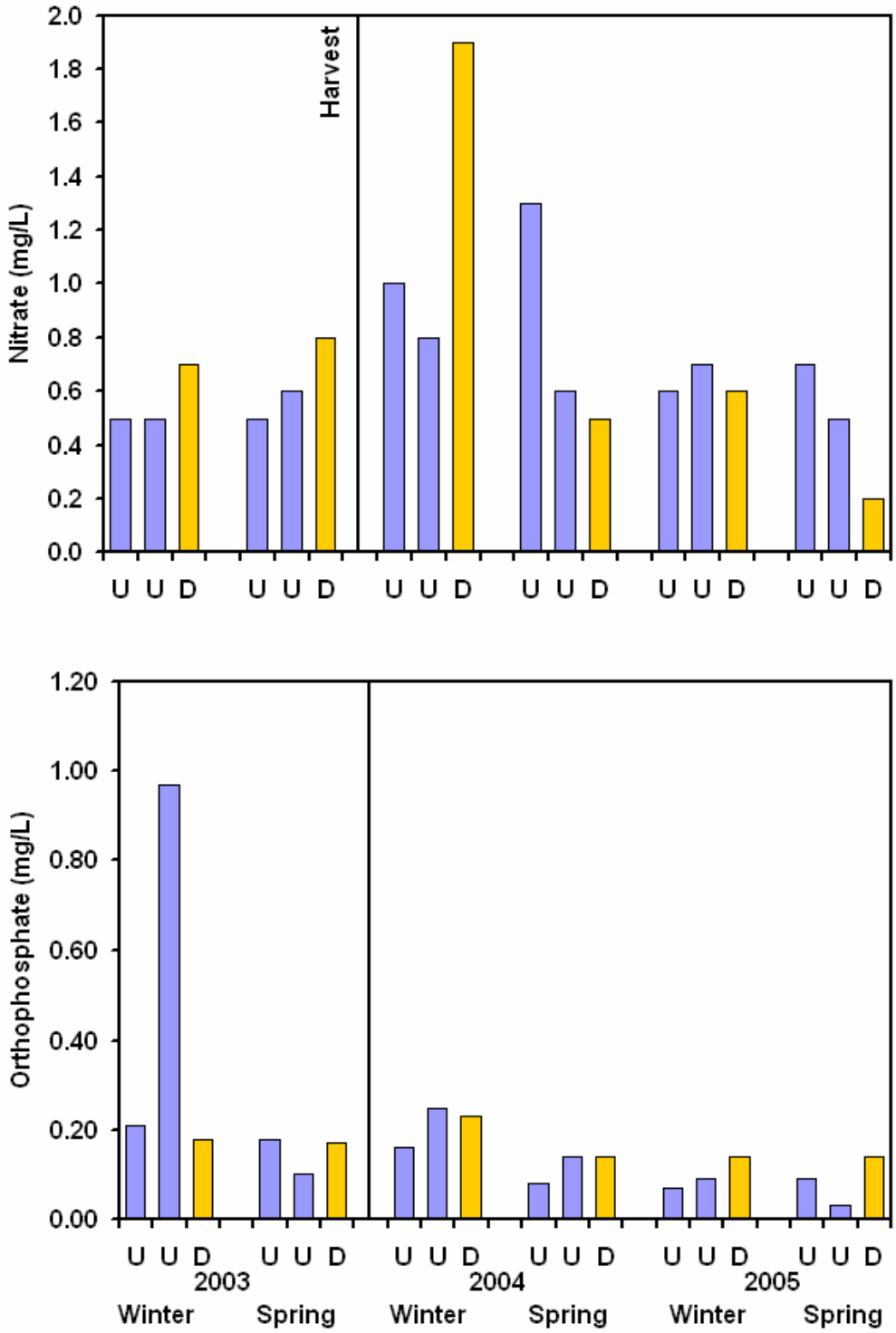

Figure 19. Nitrate and orthophosphate concentrations at Mill Branch stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods

Macroinvertebrates

Macroinvertebrate assemblage characteristics at Mill Branch principally differed between seasons. Total richness and EPT richness were each significantly greater in spring surveys, but did not differ by location upstream or downstream of the timber harvest or study year before or after the harvest (Table 25). HBI was also significantly higher in the spring, but did not differ between locations or years. Relative abundance of EPT organisms, and of Plecoptera—the major component order of the group at this stream—were significantly greater in the winter than the spring. This reflected the increased collection of the winter stonefly, *Allocapnia* sp., which was the only EPT taxon found in abundance in Mill Branch (Appendix F). Percent Trichoptera was greater in the spring, due to higher numbers of the limnephilid *Ironoquia* sp. Both *Allocapnia* sp. and *Ironoquia* sp. were, on average, more abundant in 2003.

Table 25. Mean ± standard error for macroinvertebrate assemblage characteristics at Mill Branch by season, by location upstream or downstream of the timber harvest, and by study year before or after the harvest. * indicates $p < 0.05$; ** indicates $p < 0.01$. Variables with KW were tested with non-parametric Kruskal-Wallis test instead of GLM ANOVA, due to violation of equal variance assumption.

	Season		Location		Harvest	
	Winter n = 27	Spring n = 27	Upstream n = 36	Downstream n = 18	Before n = 18	After n = 36
Total richness	14.0 ± 0.8	17.8 ± 0.6**	15.5 ± 0.6	16.6 ± 1.2	15.8 ± 0.4	15.9 ± 0.8
EPT richness^{KW}	1.9 ± 0.2	3.3 ± 0.4*	2.5 ± 0.3	2.9 ± 0.5	3.5 ± 0.4*	2.2 ± 0.3
Hilsenhoff Biotic Index^{KW}	5.7 ± 0.4	6.8 ± 0.1**	6.3 ± 0.2	6.1 ± 0.4	6.2 ± 0.2	6.3 ± 0.3
% EPT^{KW}	30 ± 4**	9 ± 2	17 ± 3	25 ± 5	23 ± 3*	17 ± 3
% Ephemeroptera^{KW}	0.3 ± 0.1	1 ± 0.2	1 ± 0.2	0.1 ± 0.1	1 ± 0.3*	0.2 ± 0.1
% Plecoptera^{KW}	28 ± 4**	5 ± 1	15 ± 3	22 ± 5	19 ± 4	16 ± 3
% Trichoptera^{KW}	1 ± 0.3	3 ± 1**	2 ± 0.3	3 ± 1	4 ± 0.4**	1 ± 0.4
% Dominant Taxon	46 ± 2	44 ± 3	46 ± 2	43 ± 4	48 ± 2	43 ± 3
% Diptera^{KW}	23 ± 4	17 ± 3	16 ± 2	28 ± 6	6 ± 1	27 ± 3**
% Chironomidae	9 ± 2	13 ± 3	10 ± 2	13 ± 3	4 ± 1	15 ± 2**
% Non-insects	42 ± 4	72 ± 3**	63 ± 4**	45 ± 5	69 ± 4**	51 ± 4
Functional Feeding Groups						
% Collectors^{KW}	62 ± 4	81 ± 2**	75 ± 3*	65 ± 4	73 ± 4	71 ± 3
% Filterers^{KW}	1 ± 0.2	1 ± 0.2	1 ± 0.2	1 ± 0.3	0.3 ± 0.1	1 ± 0.2*
% Predators^{KW}	7 ± 1	10 ± 1	8 ± 1	10 ± 2	4 ± 1	10 ± 1**
% Scrapers^{KW}	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0	0.1 ± 0.1	0.2 ± 0.1	0.1 ± 0
% Shredders^{KW}	30 ± 4**	8 ± 1	16 ± 3	24 ± 5	23 ± 4*	17 ± 3

This resulted in a significantly greater Percent EPT before the cut as opposed to after. Percent Ephemeroptera was also higher before the timber harvest, but numbers of this group were low in all years, seasons and locations.

The relative abundance of the dominant taxon did not differ by any of the three main effects. Percent Diptera and Percent Chironomidae were both greater in survey years after the harvest. This pattern was attributable to the increased collection of the culicid *Aedes* sp. and the chironomids *Heterotrissocladius marcidus* and *Zavrelimyia* sp. in 2004 and 2005. *Aedes* sp. was only found in winter 2004, when stream flow ceased. Non-insects typically dominated the macroinvertebrate assemblage in this stream. Percent non-insects, primarily *Synurella bifurca* and *Caecidotea* sp., was significantly greater in the spring, in locations upstream of the harvest, and in the study year prior to the harvest.

Differences in the relative abundances of functional feeding groups were most associated with the same taxa listed above. Percent Collectors (*Synurella bifurca* and *Caecidotea* sp.) was significantly greater in the spring, and greater upstream of the timber harvest, but did not differ between survey years. In contrast, Percent Shredders (*Allocapnia* sp. and *Ironoquia* sp.) was higher in the winter, and in the year preceding the cut, but did not statistically differ between upstream and downstream locations (Table 26).

Table 26. Mean ± standard error for macroinvertebrate assemblage characteristics at Mill Branch by the interaction of study year and location upstream or downstream of the timber harvest.

	Before Harvest		After Harvest	
	Upstream n = 12	Downstream n = 6	Upstream n = 24	Downstream n = 12
Total richness	15.7 ± 0.5	16.0 ± 0.8	15.5 ± 0.9	16.8 ± 1.7
EPT richness	3.6 ± 0.5	3.3 ± 0.6	1.9 ± 0.3	2.7 ± 0.7
Hilsenhoff Biotic Index	6.4 ± 0.2	6.0 ± 0.3	6.3 ± 0.4	6.2 ± 0.5
% EPT	20 ± 3	30 ± 7	15 ± 4	22 ± 7
% Ephemeroptera	1 ± 0.4	0.2 ± 0.2	0.3 ± 0.2	0 ± 0
% Plecoptera	16 ± 4	25 ± 8	14 ± 4	20 ± 6
% Trichoptera	3 ± 0.4	5 ± 1	1 ± 0.2	2 ± 1
% Dominant Taxon	49 ± 3	46 ± 4	44 ± 3	42 ± 6
% Diptera	5 ± 1	7 ± 1	22 ± 3	38 ± 7
% Chironomidae	3 ± 1	4 ± 1	13 ± 3	18 ± 4
% Non-insects	73 ± 4	61 ± 8	58 ± 5	38 ± 5
Functional Feeding Groups				
% Collectors	77 ± 4	64 ± 7	74 ± 4	65 ± 5
% Filterers	0.2 ± 0.1	1 ± 0.3	1 ± 0.3	1 ± 0.3
% Predators	4 ± 1	5 ± 1	10 ± 1	12 ± 3
% Scrapers	0.1 ± 0.1	0.3 ± 0.2	0.1 ± 0.1	0 ± 0
% Shredders	19 ± 4	30 ± 7	15 ± 4	22 ± 6

The relative abundance of predators (*Zavrelimyia* sp.) was greater in years following the harvest, but did not differ significantly between seasons or locations. Filterers and scrapers were not commonly collected at Mill Branch. None of the 16 assemblage characteristics measured indicated an interaction between location and survey year. Annual patterns at upstream locations consistently resembled those at the downstream location. In most cases, this could not be tested statistically due to violations of the equal variance assumption.

Euclidean distance did not clearly indicate that macroinvertebrate community composition differed on an upstream/downstream basis. Distances were usually comparable among locations, and during three periods the distance was shortest between one of the upstream stations and the downstream station (Table 27). Distances were shortest between the two upstream stations in both 2003 survey periods and in spring 2004. Results of the

Table 27. Euclidean distance between benthic macroinvertebrate samples from Mill Branch stations upstream and downstream of timber harvest during each of six survey periods, 2003-2005.

Winter		Spring	
Stream station	Euclidean Distance	Stream station	Euclidean Distance
2003		2003	
Upstream 1 - Upstream 2	37	Upstream 1 - Upstream 2	18
Upstream 2 - Downstream	83	Upstream 2 - Downstream	43
Upstream 1 - Downstream	56	Upstream 1 - Downstream	37
		Harvest	
2004		2004	
Upstream 1 - Upstream 2	132	Upstream 1 - Upstream 2	27
Upstream 2 - Downstream	182	Upstream 2 - Downstream	111
Upstream 1 - Downstream	129	Upstream 1 - Downstream	120
2005		2005	
Upstream 1 - Upstream 2	78	Upstream 1 - Upstream 2	106
Upstream 2 - Downstream	81	Upstream 2 - Downstream	54
Upstream 1 - Downstream	38	Upstream 1 - Downstream	93

PCA were summarized by plotting the 54 sample scores along Axis 1 against the scores along Axis 2 (Figure 20). The first two axes had the highest eigenvalues and accounted for 45 % and 28 % of the variance in the data set, respectively. Axis 1 was positively correlated to the abundances of *Allocapnia* sp. and *Aedes* sp., and negatively correlated to the abundances of *Synurella bifurca* and *Caecidotea* sp. Axis 2 was positively correlated to the abundances of *Synurella bifurca* and *Allocapnia* sp., and was negatively correlated

to the abundance of *Aedes* sp. Sample clustering was evident, with spring samples of all study years grouped closely along Axis 2, and to the left of 0 on Axis 1. Winter samples were additionally separated by survey year. Winter 2003 samples were clustered in the upper middle portion of the graph, whereas winter 2004 and winter 2005 samples were grouped in the upper right and lower right, respectively.

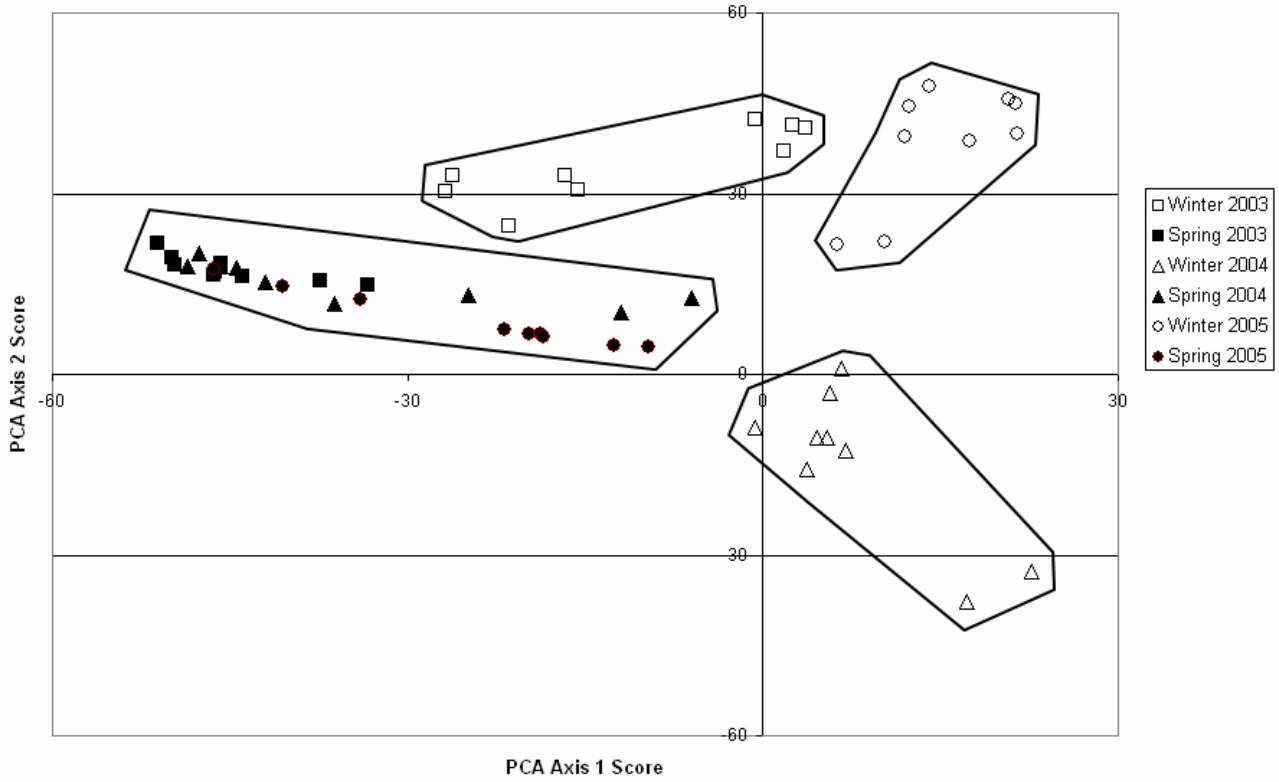

Figure 20. Scatterplot of Mill Branch benthic macroinvertebrate sample scores on PCA axes 1 and 2.

4.7 THOMPSON CREEK (VAN BUREN COUNTY, OZARK HIGHLANDS)

Water Quality

Most water quality variables at Thompson Creek did not consistently differ between areas upstream and downstream of the timber harvest either before or after the harvest (Table 28). Water temperature means were slightly lower at the station downstream of the cut in both winter and spring, probably because measurements were always made earliest in the day at this location. Likewise, dissolved oxygen concentrations were generally highest at the downstream station. Neither temperature nor dissolved oxygen appeared to vary between pre- and post-harvest survey years. Mean pH levels were slightly higher at the downstream location. Conductivity varied widely (10 to 180 mS/cm) over the course of the study, but did not exhibit any clear annual, seasonal or spatial trend. Stream discharge was always greatest at the downstream station, but did

not consistently differ between seasons. Nor did discharge appear to increase generally after the timber harvest (Table 28).

Table 28. Water quality measurements at Thompson Creek sampling stations during each of the six survey periods. Up = upstream of the harvest site; down = downstream of the harvest site.

Variable	Station	Winter 2003	Spring 2003		Winter 2004	Spring 2004	Winter 2005	Spring 2005
Temperature	1 (Up)	6.1	11.3		11.9	11.2	7.2	11.1
(^{o}C)	2 (Up)	5.8	10.8		11.9	9.6	6.5	10.6
	3 (Down)	3.8	9.1		11.9	8.8	4.5	10.0
Dissolved	1 (Up)	10.78	10.45		10.49	10.18	11.18	10.88
Oxygen	2 (Up)	10.66	10.64		10.46	10.84	11.46	10.95
(mg/L)	3 (Down)	11.96	10.74		10.56	10.64	12.76	11.21
pH	1 (Up)	6.34	6.58	Timber harvest	6.49	6.09	6.42	6.52
	2 (Up)	6.09	6.62		6.54	6.14	6.63	6.58
	3 (Down)	6.34	6.56		6.72	6.37	6.46	6.73
Conductivity	1 (Up)	176	41.8		26.7	9.85	37.5	32.0
(mS/cm)	2 (Up)	182	40.6		27.2	10.85	29.7	31.4
	3 (Down)	169	36.5		26.1	9.58	27.3	31.6
Discharge	1 (Up)	0.010	0.056		0.071	0.025	0.025	0.108
(m^3/sec)	2 (Up)	0.020	0.070		0.079	0.052	0.031	0.123
	3 (Down)	0.026			0.111	0.058	0.037	0.170

Turbidity levels were higher at the downstream station in the winter before and in all survey periods after the harvest, and were highest in spring 2005 when stream flow was also highest (Figure 21). Similarly, total suspended solids (TSS) were correlated with discharge conditions, and were highest in spring 2005. Unlike turbidity, however, TSS concentrations were not usually higher at the downstream station.

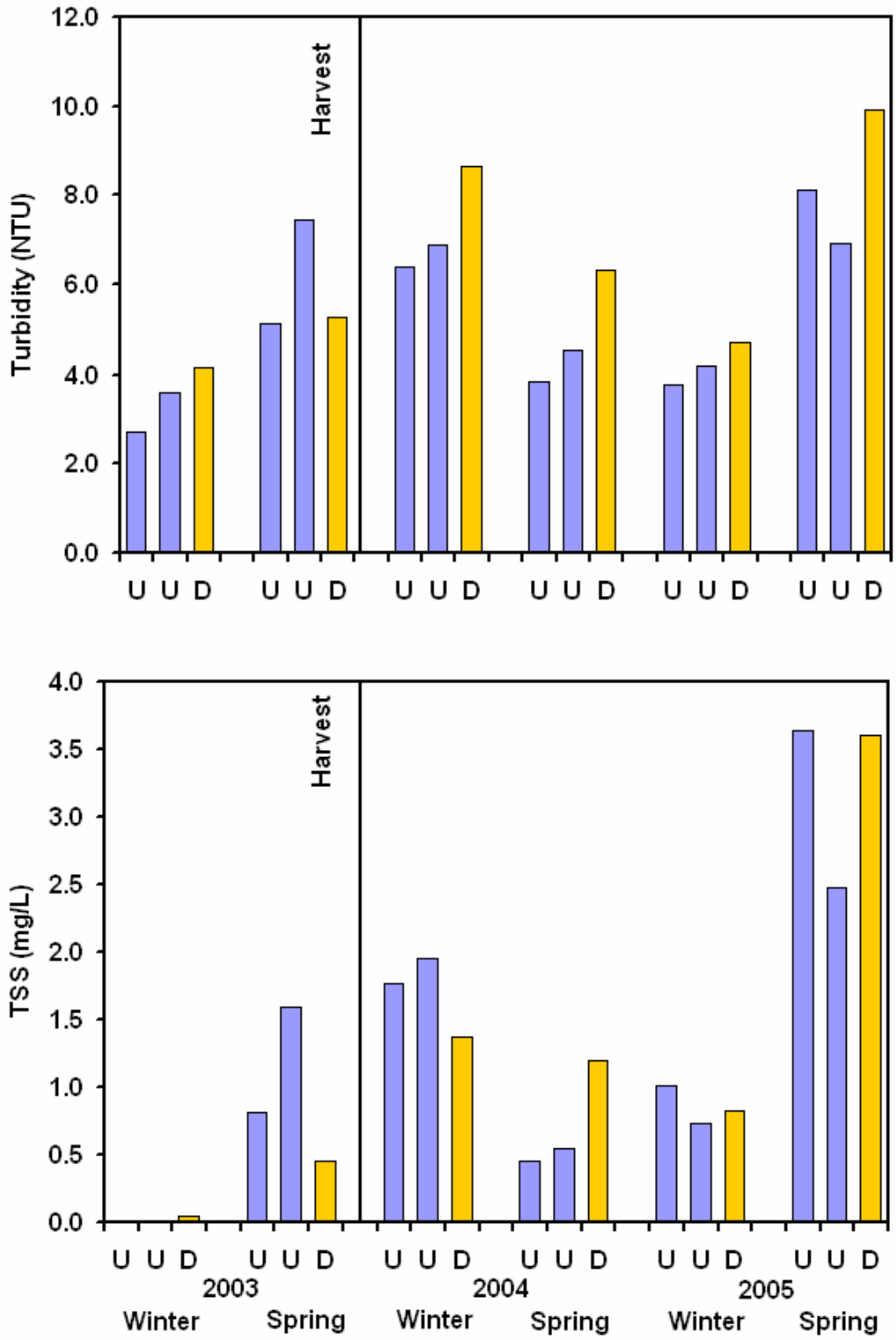

Figure 21. Turbidity and total suspended solids (TSS) concentration at Thompson Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

Nitrate and orthophosphate concentrations at the downstream station were less than or

approximately equal to those of the upstream stations in most pre- and post-harvest surveys (Figure 22). The exceptions to this pattern were the higher (~0.4 mg/L) nitrate level downstream in spring 2004, and the higher downstream orthophosphate levels in both 2004 surveys.

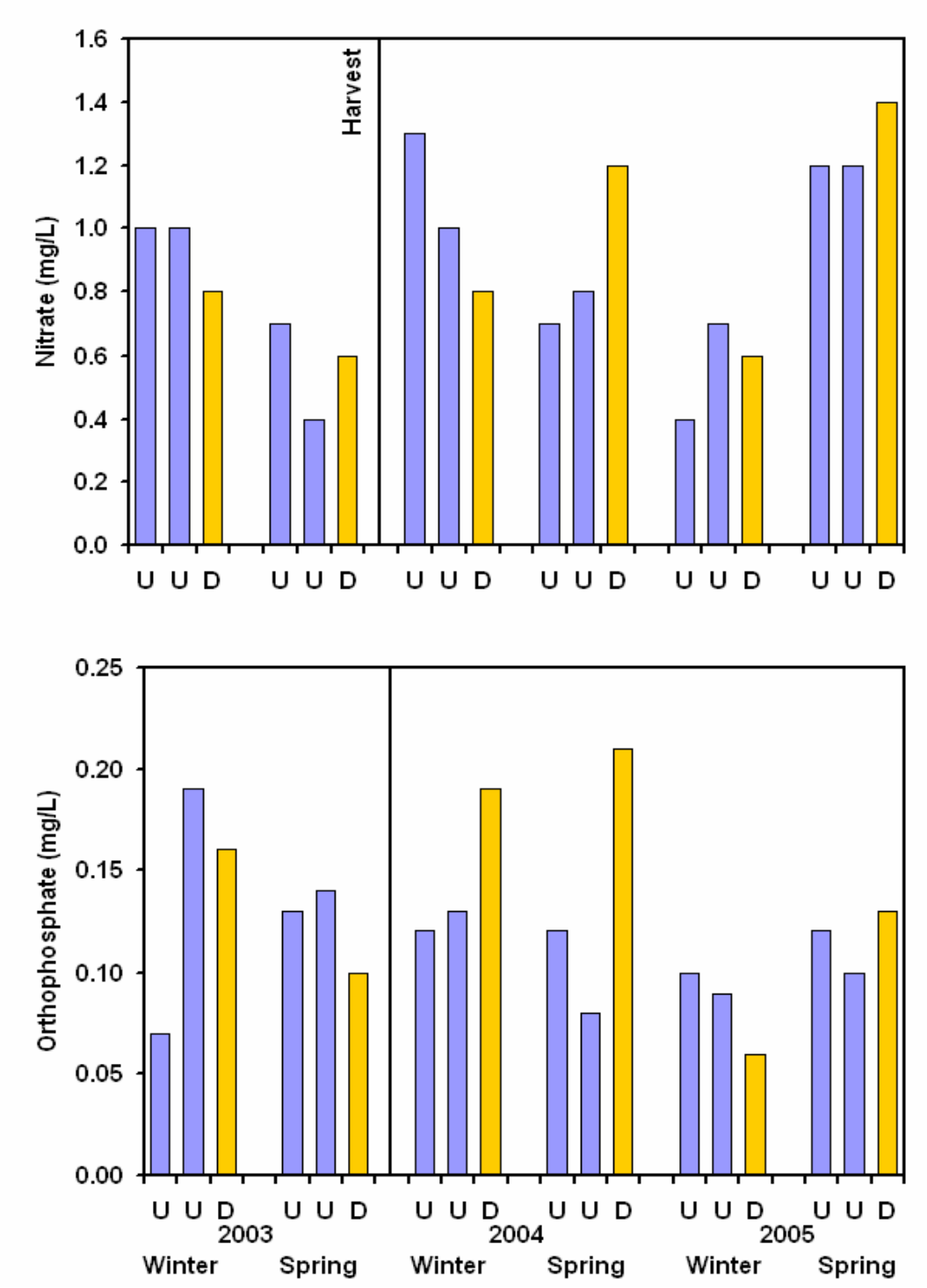

Figure 22. Nitrate and orthophosphate concentrations at Thompson Creek stations upstream (U) and downstream (D) of the timber harvest during each of six survey periods.

Nutrient levels did not conform to clear annual or seasonal patterns. A one-way analysis of variance testing whether values differed between stations, using study years as replicates, did not indicate significant differences ($\alpha = 0.05$) in any water quality variables in either spring or winter samples.

Macroinvertebrates

Total richness of macroinvertebrate assemblages was significantly greater upstream of the timber harvest, and after the harvest (both $p < 0.01$)(Table 29). There was no interaction between location and study year, however, because total richness increased after the cut at both upstream and downstream locations (Table 30). EPT richness was greater in post-harvest study years, but did not statistically differ by season or location. HBI was greater in the winter than the spring, but did not differ by location or survey year. Greater winter abundance of *Lirceus* sp., a pollution-tolerant isopod in the collector functional feeding group, was the primary factor in the significant seasonal differences in HBI, Percent Dominant Taxon, Percent Non-Insects, and Percent Collectors. In contrast, Percent EPT organisms and Percent Plecoptera were greater in the spring due to higher numbers of the stoneflies *Amphinemura* sp. and *Isoperla* sp. (Appendix G). Increased abundance of predators in the spring was also mostly attributable to the higher numbers of *Isoperla* sp. Percent Diptera and Percent Chironomidae were also greater in the spring, reflecting increased collection of the blackfly *Prosimulium* sp. and the chironomid *Polypedilum aviceps*. With regard to differences between locations, Percent Diptera, Percent Chironomidae and Percent Filterers were each greater upstream of the timber harvest (all $p < 0.01$). Increased upstream collection of *Prosimulium* sp. (Diptera, filterer), *Tipula* sp. (Diptera), *Microtendipes pedellus* gp. (Diptera, Chironomidae, filterer) and *Tribelos jucundum* (Diptera, Chironomidae) were the principal factors accounting for these trends. Percent Ephemeroptera was significantly greater after the harvest, particularly at the location downstream of the cut, due to increased abundance of *Acentrella/Plauditus* spp., *Leucrocuta* sp., *Paraleptophlebia* sp. and *Stenonema femoratum*. In contrast, Percent Plecoptera decreased significantly after the timber harvest. This pattern was also most evident at the downstream location. *Allocapnia* sp. and *Strophopteryx* sp. were the taxa most attributable for this difference. Percent Chironomidae was statistically greater after the harvest, due to increased numbers of *Microtendipes pedellus* gp., *Polypedilum aviceps*, and *Thienemannimyia* gp. (Appendix G). Percent Filterers, primarily represented by *Prosimulium* sp. and Percent Shredders, largely *Allocapnia* sp. and *Strophopteryx* spp., were greater before the cut. Percent Predators (*Isoperla* sp. and *Clioperla clio*) and Percent Scrapers (*Leucrocuta* sp. and *Stenonema femoratum*), however, were significantly greater after the harvest.

Table 29. Mean ± standard error for macroinvertebrate assemblage characteristics at Thompson Creek by season, by location upstream or downstream of the timber harvest, and by study year before or after the harvest. * indicates $p < 0.05$; ** indicates $p < 0.01$. Variables with KW superscript were tested with non-parametric Kruskal-Wallis test instead of GLM ANOVA, due to violation of equal variance assumption.

	Season		Location		Harvest	
	Winter n = 27	Spring n = 27	Upstream n = 36	Downstream n = 18	Before n = 18	After n = 36
Total richness	25.4 ± 1.2	25.7 ± 0.7	26.8 ± 0.7**	23.0 ± 1.5	22.1 ± 1.3	27.3 ± 0.7**
EPT richness^{KW}	11.2 ± 0.8	12.2 ± 0.3	11.8 ± 0.4	11.5 ± 1.0	9.8 ± 0.8	12.6 ± 0.5**
Hilsenhoff Biotic Index	5.7 ± 0.1**	4.6 ± 0.1	5.2 ± 0.1	4.9 ± 0.2	5.0 ± 0.2	5.2 ± 0.1
% EPT^{KW}	42 ± 2	48 ± 1*	43 ± 1	47 ± 3	44 ± 2	45 ± 2
% Ephemeroptera	13 ± 2	14 ± 2	14 ± 1	13 ± 3	8 ± 2	17 ± 1**
% Plecoptera^{KW}	21 ± 2	28 ± 2**	23 ± 2	29 ± 3	31 ± 3**	22 ± 2
% Trichoptera	7 ± 1	5 ± 1	7 ± 1	6 ± 1	5 ± 1	7 ± 1
% Dominant Taxon^{KW}	32 ± 2**	25 ± 1	28 ± 1	31 ± 2	29 ± 2	29 ± 1
% Diptera	16 ± 1	22 ± 2**	23 ± 1**	13 ± 1	21 ± 3	19 ± 1
% Chironomidae	9 ± 1	12 ± 1*	12 ± 1**	7 ± 1	7 ± 1	12 ± 1**
% Non-insects^{KW}	40 ± 2**	28 ± 2	32 ± 1	38 ± 3	34 ± 2	34 ± 2
Functional Feeding Groups						
% Collectors^{KW}	51 ± 2**	40 ± 2	45 ± 2	47 ± 3	45 ± 3	46 ± 2
% Filterers	10 ± 1	11 ± 2	12 ± 1**	6 ± 1	13 ± 2*	9 ± 1
% Predators^{KW}	10 ± 1	19 ± 2**	14 ± 1	15 ± 2	7 ± 1	18 ± 1**
% Scrapers^{KW}	9 ± 1	10 ± 1	9 ± 1	10 ± 2	4 ± 1	12 ± 1**
% Shredders^{KW}	20 ± 2	20 ± 2	20 ± 2	22 ± 3	30 ± 3**	16 ± 1

Table 30. Mean ± standard error for macroinvertebrate assemblage characteristics at Thompson Creek by the interaction of study year and location upstream or downstream of the timber harvest. Variables with * had significant ($p < 0.05$) interaction effects. Variables with X superscript had significant interaction effect indicated by GLM ANOVA, but treatment groups did not have equal variances.

	Before Harvest		After Harvest	
	Upstream n = 12	Downstream n = 6	Upstream n = 24	Downstream n = 12
Total richness	24.3 ± 1.2	17.5 ± 2.2	28.1 ± 0.7	25.8 ± 1.3
EPT richness	10.3 ± 0.7	8.8 ± 1.7	12.5 ± 0.5	12.8 ± 1.0
Hilsenhoff Biotic Index	5.19 ± 0.25	4.68 ± 0.24	5.26 ± 0.15	4.97 ± 0.29
% EPT	41 ± 2	49 ± 1	44 ± 2	47 ± 4
% Ephemeroptera*	10 ± 3	2 ± 1	16 ± 1	19 ± 3
% Plecoptera^{X}	26 ± 3	42 ± 3	21 ± 2	22 ± 2
% Trichoptera	5 ± 1	5 ± 2	7 ± 1	6 ± 1
% Dominant Taxon	27 ± 2	31 ± 3	28 ± 1	31 ± 4
% Diptera	26 ± 3	12 ± 3	21 ± 1	14 ± 1
% Chironomidae	10 ± 2	2 ± 0.3	13 ± 1	10 ± 1
% Non-insects	31 ± 3	39 ± 3	33 ± 2	37 ± 5
Functional Feeding Groups				
% Collectors	47 ± 4	41 ± 2	44 ± 2	50 ± 3
% Filterers	16 ± 2	9 ± 3	11 ± 1	5 ± 1
% Predators	7 ± 1	7 ± 1	17 ± 2	19 ± 2
% Scrapers	5 ± 1	3 ± 1	11 ± 1	14 ± 2
% Shredders	25 ± 3	40 ± 3	17 ± 1	12 ± 1

Euclidean distance calculations did not indicate that macroinvertebrate assemblage composition differed substantially between locations upstream and downstream of the cut. Distances were generally similar between locations (Table 31). In three of the six survey periods, the distance was shortest between one of the upstream stations and the downstream stations.

Table 31. Euclidean distance between benthic macroinvertebrate samples from Thompson Creek stations upstream and downstream of timber harvest during each of six survey periods, 2003-2005.

Winter		Spring	
Stream station	Euclidean Distance	Stream station	Euclidean Distance
2003		2003	
Upstream 1 - Upstream 2	174	Upstream 1 - Upstream 2	155
Upstream 2 - Downstream	288	Upstream 2 - Downstream	179
Upstream 1 - Downstream	172	Upstream 1 - Downstream	101
		Harvest	
2004		2004	
Upstream 1 - Upstream 2	60	Upstream 1 - Upstream 2	189
Upstream 2 - Downstream	173	Upstream 2 - Downstream	101
Upstream 1 - Downstream	149	Upstream 1 - Downstream	244
2005		2005	
Upstream 1 - Upstream 2	98	Upstream 1 - Upstream 2	102
Upstream 2 - Downstream	106	Upstream 2 - Downstream	137
Upstream 1 - Downstream	104	Upstream 1 - Downstream	130

Results of the PCA were summarized by plotting the 54 sample scores along Axis 1 against the scores along Axis 2 (Figure 23). The first two axes had the highest eigenvalues, accounting for 40 % and 22 % of the variance in the data set, respectively. Axis 1 was positively correlated to the abundances of *Strophopteryx* sp. and *Prosimulium* sp., and negatively correlated to the abundance of *Lirceus* sp. This pattern somewhat reflected an interaction of year and season abundance patterns, as the former two taxa were most numerous in the spring of the 2003 and 2004 study years. *Lirceus* sp., however, was more abundant in the winter and was very abundant in 2005. Axis 2 was positively correlated to the abundances of *Lirceus* sp. and *Allocapnia* sp. and negatively correlated to the abundances of *Leucrocuta* sp. and *Isoperla* sp. This axis appeared to be associated with seasonal differences only, as each of the taxa positively correlated with Axis 2 were more numerous in the winter and those negatively correlated were most abundant in the spring. Samples segregated moderately along both axes. Although there was some overlap, winter samples tended to be in the upper left quadrant of the scatter plot, with spring samples found below them. Spring samples from 2005 were clustered in

the lower left portion of the plot, and samples from earlier years were generally found to the right of them.

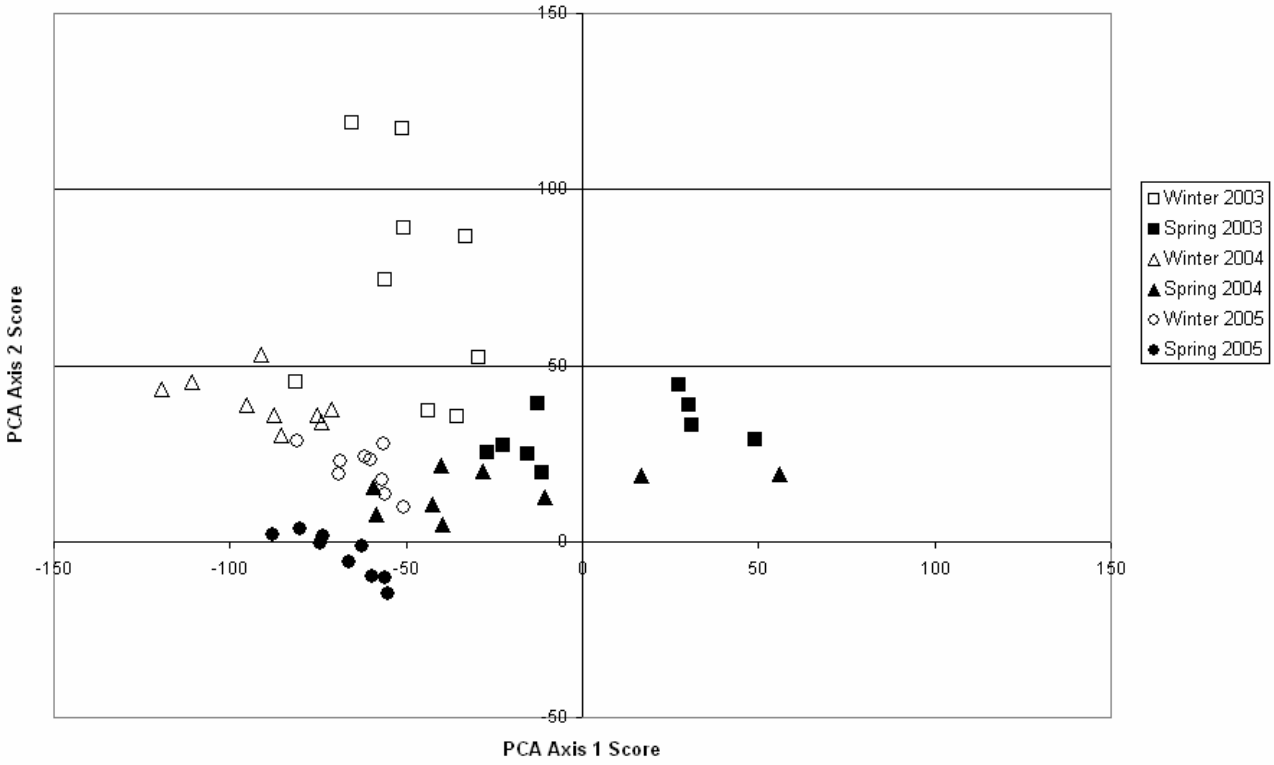

Figure 23. Scatter plot of Thompson Creek benthic macroinvertebrate sample scores on PCA axes 1 and 2.

4.8 OVERALL EFFECT OF SILVICULTURE BMPS ON BENTHIC MACROINVERTEBRATE ASSEMBLAGE PATTERNS IN ARKANSAS

Analysis of BMPs in Arkansas combing all streams and sites studied indicated a low level of effect. Very few macroinvertebrate community variables significantly differed between the main study effects, i.e., season, location above or below the harvest, and study year before or after the harvest, on a statewide basis (Table 32).

Percent Predators were greater in the spring than in the winter, and greater after the silviculture activities. In contrast, Percent Dominant Taxon was greater in the winter than in the spring. No significant interactions occurred between location and study year for any metric (Table 32).

Table 32. Overall effect of silviculture BMPs on stream benthic macroinvertebrates assemblages in Arkansas using GLM ANOVA . N = 7 for each of three study years.
* = p<0.05, ** = p< 0.01

Metric	Season (Winter vs. Spring)	Location (Upstream vs. Down)	Study Year (Before vs. After)	Location x Study Year Interaction
Total richness	---	---	---	---
EPT richness	---	---	---	---
Hilsenhoff index	---	---	---	---
% EPT	---	---	---	---
% Ephemeroptera	---	---	---	---
% Plecoptera	---	---	---	---
% Trichoptera	---	---	---	---
% Dominant taxa	Winter > Spring*	---	---	---
% Diptera	---	---	---	---
% Chironomidae	---	---	---	---
% Non-insects	---	---	---	---
Functional Feeding Groups				
% Collectors	---	---	---	---
% Filterers	---	---	---	---
% Predators	Spring > Winter*		After > Before**	---
% Scrapers	---	---	---	---
% Shredders	---	---	---	---

4.9 BMP IMPLEMENTATION SCORES AND TOTAL RICHNESS

A correlation analysis examining the relationship between the BMP implementation scores for the silviculture activities at the seven study sites and the change in total macroinvertebrate richness resulted in a Pearson correlation of –0.14 (p = 0.76). This result indicated no relationship between the degree of BMP implementation and the variation in the most sensitive macroinvertebrate community metric.

5.0 DISCUSSION

Water Quality

Water chemistry results did not reveal substantial differences attributable to the timber harvest at any of the seven streams evaluated in this study. Some variability between upstream and downstream stations was noted, but it was never statistically significant. In most cases, differences were considered within the range of natural variability.

Increased stream temperatures associated with logging were reported in studies in northern England (Gray and Edington 1969), Oregon (Brown and Krygier 1970) and New Hampshire (Burton and Likens 1973). This was hypothesized to result from the removal of the forest canopy, which led to greater insolation of the stream (Newbold et al. 1980; Campbell and Doeg 1989). More recent studies have indicated that the effect is reduced or eliminated by leaving forested buffer strips, an important aspect of BMP implementation, adjacent to the stream (Vowell and Frydenborg 2004). Kreutzweiser et al. (2005) and Haggerty et al. (2004) reported no stream temperature increases even with narrow (as low as 3 m wide) buffer strips, although in the latter study the authors felt that slash introduced to the stream acted as a thermal buffer. Part of the best management practices followed in Arkansas includes the establishment of stream management zones (SMZs) as areas of undisturbed riparian vegetative buffers that vary in width depending on local slope and soil conditions (AFC 2003). The present study suggests that the SMZs implemented in Arkansas are sufficient to prevent significant increases in stream water temperature.

Dissolved oxygen concentrations have been shown to be depressed by the addition of logging slash into adjacent streams in New Hampshire (Likens et al. 1970) and California (Burns 1972). For the BMP effectiveness study in which this trend was evaluated, dissolved oxygen did not differ between logged and unlogged sites in Florida after the timber harvest (Vowell and Frydenborg 2004). Similarly, the present study found no differences in this variable between upstream and downstream locations before or after the cuts. Further, no significant amount of logging slash was introduced into any of the seven study streams.

Likens et al. (1970) reported reduced pH and increased conductivity in a clear-cut watershed compared to an uncut watershed in New Hampshire. However, most studies reviewed did not report logging-related trends for these variables. Kedzierski and Smock (2001) found no differences in pH between undisturbed streams and streams that had been clear-cut three years previously in Virginia. Kreutzweiser et al. (2005) noted slightly, but not significantly, increased pH in streams draining clear-cut watersheds in Ontario. Of the BMP effectiveness studies reviewed, only Vowell and Frydenborg (2004) measured both pH and conductivity, and neither variable differed as a result of BMP logging. Results of the present study concur with their findings.

Early studies of silviculture effects found increased sediment transport into streams as a result of logging (Brown and Krygier 1971; Burns 1972). Gurtz et al. (1980) also reported greater amounts of particulate matter exported to streams in cut watersheds as opposed to undisturbed ones. However, Likens et al. (1970) did not find substantial differences in turbidity between cut and uncut watersheds in New Hampshire. But in

their study the logged timber was not removed, as it would be in a commercial clear-cut, and may have acted as a sediment trap protecting the stream. It has long been recognized that buffer strips adjacent to the stream as well as careful logging road placement would prevent sediment movement into stream channels (Haupt and Kidd (1965). In a Florida study of forestry BMP effectiveness, Vowell and Frydenborg (2004) found no differences in turbidity attributable to timber harvest. In the present study, turbidity and/or total suspended solids levels were frequently, though never significantly, greater at downstream stations after the harvest at three of the seven study steams (Caney Creek, Harris Creek and Thompson Creek). But the differences did not correspond to impaired biological communities in any of the three cases.

Likens et al. (1970) found that nutrient concentrations—including nitrate—increased dramatically in the stream of a clear-cut watershed in New Hampshire after the harvest. However, Noel et al. (1986) obtained mixed results with regard to evidence of increased nitrate concentrations in cutover streams when compared to undisturbed streams in the northeastern United States. In four of six cases, the cutover streams had higher nitrate levels. When BMPs were applied, no significant differences in nutrient concentrations between logged and undisturbed stream sites were observed in Florida (Vowell and Frydenborg 2004) or Ontario (Kreutzweiser et al. 2005). In the present study, variation in nutrient (nitrate and orthophosphate) concentrations was typically either unpatterned or of too small in magnitude to draw conclusions.

Increased stream flow as a result of logging was reported for watersheds in New Hampshire (Hornbeck et al. 1970) and North Carolina (Gurtz 1981). Other BMP effectiveness studies that were reviewed for this study did not directly measure stream discharge as a variable to potentially be affected by logging (Adams et al. 1995; Haggerty et al. 2004; Vowell and Frydenborg 2004; Kreutzweiser et al. 2005). In the present study, discharge frequently differed on an upstream/downstream basis, but only as a result of the increased area of watershed drained. At three of the seven study streams—Big Creek, Caney Creek, and Harris Creek—a tributary entered between the upstream and downstream stations. In these cases, stream flow clearly differed between locations. But no variation that appeared to be associated with logging activity was observed.

Water quality measurements were ancillary to the macroinvertebrate samples in this study, and were not specifically designed to reveal comprehensive, real-time differences between locations upstream and downstream of the harvest. For example, temperature and dissolved oxygen measurements were taken at different times of day for different locations. Thus, observed trends for these variables were influenced by diurnal variation that may have obscured any spatial variation if it were present. Further, trends for several of the water quality variables may have been observable only under high-flow conditions. In a study of watersheds in the Virginia coastal plain, Wynn et al. (2000) demonstrated that sediment and nutrient loadings primarily occur during storm events. For the present study, biological samples, and consequently water quality measurements, were taken by design only in low to moderate flow conditions. Thus, the possibility exists that high water flow conditions were missed that would have indicated greater physical and chemical impact.

Benthic Macroinvertebrates

Macroinvertebrate community patterns were primarily associated with seasonal variation, and to a lesser extent, annual variation. Occasional instances of community characteristics differing between locations upstream and downstream of a timber harvest were observed, but even these seemed more attributable to habitat variables than to logging effects. Total richness and/or richness of the Ephemeroptera, Plecoptera, and Trichoptera orders (= EPT richness) are very frequently used to assess the condition of macroinvertebrate communities (Barbour et al. 1992; Kerans and Karr 1994; DeShon 1995; ADEQ 2002). The principle underlying the usefulness of these variables is that healthy, stable biological communities in warm-water streams should have high species richness (DeShon 1995). Barbour et al. (1992) found that total richness was a useful characteristic for discriminating between reference sites in montane vs. valley and plains ecoregions in Colorado, Kentucky and Oregon. Total, and EPT, richness levels are expected to decrease with increasing disturbance to the system (Barbour et al., 1999). Lenat (1984) found that total richness was lower in North Carolina streams that were impaired by erosion from agricultural runoff when compared to well-managed streams. However, clear demonstration of reduced richness due to logging or logging-related effects has been more difficult to find in the literature. Newbold et al. (1980) found lower total richness in logged streams in 3 of 4 study blocks in California. Adams et al. (1995) noted that total richness and EPT richness were generally lower at South Carolina stream sites where inadequate compliance with BMP recommendations occurred. However, Hawkins et al. (1982) did not observe reduced total richness in California streams with lower amounts of canopy cover as compared to more densely covered streams. Noel et al. (1986) reported no reduction of richness in streams in clear-cut watersheds as opposed to uncut reference streams in New England. Stone and Wallace (1998) even found higher EPT richness in disturbed than reference streams in North Carolina at 1-year and 5-years post-harvest intervals. Not surprisingly then, studies in which forested buffer strips and/or additional BMPs were used to minimize logging effects have found no reductions in richness levels between cutover streams and reference streams (Boschung and O'Neil 1981; Haggerty et al. 2004; Kreutzweiser et al. 2005). In the present study, total richness and/or EPT richness were significantly lower at downstream locations at only two of seven study streams, Lloyds Creek (both) and Thompson Creek (total richness only). In each case, richness was lower at the downstream stations prior to the timber harvests; thus the patterns did not seem attributable to logging effects.

The Hilsenhoff Biotic Index (HBI) can also be used to characterize macroinvertebrate community samples. Values for this metric rise as environmental disturbance increases (Hilsenhoff 1987). A version of this metric was effective in discriminating between unimpaired and slightly impaired sites in California (Resh and Jackson 1993), and an analogous index—using different tolerance values—distinguished samples from a logged stream and a reference stream one-year after the timber harvest in North Carolina (Stone and Wallace 1998). HBI is used by the Arkansas Department of Environmental Quality as a component of its Stream Condition Index for small watersheds (ADEQ 2002). Adams et al. (1995) reported that a tolerance-based index analogous to HBI increased at logged South Carolina sites in which BMPs were inadequately implemented. In the present study, mean HBI scores were significantly lower (i.e., community quality was higher) at the station downstream of the cut at Big Creek, and significantly higher at the

downstream station at Lloyds Creek. At the latter study area, the HBI for downstream samples was higher before, as well as after, the timber harvest and therefore did not suggest a logging effect.

Mayflies, stoneflies and caddisflies (EPT), either individually or collectively, are frequently major components of macroinvertebrate communities in unimpaired upland streams (Herlihy et al. 2005). Additionally, many of the species in these orders have low to intermediate tolerances for pollution, and will disappear rapidly in systems under environmental stress (DeShon 1995). Thus, Percent EPT is expected to decrease with increasing disturbance. Lenat (1984) found that erosion from agricultural runoff caused reduced abundances of Ephemeroptera, Plecoptera, and Trichoptera in North Carolina streams. However, in studies of logging effects, it has often been found that abundances of members of these groups actually increased in streams of harvested watersheds in comparison to reference streams (Newbold et al. 1980; Gurtz and Wallace 1984; Noel et al. 1986). This phenomena has been attributed to increased primary production in the cutover streams, as a result of canopy removal and increased insolation of the streambed (Erman et al. 1977). In this study, Percent EPT did not differ significantly between upstream and downstream locations at any of the seven study sites, but the relative abundance of one or another of the constituent orders differed at three sites. At Caney Creek and Harris Creeks, Percent Plecoptera was greater at the downstream station, due to increased collection of *Amphinemura* sp., *Isoperla* sp. and *Strophopteryx* sp. (Caney Creek), and Chloroperlidae and *Paracapnia angulata* (Harris Creek). Conversely, Percent Trichoptera was statistically greater at upstream stations of Harris Creek, due to larger numbers of *Agapetus* sp., *Cheumatopsyche* sp. and *Chimarra* sp. In each of these cases, differential abundance between locations was noted prior to the timber harvest as well as after the cut; therefore no logging effects were indicated. At Thompson Creek, the interaction of location and study year was associated with opposing trends for Percent Ephemeroptera and Percent Plecoptera. After the timber harvest, Percent Ephemeroptera increased while Percent Plecoptera decreased, each by significant margins. The mayfly taxa accounting for the increased downstream abundance were all scraper or collector taxa (*Acentrella/Plauditus* spp., *Leucrocuta* sp., *Paraleptophlebia* sp. and *Stenonema femoratum*), which would fit the hypothesis of a response to increased primary production at the downstream station. This was one of the few indications of a logging effect observed in any of the seven streams included in this study.

Four community composition measures that are expected to increase with increasing disturbance are Percent Dominant Taxon, Percent Diptera, Percent Chironomidae and Percent Non-insects (Barbour et al. 1999; ADEQ 2002). Taxa in these groups are present in undisturbed macroinvertebrate assemblages, but tend to increase or even predominate in the communities of disturbed systems (DeShon 1995). Percent Dominant Taxon is used as a diagnostic characteristic by some state agencies in their stream biomonitoring programs (Bode et al. 1996; ADEQ 2002). Kerans and Karr (1994) used a similar dominance measure incorporating the two most abundant taxa in their benthic community index for rivers of the Tennessee Valley. Hawkins et al. (1982) found that this variable increased in California streams with greater amounts of open canopy in comparison to densely canopied streams. However, it did not differ between logged and unlogged streams in a North Carolina study (Stone and Wallace 1998). In the South Carolina study of logging BMP effectiveness, Percent Dominant Taxon was higher at sites in which

BMPs were poorly implemented (Adams et al. 1995). In the present study, Percent Dominant Taxon differed significantly between upstream and downstream locations at only one of the seven study sites. At Big Creek, it was greater upstream of the timber harvest, both before and after the cut, and thus did not indicate logging effects. The relative abundance of all or certain dipterans is also used in multimetric indices used for stream biomonitoring in some states (DeShon 1995; ADEQ 2002). Noel et al. (1986) reported that Percent Diptera was greater in logged streams than in undisturbed streams in their New Hampshire and Vermont study areas. In the present study significant differences in Percent Diptera were found at three of the seven streams tested. At Bailey Creek, Percent Diptera decreased after the harvest at upstream stations but did not change at the downstream station. At Caney Creek, this metric increased at upstream stations, but none of these patterns clearly indicated logging-related effects. Chironomids are a major component of the order Diptera, and generally conformed to the same trends observed for the larger group in this study. Percent Non-insects are used, in combination with a subset of the order Diptera, as a macroinvertebrate community characteristic in stream biological assessments in Ohio (DeShon 1995). In a review of other BMP effectiveness studies no information was found on the response of this group.. However, in a study of small pools of intermittent streams in Arkansas, abundances of two isopod taxa—*Caecidotea* sp. and *Lirceus* sp.—were greater in logged areas than in reference areas (Brown et al. 1997). In the present study, Percent Non-insects differed between locations at three of seven sites. At Caney Creek, relative abundance of non-insects (primarily *Caecidotea* sp.) decreased at upstream stations but increased at the downstream station after the harvest. This was another example of an assemblage shift possibly associated with silviculture activities. At Lloyds Creek and Mill Branch, Percent Non-insects were more abundant at particular locations, downstream at Lloyds Creek and upstream at Mill Branch, both before and after the harvest. Neither of these occurrences was indicative of a negative effect due to logging.

Measurement of the functional feeding group abundances allows the estimation of the food resource of a stream system; i.e., as the availability of the various food sources change, the relative abundances of different functional feeding groups will change correspondingly (Merritt and Cummins 1996). A pattern that was believed to indicate logging effects was a complex macroinvertebrate community shift where the abundance of shredders decreased and the abundances of collectors and scrapers increased (Gurtz and Wallace, 1984). This pattern fits the Vannote et al. (1980) prediction of structural patterns that would result when coarse particulate organic matter (CPOM) becomes less available and fine particulate organic matter (FPOM) becomes more available in a stream system. One would expect this resource shift to occur in response to clear-cut logging, as the principal CPOM source—the canopy—is removed and the major FPOM source—algal production—is stimulated by increased sunlight reaching the stream. In recent studies of BMP effectiveness, this shift was not reported (Adams et al. 1995; Vowell and Frydenborg 2004; Kreutzweiser et al. 2005). However, in a Washington study, the authors observed sharp increases of collectors and scrapers, but not decreased shredder abundance, in cutover streams (Haggerty et al., 2004). They speculated that large amounts of logging slash left in the cutover streams provided a short-term abundant food source for shredders, thus delaying the decrease in numbers of this group. In the present study, this compositional shift was not observed at six of the seven study sites even after

two years post-harvest. The exception involved significant increases in scrapers and collectors downstream of the harvest and after the harvest that occurred at Thompson Creek. Although the evidence was not conclusive, indications of a logging effect were occasionally observed at this stream site. However, no significantly reduced abundances of shredders at downstream locations after the timber harvest occurred at any site.

Euclidean distance measurements did not reveal clear differences in community structure between stations upstream and downstream of silviculture activities. Reference stations were as compositionally similar to downstream (treatment) stations as they were to other reference stations, indicating no change in community patterns due to timber harvest.

Principal components analysis performed on the macroinvertebrate data from each study site resulted in sample clustering that was predominantly on a seasonal basis. At Big Creek, Caney Creek, Harris Creek, Bailey Creek and Mill Branch, winter and spring samples were entirely separated, although for the latter two study streams some secondary separation between study years was also evident. At Lloyds Creek and Thompson Creek, some sample overlap occurred but clustering was again primarily related to seasonal, and to a lesser extent annual, compositional changes. Differences in composition between locations upstream and downstream of the timber harvest were minor in comparison to the temporal sources of variation. These results complemented those of the ANOVA and Kruskal-Wallis tests, further suggesting that logging and BMP implementation had minimal effects on macroinvertebrate populations.

Overall statistical evaluation of all study sites together to determine whether macroinvertebrate assemblage patterns were consistent statewide after timber harvest indicated that most of the changes noted when evaluating individual sites were particular to those sites. This suggests that BMPs implemented by Arkansas timber harvesters are effective in a multitude of ecoregions and forest types. Those changes that were observed were typically seasonal and/or annual in nature. Reduced relative abundance of the dominant taxon in the spring indicated greater assemblage diversity during this period, as opposed to the winter, in Arkansas' headwater streams. Increased relative abundance of predators in spring samples largely reflected the presence of predatory stoneflies, notably *Clioperla clio, Isoperla, Perlesta* and Chloroperlidae. The life history patterns of these taxa suggest that their late instar nymphs are most numerous in the spring, preceding emergence as adults in late spring and summer (Poulton and Stewart 1991). Greater relative abundance of predators, at stations above and below timber harvests, in study years after silviculture activities may indicate that conditions in post-harvest years were more optimal for macroinvertebrate assemblages.

The lack of a correlation between BMP implementation scores and the change in macroinvertebrate community structure after the silviculture activities suggest that all sites were above the threshold needed to cause a negative effect and further support the premise that current BMP protocols are sufficient to protect water quality. All sites had high (88-100 % of the total possible) BMP implementation scores, so an examination of a wide gradient of BMP implementation conditions was not possible and not a goal of this study.

Conclusions

Based on the water chemistry and benthic macroinvertebrate assemblage data obtained in this study, the best management practices applied after the evaluated timber harvest operations were effective in protecting water quality of adjacent streams on a state-wide basis. Additionally, no habitat degradation, e.g., sedimentation or inputs of logging slash, was observed at any of the stream study sites. No change in the stream ecosystem was evident in either year post-harvest at five of seven sites. At Caney Creek and Thompson Creek, there was some evidence of a community shift after the harvest but did not in either case correspond to any logging-related water quality or habitat differences between upstream and downstream locations. These results concur with those reported by Adams et al. (1995), Vowell and Frydenborg (2004), and Kreutzweiser et al. (2005), that compliance with silviculture best management practices does minimize adverse impacts of clear-cut logging on stream water quality.

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APPENDICES

APPENDIX A: Bailey Creek benthic macroinvertebrate data

Table A-1. Benthic macroinvertebrate counts in samples from Bailey Creek, January 7, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Branchiobdellida									
Caecidotea (unpigmented)						1			
Crangonyx	1	1	3	2				1	
Gyraulus									1
Hyalella azteca					1	3	1		
Hydracarina	1		3	1		1		3	
Lirceus	2	4	8	17	16	18	15	18	11
Menetus	1	1	1	1		2	1		
Orconectes		1	1			1	1		
Physidae	1				1	1			
Stygobromus									
Synurella bifurca		1	1			2	5		1
Turbellaria	1	1	2	1		2	1	3	1
Ephemeroptera									
Acetrella/Plauditus			1	3	6	2	2	5	6
Ameletus	1				4	5		2	1
Caenis	10	8	3	13	6	2	2	4	3
Eurylophella									
Leptophlebia									
Leptophlebiidae								2	1
Leucrocuta	1	1	6	3	3	6	3	3	6
Procloeon				2					
Rhithrogena									
Stenacron									
Stenonema femoratum	17	24	17	6	11	8	2	9	7
Plecoptera									
Allocapnia	2	3	2	4	2	2	1	1	4
Amphinemura		2	1	2			1	1	3
Chloroperlidae	2	3	2		1	1			1
Clioperla clio	3	5	4				3	3	4
Isoperla w/ vertical bars									
Perlidae									
Perlodidae		3	3	11	7	10	4	5	8
Strophopteryx			1		3	4	9	8	6
Taeniopteryx									
Zealeuctra	1	1	3	1	5				2
Trichoptera									
Agapetus		1		15	15	13	24	14	10

Cheumatopsyche									
Chimarra									
Dibusa angata									
Ironoquia									
Lepidostoma					1		1		1
Neophylax									
Polycentropus			1						
Ptilostomis									
Pycnopsyche									
Rhyacophila kiamichi		1	1				1	1	
Rhyacophila lobifera									
Triaenodes									
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Gomphidae									
Lepidoptera (not *Petrophila*)									
Libellulidae									
Sialis									
Tetrigidae (Orthoptera)									
Coleoptera									
Agabus									
Dubiraphia	1								
Helichus									
Hydroporus	1			1	1				
Laccophilus							1	1	
Psephenus									
Stenelmis			1						
Diptera (excl Chironomidae)									
Ceratopogoninae	7	4	3					1	2
Chlorotabanus									
Clinocera									
Forcipomyia							1		
Hexatoma			2						2
Prosimulium	5	10	10	7	8	11	15	4	8
Simuliidae (not *Prosimulium*)									
Tabanidae	1								
Tipula	2	10	2	1	2	2	3	1	3
Oligochaeta									
Dero	1								
Enchytraeidae	1							1	
Imm. Tubificidae w/ hair chaetae	2		2						
Imm. Tubificidae w/o hair chaetae	4	1	3		1			1	2
Lumbriculidae	2							2	
Chironomidae									
Ablabesmyia mallochi	1	1		1					
Cardiocladius							1		1
Chironomus	1								
Constempellina									
Corynoneura (w/sculpturing)	1		1						
Corynoneura (no sculpturing)				1	1				

Cricotopus bicinctus									
Cricotopus "other"									
Cricotopus/Orthocladius									
Diamesa									
Dicrotendipes (modestus/neomodestus)			1						
Eukiefferiella claripennis gp	1	1		1					1
Heterotrissocladius	1			3					2
Hydrobaenus					1				
Micropsectra									
Microtendipes pedellus gp	15	3	5	3	1		1	1	2
Natarsia									
Orthocladius (*obumbratus/robacki*)									
Parametriocnemus	1						1	3	
Paratanytarsus	1				1	2			
Paratendipes subaequalis									
Paratrichocladius/Orthocladius dorenus					2				
Phaenopsectra punctipes gp									
Polypedilum aviceps									
Polypedilum flavum									
Polypedilum illinoense gp		1	1						
Potthastia longimana gp								1	
Procladius									
Rheocricotopus cf *glabricollis*		1							
Rheocricotopus cf *unidentatus* or *"VA"*									
Stempellinella		1							
Stictochironomus	2		2						
Tanytarsus		1							
Tanytarsus "M" (Epler)		1	1						
Tanytarsus "P" (Epler)									
Thienemanniella cf *xena*									
Thienemannimyia group	1		1			1			
Tribelos cf *jucundum*	4	3	1					1	
Tvetenia cf *paucunca*									
Zavrelimyia		1							

Table A-2. Benthic macroinvertebrate counts in samples from Bailey Creek, March 14, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Branchiobdellida		2							
Caecidotea (unpigmented)									
Crangonyx						1			
Gyraulus									
Hyalella azteca	1								
Hydracarina									
Lirceus	3	6	6	12	9	6	2	11	10
Menetus									
Orconectes						1			1
Physidae									
Stygobromus								1	
Synurella bifurca					1		1		
Turbellaria	1		1				1		1
Ephemeroptera									
Acetrella/Plauditus	1	1	2	4	5	4	10	8	6
Ameletus	2		1			2		2	1
Caenis		1							4
Eurylophella									
Leptophlebia									
Leptophlebiidae	1		1			1	1	1	1
Leucrocuta	4	8	3	6	7	12	2	7	11
Procloeon									
Rhithrogena									
Stenacron									
Stenonema femoratum	8	12	8	5	1	2	2	1	4
Plecoptera									
Allocapnia									
Amphinemura	8	5	7	16	8	11	18	18	12
Chloroperlidae	3	6	2	3	1	4	2	2	5
Clioperla clio	9	3	6	7	4	1		4	3
Isoperla w/ vertical bars	18	16	10	14	11	15	7	9	7
Perlidae	1		1						1
Perlodidae									
Strophopteryx			2	1	7		5	1	
Taeniopteryx									
Zealeuctra						1			
Trichoptera									
Agapetus	5	6	3	8	12	6	7	15	9
Cheumatopsyche									
Chimarra									
Dibusa angata			1						
Ironoquia									

Lepidostoma									
Neophylax					1				
Polycentropus									
Ptilostomis									
Pycnopsyche									
Rhyacophila kiamichi	1	1	2	1	2	1		2	2
Rhyacophila lobifera									
Triaenodes									1
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Gomphidae									
Lepidoptera (not *Petrophila*)									
Libellulidae									1
Sialis									
Tetrigidae (Orthoptera)									
Coleoptera									
Agabus									
Dubiraphia								1	
Helichus									
Hydroporus				1					
Laccophilus									
Psephenus									
Stenelmis	1		2		1	2	2	1	2
Diptera (excl Chironomidae)									
Ceratopogoninae	1	2	1		1	3			
Chlorotabanus									
Clinocera	4	1	1	2					
Forcipomyia									
Hexatoma						1			1
Prosimulium	1	2	10		4	4	22	2	2
Simuliidae (not *Prosimulium*)	4	3	5	2	5	3			1
Tabanidae									
Tipula	2	3	2	3	1	2	4	3	3
Oligochaeta									
Dero									
Enchytraeidae						1			
Imm. Tubificidae w/ hair chaetae									
Imm. Tubificidae w/o hair chaetae		2		1	1	1			
Lumbriculidae							3		3
Chironomidae									
Ablabesmyia mallochi					1		1		1
Cardiocladius						1		1	
Chironomus		1							
Constempellina									
Corynoneura (w/sculpturing)		1							
Corynoneura (no sculpturing)									
Cricotopus bicinctus					1				
Cricotopus "other"									
Cricotopus/Orthocladius			1						
Diamesa									

Dicrotendipes (modestus/neomodestus)									
Eukiefferiella claripennis gp	13	7	15	9	10	8	2	1	
Heterotrissocladius									
Hydrobaenus									
Micropsectra									
Microtendipes pedellus gp									
Natarsia									
Orthocladius (*obumbratus/robacki*)	6	8				2			2
Parametriocnemus				1	2	1	7	8	4
Paratanytarsus					1	1			
Paratendipes subaequalis	1		1						
Paratrichocladius/Orthocladius dorenus	1	2	4	3	3	2			1
Phaenopsectra punctipes gp									
Polypedilum aviceps									
Polypedilum flavum									
Polypedilum illinoense gp									
Potthastia longimana gp								1	
Procladius			1						
Rheocricotopus cf *glabricollis*									
Rheocricotopus cf *unidentatus* or *"VA"*									
Stempellinella									
Stictochironomus									
Tanytarsus									
Tanytarsus "M" (Epler)									
Tanytarsus "P" (Epler)									
Thienemanniella cf *xena*				1					
Thienemannimyia group									
Tribelos cf *jucundum*		1	1						
Tvetenia cf *paucunca*							1		
Zavrelimyia									

Table A-3. Benthic macroinvertebrate counts in samples from Bailey Creek, December 15, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Branchiobdellida									1
Caecidotea (unpigmented)		1							1
Crangonyx		2	3						
Gordiidae									
Hyalella azteca				13	13	24		2	
Hydracarina									
Lirceus	51	56	42	41	44	32	57	44	53
Menetus						1		1	1
Orconectes		1			1	1	1	1	1
Physidae				1					
Sphaeriidae			1						
Stygobromus			1						
Synurella bifurca		8	2	2	3	1	2	1	1
Turbellaria	3	6	2	2	4	2	2		4
Ephemeroptera									
Acetrella/Plauditus									
Ameletus									
Caenis				3	11	8	1	2	
Eurylophella						1	1		
Leptophlebia					1		2		
Leptophlebiidae									
Leucrocuta									
Stenacron									
Stenonema femoratum									
Plecoptera									
Allocapnia	23	11	14	18	8	13	9	20	9
Amphinemura									
Chloroperlidae									
Clioperla clio									
Isoperla w/ horizontal bars									
Isoperla w/ vertical bars									
Perlidae									
Strophopteryx									
Taeniopteryx							1		1
Zealeuctra	2	2	3		2				
Trichoptera									
Agapetus									
Dibusa angata									
Hydroptila									
Ironoquia	4	3	5			1	1		3
Lepidostoma									
Polycentropus									

Ptilostomis							1		
Rhyacophila kiamichi									
Rhyacophila lobifera									
Triaenodes									
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Argia				1					
Enallagma/Ischnura									
Gomphidae (not *Stylogomphus*)									
Libellulidae	1								
Sialis									
Somatochlora									
Coleoptera									
Agabus								1	
Berosus				1		1			
Dineutus									
Dubiraphia				4		1			
Ectopria									
Helichus			1						
Hydroporus									
Psephenus								1	
Scirtidae									
Stenelmis		1	1				1		1
Diptera (excl Chironomidae)									
Ceratopogoninae			4	2		1	1	1	
Chlorotabanus									
Clinocera									
Dolichopodidae									1
Erioptera			1		1				3
Helius									
Hexatoma		3			1	1	1	1	2
Molophilus							1	1	
Prosimulium									
Simuliidae (not *Prosimulium*)									
Tabanidae	1				1		1		
Tipula	1		2				1	3	2
Oligochaeta									
Enchytraeidae	3	1	4	5	3	1	1	4	2
Haplotaxis cf *gordioides*									
Imm. Tubificidae w/ hair chaetae	9	2	2	2	4	4	7	6	5
Imm. Tubificidae w/o hair chaetae			3	2	2	5	7	2	7
Lumbriculidae	1								
Nais									
Stylaria lacustris						1			
Chironomidae									
Ablabesmyia janta/rhamphe gp									
Constempellina									
Corynoneura (no sculpturing)	1	3	7	1		1			
Cricotopus bicinctus									
Cricotopus "other"									

Dicrotendipes (modestus/neomodestus)					1	
Eukiefferiella claripennis gp					1	
Heterotrissocladius	2				3	1
Hydrobaenus						
Larsia						
Microtendipes pedellus gp			1		1	
Nanocladius cf *alternatherae*		1				
Natarsia						
Orthocladius (*obumbratus/robacki*)						
Parachaetocladius						
Parametriocnemus						
Paratanytarsus		1				
Paratrichocladius/Orthocladius dorenus						
Phaenopsectra punctipes gp						
Polypedilum aviceps						
Polypedilum illinoense gp						1
Stenochironomus						
Stictochironomus					2	
Thienemannimyia group						
Tribelos cf *jucundum*						
Tvetenia cf *paucunca*						
Zavrelimyia				1	1	

Table A-4. Benthic macroinvertebrate counts in samples from Bailey Creek, March 23, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Branchiobdellida									
Caecidotea (unpigmented)									
Crangonyx		1						1	
Gordiidae									
Hyalella azteca									
Hydracarina				1	1			2	
Lirceus	1	1	3	8	4	5	7	6	5
Menetus									
Orconectes		1				1			2
Physidae									
Sphaeriidae									
Stygobromus									
Synurella bifurca							1		2
Turbellaria			1				1	1	
Ephemeroptera									
Acetrella/Plauditus	7	9	14	9	11	8	10	11	7
Ameletus		1	1					1	
Caenis	1			1					
Eurylophella		1	1		1	2	1		
Leptophlebia									
Leptophlebiidae	3	4	1	3	1	3		1	
Leucrocuta	5	3	4	7	1	4	1	1	
Stenacron									
Stenonema femoratum							2	2	
Plecoptera									
Allocapnia									
Amphinemura	18	16	13	18	19	12	14	19	27
Chloroperlidae	4	8	2	3	5	3	1		2
Clioperla clio	10	2	8	4	4	5	6	8	11
Isoperla w/ horizontal bars									
Isoperla w/ vertical bars	11	13	8	9	11	8	9	7	6
Perlidae	2		1	1		2	2		
Strophopteryx		1	1				1	1	
Taeniopteryx									
Zealeuctra									
Trichoptera									
Agapetus	6	7	6	4	6	3	4	4	5
Dibusa angata	9	11	6	6	13	15	7	1	7
Hydroptila					1		4	3	5
Ironoquia									
Lepidostoma									
Polycentropus									

Ptilostomis									
Rhyacophila kiamichi	2	3		4	1	2	2	1	1
Rhyacophila lobifera								1	
Triaenodes									
Wormaldia		1							2
Other Insects (Od,Hem,Meg,Lep)									
Argia									
Enallagma/Ischnura									
Gomphidae (not *Stylogomphus*)									
Libellulidae									
Sialis									
Somatochlora									
Coleoptera									
Agabus									
Berosus									
Dineutus									
Dubiraphia									
Ectopria									
Helichus									1
Hydroporus									
Psephenus									
Scirtidae									
Stenelmis		1		3	2			5	1
Diptera (excl Chironomidae)									
Ceratopogoninae	1		1	1	2	3	1	3	1
Chlorotabanus									
Clinocera	2		1		1			1	
Dolichopodidae									
Erioptera									
Helius									
Hexatoma				1				1	
Molophilus									
Prosimulium	3	2	4		1	1	3	3	1
Simuliidae (not *Prosimulium*)	1	2	9	1	1	4	3	5	5
Tabanidae									1
Tipula				1					
Oligochaeta									
Enchytraeidae			2				2	2	
Haplotaxis cf *gordioides*		1							
Imm. Tubificidae w/ hair chaetae	3	1	3				1		1
Imm. Tubificidae w/o hair chaetae	1	2	1			1	1		
Lumbriculidae									
Nais		1				1			
Stylaria lacustris									
Chironomidae									
Ablabesmyia janta/rhamphe gp									
Constempellina		2		1	4	1	1		2
Corynoneura (no sculpturing)									
Cricotopus bicinctus									
Cricotopus "other"	1	2	2		2	10	3	2	1

Dicrotendipes (modestus/neomodestus)							1		
Eukiefferiella claripennis gp			2			1			
Heterotrissocladius									
Hydrobaenus									
Larsia		1				2	1		
Microtendipes pedellus gp									
Nanocladius cf *alternatherae*									
Natarsia				1					
Orthocladius (*obumbratus/robacki*)				2	1	2	2		
Parachaetocladius	1								
Parametriocnemus	2			7	3	1	6	5	2
Paratanytarsus									
Paratrichocladius/Orthocladius dorenus	4	1	5	3	4				
Phaenopsectra punctipes gp				1					
Polypedilum aviceps									
Polypedilum illinoense gp									
Stenochironomus									
Stictochironomus									
Thienemannimyia group									
Tribelos cf *jucundum*									
Tvetenia cf *paucunca*	2	1					2	2	2
Zavrelimyia									

Table A-5. Benthic macroinvertebrate counts in samples from Bailey Creek, December 20, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Ancylidae									
Caecidotea (unpigmented)									
Crangonyx	1	1	1	1	1	2			
Erpobdellidae									
Glossiphoniidae									
Hyalella azteca									
Hydracarina				1		1		1	1
Lirceus	13	13	18	12	18	11	14	9	7
Menetus									
Orconectes	1					1			
Physidae								1	
Sphaeriidae									
Stygobromus									
Synurella bifurca		3	1	3	3	2	5	7	11
Turbellaria	3				3	1	3	2	1
Ephemeroptera									
Acetrella/Plauditus	11	10	8	9	6	3	3	5	5
Ameletus	1				2				1
Caenis				1	2	1			
Eurylophella									
Leptophlebiidae	1			1					
Leucrocuta	5	6	2	3	3	4	2	2	3
Paraleptophlebia									
Stenonema femoratum			1			4	1	7	1
Plecoptera									
Allocapnia		1		7	10	11	2	3	1
Amphinemura									
Chloroperlidae	2	2	2	2		1			
Clioperla clio	12	16	24	14	15	10	10	3	3
Isoperla w/ vertical bars	6	4	2	2	5	3	1	1	1
Perlesta									
Perlidae	3	2	1	1	2	1	1	2	3
Strophopteryx	7	8	6	5	5	3	18	17	13
Taeniopteryx				1		1			
Zealeuctra			1			2		1	
Trichoptera									
Agapetus	5	12	9	13	9	15	9	9	12
Cheumatopsyche									
Dibusa angata									
Hydroptila									
Ironoquia		1					1		
Lepidostoma			1		2		4	1	2

Neophylax			1						
Polycentropus									
Ptilostomis		1							
Pycnopsyche									
Rhyacophila kiamichi		1	1		1				1
Rhyacophila lobifera	1	4	1		2	2	1		
Triaenodes	1								4
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Cordulegaster									
Sialis									
Somatochlora									
Coleoptera									
Agabus		1					1		
Dineutus									
Ectopria									1
Helichus									
Hydroporus						2		2	
Lampyridae									
Microcylloepus					1				
Stenelmis		1	5	1				1	1
Diptera (excl Chironomidae)									
Ceratopogoninae				2	2	5		1	1
Clinocera						1			
Hexatoma	1	1	1	2		1	1		1
Limnophila									
Prosimulium	14	3	4	9	2	4	11	8	14
Simuliidae (not *Prosimulium*)	1							1	1
Tabanidae									
Tipula	1	2	1	2	1	1	1	2	1
Oligochaeta									
Dero	1								
Enchytraeidae			1	1		2	1		
Haplotaxis gordioides									
Imm. Tubificidae w/ hair chaetae	2			1			3	2	2
Imm. Tubificidae w/o hair chaetae		1							
Lumbriculidae		2	1						1
Nais									
Stylaria lacustris									
Chironomidae									
Ablabesmyia mallochi									
Cardiocladius									
Constempellina		1							
Corynoneura (w/sculpturing)									
Cricotopus bicinctus				1					
Cricotopus cf *luciae*				1					
Cricotopus "other"									
Cricotopus/Orthocladius									
Diamesa									
Eukiefferiella claripennis gp	2	1		1				3	2

Eukiefferiella devonica gp							1		
Heterotrissocladius	1	1		1	1				
Hydrobaenus								1	
Microtendipes pedellus gp								1	
Nanocladius (N.) spiniplenus gp.	1								
Natarsia				1					
Orthocladius (*obumbratus/robacki*)			1			1	2		1
Orthocladius cf *oliveri*									
Parachaetocladius									
Parametriocnemus			3		2	3	1		
Paratrichocladius/Orthocladius dorenus	2		2		1			1	
Phaenopsectra obediens gp									
Polypedilum aviceps								1	
Polypedilum illinoense gp				1					
Potthastia longimana gp									
Psectrocladius psilopterus gp									
Rheotanytarsus							1		
Synorthocladius semivirens									
Tanytarsus "U" (Epler)									
Thienemanniella cf *xena*					1			1	3
Thienemannimyia group	1	1					1	2	1
Tribelos cf *jucundum*									
Tvetenia cf *paucunca*			1			1	1	1	
Zavrelimyia								1	

Table A-6. Benthic macroinvertebrate counts in samples from Bailey Creek, March 19, 2005.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Ancylidae									
Caecidotea (unpigmented)									
Crangonyx	1			2					
Erpobdellidae									
Glossiphoniidae									
Hyalella azteca									
Hydracarina									
Lirceus	4	5	4	8	5	4	7	9	5
Menetus									
Orconectes		1	1					2	
Physidae									
Sphaeriidae									
Stygobromus									
Synurella bifurca			1					1	
Turbellaria									
Ephemeroptera									
Acetrella/Plauditus	5	5	6	7	6	2	7	3	1
Ameletus					1	1	1	1	
Caenis							1	1	1
Eurylophella			1						
Leptophlebiidae									
Leucrocuta	9	11	10	10	9	10	7	14	7
Paraleptophlebia		1	2	3	2	3	5	3	1
Stenonema femoratum			1				2	1	5
Plecoptera									
Allocapnia									
Amphinemura	7	10	8	7	7	11	9	5	13
Chloroperlidae	10	16	11	8	5	8	5	3	4
Clioperla clio	2	2	3	1	1	1	1	2	3
Isoperla w/ vertical bars	15	12	10	9	12	8	5	3	4
Perlesta	4	2	4	2	1	3	3	4	3
Perlidae									
Strophopteryx			1						
Taeniopteryx									
Zealeuctra									
Trichoptera									
Agapetus	4	3	5	2	2	2	2	4	6
Cheumatopsyche									
Dibusa angata	10	14	11	7	11	9	7	8	7
Hydroptila								2	2
Ironoquia									

Lepidostoma									
Neophylax									
Polycentropus									
Ptilostomis									
Pycnopsyche									
Rhyacophila kiamichi		2	1	2	1			1	1
Rhyacophila lobifera			1				1		
Triaenodes									
Wormaldia		1					1	1	1
Other Insects (Od,Hem,Meg,Lep)									
Cordulegaster									
Sialis									
Somatochlora									
Coleoptera									
Agabus							1		
Dineutus									
Ectopria									
Helichus									
Hydroporus							1	1	
Lampyridae									
Microcylloepus									
Stenelmis	1	1							1
Diptera (excl Chironomidae)									
Ceratopogoninae								2	1
Clinocera						2			
Hexatoma	1		1	1			1		1
Limnophila									
Prosimulium	2		2	1	2	1	11	1	3
Simuliidae (not *Prosimulium*)				1	1	1	1	1	
Tabanidae									
Tipula	1			1		1		1	
Oligochaeta									
Dero									
Enchytraeidae									1
Haplotaxis gordioides									
Imm. Tubificidae w/ hair chaetae			1					2	4
Imm. Tubificidae w/o hair chaetae									1
Lumbriculidae									
Nais									
Stylaria lacustris									
Chironomidae									
Ablabesmyia mallochi					2		2	4	
Cardiocladius									
Constempellina	1				3				
Corynoneura (w/sculpturing)								2	
Cricotopus bicinctus									
Cricotopus cf *luciae*				6	1	9			1
Cricotopus "other"	1		1		1			2	1
Cricotopus/Orthocladius									
Diamesa									

Eukiefferiella claripennis gp	1	1	3		2	1	1		
Eukiefferiella devonica gp				1	1				1
Heterotrissocladius									
Hydrobaenus	1			4					
Microtendipes pedellus gp									
Nanocladius (N.) spiniplenus gp.									
Natarsia									
Orthocladius (*obumbratus/robacki*)	2			3	3	1	1	1	
Orthocladius cf *oliveri*	1					2			
Parachaetocladius									
Parametriocnemus	4	5	4	3	4	8	2	4	8
Paratrichocladius/Orthocladius dorenus	3	1	2	2	1				
Phaenopsectra obediens gp									
Polypedilum aviceps	7	3	2	2	5	6	7	5	10
Polypedilum illinoense gp									
Potthastia longimana gp								1	
Psectrocladius psilopterus gp									
Rheotanytarsus									
Synorthocladius semivirens								1	
Tanytarsus "U" (Epler)	1		1	3	7	1	5		1
Thienemanniella cf *xena*			1						
Thienemannimyia group			1		1			2	2
Tribelos cf *jucundum*							1		
Tvetenia cf *paucunca*	2	2		2	1	4	2	2	
Zavrelimyia		2		2	2	1			

APPENDIX B: Big Creek benthic macroinvertebrate data

Table B-1. Benthic macroinvertebrate counts in samples from Big Creek, January 22, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Crangonyx									
Hyalella azteca									
Hydracarina					1			1	2
Lirceus	1		1	6	3		3	2	1
Menetus									
Orconectes					1				
Physidae									1
Turbellaria									
Ephemeroptera									
Acentrella/Plauditus	1		1	1		1	2	1	
Acerpenna									
Ameletus									
Caenis	1	1		3	4	2		1	1
Diphetor									
Eurylophella									
Isonychia	5	8	5	7	10	7	15	6	22
Leptophlebiidae									
Leucrocuta									
Stenacron			1		1		1	3	3
Stenonema femoratum	8	5	5	4	9	10	4	9	4
Stenonema pulchellum/terminatum	13	13	20	20	24	6	7	7	4
Plecoptera									
Acroneuria									
Allocapnia	6	11	12	6	4	6	9	10	12
Amphinemura									
Chloroperlidae	1			1		2	1		1
Clioperla clio	1	3	1	3	1	2	1		
Hydroperla crosbyi									
Isoperla w/ horizontal bars									
Isoperla w/ vertical bars									
Perlidae									
Prostoia									
Strophopteryx	1	5	1	3		1	1		
Taeniopteryx	3	5	1	2	2	4	3		
Trichoptera									
Agapetus	1	2	2	7	4	17	11	20	10
Ceraclea (ancylus or flava)									
Cheumatopsyche	1	4	1	5		2	1	3	7
Chimarra	8	9	1	3		1	1	2	5

Dibusa angata						1		2	
Helicopsyche						1			
Hydropsyche									
Hydroptila									
Lepidostoma									
Micrasema							2		1
Neophylax									
Pycnopsyche		1							
Rhyacophila kiamichi									
Rhyacophila lobifera			1	2					
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Argia			1			1			
Corydalus			1	2		2			
Gomphidae (not *Stylogomphus*)			1						
Nigronia serricornis					1		1		
Petrophila									
Coleoptera									
Ancyronyx variegata									
Dubiraphia					1	1		1	1
Ectopria									
Helichus									
Psephenus							1	3	
Stenelmis		1	4	1	1			1	
Diptera (excl Chironomidae)									
Ceratopogoninae							1		
Chelifera									
Clinocera									
Hemerodromia		1							
Hexatoma				2	1		1		
Prosimulium	41	16	23	12	25	26	15	14	9
Simuliidae (not *Prosimulium*)									
Tabanidae									
Tipula		4	3	1	1				
Tipulidae (other than above genera)									
Oligochaeta									
Imm. Tubificidae w/ hair chaetae									
Lumbriculidae									
Lumbriculidae (w/proboscis)	1	2		1					1
Chironomidae									
Cardiocladius									
Chaetocladius									
Corynoneura (w/ sculpturing)						1			
Cricotopus bicinctus									
Cricotopus "other"									
Cricotopus/Orthocladius									
Eukiefferiella claripennis gp	2	1	3	1		1	3	2	1
Hydrobaenus								1	
Micropsectra									
Microtendipes pedellus gp			1						

Orthocladius (Euortho.) w/13 teeth									
Orthocladius (*obumbratus/robacki*)	1	3	3	3	2	1	2		1
Parachaetocladius	1	1	1	2			2	3	
Parametriocnemus		1	2	1				1	
Phaenopsectra punctipes gp									
Polypedilum aviceps						1			
Polypedilum fallax	1								
Rheotanytarsus							2		1
Smittia							1		
Stempellinella			2		1		1		1
Stenochironomus							1		
Tanytarsus "C" (Epler)									
Tanytarsus "M" (Epler)	2	3	2		2	1	7	6	11
Thienemannimyia group				1	1	1		1	
Tvetenia cf *paucunca*									
Tvetenia cf *vitracies*						1			
Xylotopus par									
Zavrelimyia									

Table B-2. Benthic macroinvertebrate counts in samples from Big Creek, March 15, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Crangonyx									
Hyalella azteca									
Hydracarina	1				1			1	1
Lirceus		1	2	4	6	4	2	3	4
Menetus						1			
Orconectes		1			1				
Physidae									
Turbellaria									
Ephemeroptera									
Acentrella/Plauditus	5		6	1	3	2	3	4	2
Acerpenna					2	2	2		
Ameletus									
Caenis	1	1		3	5	5			
Diphetor									
Eurylophella			2						
Isonychia	1	2	6	6	2	4	6	10	8
Leptophlebiidae	1				1				1
Leucrocuta									
Stenacron	1	2	1	4	5		6	6	4
Stenonema femoratum	5	3	11	7	9	8	3	4	11
Stenonema pulchellum/terminatum	6	8	9	9	8	9	8	8	9
Plecoptera									
Acroneuria									
Allocapnia		2	1						
Amphinemura	3	1	4		4	2	3	6	1
Chloroperlidae	9	3	2	4	5	2	2	1	4
Clioperla clio	1	1				2			1
Hydroperla crosbyi								1	1
Isoperla w/ horizontal bars	1	2	1	3	1	2	4	3	4
Isoperla w/ vertical bars	2	2	1	4			3	3	2
Perlidae			1	1					
Prostoia									
Strophopteryx			1						
Taeniopteryx									
Trichoptera									
Agapetus	3	6	8	16	7	9	19	12	8
Ceraclea (ancylus or flava)									
Cheumatopsyche	2	3		2	2			2	1
Chimarra	2	3	2		1	1			

Dibusa angata			1	3	4		2	2	1
Helicopsyche					1				
Hydropsyche									
Hydroptila	1	3	4	1		1	1	3	1
Lepidostoma									
Micrasema							2		1
Neophylax									
Pycnopsyche									
Rhyacophila kiamichi	3	2	1	2			2	3	
Rhyacophila lobifera									
Wormaldia								1	
Other Insects (Od,Hem,Meg,Lep)									
Argia					1				
Corydalus		1							
Gomphidae (not *Stylogomphus*)									
Nigronia serricornis		1	1				1	2	2
Petrophila									
Coleoptera									
Ancyronyx variegata									
Dubiraphia									
Ectopria									1
Helichus					1				
Psephenus					1		2	1	1
Stenelmis	21	17	14	11	6	10	7	4	10
Diptera (excl Chironomidae)									
Ceratopogoninae						1			
Chelifera	1	2					1		1
Clinocera	2	2	2	1	4	3	2	1	3
Hemerodromia									
Hexatoma	4	3	4	2	1	4	3	3	1
Prosimulium	2	4	1	9	1	8	2		2
Simuliidae (not *Prosimulium*)	4	1			2	2	1	1	2
Tabanidae				1					
Tipula		1	2		1	1			
Tipulidae (other than above genera)									
Oligochaeta									
Imm. Tubificidae w/ hair chaetae									
Lumbriculidae									1
Lumbriculidae (w/proboscis)			1						2
Chironomidae									
Cardiocladius							1		
Chaetocladius									
Corynoneura (w/ sculpturing)									
Cricotopus bicinctus		1							
Cricotopus "other"	1	3			1			1	2
Cricotopus/Orthocladius		1				2	1	3	
Eukiefferiella claripennis gp	2	3	1	1	3	5		1	
Hydrobaenus									
Micropsectra	1	1							
Microtendipes pedellus gp									

Orthocladius (Euortho.) w/13 teeth									
Orthocladius (*obumbratus/robacki*)	8	6	4	3	5	5	6	2	1
Parachaetocladius									
Parametriocnemus	1	2			1	1			1
Phaenopsectra punctipes gp									
Polypedilum aviceps	2	4	3	1	1	3	5	5	4
Polypedilum fallax									
Rheotanytarsus								1	
Smittia									
Stempellinella									
Stenochironomus									
Tanytarsus "C" (Epler)				1					
Tanytarsus "M" (Epler)	1	1	2		1	1		1	1
Thienemannimyia group	2		1		2				
Tvetenia cf *paucunca*									
Tvetenia cf *vitracies*									
Xylotopus par									
Zavrelimyia								1	

Table B-3. Benthic macroinvertebrate counts in samples from Big Creek, December 16, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Crangonyx				1					
Caecidotea (unpigmented)									
Erpobdellidae									
Hyalella azteca		1							
Hydracarina									
Lirceus	10	13	7		2	1	2	3	2
Menetus			1						
Orconectes					1	1			
Physidae						1			
Sphaeriidae									
Turbellaria	1			1					
Ephemeroptera									
Acentrella/Plauditus								1	
Acerpenna	2			1	3	2		2	
Baetisca lacustris									
Caenis			1	8	8	4	2	1	1
Diphetor								1	
Eurylophella			1						
Isonychia	10	10	9	22	19	14	16	16	16
Leptophlebiidae	2	1		2			1		
Stenacron	1		3	2	1	1	1	2	3
Stenonema femoratum	13	13	18	8	13	8	4	11	4
Stenonema pulchellum/terminatum	8	5	12	21	21	23	21	15	26
Plecoptera									
Acroneuria						2	2		
Allocapnia		2	1	1		1	4	4	6
Amphinemura									
Chloroperlidae									
Clioperla clio	1	2	2				2		
Hydroperla crosbyi					1				
Isoperla w/ horizontal bars									
Isoperla w/ vertical bars									
Perlesta							1	1	
Perlidae									
Strophopteryx	1								
Taeniopteryx	2	1	1	1	1	1		1	3
Trichoptera									
Agapetus					1	2	1	2	4
Ceraclea (ancylus or flava)									

Cheumatopsyche	11	6	8	3	2	4	6	3	2
Chimarra	21	24	9	10	6	20	17	15	6
Dibusa angata									
Helicopsyche									
Hydropsyche				1	4	1			
Hydroptila									
Lepidostoma									
Micrasema									
Oecetis					1				
Oxyethira									
Polycentropus							1		
Ptilostomis									
Pycnopsyche		1	1			1	1	1	1
Rhyacophila kiamichi									
Other Insects (Od,Hem,Meg,Lep)									
Argia	1		1					1	1
Boyeria									
Calopteryx									
Corydalus						1			
Enallagma/Ischnura									
Gomphidae (cf *Stylogomphus*)									
Gomphidae (not *Stylogomphus*)									
Hagenius brevistylus									
Nigronia serricornis					1		1	1	1
Petrophila									
Sialis									
Coleoptera									
Ancyronyx variegata									
Berosus									
Dubiraphia					1				
Ectopria									
Helichus		1					2		
Psephenus				1	1			3	2
Stenelmis		4	1	3			2	1	3
Diptera (excl Chironomidae)									
Chelifera									
Clinocera									
Hemerodromia									2
Hexatoma		1		2	2	1	2	2	3
Prosimulium	1		1	1	1			1	1
Pseudolimnophila									
Simuliidae (not *Prosimulium*)	3	2	2	2	2	3	2	1	1
Tabanidae									
Tipula	2	2	4		2	3	4		2
Oligochaeta									
Enchytraeidae									
Haemonais waldvogeli									
Imm. Tubificidae w/ hair chaetae									
Imm. Tubificidae w/o hair chaetae			1						1
Lumbriculidae	1								

Lumbriculidae (w/proboscis)									
Chironomidae									
Corynoneura (w/ sculpturing)									
Cricotopus bicinctus									
Cricotopus "other"									
Diamesa									
Dicrotendipes (modestus/neomodestus)		1							
Diplocladius cultriger						2			
Eukiefferiella claripennis gp				1			1		
Hydrobaenus							1		
Micropsectra									
Microtendipes pedellus gp			2						
Nanocladius cf *spliniplenus*									
Orthocladius (Eudact.) dubitatus									
Orthocladius (obumbratus/robacki)									
Parachaetocladius								1	2
Parametriocnemus	1			3			1	1	1
Paratrichocladius/Orthocladius dorenus								3	
Polypedilum aviceps			1		1				
Polypedilum flavum									
Polypedilum illinoense gp									
Pseudochironomus									
Rheocricotopus cf *robacki*									
Rheotanytarsus		1		1		1		2	1
Stempellinella			1						
Stenochironomus									
Stictochironomus			1						
Tanytarsus "A" (Epler)									
Tanytarsus "C" (Epler)									
Tanytarsus "M" (Epler)	2	2	6	1	3		1	1	4
Thienemannimyia group	6	6	5	3	2	2	1	3	1
Tribelos cf *jucundum*		1							

Table B-4. Benthic macroinvertebrate counts in samples from Big Creek, March 24, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Crangonyx									
Caecidotea (unpigmented)									
Erpobdellidae									
Hyalella azteca									
Hydracarina									
Lirceus	1	1		1	1	1	3		
Menetus									
Orconectes				1	1				
Physidae									
Sphaeriidae									
Turbellaria									
Ephemeroptera									
Acentrella/Plauditus	6	5	7	5	4	4	6	2	3
Acerpenna		1		5	2	1			2
Baetisca lacustris									
Caenis		1		3	1	2			2
Diphetor							1		1
Eurylophella					1				1
Isonychia	3	4	6	8	5	5	10	12	12
Leptophlebiidae									
Stenacron					1		1	1	
Stenonema femoratum	2	4	4	1	7	2	7	8	2
Stenonema pulchellum/terminatum	8	4	7	14	13	11	17	21	5
Plecoptera									
Acroneuria									
Allocapnia									
Amphinemura	2	1				1			1
Chloroperlidae	2	3	2	1	1	3	2	2	4
Clioperla clio			2						
Hydroperla crosbyi									
Isoperla w/ horizontal bars	1		1		2		4	2	2
Isoperla w/ vertical bars	1	1		1	2				1
Perlesta		1		1	1	1		1	
Perlidae									
Strophopteryx			1						
Taeniopteryx									
Trichoptera									
Agapetus		1	1	3			1	2	2

Ceraclea (ancylus or flava)									
Cheumatopsyche	3	3		1	3	3		1	2
Chimarra	5	2	5	1	4	2	2	3	8
Dibusa angata				1					
Helicopsyche								1	
Hydropsyche							2		
Hydroptila		1		1		1	1	2	2
Lepidostoma									
Micrasema									
Oecetis	1			2					
Oxyethira		1							
Polycentropus									
Ptilostomis									
Pycnopsyche									
Rhyacophila kiamichi			1				1	1	
Other Insects (Od,Hem,Meg,Lep)									
Argia						1			
Boyeria									
Calopteryx									
Corydalus			1					1	
Enallagma/Ischnura									
Gomphidae (cf *Stylogomphus*)							1		
Gomphidae (not *Stylogomphus*)									1
Hagenius brevistylus									
Nigronia serricornis							1	2	
Petrophila				1					1
Sialis									
Coleoptera									
Ancyronyx variegata							1		
Berosus									
Dubiraphia									
Ectopria						1			
Helichus									1
Psephenus							2		1
Stenelmis	7	9	7	6	9	6	4	5	5
Diptera (excl Chironomidae)									
Chelifera	2		3	3	3	4	2	2	3
Clinocera	1						1		
Hemerodromia						1			
Hexatoma	2	8	2	2	3	2	1	1	
Prosimulium		1	5			1			1
Pseudolimnophila									
Simuliidae (not *Prosimulium*)	7	2	5	4	1	5	2	3	3
Tabanidae		1	1	2					
Tipula	1	1	2	1	1			1	
Oligochaeta									
Enchytraeidae									
Haemonais waldvogeli		1							
Imm. Tubificidae w/ hair chaetae									
Imm. Tubificidae w/o hair chaetae							1		

Lumbriculidae									
Lumbriculidae (w/proboscis)									
Chironomidae									
Corynoneura (w/ sculpturing)						1			
Cricotopus bicinctus									
Cricotopus "other"						1	1	1	4
Diamesa									
Dicrotendipes (modestus/neomodestus)									
Diplocladius cultriger									
Eukiefferiella claripennis gp		1	2		1		1		1
Hydrobaenus									
Micropsectra									
Microtendipes pedellus gp									
Nanocladius cf *spliniplenus*									
Orthocladius (Eudact.) dubitatus				1	1	1	1		
Orthocladius (obumbratus/robacki)		3	1	3	3	1	1	1	1
Parachaetocladius									
Parametriocnemus	1	1							
Paratrichocladius/Orthocladius dorenus	1	2							
Polypedilum aviceps	32	29	29	22	26	32	17	21	27
Polypedilum flavum	4	1		1		2			
Polypedilum illinoense gp		1					1		
Pseudochironomus									
Rheocricotopus cf *robacki*			1					1	
Rheotanytarsus	1				1			1	
Stempellinella									
Stenochironomus									
Stictochironomus									
Tanytarsus "A" (Epler)									
Tanytarsus "C" (Epler)	1								
Tanytarsus "M" (Epler)		1		1	1				
Thienemannimyia group	5	4	4	3	1	4	4	1	1
Tribelos cf *jucundum*									

Table B-5. Benthic macroinvertebrate counts in samples from Big Creek, December 18, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Crangonyx				1					
Caecidotea (unpigmented)									
Hyalella azteca					1	1			
Hydracarina		1							
Lirceus			1		2	1	1	1	1
Menetus			1						
Orconectes		1					1		
Physidae									
Sphaeriidae	1	1					1	1	1
Stygobromus									
Turbellaria	1							1	
Unionidae									
Ephemeroptera									
Acentrella/Plauditus	1			1	1	1	3	1	4
Acerpenna		1	1	1	2	1	2		
Baetis flavistriga							1		
Baetisca lacustris							1		
Caenis	2	3	5	2	4	3	3	5	6
Diphetor							1	1	
Eurylophella									
Isonychia	5	9	8	12	15	9	1	2	2
Leptophlebia	1	2	2		1	1			
Leptophlebiidae									
Leucrocuta									
Paraleptophlebia			1		1	1			1
Procloeon		1		2	2	2			
Stenacron	2	2				2	1	1	1
Stenonema femoratum	6	16	14	9	12	5	17	13	14
Stenonema pulchellum/terminatum	27	23	14	26	19	28	10	12	13
Plecoptera									
Acroneuria									2
Allocapnia	6	3	6	3	2	3	8	11	11
Amphinemura									
Chloroperlidae		1					1		
Clioperla clio	1	2	3	1			1	1	1
Hydroperla crosbyi	1							1	
Isoperla w/ horizontal bars								2	
Isoperla w/ vertical bars									

Perlesta		1	1	1	1	2	1	1	1
Strophopteryx	1		1	1				2	2
Taeniopteryx	2	1	3	2	4		2	2	2
Trichoptera									
Agapetus	2	1	1	1		2	1	2	1
Ceraclea (ancylus or flava)									
Cheumatopsyche		2	2	5	5	3	3		2
Chimarra	5	11	4	12	9	10	3	1	2
Dibusa angata								1	
Helicopsyche									
Hydropsyche	1								
Hydroptila									
Lepidostoma				1					
Micrasema							2	1	
Oecetis									
Polycentropus									
Ptilostomis									
Pycnopsyche			1	1		2	1		
Rhyacophila kiamichi								1	
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Argia		1							1
Basiaeschna janata									
Calopteryx				1					
Corydalus	1			2	1		1	2	5
Dromogomphus									
Enallagma/Ischnura		1				1			
Epitheca (Tetragoneuria)									
Gomphidae (cf *Stylogomphus*)			1				1	1	
Gomphidae (not *Stylogomphus*)									
Hagenius brevistylus									
Macromia						1			
Nigronia serricornis				1			1	2	1
Petrophila				1					
Coleoptera									
Agabus									
Ancyronyx variegata			2	1					
Berosus									
Dubiraphia						1	2		1
Ectopria	1		1						1
Helichus	1	2							
Psephenus			1		1	1	4	6	2
Stenelmis	9	4	5	1	4	4	2	6	1
Diptera (excl Chironomidae)									
Ceratopogoninae									
Chelifera							1		
Clinocera									
Hemerodromia		1				1	1	1	
Hexatoma	1	1		2	2	3	1	3	1
Pilaria									

Prosimulium	4	1	2	1	1	1	2	3	6
Simuliidae (not *Prosimulium*)	7	2	9	2	3	4	4	2	7
Tabanidae						1			
Tipula			1				1	1	
Oligochaeta									
Enchytraeidae	1				1			1	
Imm. Tubificidae w/o hair chaetae	5		1						
Lumbriculidae	2				2			2	
Lumbriculidae (w/proboscis)							2		
Chironomidae									
Ablabesmyia mallochi									
Cardiocladius									
Chironomus	1								
Clinotanypus									
Corynoneura (w/ sculpturing)									
Cricotopus bicinctus									
Cricotopus cf *luciae*	1		2	1			1		1
Cricotopus "other"								1	
Cryptochironomus									
Eukiefferiella claripennis gp			1	1				1	2
Eukiefferiella devonica gp									
Heterotrissocladius							1		
Hydrobaenus									
Micropsectra									
Microtendipes pedellus gp		1				1	1		
Nanocladius cf *downesi*									
Orthocladius (Euortho) w/13 teeth					2				
Orthocladius (*obumbratus/robacki*)							1		
Parachaetocladius								1	
Parametriocnemus									1
Paratrichocladius/Orthocladius dorenus									
Phaenopsectra punctipes gp									
Polypedilum aviceps		1	2			1			1
Polypedilum fallax									
Polypedilum flavum									
Polypedilum scalaenum gp									
Potthastia longimana gp									
Psectrocladius psilopterus gp									
Pseudochironomus									
Rheocricotopus cf *robacki*									
Rheotanytarsus									
Stenochironomus							1		
Tanytarsus "M" (Epler)				1		2	5	2	1
Thienemannimyia group	1	3	3	3	2	1	1	1	1
Tvetenia cf *paucunca*									
Tvetenia cf *vitracies*									
Zavrelimyia									

Table B-6. Benthic macroinvertebrate counts in samples from Big Creek, April 5, 2005.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Crangonyx									
Caecidotea (unpigmented)									
Hyalella azteca									
Hydracarina									
Lirceus	1		1	1	1	1	4	2	3
Menetus									
Orconectes	1								
Physidae									
Sphaeriidae			1	1	2				
Stygobromus									
Turbellaria					1				
Unionidae									
Ephemeroptera									
Acentrella/Plauditus	9	7	12	2	6	12	11	10	4
Acerpenna						1			3
Baetis flavistriga									
Baetisca lacustris									
Caenis	2	1	1	1	4	2	2	3	1
Diphetor	1						2	1	2
Eurylophella	1	1						1	
Isonychia	1	3	2	4	3	5	1	1	3
Leptophlebia									
Leptophlebiidae									1
Leucrocuta									
Paraleptophlebia									
Procloeon									
Stenacron				3	1		1	2	1
Stenonema femoratum	3	2	4	3	1	1	5	6	2
Stenonema pulchellum/terminatum	11	10	9	12	21	8	6	12	12
Plecoptera									
Acroneuria							1	1	1
Allocapnia									
Amphinemura	4	6	6	3		3	3	1	2
Chloroperlidae	6	5	6	3	6	7	8	7	6
Clioperla clio									
Hydroperla crosbyi									
Isoperla w/ horizontal bars		2		1	1	1	1	1	2

Isoperla w/ vertical bars		1	3	1		1			1
Perlesta	3	5	5	7	5	6	5	6	3
Strophopteryx									
Taeniopteryx									
Trichoptera									
Agapetus	1		1	3	2	1		2	1
Ceraclea (ancylus or flava)				2					
Cheumatopsyche		1							
Chimarra	2	8	1	3	3	4	1	1	
Dibusa angata							1		1
Helicopsyche								2	
Hydropsyche									
Hydroptila		2	4	2	1		1	3	2
Lepidostoma									
Micrasema									
Oecetis						1			
Polycentropus									1
Ptilostomis									
Pycnopsyche									
Rhyacophila kiamichi									
Wormaldia				1			5	4	3
Other Insects (Od,Hem,Meg,Lep)									
Argia			1	1					1
Basiaeschna janata									
Calopteryx									
Corydalus		1			2	1	1	1	2
Dromogomphus									
Enallagma/Ischnura									
Epitheca (Tetragoneuria)									
Gomphidae (cf *Stylogomphus*)								1	
Gomphidae (not *Stylogomphus*)		1							
Hagenius brevistylus			1						
Macromia						1			
Nigronia serricornis	1						2		
Petrophila						1			
Coleoptera									
Agabus									
Ancyronyx variegata		1				1			1
Berosus		1							
Dubiraphia		1				1			
Ectopria							1		
Helichus		1					1		
Psephenus						1	3	5	2
Stenelmis	15	7	14	15	10	12	9	8	11
Diptera (excl Chironomidae)									
Ceratopogoninae			1						
Chelifera	1		3	1	1	1			
Clinocera							1		
Hemerodromia				1	2	1	1	1	1
Hexatoma		5	3	1	4	2	2	4	2

Pilaria									
Prosimulium							2	1	2
Simuliidae (not *Prosimulium*)	3	5	7	8	8	7	4	2	4
Tabanidae			1		1				
Tipula	2	1	1	1	1	1		1	
Oligochaeta									
Enchytraeidae									
Imm. Tubificidae w/o hair chaetae							1		
Lumbriculidae		1	1				1	1	
Lumbriculidae (w/proboscis)	1								
Chironomidae									
Ablabesmyia mallochi						1			
Cardiocladius									1
Chironomus									
Clinotanypus									
Corynoneura (w/ sculpturing)									
Cricotopus bicinctus									
Cricotopus cf *luciae*	2	1	1		2	2		1	
Cricotopus "other"	1								
Cryptochironomus						1			
Eukiefferiella claripennis gp	3					1		1	1
Eukiefferiella devonica gp								1	
Heterotrissocladius									
Hydrobaenus									
Micropsectra									
Microtendipes pedellus gp									
Nanocladius cf *downesi*									1
Orthocladius (Euortho) w/13 teeth			1		1				
Orthocladius (*obumbratus/robacki*)	2		1	1		1			
Parachaetocladius									
Parametriocnemus	1								
Paratrichocladius/Orthocladius dorenus									
Phaenopsectra punctipes gp									
Polypedilum aviceps	18	15	6	13	4	7	11	4	8
Polypedilum fallax									
Polypedilum flavum			1	2	3				2
Polypedilum scalaenum gp	1								
Potthastia longimana gp					1				
Psectrocladius psilopterus gp									
Pseudochironomus									
Rheocricotopus cf *robacki*	1		1						2
Rheotanytarsus		1		1			1		1
Stenochironomus									1
Tanytarsus "M" (Epler)									
Thienemannimyia group	2	3		2	2	2	1	1	2
Tvetenia cf *paucunca*						1		1	
Tvetenia cf *vitracies*		1							
Zavrelimyia									

APPENDIX C: Caney Creek benthic macroinvertebrate data

Table C-1. Benthic macroinvertebrate counts in samples from Caney Creek, January 23, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	62	66	58	68	66	64	10	19	29
Helisoma									
Hydracarina									3
Menetus			1						
Orconectes			1	1	2	1			
Stygobromus									
Synurella bifurca	1	3	4	6	3	1		1	4
Turbellaria	1	2	3				1	1	7
Ephemeroptera									
Acentrella/Plauditus								1	
Ameletus									
Diphetor									
Leptophlebiidae	1	1	2	1	1	4			
Leucrocuta							3		
Paraleptophlebia									
Siphlonurus	18	15	12	6	10	10			
Stenonema femoratum									
Tricorythodes									
Plecoptera									
Allocapnia	3	1	1	3	1	6	5	3	6
Amphinemura									2
Chloroperlidae							1		2
Clioperla clio							2	9	5
Isoperla w/ vertical bars							1		
Perlidae									
Strophopteryx		1	1				4	13	17
Zealeuctra	2	2	3				1		
Trichoptera									
Agapetus							4	3	3
Ironoquia	1			1					
Lepidostoma		1		1					
Neophylax									
Polycentropus	1	2							
Pycnopsyche					1				
Rhyacophila kiamichi									
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Aquarius									
Libellulidae									

Nigronia serricornis									
Notonecta									
Coleoptera									
Agabus	2	1	3		1	4			
Dineutus									
Helichus									
Hydroporus	1				1	1			
Oreodytes									
Psephenus								3	
Stenelmis									
Diptera (excl Chironomidae)									
Ceratopogoninae									
Chlorotabanus									
Clinocera									
Hexatoma									
Pilaria								1	1
Prosimulium		1	1	1			60	43	11
Simuliidae (not *Prosimulium*)			2						
Tabanidae					1				
Tipula									1
Oligochaeta									
Dero									
Enchytraeidae		1							
Lumbriculidae		1		1		1			
Nais									
Chironomidae									
Bryophaenocladius									
Constempellina							2		
Corynoneura (no sculpturing)	4	1	2	1	2	5	1		1
Cricotopus "other"									
Cricotopus/Orthocladius									
Eukiefferiella claripennis gp.			1	1	2			1	2
Heterotrissocladius			1	1		1			1
Mesocricotopus									
Micropsectra							1		
Natarsia	1		1						
Orthocladius (Euortho) w/13 teeth									
Orthocladius (obumbratus/robacki)							1		
Parachaetocladius							1		1
Parametriocnemus	1							1	1
Paratrichocladius/Orthocladius dorenus			1	3	2	1	1		1
Platysmittia cf *fimbriata*									
Polypedilum aviceps									
Potthastia longimana gp.									
Rheocricotopus cf *unidentatus* or "VA"									
Stictochironomus				2	1				
Stilocladius cf *clinopecten*								1	1
Tanytarsus "L" (Epler)									
Tanytarsus "M" (Epler)									
Thienemannimyia group									

Tribelos cf *jucundum*									
Zavrelimyia	1	1		2	3	6	1	1	1

Table C-2. Benthic macroinvertebrate counts in samples from Caney Creek, March 27, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	4	5	4	8	10	11	2	3	4
Helisoma									
Hydracarina									
Menetus									
Orconectes								1	
Stygobromus									
Synurella bifurca			1		1				
Turbellaria	2		1				2		1
Ephemeroptera									
Acentrella/Plauditus			2	3	2			2	
Ameletus		1							
Diphetor						1			
Leptophlebiidae									
Leucrocuta	30	36	26	28	26	33	26	20	18
Paraleptophlebia	3	11	4	10	13	13	4	9	6
Siphlonurus									
Stenonema femoratum		1		1	2	3			
Tricorythodes								1	
Plecoptera									
Allocapnia									
Amphinemura	23	20	24	21	20	12	37	38	33
Chloroperlidae	4	5	5	3	4	3	3		4
Clioperla clio	5	2	3	2	3	5	3	1	1
Isoperla w/ vertical bars	6		4	4	3	4	7	3	9
Perlidae				2		2	1	2	
Strophopteryx									
Zealeuctra									
Trichoptera									
Agapetus	3	3	2	2	1	3	2	2	3
Ironoquia									
Lepidostoma									
Neophylax									
Polycentropus									
Pycnopsyche									
Rhyacophila kiamichi			4	1	1			1	1
Wormaldia	2		4		1	2	1	2	5
Other Insects (Od,Hem,Meg,Lep)									
Aquarius		1							
Libellulidae									
Nigronia serricornis	1	1	4			1			
Notonecta									

Coleoptera									
Agabus									
Dineutus								2	
Helichus									
Hydroporus						1			
Oreodytes									
Psephenus		1							
Stenelmis		1					3		2
Diptera (excl Chironomidae)									
Ceratopogoninae				1					
Chlorotabanus									
Clinocera	2				1				
Hexatoma	1					1			
Pilaria									
Prosimulium			1					2	1
Simuliidae (not *Prosimulium*)	2	3	5	1	5	1	2	4	9
Tabanidae									
Tipula	1	1	2	2					
Oligochaeta									
Dero				1					
Enchytraeidae									
Lumbriculidae				1		1	1		
Nais						1			
Chironomidae									
Bryophaenocladius									
Constempellina	1						3	1	
Corynoneura (no sculpturing)									
Cricotopus "other"	1	1			1				
Cricotopus/Orthocladius									
Eukiefferiella claripennis gp.	1		1						
Heterotrissocladius									
Mesocricotopus									
Micropsectra		1		2	1		1	1	
Natarsia									
Orthocladius (Euortho) w/13 teeth									
Orthocladius (obumbratus/robacki)	1								
Parachaetocladius									
Parametriocnemus								2	
Paratrichocladius/Orthocladius dorenus				1					
Platysmittia cf *fimbriata*				1					
Polypedilum aviceps	7	3	2	1	1		1		
Potthastia longimana gp.		1							
Rheocricotopus cf *unidentatus* or "VA"		1		3	3	1		1	2
Stictochironomus									
Stilocladius cf *clinopecten*									
Tanytarsus "L" (Epler)									
Tanytarsus "M" (Epler)		1	1			1			
Thienemannimyia group									
Tribelos cf *jucundum*				1					
Zavrelimyia					1		1	2	1

Table C-3. Benthic macroinvertebrate counts in samples from Caney Creek, December 18, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	50	47	40	46	56	51	33	32	45
Caecidotea (unpigmented)			1		1				1
Gordiidae									
Hydracarina					1				
Orconectes		1							1
Stygobromus									
Synurella bifurca	3	2	2	2	6	5	5	2	6
Turbellaria		1	2			1			
Ephemeroptera									
Acentrella/Plauditus							1	1	
Ameletus	1								
Caenis									
Diphetor			1						
Leptophlebia				1	1	2			
Leptophlebiidae	1		1						
Leucrocuta		1							
Paraleptophlebia									
Stenonema femoratum	2	2	5	7	14	6	2	1	2
Plecoptera									
Allocapnia	7	8	10	3	4	3	27	32	17
Amphinemura									
Chloroperlidae									
Clioperla clio	6	4	5	2		2	1		
Isoperla w/ vertical bars									
Perlidae									
Strophopteryx	3		2	1	1	1	11	13	11
Taeniopteryx							1		1
Zealeuctra	1			2		2	2	1	4
Trichoptera									
Agapetus	2	2	2	1	2				
Diplectrona metequi			1						
Diplectrona modesta	1	1	1	3		9			
Hydroptila									
Ironoquia									
Lepidostoma	1	1		1		2			
Neophylax	1	1							
Polycentropus	1	2						1	1
Pycnopsyche			1						
Rhyacophila kiamichi									
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									

Aquarius									
Chauliodes pectinicornis									
Gomphidae (not *Stylogomphus*)									
Helocordulia				1					
Nigronia serricornis	1	2	2	1					
Sialis									
Somatochlora									
Coleoptera									
Agabus	1								
Dubiraphia									
Ectopria									
Helichus									
Hydroporus									
Laccophilus		1		1					
Psephenus	1	1							2
Stenelmis							2	4	
Stenus				1					
Diptera (excl Chironomidae)									
Ceratopogoninae					1				
Clinocera									
Hexatoma			1			1			
Prosimulium		1		1			2		1
Pseudolimnophila									
Simuliidae (not *Prosimulium*)								1	
Stratiomyidae									
Tabanidae							1	1	
Tipula	11	9	13	20	11	12	1	5	4
Oligochaeta									
Enchytraeidae								1	
Imm. Tubificidae w/ hair chaetae									
Imm. Tubificidae w/o hair chaetae				2					
Lumbriculidae	1	2	1			1	5	3	2
Nais									
Chironomidae									
Constempellina		1							
Corynoneura (w/ sculpturing)							1		
Corynoneura (no sculpturing)									
Cricotopus "other"									
Eukiefferiella claripennis gp.		1					4	2	
Heterotrissocladius				1					
Micropsectra									
Microtendipes pedellus gp				1					
Natarsia									1
Parachaetocladius	2	7	7		1	1	1		1
Parakiefferiella "E" (Epler)									
Parametriocnemus									
Paratanytarsus									
Paratrichocladius/Orthocladius dorenus									
Polypedilum aviceps									
Polypedilum halterale gp									

Rheocricotopus cf *unidentatus* or "VA"									
Stenochironomus									
Tanytarsus "M" (Epler)		1	1						
Thienemannimyia group	1								
Tribelos cf *jucundum*						1			
Trissopelopia	1	1	1				1		
Tvetenia cf *paucunca*									
Zavrelimyia	1			2					

Table C-4. Benthic macroinvertebrate counts in samples from Caney Creek, March 16, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	9	15	7	24	16	29	5	6	3
Caecidotea (unpigmented)									
Gordiidae									
Hydracarina			1						
Orconectes				1					
Stygobromus						1			
Synurella bifurca	1	1	1			1	2	4	2
Turbellaria			1			1	2		2
Ephemeroptera									
Acentrella/Plauditus	1		1	1	2		7	5	4
Ameletus		1	1	1	1				
Caenis									
Diphetor									
Leptophlebia									
Leptophlebiidae									

Leucrocuta	15	21	19	13	12	16	5	4	4
Paraleptophlebia	9	8	13	10	15	8	4	7	3
Stenonema femoratum		2		13	8	8			
Plecoptera									
Allocapnia									
Amphinemura	17	10	12	3	8	7	21	12	12
Chloroperlidae	7	7	4	3	4	4	1		
Clioperla clio	5	2	5				1	4	1
Isoperla w/ vertical bars	9	10	11	7	5	3	18	17	34
Perlidae									
Strophopteryx				1			1	4	
Taeniopteryx									
Zealeuctra									
Trichoptera									
Agapetus	6	3	2	6	7	1	8	3	2
Diplectrona metequi									
Diplectrona modesta						1			
Hydroptila						1	1		
Ironoquia									
Lepidostoma									
Neophylax	1	1			1				
Polycentropus			1	1		2			
Pycnopsyche									
Rhyacophila kiamichi				1	2		1	1	1
Wormaldia	5	2	1		2		1	2	3
Other Insects (Od,Hem,Meg,Lep)									
Aquarius									
Chauliodes pectinicornis									
Gomphidae (not *Stylogomphus*)									
Helocordulia									
Nigronia serricornis			4						
Sialis									
Somatochlora									
Coleoptera									
Agabus									
Dubiraphia									1
Ectopria									
Helichus									
Hydroporus								1	
Laccophilus	1				1		1		
Psephenus				1		1	2	1	
Stenelmis			1				4	2	3
Stenus									
Diptera (excl Chironomidae)									
Ceratopogoninae								2	
Clinocera				1			1	1	
Hexatoma		3			1	1			
Prosimulium	1		2					2	
Pseudolimnophila									
Simuliidae (not *Prosimulium*)		1	1		1		3	4	4

Stratiomyidae									
Tabanidae	1								
Tipula	1	3	2	1	3		2		1
Oligochaeta									
Enchytraeidae					1				1
Imm. Tubificidae w/ hair chaetae					1				
Imm. Tubificidae w/o hair chaetae				1				1	
Lumbriculidae	1		1	2	1		2	3	2
Nais									
Chironomidae									
Constempellina			1			1	6	8	12
Corynoneura (w/ sculpturing)									
Corynoneura (no sculpturing)									
Cricotopus "other"									
Eukiefferiella claripennis gp.		1				1		2	
Heterotrissocladius			1	1		1			
Micropsectra	3	3	2			2			
Microtendipes pedellus gp									
Natarsia									2
Parachaetocladius									
Parakiefferiella "E" (Epler)				1	1				
Parametriocnemus	1	1			1				
Paratanytarsus						1			
Paratrichocladius/Orthocladius dorenus									
Polypedilum aviceps	2							1	
Polypedilum halterale gp									
Rheocricotopus cf *unidentatus* or "VA"				3	2	1			
Stenochironomus									
Tanytarsus "M" (Epler)			2			1			
Thienemannimyia group	3		2						
Tribelos cf *jucundum*									
Trissopelopia		2	1	2					
Tvetenia cf *paucunca*	1	1						2	1
Zavrelimyia		2		2	4	7	1	1	2

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Table C-5. Benthic macroinvertebrate counts in samples from Caney Creek, December 17, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	14	11	15	31	21	41	18	27	9
Caecidotea (unpigmented)									
Helisoma									
Hydracarina	1			1		1			
Menetus									
Orconectes					1				1
Sphaeriidae									
Stygobromus									
Synurella bifurca	1	4	1		3	1	3	2	4
Turbellaria	3	2	2	2	1	2	1	2	1
Ephemeroptera									
Acentrella/Plauditus		2	1		1		4	1	3
Acerpenna								1	
Ameletus			1	1		1			
Caenis									
Diphetor									
Leptophlebia					1				
Leptophlebiidae	4	7	6	2	5	4	4	5	2
Leucrocuta	7	9	10	9	6	7	6	12	13
Paraleptophlebia									
Stenacron								1	
Stenonema femoratum	6	6	2	2	5	3	3	2	3
Plecoptera									
Allocapnia	9	12	10	5	13	4	8	6	5
Amphinemura									
Chloroperlidae	2	1	1	1	3	1	2	1	3
Clioperla clio	11	17	18	8	11	4	13	5	11
Isoperla w/ vertical bars	1	2	1	1		1	1	3	2
Perlesta									
Perlidae	2			1			2	1	2
Perlinella drymo									
Strophopteryx	3	2	3	1	2	4	4	1	5
Zealeuctra	1	1	1	1	2	2			1
Trichoptera									
Agapetus	1	3	4	2	5	2	2	2	2
Chimarra									
Diplectrona modesta		1	1						1
Hydroptila									1
Lepidostoma	3	3	1	1	3	1	1	3	5
Neophylax									
Polycentropus			1	1	1			2	2

Pycnopsyche							1		
Rhyacophila kiamichi			1						
Wormaldia			1					1	
Other Insects (Od,Hem,Meg,Lep)									
Aquarius									
Calopteryx									
Enallagma									
Microvelia									
Nigronia serricornis									
Pyralidae									
Sialis									
Somatochlora									
Coleoptera									
Agabus						1			
Dineutus									
Dubiraphia					1				
Hydroporus	1		2	1				1	
Psephenus				1			2	1	1
Staphylinidae	1								
Stenelmis								2	1
Diptera (excl Chironomidae)									
Ceratopogoninae		1							
Clinocera									1
Dolichopodidae									
Hexatoma			1	1		1			
Pilaria						1			
Prosimulium	1	1	1			1	5	1	2
Pseudolimnophila			1						
Simuliidae (not *Prosimulium*)					1				
Tabanidae				1			1		
Tipula	7	2	2	3	3	1	10	5	8
Oligochaeta									
Dero									
Enchytraeidae						1			
Imm. Tubificidae w/ hair chaetae					1				
Imm. Tubificidae w/o hair chaetae									
Lumbriculidae	2		1	1	1		3	2	1
Nais									
Chironomidae									
Ablabesmyia mallochi									
Constempellina									
Corynoneura (w/ sculpturing)				2					
Corynoneura (no sculpturing)					1				
Cricotopus cf *luciae*							1		
Cricotopus "other"			1						1
Cryptochironomus									
Dicrotendipes modestus/neomodestus									
Eukiefferiella claripennis gp.	1	1					1		
Heterotrissocladius	3	1	5	2	2	1		5	1
Micropsectra									

Microtendipes pedellus gp				1					
Natarsia									
Nilotanypus cf *fimbriata*									
Orthocladius (obumbratus/robacki)									
Parachaetocladius	3	4	3	7	1		1	1	1
Parametriocnemus	8	7	1	4	3	8	1	1	4
Paratanytarsus									
Paratrichocladius/Orthocladius dorenus									
Platysmittia									
Polypedilum aviceps	1			1					1
Polypedilum illinoense gp				1					
Psectrocladius cf *elatus*									
Rheocricotopus cf *robacki*									
Rheocricotopus cf *unidentatus* or "VA"									
Stictochironomus				1					
Tanytarsus "D" (Epler)									
Tanytarsus "M" (Epler)	1								
Tanytarsus "O" (Epler)									
Tanytarsus "U" (Epler)									
Thienemanniella cf *xena*								1	
Thienemannimyia group					1	2			
Tribelos cf *jucundum*				1		1		1	2
Trissopelopia	1		1			1		1	
Unniella									
Zavrelimyia	1			2	1	2	2		

Table C-6. Benthic macroinvertebrate counts in samples from Caney Creek, March 17, 2005.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	17	16	17	20	29	26	14	10	15
Caecidotea (unpigmented)									
Helisoma								1	
Hydracarina									
Menetus								1	
Orconectes		1					1	1	
Sphaeriidae									
Stygobromus									
Synurella bifurca								1	1
Turbellaria	1			1	1				
Ephemeroptera									
Acentrella/Plauditus						1	3	2	3
Acerpenna									
Ameletus									
Caenis									1
Diphetor									
Leptophlebia									
Leptophlebiidae									
Leucrocuta	32	31	29	31	23	25	25	28	20
Paraleptophlebia	20	8	15	14	13	14	12	15	9
Stenacron									
Stenonema femoratum	2	2	1	5	6	2	1	2	
Plecoptera									
Allocapnia									
Amphinemura	1	1	2			2	6	5	7
Chloroperlidae	7	11	8	7	12	11	7	11	5
Clioperla clio		4	1				3		1
Isoperla w/ vertical bars	2	1	1		2	2	3	2	1
Perlesta									
Perlidae									
Perlinella drymo									
Strophopteryx									
Zealeuctra									
Trichoptera									
Agapetus	1	4	5	1	2				1
Chimarra									
Diplectrona modesta									
Hydroptila	1	2	2					1	2
Lepidostoma									
Neophylax									
Polycentropus	1	1	1		1			1	2

Pycnopsyche									1
Rhyacophila kiamichi		1							2
Wormaldia	1								
Other Insects (Od,Hem,Meg,Lep)									
Aquarius									1
Calopteryx									
Enallagma									
Microvelia							1		
Nigronia serricornis			1						
Pyralidae									
Sialis									
Somatochlora		1							
Coleoptera									
Agabus									
Dineutus									
Dubiraphia									
Hydroporus				1		1		1	
Psephenus			1	1	1		1	1	3
Staphylinidae			1						
Stenelmis	1						3	2	1
Diptera (excl Chironomidae)									
Ceratopogoninae	1	1		1	1		1		
Clinocera		1							
Dolichopodidae							1		
Hexatoma				1		1		1	
Pilaria									
Prosimulium									
Pseudolimnophila									
Simuliidae (not *Prosimulium*)							1		1
Tabanidae									
Tipula		1	1		2	1			1
Oligochaeta									
Dero									
Enchytraeidae									
Imm. Tubificidae w/ hair chaetae				1					1
Imm. Tubificidae w/o hair chaetae						2			
Lumbriculidae	1				1	1		2	1
Nais									
Chironomidae									
Ablabesmyia mallochi				2			9	3	1
Constempellina								3	1
Corynoneura (w/ sculpturing)		1						1	
Corynoneura (no sculpturing)									
Cricotopus cf *luciae*							1		
Cricotopus "other"			1			1			
Cryptochironomus									
Dicrotendipes modestus/neomodestus									
Eukiefferiella claripennis gp.									
Heterotrissocladius									
Micropsectra	2		1	2			1		

Microtendipes pedellus gp									1
Natarsia						1			1
Nilotanypus cf *fimbriata*									
Orthocladius (obumbratus/robacki)							1		
Parachaetocladius									
Parametriocnemus									
Paratanytarsus									
Paratrichocladius/Orthocladius dorenus									
Platysmittia					1				
Polypedilum aviceps	3	5	6		1		1	2	1
Polypedilum illinoense gp					1				
Psectrocladius cf *elatus*									
Rheocricotopus cf *robacki*									1
Rheocricotopus cf *unidentatus* or "VA"	2	1	2	2		2		2	2
Stictochironomus				1					
Tanytarsus "D" (Epler)								1	1
Tanytarsus "M" (Epler)	1		2						1
Tanytarsus "O" (Epler)									
Tanytarsus "U" (Epler)									
Thienemanniella cf *xena*									
Thienemannimyia group			2		2	3	1		2
Tribelos cf *jucundum*				4			1		4
Trissopelopia					1				
Unniella									
Zavrelimyia	3	6		5		4	2		4

APPENDIX D: Harris Creek benthic macroinvertebrate data

Table D-1. Benthic macroinvertebrate counts in samples from Harris Creek, January 24, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Elimia	1						2		1
Hyalella azteca									
Hydracarina	1		1				1		1
Lirceus					1				
Orconectes	1				1				
Synurella bifurca									
Turbellaria									
Ephemeroptera									
Acentrella/Plauditus	9	14	7	14	7	13	7	18	12
Acerpenna	3			1		1		1	
Ameletus									
Baetis flavistriga									
Caenis	2	2	2		1			1	
Diphetor									
Ephemera									
Eurylophella	2	1	2		1			1	
Isonychia	3	8	9	12	10	9	14	21	13
Leptophlebia									1
Leptophlebiidae									
Leucrocuta						1	2		1
Paraleptophlebia								1	
Stenacron	1	3			2	3	3	3	3
Stenonema femoratum	9	10	4	2		1	5		1
Stenonema mediopunctatum	9	12	10	16	20	22	16	9	16
Stenonema pulchellum/terminatum				1	1		1	1	1
Stenonema terminatum variant		5		1	1	3	1	3	
Plecoptera									
Acroneuria						1			
Agnetina				1					
Allocapnia			2	1	1	4	6	5	2
Amphinemura									
Chloroperlidae									
Clioperla clio				1	1	2			
Helopicus natalis									
Isoperla w/ vertical bars	9	6	4	3	5	3	3	3	2
Neoperla									
Paracapnia angulata									
Perlesta									
Strophopteryx	2					1	1		

Taeniopteryx	5	5	4	4	3	5	5	2	5
Trichoptera									
Agapetus	4		2	1	3	1	2		
Cheumatopsyche	7	7	12	20	8	6	4	10	15
Chimarra	1	3	3	3	4	3	2		3
Diplectrona modesta									
Helicopsyche									
Hydropsyche									
Hydroptila									
Lepidostoma									
Neophylax						1	2		
Polycentropus						1			
Psychomyia flavida									
Pycnopsyche									
Rhyacophila kiamichi					1				
Stactobiella									
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Argia		1	1		1			1	2
Calopteryx									
Corydalus		1		2	2	1		2	4
Enallagma									
Gomphidae (cf *Stylogomphus*)	2	3			1			1	1
Nigronia serricornis		1			1	3	1		
Petrophila					1	1			
Sialis									
Coleoptera									
Dubiraphia									
Ectopria				1					
Helichus									
Microcylloepus				1					
Optioservus	8	1	8	2	5	4	5	1	4
Psephenus	2	1	2	2	7	1	3		1
Stenelmis						1	1		
Diptera (excl Chironomidae)									
Chlorotabanus									
Clinocera		2						1	
Hexatoma			1						
Prosimulium	11	10	13	8	8	5	8	12	6
Simuliidae (not *Prosimulium*)									
Tabanidae									
Tipula	1	1	2	1	1		2		
Oligochaeta									
Dero									
Imm. Tubificidae w/o hair chaetae									
Lumbriculidae									
Pristinella									
Chironomidae									
Ablabesmyia mallochi									
Cardiocladius									

Corynoneura (no sculpturing)			2						
Cricotopus "other"								1	
Cricotopus/Orthocladius									
Cryptochironomus									
Dicrotendipes modestus/neomodestus									
Eukiefferiella claripennis gp									2
Eukiefferiella cf *tirolensis*	2		1				1		2
Micropsectra									
Microtendipes pedellus gp	1								
Nanocladius alternatherae gp									
Nanocladius downesi									
Orthocladius (Euortho) w/13 teeth								1	1
Orthocladius obumbratus/robacki									
Parametriocnemus						1			
Paratanytarsus									
Polypedilum aviceps									
Rheocricotopus cf *robacki*									
Rheocricotopus cf *unidentatus* or "VA"									
Rheotanytarsus					1				
Sympotthastia cf *zavreli*									
Tanytarsus									
Tanytarsus "A" (Epler)									
Tanytarsus "M" (Epler)									
Tanytarsus "O" (Epler)									
Tanytarsus "T" (Epler)									
Thienemannimyia gp	4	3	5	2	1	2	1	1	
Tvetenia cf *paucunca*			3				1		

Table D-2. Benthic macroinvertebrate counts in samples from Harris Creek, March 27, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Elimia	1	1	1	3		3		2	
Hyalella azteca		3							
Hydracarina								1	
Lirceus				1	1				1
Orconectes				1	1		1	1	
Synurella bifurca									
Turbellaria	1					1			
Ephemeroptera									
Acentrella/Plauditus	9	12	4	7	9	6	4	8	5
Acerpenna	2	1	4		3	2	4	4	5
Ameletus									
Baetis flavistriga								1	
Caenis				2	1				2
Diphetor	2		1				1		
Ephemera									
Eurylophella	3	2	2	4	1	1		2	2
Isonychia	12	11	8	2	2	7	8	9	11
Leptophlebia									
Leptophlebiidae									
Leucrocuta	6		4	4	1	3		2	3
Paraleptophlebia		1	1	1	2	1	1	2	1
Stenacron	1	3	2	3	3	4	3	1	2
Stenonema femoratum	1	8	1	3	3	1	2		1
Stenonema mediopunctatum	12	7	17	6	16	5	13	8	12
Stenonema pulchellum/terminatum			1	1	1	2	2	1	2
Stenonema terminatum variant	7	5	8	2	4	2	4	3	8
Plecoptera									
Acroneuria					1	1	1		
Agnetina									
Allocapnia									
Amphinemura	7	6	5	2	3	10	5	8	5
Chloroperlidae	2		1	1	4	1	3	1	1
Clioperla clio									
Helopicus natalis			1						
Isoperla w/ vertical bars	6	1	6	8	8	12	5	8	7
Neoperla								1	
Paracapnia angulata									
Perlesta		1							
Strophopteryx									
Taeniopteryx									
Trichoptera									
Agapetus	2	2	1	4	2	6	1	2	2

Cheumatopsyche	3	4	5	4	4	2	5	1	2
Chimarra			4	1		4	1	1	2
Diplectrona modesta									
Helicopsyche									
Hydropsyche									
Hydroptila				2	1			3	
Lepidostoma									
Neophylax		1							
Polycentropus						1	1		
Psychomyia flavida									
Pycnopsyche									
Rhyacophila kiamichi		3	3	1	1	1	2		1
Stactobiella									
Wormaldia									1
Other Insects (Od,Hem,Meg,Lep)									
Argia	1	1	1	1		1		1	1
Calopteryx			1					1	
Corydalus	1	1	1	4	2	1	3	2	5
Enallagma									
Gomphidae (cf *Stylogomphus*)		1			1				
Nigronia serricornis	1		3	1	1		1		
Petrophila					2				
Sialis									
Coleoptera									
Dubiraphia									
Ectopria									
Helichus									
Microcylloepus	2			1		1		2	
Optioservus	1	2			1	2	3	3	2
Psephenus	4	3	5	14	9	2	3	2	2
Stenelmis					1		2	3	
Diptera (excl Chironomidae)									
Chlorotabanus									
Clinocera							1		
Hexatoma									
Prosimulium	2	2		3	1	7	2	2	1
Simuliidae (not *Prosimulium*)	3	6	1	1	2	5	4	1	2
Tabanidae									
Tipula					1		1	4	
Oligochaeta									
Dero				1					
Imm. Tubificidae w/o hair chaetae					1				
Lumbriculidae					1				
Pristinella									
Chironomidae									
Ablabesmyia mallochi						1			
Cardiocladius									
Corynoneura (no sculpturing)									
Cricotopus "other"	1	1	1				1		1
Cricotopus/Orthocladius							1		

Cryptochironomus		1							
Dicrotendipes modestus/neomodestus		1							
Eukiefferiella claripennis gp		1							1
Eukiefferiella cf *tirolensis*			1		1				
Micropsectra									
Microtendipes pedellus gp									
Nanocladius alternatherae gp									
Nanocladius downesi									1
Orthocladius (Euortho) w/13 teeth		1				1			
Orthocladius obumbratus/robacki	3	1	1			1	6	4	1
Parametriocnemus								1	2
Paratanytarsus	1								
Polypedilum aviceps				1			1		1
Rheocricotopus cf *robacki*	1	2	1	2		1	2	2	1
Rheocricotopus cf *unidentatus* or "VA"		1							
Rheotanytarsus	1	2	1		1			1	
Sympotthastia cf *zavreli*									
Tanytarsus									
Tanytarsus "A" (Epler)					1		1		
Tanytarsus "M" (Epler)								1	
Tanytarsus "O" (Epler)	1								
Tanytarsus "T" (Epler)		1							
Thienemannimyia gp			3	8	2		1		3
Tvetenia cf *paucunca*						1			

Table D-3. Benthic macroinvertebrate counts in samples from Harris Creek, January 5, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Branchiobdellida									
Elimia	2					1			
Gordiidae									
Hydracarina	1						1		
Lirceus									
Orconectes	1								
Stygobromus									
Turbellaria									
Ephemeroptera									
Acentrella/Plauditus	3	6	5	4	6	9	5	9	3
Acerpenna	1	1	2	1	1	2	1	3	2
Baetis flavistriga								1	
Caenis			1	1					
Diphetor	3	1	1	1	1	1	1	2	5
Ephemera			1						
Eurylophella	1		1	1		1			
Isonychia	3	7	3	10	13	5	15	9	16
Leptophlebia		5		2	3	1			
Leptophlebiidae									
Leucrocuta	2	1	2	2	2				1
Paraleptophlebia		1	1	1		1		1	1
Stenacron	6	1	5	4	2	1	2	1	
Stenonema femoratum	7	4	5	1	1	12	1	2	
Stenonema mediopunctatum	11	8	13	12	13	5	14	11	14
Stenonema pulchellum/terminatum				1	2	3	6	2	7
Stenonema terminatum variant	1		4	1		2	2		2
Plecoptera									
Acroneuria		2	1		1		2		1
Agnetina									
Allocapnia	7	6	7	4	5	8	4	9	6
Amphinemura									
Chloroperlidae									
Clioperla clio									
Helopicus natalis					1			1	
Isoperla w/ vertical bars	4	2	5	2	3	1	3	2	3
Neoperla									
Paracapnia angulata							2	2	3
Strophopteryx		1	1	2			3	1	2
Taeniopteryx			4	2	1	4	2	2	4
Zealeuctra								1	
Trichoptera									
Agapetus	2	2	3	4	7	2	2	4	2

Cheumatopsyche	4	8	8	14	10	17	7	5	6
Chimarra	7	9	4	5	5	6	8	4	6
Hydropsyche									
Hydroptila									
Lepidostoma						1			
Neophylax				1		1	1	2	1
Polycentropus			1				1		
Pycnopsyche				1					1
Rhyacophila kiamichi	1		1				1	1	
Stactobiella		3		1		1			
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Argia	1	1					1		
Corydalus	1		1			1			
Gomphidae (cf *Stylogomphus*)	1				1				1
Nigronia serricornis	1		2			1			
Petrophila				1					
Sialis		1							
Coleoptera									
Ectopria						1			
Microcylloepus									
Optioservus	3	2	4	2	3	2	2		2
Psephenus	3	3	3	1	1	2	2	2	1
Stenelmis	1				1			3	
Diptera (excl Chironomidae)									
Clinocera									
Hemerodromia									
Prosimulium	3	8	3	9	5	2	3	7	1
Simuliidae (not *Prosimulium*)	1		2	1					
Tabanidae									
Tipula	2	1		1			1	3	1
Oligochaeta									
Enchytraeidae	1								
Imm. Tubificidae w/o hair chaetae			1						
Lumbriculidae									
Nais									
Chironomidae									
Ablabesmyia mallochi									
Brillia cf *flavifrons*						1		1	1
Corynoneura (w/ sculpturing)	1			1					
Cricotopus "other"			1						
Cryptochironomus									
Dicrotendipes modestus/neomodestus									
Djalmabatista pulchra									
Eukiefferiella claripennis gp					1				
Eukiefferiella cf *tirolensis*									
Hydrobaenus "O" (Epler)									
Labrundinia cf *pilosella*									
Micropsectra "C" (Epler)									
Micropsectra "D" (Epler)									

Microtendipes pedellus gp	1	3			1				
Orthocladius (Euortho) w/13 teeth		5		1		1			
Orthocladius obumbratus/robacki									
Parametriocnemus	2		1	1	2	1	1	1	1
Paratrichocladius/Orthocladius dorenus									
Polypedilum aviceps									
Polypedilum flavum				1	2	1		1	4
Polypedilum halterale gp									
Polypedilum illinoense gp									
Potthastia longimana gp									
Pseudochironomus									
Rheocricotopus cf *robacki*	1								
Rheotanytarsus								1	
Stempellinella		1							
Sympotthastia cf *zavreli*	2						1	1	
Tanytarsus "A" (Epler)									
Tanytarsus "L" (Epler)									
Tanytarsus "M" (Epler)	2						1	1	
Thienemannimyia gp	1		1		1	1		1	1
Tribelos cf *jucundum*									
Trissopelopia	3	3		1	3		3	2	1
Tvetenia cf *paucunca*	1	4	1	2	1	1	1	1	
Zavrelimyia	1		1		1				

Table D-4. Benthic macroinvertebrate counts in samples from Harris Creek, March 17, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Branchiobdellida									
Elimia		1		1					
Gordiidae									
Hydracarina		1						1	1
Lirceus									
Orconectes	1		1			1	1	1	1
Stygobromus		1							1
Turbellaria			1				1		
Ephemeroptera									
Acentrella/Plauditus	14	9	5	8	5	13	9	8	7
Acerpenna	1	2			1		2	3	3
Baetis flavistriga									
Caenis	1		1		2			1	3
Diphetor	4	1	2	2	1	1	6	3	5
Ephemera									
Eurylophella	3	3	2	2	4	2		3	4
Isonychia	1	6	9	1	5	6	5	5	6
Leptophlebia									
Leptophlebiidae								1	
Leucrocuta	5		3	4	2	2	1	4	2
Paraleptophlebia	2	2	1			1	4		
Stenacron			2	4	6	1	2	4	1
Stenonema femoratum	7	4	5	4	3	5	3	2	4
Stenonema mediopunctatum	11	5	6	16	4	16	5	8	6
Stenonema pulchellum/terminatum			2		2	3	3	1	2
Stenonema terminatum variant	3	6	2	1	2	3	4	3	5
Plecoptera									
Acroneuria	1					1			
Agnetina			1						
Allocapnia									
Amphinemura	3	3	3	3	2		3	3	1
Chloroperlidae	2	1	1				3	2	4
Clioperla clio									
Helopicus natalis									
Isoperla w/ vertical bars	4	4	10	8	9	7	5	9	10
Neoperla					1				
Paracapnia angulata									
Strophopteryx									
Taeniopteryx									
Zealeuctra									
Trichoptera									
Agapetus	3	2	1	5	4	1	2	1	2

Cheumatopsyche	6	9	5	2	3	11	5		2
Chimarra		4	1	1	3	4	2	2	
Hydropsyche									
Hydroptila									
Lepidostoma									
Neophylax									
Polycentropus				1					
Pycnopsyche									
Rhyacophila kiamichi									
Stactobiella									
Wormaldia			1					1	
Other Insects (Od,Hem,Meg,Lep)									
Argia		1							
Corydalus	1			2	1	1		1	1
Gomphidae (cf *Stylogomphus*)	1	2	2					1	
Nigronia serricornis		1	1		1				
Petrophila									
Sialis	1								
Coleoptera									
Ectopria									
Microcylloepus			1				1	1	
Optioservus	2	1							1
Psephenus	4	3	2	7	9	2	5	4	6
Stenelmis		1	1						2
Diptera (excl Chironomidae)									
Clinocera		1							
Hemerodromia									
Prosimulium		1	1			1		1	
Simuliidae (not *Prosimulium*)	4	3	2	1	1	2	2	2	4
Tabanidae		1		3	1			1	1
Tipula	1		2	2	1	2	1		
Oligochaeta									
Enchytraeidae									
Imm. Tubificidae w/o hair chaetae	1						1	2	1
Lumbriculidae		1		1					1
Nais									
Chironomidae									
Ablabesmyia mallochi		2	2				1	1	1
Brillia cf *flavifrons*									
Corynoneura (w/ sculpturing)									
Cricotopus "other"							1		
Cryptochironomus									1
Dicrotendipes modestus/neomodestus								1	
Djalmabatista pulchra									
Eukiefferiella claripennis gp									
Eukiefferiella cf *tirolensis*									
Hydrobaenus "O" (Epler)	1								
Labrundinia cf *pilosella*									
Micropsectra "C" (Epler)		1			1		1	2	
Micropsectra "D" (Epler)									

Microtendipes pedellus gp	1				1				
Orthocladius (Euortho) w/13 teeth									
Orthocladius obumbratus/robacki							1	1	
Parametriocnemus	1	1	1		1		1	1	1
Paratrichocladius/Orthocladius dorenus									
Polypedilum aviceps	3	12	14	11	7	6	7	6	2
Polypedilum flavum									
Polypedilum halterale gp			1						
Polypedilum illinoense gp									
Potthastia longimana gp									
Pseudochironomus									
Rheocricotopus cf *robacki*	1		1		4			2	2
Rheotanytarsus	1								
Stempellinella									
Sympotthastia cf *zavreli*									
Tanytarsus "A" (Epler)									
Tanytarsus "L" (Epler)					1	1			
Tanytarsus "M" (Epler)		1	1			4			
Thienemannimyia gp		1	1	4	8	1	8	2	2
Tribelos cf *jucundum*									
Trissopelopia	4	1	1	5	4	1	2	3	1
Tvetenia cf *paucunca*		1	1	1		1	1	2	
Zavrelimyia	1						1		3

Table D-5. Benthic macroinvertebrate counts in samples from Harris Creek, December 16, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Elimia									
Glossiphoniidae						1			
Hydracarina				1					
Lirceus						1		1	
Orconectes		1	1	1	1				1
Synurella bifurca							1		
Turbellaria			1		1				
Ephemeroptera									
Acentrella/Plauditus	11	4	7	12	9	16	11	12	14
Acerpenna	1	6	2	3		3	1	3	5
Ameletus									
Baetis flavistriga			3	2	3	1	1	1	3
Caenis					1	1			
Diphetor	1				2		2	1	2
Ephemera									
Eurylophella	2	3	2	1	1		2	1	
Isonychia	2	5	8	14	10	12	11	10	8
Leptophlebia									
Leptophlebiidae	1	4	2	1	2	2	3	4	2
Leucrocuta	4	7	8	6	6	5	6	3	4
Paraleptophlebia									
Stenacron	5	5	5	6	5	3	5	7	6
Stenonema femoratum	2	5		2	3	4	7	2	5
Stenonema mediopunctatum	8	10	18	9	10	8	10	10	8
Stenonema pulchellum/terminatum	2	2				3		2	2
Stenonema terminatum variant	3		3	2	2	3	3	2	1
Plecoptera									
Acroneuria		2		1			1		
Agnetina	1				1	1			
Allocapnia	9	6	6	2	3	4	11	11	11
Amphinemura									
Chloroperlidae									
Clioperla clio		1			1		1	2	
Helopicus natalis	1		1	1					
Isoperla w/ vertical bars	3	1	3	1	2	2	1	2	2
Neoperla	1			1					
Paracapnia angulata	1	2	1					3	
Strophopteryx	1			1		1			1
Taeniopteryx	2	3	4	4	3	2	2	5	2
Zealeuctra		1							
Trichoptera									
Agapetus	2	1	1	1		1	2	1	1

Cheumatopsyche	15	6	10	8	9	6	10	6	5
Chimarra	3	1	2	4	11	4	2		2
Dibusa angata									
Diplectrona modesta									
Helicopsyche									
Hydropsyche	2								
Lepidostoma						1			
Neophylax	1	1							
Polycentropus									1
Psychomyia flavida									
Pycnopsyche		1						1	2
Rhyacophila kiamichi									
Stactobiella									
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Argia		2							
Boyeria									
Calopteryx									
Corydalus						1			1
Gomphidae (cf *Stylogomphus*)	1	1	1						
Hagenius brevistylus									
Nigronia serricornis		1		1					
Petrophila	1								
Sialis									
Coleoptera									
Ectopria						1			
Microcylloepus									
Optioservus	2	2	3	4	2	3	1	2	2
Psephenus	4	3	2	1	4	1	2	1	2
Stenelmis		2							
Diptera (excl Chironomidae)									
Clinocera									
Dicranota									
Dolichopodidae					1				
Hexatoma									
Prosimulium		1	1	2	3	3	2	2	1
Simuliidae (not *Prosimulium*)	1		1	3		2	1	1	1
Tabanidae									
Tipula	1	1	1		2		1		1
Oligochaeta									
Enchytraeidae									
Imm. Tubificidae w/ hair chaetae									
Imm. Tubificidae w/o hair chaetae									
Lumbriculidae									
Chironomidae									
Ablabesmyia mallochi									
Brillia cf *flavifrons*		1							
Corynoneura (w/ sculpturing)									
Cricotopus cf *luciae*									
Eukiefferiella claripennis gp	1					2			

Eukiefferiella cf *tirolensis*	1		1	1				3
Heterotrissocladius								
Labrundinia cf *pilosella*								
Micropsectra "C" (Epler)								
Microtendipes pedellus gp								
Orthocladius (Euortho) w/13 teeth				1			1	
Orthocladius obumbratus/robacki								
Parametriocnemus	1	1	1		1			
Paratrichocladius/Orthocladius dorenus								
Polypedilum aviceps				1				
Polypedilum illinoense gp								
Rheocricotopus cf *robacki*								
Rheocricotopus cf *unidentatus*								
Synorthocladius semivirens								
Tanytarsus "M" (Epler)								
Thienemanniella cf *xena*		1						
Thienemannimyia gp	1	3	1	1	1	1	2	1
Trissopelopia	1	3		1		1		
Tvetenia cf *paucunca*	1							
Zavrelimyia							1	

Table D-6. Benthic macroinvertebrate counts in samples from Harris Creek, March 16, 2005.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Elimia	1			1		1			1
Glossiphoniidae									
Hydracarina						1	1		
Lirceus									
Orconectes		1		1	1			1	
Synurella bifurca									
Turbellaria	1	1							
Ephemeroptera									
Acentrella/Plauditus	11	6	6	9	9	9	3	7	4
Acerpenna	4	4	4	2		1	5	2	6
Ameletus									1
Baetis flavistriga		1				1	2		1
Caenis		2						1	1
Diphetor	1	5	4	5	5	9	7	6	8
Ephemera									
Eurylophella	2	5	2	3	3	2	6		1
Isonychia	5		3	3	3	7	8	13	5
Leptophlebia									
Leptophlebiidae									
Leucrocuta	10	14	22	8	6	6	7	5	7
Paraleptophlebia	1	5	5	4	2	1	5	2	4
Stenacron	5	9	6	3	4	1	3	2	2
Stenonema femoratum		3	2		2	2	2	3	2
Stenonema mediopunctatum	3	6	1	5	13	10	3	5	5
Stenonema pulchellum/terminatum	1	1	3	1					
Stenonema terminatum variant	3	2	4	3	1	5	1	2	2
Plecoptera									
Acroneuria	1		1				1	1	3
Agnetina		2			2	1			
Allocapnia									
Amphinemura	3	1	4	5	6	1	3	7	1
Chloroperlidae	1	2	3	3	1	1	2	3	5
Clioperla clio			1	1					
Helopicus natalis									
Isoperla w/ vertical bars	11	4	3	5	7	11	7	15	11
Neoperla			1				1		
Paracapnia angulata									
Strophopteryx									
Taeniopteryx									
Zealeuctra									
Trichoptera									
Agapetus	2	2	1	3	2	3	2	1	3
Cheumatopsyche	5	4	2	5	10	3		4	

Chimarra	2		3	1	1	1	2	1	1
Dibusa angata									
Diplectrona modesta									
Helicopsyche				1					
Hydropsyche									
Lepidostoma									1
Neophylax									
Polycentropus	1								
Psychomyia flavida							2		
Pycnopsyche									
Rhyacophila kiamichi	1	2				1		1	1
Stactobiella	1								
Wormaldia						1			
Other Insects (Od,Hem,Meg,Lep)									
Argia		1							
Boyeria									
Calopteryx							1		
Corydalus	1			2	3	1			
Gomphidae (cf *Stylogomphus*)	2				1		1		
Hagenius brevistylus									
Nigronia serricornis		4					1	1	
Petrophila									
Sialis									
Coleoptera									
Ectopria									
Microcylloepus									1
Optioservus	1	1	1	2		3			1
Psephenus	3	3	1	5	1	3	2	4	2
Stenelmis					1	3	3	3	6
Diptera (excl Chironomidae)									
Clinocera					1		2		
Dicranota									
Dolichopodidae									
Hexatoma									
Prosimulium	4	1	2	3	2	2			
Simuliidae (not *Prosimulium*)	1		1	3	1		1	1	2
Tabanidae	1							1	
Tipula				1	1	1			
Oligochaeta									
Enchytraeidae									
Imm. Tubificidae w/ hair chaetae									1
Imm. Tubificidae w/o hair chaetae					1				
Lumbriculidae	2	2		1	1	1			
Chironomidae									
Ablabesmyia mallochi	1				1	1			
Brillia cf *flavifrons*									
Corynoneura (w/ sculpturing)									
Cricotopus cf *luciae*			1	1					
Eukiefferiella claripennis gp			1						
Eukiefferiella cf *tirolensis*									

Heterotrissocladius									
Labrundinia cf *pilosella*							1		
Micropsectra "C" (Epler)								1	
Microtendipes pedellus gp									
Orthocladius (Euortho) w/13 teeth									
Orthocladius obumbratus/robacki	1						1		
Parametriocnemus		1	1	1		1	4	1	1
Paratrichocladius/Orthocladius dorenus					1				
Polypedilum aviceps		2	5	4		1	2	3	4
Polypedilum illinoense gp			1						
Rheocricotopus cf *robacki*	2		2	2	2		2		2
Rheocricotopus cf *unidentatus*									
Synorthocladius semivirens									
Tanytarsus "M" (Epler)	1	1			1				1
Thienemanniella cf *xena*									
Thienemannimyia gp	2		2	1	3		3		1
Trissopelopia	2	1		2	1	3	3	3	
Tvetenia cf *paucunca*			1						
Zavrelimyia		1				1			2

APPENDIX E: Lloyds Creek benthic macroinvertebrate data

Table E-1. Benthic macroinvertebrate counts in samples from Lloyds Creek, January 10, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	6	2	4	2	2	2	2	2	5
Cambaridae	2	1	2	1	1	1	1	1	2
Crangonyx		2	3	2	1	1	1	1	1
Erpobdellidae									1
Glossiphoniidae									
Hirudinidae									
Hyalella azteca	1	1	3	1	1	3		1	
Hydracarina	2	1	1	1	1	1			
Lirceus	4	8	7	4	1	1	1	2	1
Menetus						1			
Palaemonetes kadiakensis	2	2	2	2	3	4	1		1
Synurella bifurca	4	1	2	1			1	2	1
Turbellaria									
Ephemeroptera									
Callibaetis	1	1							
Trichoptera									
Ironoquia							1		
Polycentropus									
Ptilostomis	1	1	1				1		
Pycnopsyche				1					
Other Insects (Od,Hem,Meg,Lep)									
Sigara hydatotrephes	2	1	1	2	1	2	1		
Dromogomphus									
Enallagma/Ischnura	1		1		1		1		
Epitheca (Tetragoneuria)	1	1	1	1	1			1	
Libellula									
Nasiaeschna pentacantha					1				1
Pachydiplax longipennis									
Ranatra buenoi									
Sialis		1		1	1	1			1
Trichocorixa				1					
Coleoptera									
Berosus					1				
Carabidae									
Coptotomus			1						
Dineutus									
Gyrinus									1
Hydroporus	4	6	4	3	2	2	3	2	4
Peltodytes	1	1		1	1	1		1	
Scirtidae									

Stenus						1			
Diptera (excl Chironomidae)									
Ceratopogoninae	1	1	1	1	2	2			
Chaoborus	1	1	2	1	2	1		2	2
Dolichopodidae				1					
Forcipomyia									
Pilaria									
Sphaeriomias									
Tabanidae			1		1	1			
Oligochaeta									
Dero									
Enchytraeidae									
Haemonais waldvogeli		1							
Imm. Tubificidae w/ hair chaetae	8	6	6	3	1	4	9	7	8
Imm. Tubificidae w/o hair chaetae	5	6	13	14	14	16	6	12	14
Lumbriculidae							1		
Lumbriculidae (w/proboscis)									
Nais									
Chironomidae									
Ablabesmyia janta/rhamphe gp									
Ablabesmyia (Karelia)									
Chironomus	3	2	3			1		1	
Cladopelma	1								
Clinotanypus	5	4	4	2				1	
Cricotopus/Orthocladius	1			1					
Dicrotendipes modestus/neomodestus		2	3	2	7	1		1	
Dicrotendipes leucoscelis	1								
Dicrotendipes simpsoni						1			
Einfeldia "A" (Epler)									2
Glyptotendipes									
Guttipelopia	1	2				1			
Gymnometriocnemus									
Hydrobaenus	29	29	26	43	47	46	60	49	38
Kiefferulus	1	3	1		2		1	1	
Labrundinia "C" (Epler)									
Larsia									
Nanocladius									
Omisus	2	3	2				3	8	8
Parachironomus cf *carinatus*									
Parachironomus chaetoalus cmplx									
Parachironomus tenuicaudatus cmplx									2
Parakiefferiella "D" (Epler)									1
Paratrichocladius/Orthocladius dorenus								2	
Polypedilum halterale gp									
Polypedilum illinoense gp	1	1					1		
Potthastia longimana gp.									
Procladius	8	5	5	5	5	5	5	2	5
Tanypus				1				1	
Tanytarsus		1		1					
Tanytarsus "G" (Epler)									1

Tanytarsus "N" (Epler)									
Tanytarsus "Q" (Epler)									
Tribelos cf *fuscicorne*		1		1					
Zavreliella marmorata		1							
Zavrelimyia		1							

Table E-2. Benthic macroinvertebrate counts in samples from Lloyds Creek, March 17, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	4	3	3	1	4	3	16	6	6
Cambaridae	2	2	3	2	3		9	5	4
Crangonyx	5	4	5	3	1		3	9	13
Erpobdellidae									
Glossiphoniidae			1						
Hirudinidae		1							
Hyalella azteca	5	3	6	9	6	12			
Hydracarina	2	1	2	6	2	2	1		
Lirceus	9	6	9	2	4	2	1	2	1
Menetus		2			2	3	4	2	1
Palaemonetes kadiakensis	8	19	11	11	13	7	9	7	7
Synurella bifurca	1				1			2	1
Turbellaria					1	1		1	
Ephemeroptera									
Callibaetis	1	1			1	1			
Trichoptera									
Ironoquia	2		4		3		2		3
Polycentropus				2			1		3
Ptilostomis	1	1							
Pycnopsyche									
Other Insects (Od,Hem,Meg,Lep)									
Sigara hydatotrephes		2		1	2	1			
Dromogomphus	1		1						
Enallagma/Ischnura	2	1	2	2	4	4	1	2	
Epitheca (Tetragoneuria)	1	2	2	1	2				3
Libellula	2	1							
Nasiaeschna pentacantha									1
Pachydiplax longipennis			2		2	1			
Ranatra buenoi			1				1		

Sialis	3		1	1				1	
Trichocorixa					2				
Coleoptera									
Berosus		1							
Carabidae	1								
Coptotomus									
Dineutus					1				1
Gyrinus		1							
Hydroporus	3	3	7	8	6	7	8	21	10
Peltodytes					1	1			
Scirtidae		1				1			
Stenus									
Diptera (excl Chironomidae)									
Ceratopogoninae		1				6			
Chaoborus	1	1							
Dolichopodidae									
Forcipomyia			1						
Pilaria				1					
Sphaeriomias					1				
Tabanidae				1				1	
Oligochaeta									
Dero	2	1	1			1			
Enchytraeidae	1	2	2	3	1	2	1	1	
Haemonais waldvogeli									
Imm. Tubificidae w/ hair chaetae	9	11	3	2	1	1	20	16	6
Imm. Tubificidae w/o hair chaetae	2	5	4	8	4	9	7	4	13
Lumbriculidae		1		1					1
Lumbriculidae (w/proboscis)							1		
Nais	2	4	1	4	1	5		1	
Chironomidae									
Ablabesmyia janta/rhamphe gp						1			
Ablabesmyia (Karelia)		1							
Chironomus		2	1						
Cladopelma	2			1		1		2	
Clinotanypus									
Cricotopus/Orthocladius	1								
Dicrotendipes modestus/neomodestus	4	4	10	10	15	8			1
Dicrotendipes leucoscelis									
Dicrotendipes simpsoni	1				1	1	1		2
Einfeldia "A" (Epler)									
Glyptotendipes	1			3		2			
Guttipelopia	1	1	1	2	3	1			
Gymnometriocnemus				1				1	
Hydrobaenus			3			1			
Kiefferulus	3	2		1				1	2
Labrundinia "C" (Epler)	1								
Larsia						1			
Nanocladius						1			
Omisus	2	1	4				3	3	3
Parachironomus cf *carinatus*					2	1			

Parachironomus chaetoalus cmplx	2								
Parachironomus tenuicaudatus cmplx									
Parakiefferiella "D" (Epler)	1			1	1	1	1		5
Paratrichocladius/Orthocladius dorenus								1	
Polypedilum halterale gp						1			
Polypedilum illinoense gp	2	4	1	2	3	2	1	3	3
Potthastia longimana gp.									1
Procladius	1		4	6	3	5	9	6	6
Tanypus	1		2	1	1			1	2
Tanytarsus	1								1
Tanytarsus "G" (Epler)					1			1	
Tanytarsus "N" (Epler)				1		1			
Tanytarsus "Q" (Epler)		1		2					
Tribelos cf *fuscicorne*									
Zavreliella marmorata	6	3	2			2			
Zavrelimyia					1				

Table E-3. Benthic macroinvertebrate counts in samples from Lloyds Creek, December 28, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	14	23	14	11	5	5	47	46	40
Cambaridae					1	2	3	4	3
Crangonyx			2	1		1	2	1	
Glossiphoniidae								1	
Helisoma					1				
Hyalella azteca	10	7	14	10	8	7			
Hydracarina		1	1	1	1	1			
Lirceus	4	1	1		1	1	5	5	6
Menetus		2	1			1	1		
Palaemonetes kadiakensis	3	6	3	6	2	4			1
Physidae								1	
Sphaeriidae	2	1				1	1	2	1
Synurella bifurca				1					1
Turbellaria	2	1	2		1	1		1	
Ephemeroptera									
Caenis									
Callibaetis	1	1	2		1	1			
Trichoptera									
Ironoquia							1		
Polycentropus									
Ptilostomis	4	8	4	8	8	8	4	11	7
Other Insects (Od,Hem,Meg,Lep)									
Arigomphus									
Enallagma/Ischnura	4	2	6	7	5	8			
Epitheca (Tetragoneuria)		4	2		2	3			
Hesperocorixa		1			1	2			
Lepidoptera (not *Petrophila*)						1	1	1	
Libellula				1					
Nasiaeschna pentacantha			1						
Pachydiplax longipennis	4	1	1	1	3	4			
Perithemis				1					
Ranatra buenoi	1				1				1
Sialis									
Sigara hydatotrephes			1						
Trichocorixa			1		1				
Coleoptera									
Agabus								1	
Coptotomus									3
Dineutus									
Gyrinus									
Hydrocanthus									
Hydroporus	5	1	3		1	1	8	5	9
Peltodytes				2	1	2			
Rhantus									
Scirtidae	1								

Stenus									
Diptera (excl Chironomidae)									
Atrichopogon									
Ceratopogoninae		1	1	2	1	2	1	1	1
Chaoborus	17	2	3	3	5	3		1	
Chlorotabanus				2		2		1	
Dolichopodidae							1		
Helius									2
Pseudolimnophila		2	1	3	3	5			
Simuliidae (not *Prosimulium*)									
Tabanidae					2				
Oligochaeta									
Dero	4	9	6	2	2	3			
Enchytraeidae									3
Haemonais waldvogeli	1		1		2				
Imm. Tubificidae w/ hair chaetae	1		2	1	1		13	8	3
Imm. Tubificidae w/o hair chaetae		9	3	7	8	3	7	1	4
Lumbriculidae	2	1	1				1		
Lumbriculidae (w/proboscis)									
Nais	5	10	8	10	8	8			1
Pristina				1					
Chironomidae									
Ablabesmyia (Karelia)									
Chironomus	1			2	2	1			
Cladopelma									
Clinotanypus				1	3				
Dicrotendipes modestus/neomodestus				4	3	3			
Einfeldia "A" (Epler)									
Glyptotendipes				2	2				
Guttipelopia				1	3	4			
Hydrobaenus		1		2			4	4	13
Kiefferulus	3		5	3	2	2			
Labrundinia "C" (Epler)									
Larsia									
Omisus	8	2	2	2	2	2			
Orthocladius cf *oliveri*					1			1	
Parachironomus chaetoalus cmplx									
Parachironomus tenuicaudatus cmplx									
Parakiefferiella "D" (Epler)			1	1	2	2			
Parametriocnemus								1	
Paratanytarsus									
Polypedilum illinoense gp	2		4			1		2	1
Procladius				1	1	3		1	
Psectrotanypus cf *dyari*		2			1				
Tanypus			1						
Tanytarsus "V" (Epler)	1	1	2		2	2			
Thienemannimyia gp									
Zavreliella marmorata									
Zavrelimyia									

Table E-5. Benthic macroinvertebrate counts in samples from Lloyds Creek, December 15, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Ancylidae									
Caecidotea	2	3	2	2	2	2	3	2	1
Cambaridae	1		2			1	2	1	2
Crangonyx	1	5	4	1		1	4	5	6
Glossiphoniidae						1	1	1	1
Hyalella azteca	3	4	3	3	4	8		2	2
Hydracarina		1		1					
Lirceus							3	2	2
Menetus					1		1		
Palaemonetes kadiakensis	2	2	2	1	1	2			1
Sphaeriidae		2	1	1			1	1	1
Synurella bifurca	1	1	1	1	1		1	1	
Turbellaria			1	1					
Ephemeroptera									
Caenis		1	1		1				
Callibaetis	3	2	1	2	1	3			1
Trichoptera									
Polycentropus									
Ptilostomis							2	4	1
Other Insects (Od,Hem,Meg,Lep)									
Corixidae (other than listed genera)						3			
Dromogomphus									
Enallagma/Ischnura	3	1	4	2	2	2	1		
Epitheca (Tetragoneuria)	1	2					1		
Hesperocorixa									
Libellula			2	1	1		1		
Nasiaeschna pentacantha		1							1
Notonecta		1							
Pachydiplax longipennis						1	1		
Ranatra australis									
Ranatra buenoi	1					1	1	1	
Sialis		1						1	1
Sigara hydatotrephes				1	2	3			
Coleoptera									
Coptotomus							3		2
Dineutus				1		2	2	1	1
Hydrocanthus									
Hydroporus	10	5	7	4	3	6	7	2	7
Peltodytes									
Scirtidae						1			
Diptera (excl Chironomidae)									
Atrichopogon									
Ceratopogoninae			1	1	1			1	

Chaoborus	2	3	1	1	2	2	2	3	1
Helius							1		
Pilaria									1
Pseudolimnophila				1	1				
Simuliidae (not *Prosimulium*)						1			
Tipula									
Oligochaeta									
Dero									
Enchytraeidae	1	2	1	3	3	1	4	2	3
Haemonais waldvogeli	1	1		1	2	1	1		
Imm. Tubificidae w/ hair chaetae	5	9	4	3	3	1	9	14	12
Imm. Tubificidae w/o hair chaetae	5	1	3	4	2	1	3	4	1
Lumbriculidae			1						
Lumbriculidae (w/proboscis)								1	
Nais	1		1				1		
Chironomidae									
Ablabesmyia mallochi		1							
Ablabesmyia (Karelia)	1								
Chironomus	1	2	8	5	2	1	5	4	1
Cladopelma									
Clinotanypus							1		1
Dicrotendipes modestus/neomodestus	1		1		4	2	1		
Dicrotendipes simpsoni	1				1	1	2	1	2
Einfeldia "A" (Epler)						1			
Glyptotendipes	3		2	3	2	2	2		1
Guttipelopia	1	4	2	6		2			
Hydrobaenus	37	27	22	20	46	31	14	19	7
Kiefferulus	8	3	4	6	4	3	2	2	7
Labrundinia									
Microtendipes pedellus gp									
Nanocladius cf *alternatherae*		2							
Nanocladius crassicornis/rectinervis						1	1	5	5
Natarsia							1		
Omisus	2	8	9	9		3	1	11	8
Orthocladius cf *oliveri*	1					2			
Parachironomus chaetoalus cmplx									
Parachironomus cf *potamogeti*									
Parachironomus tenuicaudatus cmplx			1					1	3
Parakiefferiella "D" (Epler)		1	2	2	1	2	5	3	9
Paratanytarsus									
Polypedilum illinoense gp	1	2	3	2		1			1
Potthastia longimana gp									1
Procladius			1	2	1		2		2
Psectrotanypus cf *dyari*									
Tanypus		1		5				3	2
Tanytarsus "E" (Epler)									
Tanytarsus "G" (Epler)				2	1				
Tanytarsus "L" (Epler)					2	1	1		
Thienemannimyia gp						1			
Unniella									

Zavreliella marmorata	1	2	1	3	2	5	2	2
Zavrelimyia			1			1		

Table E-6. Benthic macroinvertebrate counts in samples from Lloyds Creek, March 14, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Ancylidae								1	
Caecidotea	6	8	9	6	6	9	11	10	8
Cambaridae		2						1	1
Crangonyx	8	11	19	4	5	7	12	8	9
Glossiphoniidae							1		
Hyalella azteca	12	12	12	21	15	8			1
Hydracarina				2	1				
Lirceus	1		2	2	2		4	8	8
Menetus				1					
Palaemonetes kadiakensis	2	3	6	1	4	1			
Sphaeriidae		1	1		1		2	1	1
Synurella bifurca									
Turbellaria									
Ephemeroptera									
Caenis	1		1			1			
Callibaetis		1		4	1	2	1		
Trichoptera									
Polycentropus					1				
Ptilostomis	1								
Other Insects (Od,Hem,Meg,Lep)									
Corixidae (other than listed genera)									
Dromogomphus	1								
Enallagma/Ischnura	5	6	5	2	6	2	1	3	2
Epitheca (Tetragoneuria)	2	1	1	2	1	2	1		1
Hesperocorixa				1					
Libellula				1	1				
Nasiaeschna pentacantha					1		1		
Notonecta									

Pachydiplax longipennis	2	2			2			3	
Ranatra australis								1	
Ranatra buenoi	2	1	2		1				1
Sialis								1	1
Sigara hydatotrephes									
Coleoptera									
Coptotomus									
Dineutus					1				
Hydrocanthus							1		
Hydroporus	5	2	4	7	7	5	5	12	8
Peltodytes	1								
Scirtidae	1			2	3				2
Diptera (excl Chironomidae)									
Atrichopogon	1		2			1	1	2	4
Ceratopogoninae	3	2	2	2	2	6	2		2
Chaoborus		1	1	1	1	2	1		
Helius									
Pilaria									
Pseudolimnophila									
Simuliidae (not *Prosimulium*)									
Tipula						1			
Oligochaeta									
Dero					2	2			
Enchytraeidae	1		2	1	1	8	1	6	3
Haemonais waldvogeli				4	3	2	1		
Imm. Tubificidae w/ hair chaetae	4	5	4	1	2	3	9	10	10
Imm. Tubificidae w/o hair chaetae	6	5	2	4	1	6	3	5	8
Lumbriculidae						1			
Lumbriculidae (w/proboscis)				1					
Nais	2	4	4	7	4	1	3		2
Chironomidae									
Ablabesmyia mallochi		2		1			2		
Ablabesmyia (Karelia)	1	1		2	1	1			
Chironomus	4	4			1	1	1		1
Cladopelma								1	
Clinotanypus									1
Dicrotendipes modestus/neomodestus	1			3	1				
Dicrotendipes simpsoni				1	3	1			
Einfeldia "A" (Epler)				1					
Glyptotendipes				1	1	2			
Guttipelopia		6		2	4	1			
Hydrobaenus									
Kiefferulus	3	1	2	3	4	3	2	2	3
Labrundinia		1							1
Microtendipes pedellus gp					1				
Nanocladius cf *alternatherae*									
Nanocladius crassicornis/rectinervis	1						1	2	1
Natarsia									
Omisus	9	8	7	1	4	2	8	8	4
Orthocladius cf *oliveri*									

Parachironomus chaetoalus cmplx							2		
Parachironomus cf *potamogeti*	2	1			2			1	1
Parachironomus tenuicaudatus cmplx				1					
Parakiefferiella "D" (Epler)			2			1	4		
Paratanytarsus					1			1	
Polypedilum illinoense gp	2				1	2		1	1
Potthastia longimana gp		1	1	1			1		1
Procladius			1						4
Psectrotanypus cf *dyari*	1								
Tanypus	1	1				1	2	1	
Tanytarsus "E" (Epler)						1			
Tanytarsus "G" (Epler)		2					3		
Tanytarsus "L" (Epler)				1		2	2	1	2
Thienemannimyia gp									
Unniella	1								
Zavreliella marmorata	1	2	1	1	1	2	11	5	2
Zavrelimyia	6	3	7	4		10		5	6

APPENDIX E: Mill Branch benthic macroinvertebrate data

Table F-1. Benthic macroinvertebrate counts in samples from Mill Branch, January 9, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	4	16	12	9	16	18	8	10	4
Caecidotea (unpigmented)								1	
Cambaridae		3	1	1	2	4	2	3	2
Faxonella	2								
Hydracarina			1						
Synurella bifurca	48	36	27	46	34	35	24	22	22
Turbellaria		1	1	2		2		1	2
Ephemeroptera									
Caenis			1		1	2			
Siphlonurus									
Stenonema pulchellum/terminatum	1								
Plecoptera									
Allocapnia	24	28	44	21	26	17	44	44	39
Amphinemura									
Zealeuctra									
Trichoptera									
Ironoquia	3	1	1	2	3	2	3	4	4
Polycentropus									
Rhyacophila kiamichi			1						
Rhyacophila lobifera									
Other Insects (Od,Hem,Meg,Lep)									
Cordulegaster									
Corixidae									
Enallagma/Ischnura			1						
Libellula		1		1	1	1			
Coleoptera									
Agabus		2	1						
Coptotomus									
Hydroporus	2	1			1		1	2	2
Scirtidae									
Diptera (excl Chironomidae)									
Ceratopogoninae									
Chaoborus			1						
Erioptera	1						2		1
Helius							1		
Pilaria				1					
Simuliidae (not *Prosimulium*)									
Stratiomyidae									1
Tabanidae		1	1		1	1		3	1
Tipula	1								
Tipulidae (other than above genera)						1			

Oligochaeta									
Dero				1		1			
Enchytraeidae	4	5	4		2	4	3	4	7
Haemonais waldvogeli				4	1				
Haplotaxis gordioides									
Imm. Tubificidae w/ hair chaetae	3	1	1	3	4	1			
Imm. Tubificidae w/o hair chaetae					2		1		
Lumbriculidae	1	3			3		4	2	5
Lumbriculidae (w/proboscis)						1	1		
Nais				1		2			1
Chironomidae									
Cardiocladius				2					
Corynoneura (no sculpturing)				3		2		2	2
Dicrotendipes simpsoni									
Diplocladius cultriger	1			1			2		
Heterotrissocladius	4			2	3	3	4	1	4
Hydrobaenus									
Larsia		1							
Natarsia			1						1
Parametriocnemus									
Paratanytarsus									1
Polypedilum halterale gp						1			
Polypedilum illinoense gp			1			2			
Tanytarsus								1	1
Thienemannimyia gp									
Tvetenia cf GA/NC (Epler)	1								

Table F-2. Benthic macroinvertebrate counts in samples from Mill Branch, March 16, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	14	12	9	13	8	10	9	14	8
Caecidotea (unpigmented)									1
Cambaridae			2	3	2	4	1		
Faxonella									
Hydracarina									
Synurella bifurca	55	60	56	52	61	57	44	39	63
Turbellaria	2		2	1	1	1	1	4	1
Ephemeroptera									
Caenis	1		1						
Siphlonurus	1		3			3			
Stenonema pulchellum/terminatum							1		
Plecoptera									
Allocapnia	1						1	2	2
Amphinemura	3	2	2		2	2	1	2	1
Zealeuctra	1	3	2	3	3	2	4	5	6
Trichoptera									
Ironoquia	3	6	4	5	3	3	9	4	4
Polycentropus						1			
Rhyacophila kiamichi						1		1	
Rhyacophila lobifera	1								
Other Insects (Od,Hem,Meg,Lep)									
Cordulegaster									1
Corixidae					1				
Enallagma/Ischnura						1			
Libellula									
Coleoptera									
Agabus									
Coptotomus	1								
Hydroporus	2						1	2	
Scirtidae									1
Diptera (excl Chironomidae)									
Ceratopogoninae		1	1		2	1	1	1	
Chaoborus									
Erioptera									
Helius									
Pilaria							1		
Simuliidae (not *Prosimulium*)	1		1					1	
Stratiomyidae									
Tabanidae		1		2	2	2	4		3
Tipula									
Tipulidae (other than above genera)									
Oligochaeta									
Dero									
Enchytraeidae	7	3	5	11	2		15	14	5

Haemonais waldvogeli									
Haplotaxis gordioides						1	1		1
Imm. Tubificidae w/ hair chaetae	4	3	6	5	8	9		1	
Imm. Tubificidae w/o hair chaetae			1	1	2	1			
Lumbriculidae	2	6	3		2		2	8	2
Lumbriculidae (w/proboscis)						1	1	1	
Nais									
Chironomidae									
Cardiocladius									
Corynoneura (no sculpturing)		1		1					
Dicrotendipes simpsoni				1					
Diplocladius cultriger									
Heterotrissocladius		2					1		
Hydrobaenus			1						
Larsia			1				2	1	1
Natarsia	1			1					
Parametriocnemus					1				
Paratanytarsus									
Polypedilum halterale gp									
Polypedilum illinoense gp									
Tanytarsus									
Thienemannimyia gp				1					
Tvetenia cf GA/NC (Epler)									

Table F-3. Benthic macroinvertebrate counts in samples from Mill Branch, December 27, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea				2		1	1		
Caecidotea (unpigmented)									
Cambaridae	11	4	7	5	15	12	9	4	8
Crangonyx			1				1		1
Physidae		1							
Synurella bifurca				4	4	9			
Turbellaria				1					
Plecoptera									
Allocapnia	5	8	1		5	2	1	10	
Amphinemura									
Isoperla w/ vertical bars									
Zealeuctra									
Trichoptera									
Ironoquia									
Polycentropus									
Ptilostomis						1			
Rhyacophila kiamichi									
Rhyacophila lobifera									
Other Insects (Od,Hem,Meg,Lep)									
Enallagma/Ischnura									
Gerris									
Libellulidae				1					
Nasiaeschna pentacantha	1								
Notonecta						1		3	
Somatochlora									
Coleoptera									
Curculionidae									1
Dineutus									
Hydroporus	4	14	4		2	1	5	3	1
Thermonectus								1	
Diptera (excl Chironomidae)									
Aedes	10	7	19	15	19	9	71	75	18
Ceratopogoninae								1	
Eriopterini									
Pilaria									
Simuliidae (not *Prosimulium*)									
Tabanidae				2	2	1			
Oligochaeta									
Enchytraeidae				1					
Haemonais waldvogeli					1				
Haplotaxis gordioides									
Imm. Tubificidae w/ hair chaetae	2	3	1	54	36	41			2
Imm. Tubificidae w/o hair chaetae	3	3	3	8	13	17		1	
Lumbriculidae									

Lumbriculidae (w/proboscis)				1				
Nais						4		
Chironomidae								
Corynoneura (w/ sculpturing)						1		
Diplocladius cultriger								
Heterotrissocladius								
Hydrobaenus			4	1	1	1	1	
Larsia								
Natarsia					1			
Polypedilum illinoense gp	1						1	3
Tanytarsus "V" (Epler)		2	3	1	3			
Tvetenia cf GA/NC (Epler)								

Table F-4. Benthic macroinvertebrate counts in samples from Mill Branch, March 20, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	9	8	6	7	9	11	5	7	5
Caecidotea (unpigmented)								2	
Cambaridae	1	3		3	1	4			
Crangonyx	2	1		1	3	8	1		
Physidae									
Synurella bifurca	57	59	55	60	45	51	13	31	18
Turbellaria	1	1	2	1			1	1	
Plecoptera									
Allocapnia	1	2	1				9	3	7
Amphinemura	1		1	1			4	4	5
Isoperla w/ vertical bars			1				1	3	1
Zealeuctra	1	2	1	1		2	11	10	6
Trichoptera									
Ironoquia	2	2	4	2	1	2	2	6	6
Polycentropus					1	1			
Ptilostomis									
Rhyacophila kiamichi	1						1	2	3
Rhyacophila lobifera								1	
Other Insects (Od,Hem,Meg,Lep)									
Enallagma/Ischnura						1			
Gerris		1							
Libellulidae						1			
Nasiaeschna pentacantha									
Notonecta									
Somatochlora									2
Coleoptera									
Curculionidae									
Dineutus	1				1				
Hydroporus	1	1	1		2				
Thermonectus									
Diptera (excl Chironomidae)									
Aedes									
Ceratopogoninae	1	3		1	3				2
Eriopterini	1	1	2				1	1	1
Pilaria	1					1		1	
Simuliidae (not *Prosimulium*)	3		2	1			3	2	3
Tabanidae	1	1	2	2	2				
Oligochaeta									
Enchytraeidae	2	9	10	6	6	3	13	10	15
Haemonais waldvogeli									
Haplotaxis gordioides						1		1	1
Imm. Tubificidae w/ hair chaetae	8	2	7	7	16	3		1	9
Imm. Tubificidae w/o hair chaetae	1			2	6	6			4

Lumbriculidae	1						1	2	
Lumbriculidae (w/proboscis)					1	2			
Nais		1							
Chironomidae									
Corynoneura (w/ sculpturing)									
Diplocladius cultriger				1					1
Heterotrissocladius	3	1	4	4	3	2	24	9	6
Hydrobaenus			1						2
Larsia		2				1	8	3	3
Natarsia									
Polypedilum illinoense gp									
Tanytarsus "V" (Epler)									
Tvetenia cf GA/NC (Epler)							2		

Table F-5. Benthic macroinvertebrate counts in samples from Mill Branch, December 30, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	1		1	1	1	1	3	1	3
Cambaridae		3	1	2	1	5	4	4	2
Crangonyx	3		1	2	3	3	1	3	
Hydracarina				1		1			
Physidae				1					
Stygobromus				1					
Synurella bifurca	9	11	12	8	10	11	18	16	19
Turbellaria	1								
Ephemeroptera									
Caenis latipennis gp						2			
Plecoptera									
Allocapnia	52	56	56	27	47	24	51	47	56
Amphinemura									
Isoperla w/ vertical bars									
Zealeuctra			1	1		2	3	3	1
Trichoptera									
Ironoquia									
Rhyacophila kiamichi	1		1						1
Rhyacophila lobifera									1
Other Insects (Od,Hem,Meg,Lep)									
Aeshnidae		1							
Cordulegaster									
Somatochlora		1			1				2
Coleoptera									
Helichus									
Hydroporus	3	1	1	3	3	2	2	1	1
Diptera (excl Chironomidae)									
Ceratopogoninae		2						1	2
Dolichopodidae		1							
Empididae				1					
Pilaria								4	
Pseudolimnophila					1				
Simuliidae (not *Prosimulium*)									
Tabanidae		1	1	1		2			
Oligochaeta									
Dero									
Enchytraeidae			1	1		2	1	1	1
Haplotaxis gordioides									
Imm. Tubificidae w/ hair chaetae	18	7	8	12	3	8	1	4	5
Imm. Tubificidae w/o hair chaetae				2		1		5	
Lumbriculidae		1	1		1		1	2	
Lumbriculidae (w/proboscis)	1			1	1				
Nais				1	2	1			

Chironomidae									
Chironomus				1		1		1	
Corynoneura (no sculpturing)	3	6		2	5	3	5		
Cricotopus/Orthocladius					1				1
Dicrotendipes simpsoni				1					
Diplocladius cultriger									
Eukiefferiella claripennis gp									
Heterotrissocladius	8	7	13	25	12	28	7	4	4
Hydrobaenus (not O)									
Hydrobaenus "O" (Epler)									
Kiefferulus				1					
Natarsia									
Omisus									
Orthocladius obumbratus/robacki									
Orthocladius cf *oliveri*									
Parakiefferiella "D" (Epler)									
Parametriocnemus							1		
Polypedilum illinoense gp		1	1	1					
Potthastia longimana gp									
Rheocricotopus cf VA (Epler)									
Stilocladius									
Tanytarsus "V" (Epler)					1			1	
Thienemannimyia gp									
Tvetenia cf *paucunca*					1		1		
Zavrelimyia		1	1	3	6	3	1	2	1

Table F-6. Benthic macroinvertebrate counts in samples from Mill Branch, March 15, 2005.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea	5	6	12	10	8	12	14	7	9
Cambaridae	6	4	6			3	1	3	4
Crangonyx	1	8	7	12	16	14	8	7	10
Hydracarina									
Physidae									
Stygobromus									
Synurella bifurca	58	43	49	13	28	16	23	23	22
Turbellaria	1								
Ephemeroptera									
Caenis latipennis gp				4					
Plecoptera									
Allocapnia						1			
Amphinemura	3		4		2	1		1	1
Isoperla w/ vertical bars									1
Zealeuctra									
Trichoptera									
Ironoquia		1							
Rhyacophila kiamichi									
Rhyacophila lobifera									
Other Insects (Od,Hem,Meg,Lep)									
Aeshnidae									
Cordulegaster			1						
Somatochlora	1				1				3
Coleoptera									
Helichus	1								
Hydroporus	1	2	2	2	5	8	2	2	
Diptera (excl Chironomidae)									
Ceratopogoninae		2	2			2	1	1	1
Dolichopodidae									
Empididae									
Pilaria		1	1			2	2		1
Pseudolimnophila									
Simuliidae (not *Prosimulium*)	2		3			1	1	2	2
Tabanidae				1	1	1	2		2
Oligochaeta									
Dero									1
Enchytraeidae		1		1		1		1	
Haplotaxis gordioides							1		
Imm. Tubificidae w/ hair chaetae	2	7	3	3	11	5	3	1	1
Imm. Tubificidae w/o hair chaetae	1			2		2	1	1	1
Lumbriculidae			1				1	4	5
Lumbriculidae (w/proboscis)			1	5	3	6	1	1	
Nais			2	1	2		4	2	1
Chironomidae									

Chironomus		1					1		
Corynoneura (no sculpturing)	1	4	1	3	2		1		
Cricotopus/Orthocladius									
Dicrotendipes simpsoni									
Diplocladius cultriger								1	
Eukiefferiella claripennis gp	2					1			1
Heterotrissocladius	5	9		26	13	11	6	9	5
Hydrobaenus (not O)				1			1	1	
Hydrobaenus "O" (Epler)								5	1
Kiefferulus									
Natarsia									1
Omisus					1				
Orthocladius obumbratus/robacki								1	
Orthocladius cf *oliveri*	2		1	1		2	3	8	3
Parakiefferiella "D" (Epler)									1
Parametriocnemus	2					1		2	2
Polypedilum illinoense gp		1			1	2		1	
Potthastia longimana gp							1		
Rheocricotopus cf VA (Epler)							1		
Stilocladius			1						
Tanytarsus "V" (Epler)				1		1			
Thienemannimyia gp									2
Tvetenia cf *paucunca*								1	
Zavrelimyia	6	10	3	14	6	7	21	15	19

APPENDIX G: Thompson Creek benthic macroinvertebrate data

Table G-1. Benthic macroinvertebrate counts in samples from Thompson Creek, January 14, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea (unpigmented)	1							1	1
Crangonyx	4	9		3	2	2	5	12	6
Gordiidae									
Hyalella azteca									
Hydracarina									1
Lirceus	28	21	31	31	38	45	37	28	37
Menetus									
Orconectes					1				
Stygobromus									
Turbellaria			1	4		1	2		
Ephemeroptera									
Acentrella/Plauditus									
Ameletus									
Caenis			1	28	15	7			
Eurylophella									1
Leptophlebia									
Leptophlebiidae									
Paraleptophlebia									
Siphlonurus									
Stenacron	2	2	3	1	2				
Stenonema femoratum			3	4	7	1			1
Plecoptera									
Acroneuria									
Allocapnia	24	12	19	4	2	5	36	34	25
Amphinemura									
Chloroperlidae									
Clioperla clio		1		1	1		2	1	6
Isoperla w/ vertical bars									
Prostoia	1	1							
Strophopteryx	8	11	13	8	7	8	9	14	12
Zealeuctra	3	1	1		1	1	4		1
Trichoptera									
Agapetus		2			1	1			
Cheumatopsyche					1				
Chimarra	2	2	2	1	2	3			
Dibusa angata									
Hydroptila									
Lepidostoma	1	1			1	1			
Neophylax	1								
Polycentropus		1			1				
Pycnopsyche								1	
Rhyacophila kiamichi		1	1				1		

Rhyacophila lobifera									
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Enallagma									
Gomphidae (cf *Stylogomphus*)			1		1	2			
Lepidoptera (not *Petrophila*)									
Nigronia serricornis	1	2	1			3			
Sialis			1						
Coleoptera									
Agabus								1	1
Dubiraphia									
Ectopria		1	1		1	1			
Enochrus									
Hydroporus									
Laccophilus					1				
Psephenus					1				
Stenelmis									
Diptera (excl Chironomidae)									
Ceratopogoninae									
Clinocera									
Dasyhelea									
Dicranota									
Dolichopodidae									
Hexatoma		1							
Prosimulium	12	13	11	3	3	7	2	2	4
Pseudolimnophila	1	5			2	6			
Simuliidae (not *Prosimulium*)								1	
Tabanidae									
Tipula	1	3	1		2	1			1
Tipulidae (other than above genera)				1					
Oligochaeta									
Enchytraeidae	2	1							1
Imm. Tubificidae w/ hair chaetae									
Imm. Tubificidae w/o hair chaetae									
Lumbriculidae	1			1				3	
Nais									
Chironomidae									
Ablabesmyia janta/rhamphe gp									
Ablabesmyia mallochi									
Chironomus		1							
Constempellina									
Corynoneura (no sculpturing)		1		1					
Dicrotendipes modestus/neomodestus									
Eukiefferiella claripennis gp	5	2	3		1		2		
Heterotrissocladius	1	2	2	1					
Micropsectra									
Microtendipes pedellus gp				4	1	1			
Natarsia			1		2				
Nilothauma						1			
Orthocladius obumbratus/robacki									

Pagastiella							
Parachaetocladius							
Parametriocnemus							
Paratanytarsus	1						
Platysmittia cf *fimbriata*							
Polypedilum aviceps							
Procladius					1		
Pseudochironomus							
Stictochironomus		2					
Tanytarsus					1		
Tanytarsus "M" (Epler)							
Tanytarsus "P" (Epler)							
Thienemannimyia gp			1		1	1	
Tribelos cf *jucundum*		1	1	3	2	1	
Tvetenia cf *paucunca*							
Zavrelimyia			1	1		1	2

Table G-2. Benthic macroinvertebrate counts in samples from Thompson Creek, March 13, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea (unpigmented)			1				2	1	
Crangonyx	2	1	5		2		7	7	10
Gordiidae									
Hyalella azteca				1		3			
Hydracarina									
Lirceus	13	14	19	23	18	24	21	27	13
Menetus									
Orconectes				1					
Stygobromus					1				1
Turbellaria	2	1		3	1		2	3	1
Ephemeroptera									
Acentrella/Plauditus	3		1	6	2	3		1	2
Ameletus			1					1	
Caenis				3	5	8			
Eurylophella									
Leptophlebia					1				
Leptophlebiidae			1	1					1
Paraleptophlebia							2		
Siphlonurus							1		
Stenacron	1	2	1	1					
Stenonema femoratum				4	3	1		1	
Plecoptera									
Acroneuria									
Allocapnia						1		1	
Amphinemura	9	10	15	5	4	3	1	2	6
Chloroperlidae			1	1				1	
Clioperla clio		4	1		2	1	2	1	2
Isoperla w/ vertical bars	4	5	6	4	4	1		3	2
Prostoia									
Strophopteryx	23	22	12	14	8	7	32	20	19
Zealeuctra	2	2	3				3	5	5
Trichoptera									
Agapetus			1	3	4	2	2	1	2
Cheumatopsyche									
Chimarra	2					2			
Dibusa angata					1				
Hydroptila									
Lepidostoma		1	4	3	1		3	2	3
Neophylax				1			1	2	4
Polycentropus	1					1			1
Pycnopsyche									
Rhyacophila kiamichi	1	1	1		1	2	2	2	2
Rhyacophila lobifera									
Wormaldia			1	1	2	2	1		1

Other Insects (Od,Hem,Meg,Lep)									
Enallagma									
Gomphidae (cf *Stylogomphus*)									
Lepidoptera (not *Petrophila*)									
Nigronia serricornis	1								
Sialis				1					
Coleoptera									
Agabus							1		
Dubiraphia				1					
Ectopria		1	1						
Enochrus									
Hydroporus									
Laccophilus									
Psephenus									
Stenelmis	2							1	
Diptera (excl Chironomidae)									
Ceratopogoninae									
Clinocera		1				2			
Dasyhelea			1						
Dicranota							1		
Dolichopodidae							2		
Hexatoma	1		1			1			
Prosimulium	24	26	6	6	18	12	10	13	21
Pseudolimnophila	2	2	2			3			
Simuliidae (not *Prosimulium*)						1			
Tabanidae									
Tipula	1			1		2		1	
Tipulidae (other than above genera)									
Oligochaeta									
Enchytraeidae		1	2				1	2	1
Imm. Tubificidae w/ hair chaetae				2					
Imm. Tubificidae w/o hair chaetae					1				
Lumbriculidae		3					2	1	
Nais									
Chironomidae									
Ablabesmyia janta/rhamphe gp									
Ablabesmyia mallochi					1				
Chironomus			1						
Constempellina									
Corynoneura (no sculpturing)									
Dicrotendipes modestus/neomodestus						1			
Eukiefferiella claripennis gp	1	1							
Heterotrissocladius		1		1					
Micropsectra	1				2		1		
Microtendipes pedellus gp	1		1		2	3			
Natarsia			1	2	2	1			
Nilothauma									
Orthocladius obumbratus/robacki		1	4	1		1			
Pagastiella					1				
Parachaetocladius									1

Parametriocnemus	2			1			
Paratanytarsus							
Platysmittia cf *fimbriata*				1	1		2
Polypedilum aviceps							
Procladius							
Pseudochironomus							
Stictochironomus		1					
Tanytarsus							
Tanytarsus "M" (Epler)		4		2	1		
Tanytarsus "P" (Epler)							
Thienemannimyia gp			1				
Tribelos cf *jucundum*	1	1	9	9	9		
Tvetenia cf *paucunca*					1		
Zavrelimyia						1	

Table G-3. Benthic macroinvertebrate counts in samples from Thompson Creek, December 17, 2003.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Branchiobdellida			1						
Caecidotea (unpigmented)		1		1	2				2
Crangonyx	6	4	3	1	1	1	7	4	5
Hyalella azteca					2	1		3	2
Hydracarina									
Lirceus	36	25	29	37	30	31	50	60	36
Orconectes	1	1		2		1	1	1	
Stygobromus		1							
Turbellaria		2	2	1	2				2
Ephemeroptera									
Acentrella/Plauditus									
Acerpenna							1		
Ameletus									
Caenis	2	1	3	2	1	3			
Diphetor		2							
Eurylophella									
Leptophlebiidae									
Leucrocuta									
Procloeon									
Stenacron	3		3		3	2	1		1
Stenonema femoratum	6	9	13	15	12	8	5	5	6
Plecoptera									
Allocapnia	9	5	7	3	4	6	1	3	4
Amphinemura									
Chloroperlidae									
Clioperla clio		1	3	4	2	3	1	4	7
Isoperla w/ vertical bars									
Perlidae									
Strophopteryx	4	6	4	2	1	2	7	3	3
Taeniopteryx									
Zealeuctra		1	1	1	1		1		
Trichoptera									
Agapetus							1		
Cheumatopsyche		1		1			1		2
Chimarra	2	8	6	2	9	8	2	1	
Diplectrona modesta									
Hydropsyche									
Hydroptila									
Ironoquia							1		
Lepidostoma	3	5	4	1	2	2	2		
Neophylax		1				1	1		
Polycentropus		2							
Pycnopsyche		1	2		1	1	2	1	1
Rhyacophila kiamichi									2

Rhyacophila lobifera	2	1	2						
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Enallagma/Ischnura									
Gomphidae (cf *Stylogomphus*)			1						
Gomphidae (not *Stylogomphus*)									
Nigronia serricornis		2				1			1
Sialis				1		1			
Somatochlora									
Coleoptera									
Agabus									
Berosus					1				
Ectopria									
Helichus									
Hydroporus					1				
Laccophilus									
Psephenus	1				1	1	2	4	2
Stenelmis	1								
Diptera (excl Chironomidae)									
Ceratopogoninae								1	2
Clinocera									
Hemerodromia									2
Hexatoma									
Prosimulium	5	4	5	5	3	2	2		2
Pseudolimnophila		1			1	2			
Simuliidae (not *Prosimulium*)	2	1	1	1		1			
Tabanidae									
Tipula	4	2	4	3	1	4	1	1	1
Oligochaeta									
Enchytraeidae	4	2	2	1			4	2	1
Imm. Tubificidae w/ hair chaetae					2				
Imm. Tubificidae w/o hair chaetae					3	3			
Lumbriculidae	1	1					1		3
Nais									
Chironomidae									
Ablabesmyia janta/rhamphe gp						1			
Ablabesmyia mallochi						1			
Corynoneura (no sculpturing)									
Corynoneura (w/ sculpturing)		1	1						
Cryptochironomus									
Dicrotendipes lucifer/nervosus									
Eukiefferiella claripennis gp	3		2	2	1	1		1	2
Heterotrissocladius	1	2				1			
Larsia									
Micropsectra		1							1
Microtendipes pedellus gp		2	1	7	4	5		2	
Natarsia									
Orthocladius (Euortho) w/13 teeth								1	
Orthocladius obumbratus/robacki									
Orthocladius (Ortho) "other"									

Parachaetocladius						3		
Parakiefferiella "E" (Epler)								1
Parametriocnemus			1	1	1	1		5
Paratanytarsus								
Platysmittia cf *fimbriata*								
Polypedilum aviceps				1				
Polypedilum illinoense gp								
Rheocricotopus cf *unidentatus* or "VA"								
Rheotanytarsus							1	
Stempellinella								
Stictochironomus	1			1				
Tanytarsus "M" (Epler)								
Thienemanniella cf *xena*								1
Thienemannimyia group	1		2	1	1	1	1	2
Tribelos cf *jucundum*		2	3	4	4			
Tvetenia cf *paucunca*								1
Zavrelimyia	2	1	1	1			1	

Table G-4. Benthic macroinvertebrate counts in samples from Thompson Creek, March 14, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Branchiobdellida									
Caecidotea (unpigmented)								1	
Crangonyx		1	1				3	1	3
Hyalella azteca								1	
Hydracarina					1				
Lirceus	6	17	14	26	35	28	28	25	29
Orconectes				1					
Stygobromus			1	1					
Turbellaria	1	1	1		2		2	2	2
Ephemeroptera									
Acentrella/Plauditus	2	1	2	1		2	6	1	6
Acerpenna							3	1	
Ameletus									
Caenis	3	1				1		1	
Diphetor						2			
Eurylophella									
Leptophlebiidae	1	2	4	1	1		4	3	2
Leucrocuta				1				4	1
Procloeon									
Stenacron	1		1						
Stenonema femoratum	4	6	1	6	4	2	2	1	
Plecoptera									
Allocapnia									
Amphinemura	13	6	10	7	10	6	7	9	12
Chloroperlidae	1		1		1	1	2	3	2
Clioperla clio	1	3	3	3	2	1	2		1
Isoperla w/ vertical bars	6	16	13	8	6	17	10	15	17
Perlidae	1	1		1					1
Strophopteryx	18	9	18	10	3	8	5	2	4
Taeniopteryx									
Zealeuctra		4	3						
Trichoptera									
Agapetus			1	1	1		3	2	5
Cheumatopsyche									
Chimarra					2	1	1	1	
Diplectrona modesta									
Hydropsyche									
Hydroptila			1						1
Ironoquia									
Lepidostoma									
Neophylax									
Polycentropus			1		1			1	
Pycnopsyche	1								
Rhyacophila kiamichi	3	2	2	1	1			1	

Rhyacophila lobifera									
Wormaldia		5		2	2	5	1		
Other Insects (Od,Hem,Meg,Lep)									
Enallagma/Ischnura									
Gomphidae (cf *Stylogomphus*)									
Gomphidae (not *Stylogomphus*)									
Nigronia serricornis				1					
Sialis	1	1							
Somatochlora									
Coleoptera									
Agabus									
Berosus									
Ectopria						1			
Helichus									
Hydroporus									
Laccophilus								1	
Psephenus							1		1
Stenelmis			1						
Diptera (excl Chironomidae)									
Ceratopogoninae					2			1	
Clinocera				1	2	1			
Hemerodromia									
Hexatoma								1	
Prosimulium	27	12	7	5	15	4	5	6	5
Pseudolimnophila	1		3		1				
Simuliidae (not *Prosimulium*)									
Tabanidae						2			
Tipula	2	2	1	1		1			1
Oligochaeta									
Enchytraeidae	1					1	2	1	
Imm. Tubificidae w/ hair chaetae									
Imm. Tubificidae w/o hair chaetae			2	2					
Lumbriculidae		1						1	
Nais				3	1	1			
Chironomidae									
Ablabesmyia janta/rhamphe gp									
Ablabesmyia mallochi	1	2							
Corynoneura (no sculpturing)									
Corynoneura (w/ sculpturing)									
Cryptochironomus									
Dicrotendipes lucifer/nervosus									
Eukiefferiella claripennis gp	2	1	1	2		3	2	1	2
Heterotrissocladius									
Larsia									1
Micropsectra								2	1
Microtendipes pedellus gp				1					
Natarsia									
Orthocladius (Euortho) w/13 teeth									
Orthocladius obumbratus/robacki						1	1		
Orthocladius (Ortho) "other"									

Parachaetocladius									
Parakiefferiella "E" (Epler)									
Parametriocnemus					3		1		
Paratanytarsus								1	
Platysmittia cf *fimbriata*									1
Polypedilum aviceps	1	1		5	1	1	5	5	2
Polypedilum illinoense gp					1				
Rheocricotopus cf *unidentatus* or "VA"									
Rheotanytarsus									
Stempellinella							2		
Stictochironomus									
Tanytarsus "M" (Epler)				2			2		
Thienemanniella cf *xena*						1		1	
Thienemannimyia group		1	2	1	1	2		3	
Tribelos cf *jucundum*	1			3	1	3			
Tvetenia cf *paucunca*		1	1	1		1			
Zavrelimyia	1	3	4	2		3		1	

Table G-5. Benthic macroinvertebrate counts in samples from Thompson Creek, December 21, 2004.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea (unpigmented)	2	1			1				2
Crangonyx	1	4	3	2		3	2	5	
Hyalella azteca			2	1		1		1	
Hydracarina		1						1	1
Lirceus	29	29	27	26	26	32	23	24	19
Orconectes				1	1			1	
Stygobromus					2		1		
Turbellaria	2	1	2	1	2	1	1		1
Ephemeroptera									
Acentrella/Plauditus	2	2	2	5		1	7	7	9
Acerpenna							2	1	2
Ameletus									
Baetis flavistriga									1
Caenis					3	2			1
Diphetor	5	2	5	5	1	3		2	2
Eurylophella								1	
Leptophlebiidae	1	4	4	1			5	3	2
Leucrocuta	2	2	1	2			5	5	8
Paraleptophlebia									
Procloeon									
Stenacron		2						1	1
Stenonema femoratum	6	1	7	6	5	6	7	4	10
Plecoptera									
Allocapnia	3	2		4	6	5	3	6	2
Amphinemura						1			
Chloroperlidae	1	2		1	2	1	4	3	3
Clioperla clio	11	7	6	3	5	6	6	6	9
Isoperla w/ vertical bars		5	3	4	2	1	6	4	3
Perlesta									
Perlidae	2	1	1		1	1	1		
Perlinella drymo									
Strophopteryx	3	6	5	2	5	1	4	1	3
Zealeuctra	3	2	1	1	2	3			
Trichoptera									
Agapetus	2	1		3	1	1	3	2	1
Cheumatopsyche					1				
Chimarra		3	1	5	10		3	1	2
Dibusa angata									
Hydropsyche									
Hydroptila									
Lepidostoma	3	3	9	1	2	3	2		2
Neophylax									
Paranyctiophylax									
Polycentropus	3		1	1		1	1	1	

Pycnopsyche		1					2	3	1
Rhyacophila kiamichi		1	1	1			1		
Rhyacophila lobifera									
Triaenodes									
Wormaldia									
Other Insects (Od,Hem,Meg,Lep)									
Aquarius									
Argia									
Calopteryx									
Corydalus									
Enallagma									
Gomphidae (cf *Stylogomphus*)									
Gomphidae (not *Stylogomphus*)									
Hagenius brevistylus		1							
Nigronia serricornis									
Sialis									
Coleoptera									
Agabus			1						
Dubiraphia					1				
Ectopria				1		1			
Hydroporus									
Psephenus					1		3	2	
Stenelmis					1				
Diptera (excl Chironomidae)									
Ceratopogoninae									
Clinocera									
Dixa						1			
Hexatoma								1	
Prosimulium	1	1	2	2	1	1	1	2	1
Pseudolimnophila				1		1			
Simuliidae (not *Prosimulium*)	4	2	1		1	1		1	1
Tabanidae									
Tipula	1	3	6	6	6	3	3	2	1
Oligochaeta									
Enchytraeidae								1	
Imm. Tubificidae w/ hair chaetae				1					
Imm. Tubificidae w/o hair chaetae					1				
Lumbriculidae			1						1
Chironomidae									
Ablabesmyia janta/rhamphe gp									
Ablabesmyia mallochi									
Cardiocladius		1							
Constempellina									
Corynoneura (w/ sculpturing)								1	
Cricotopus bicinctus									
Cricotopus cf *luciae*									
Cricotopus/Orthocladius									
Cryptochironomus									
Dicrotendipes modestus/neomodestus				1					
Eukiefferiella claripennis gp					1		1		

Heterotrissocladius	2	2	3	4	1	1		1	4
Micropsectra									
Microtendipes pedellus gp	6	4	3	1	4	6	2		3
Natarsia									
Orthocladius obumbratus/robacki									
Parachaetocladius									
Parametriocnemus				1		1			
Paratanytarsus									
Paratrichocladius/Orthocladius dorenus									
Polypedilum aviceps	1			1		1		1	1
Polypedilum fallax gp									
Polypedilum illinoense gp									
Pseudochironomus									
Rheotanytarsus		1							
Stictochironomus	2					1		1	
Tanytarsus "D" (Epler)									
Tanytarsus "M" (Epler)									
Thienemanniella cf *xena*					1				
Thienemannimyia group	2	1	2	4	2	5		1	
Tribelos cf *jucundum*		1		1		1			
Tvetenia cf *paucunca*									
Zavrelimyia					1	3	1	3	3

Table G-6. Benthic macroinvertebrate counts in samples from Thompson Creek, March 30, 2005.

	Station 1			Station 2			Station 3		
	a	b	c	a	b	c	a	b	c
Non-insect									
Caecidotea (unpigmented)		1						1	
Crangonyx		1	4		1		1	1	
Hyalella azteca				1	3	4			
Hydracarina									
Lirceus	36	31	17	20	32	26	26	20	28
Orconectes	1			1	1			1	
Stygobromus			1	1					
Turbellaria			1	1	1				
Ephemeroptera									
Acentrella/Plauditus	3	1	3	3		1	6	1	4
Acerpenna					1		1		
Ameletus				1					
Baetis flavistriga									
Caenis	1	1		2	1	3		2	1
Diphetor					1				1
Eurylophella									
Leptophlebiidae									
Leucrocuta	11	21	7	6	11	6	10	23	15
Paraleptophlebia	8	6	5	2	5	8	7	3	6
Procloeon					1				
Stenacron				1		1			1
Stenonema femoratum	2	2	4	4	4	10	2	2	1
Plecoptera									
Allocapnia									
Amphinemura	3	4	5	6	1	1	3	4	5
Chloroperlidae	5	8	7	2	3	2	14	11	9
Clioperla clio	1	1	4	1		1			
Isoperla w/ vertical bars	5	5	13	6	9	9	10	8	6
Perlesta	4	2	2				2	1	4
Perlidae									
Perlinella drymo									
Strophopteryx									
Zealeuctra									
Trichoptera									
Agapetus	3			1		1	1	1	2
Cheumatopsyche									
Chimarra									
Dibusa angata								1	
Hydropsyche									
Hydroptila							1	2	
Lepidostoma		1							
Neophylax									
Paranyctiophylax						1			

Polycentropus	1	2	2	1	1				1
Pycnopsyche				1					
Rhyacophila kiamichi			1						
Rhyacophila lobifera									
Triaenodes									
Wormaldia	1		1						1
Other Insects (Od,Hem,Meg,Lep)									
Aquarius	1			1					
Argia									
Calopteryx									
Corydalus									
Enallagma					1				
Gomphidae (cf *Stylogomphus*)									
Gomphidae (not *Stylogomphus*)					1				
Hagenius brevistylus									
Nigronia serricornis			1		1				
Sialis									
Coleoptera									
Agabus									
Dubiraphia					1				
Ectopria				3	2				
Hydroporus									
Psephenus	1						5	3	
Stenelmis								1	
Diptera (excl Chironomidae)									
Ceratopogoninae									
Clinocera				1	1	1		1	1
Dixa									
Hexatoma									
Prosimulium	1								
Pseudolimnophila									
Simuliidae (not *Prosimulium*)	1						1		
Tabanidae									
Tipula	2	1	2	2	1	1	1		1
Oligochaeta									
Enchytraeidae	1					1			
Imm. Tubificidae w/ hair chaetae									
Imm. Tubificidae w/o hair chaetae									1
Lumbriculidae				3	1	1		1	
Chironomidae									
Ablabesmyia janta/rhamphe gp									
Ablabesmyia mallochi			1	1	2	7	1		
Cardiocladius									
Constempellina									
Corynoneura (w/ sculpturing)									
Cricotopus bicinctus						1			
Cricotopus cf *luciae*									
Cricotopus/Orthocladius		1							
Cryptochironomus									
Dicrotendipes modestus/neomodestus									

Eukiefferiella claripennis gp	1			1					
Heterotrissocladius									
Micropsectra	1	1		2	2	1		2	
Microtendipes pedellus gp	1	1	4	3		1	1		
Natarsia			1						
Orthocladius obumbratus/robacki									
Parachaetocladius									
Parametriocnemus				1					1
Paratanytarsus				1					
Paratrichocladius/Orthocladius dorenus					1	1			
Polypedilum aviceps	2	2	8	12	5	1	5	4	4
Polypedilum fallax gp									
Polypedilum illinoense gp						1			
Pseudochironomus									
Rheotanytarsus									
Stictochironomus									
Tanytarsus "D" (Epler)					1				
Tanytarsus "M" (Epler)	1		1					2	3
Thienemanniella cf *xena*									
Thienemannimyia group	2	2	2	4	3	5	2	2	4
Tribelos cf *jucundum*		3	1	4					
Tvetenia cf *paucunca*						1			
Zavrelimyia		2	2		1	3		2	