National Water-Quality Assessment Program

PERIPHYTON COMMUNITIES IN STREAMS OF THE OZARK PLATEAUS AND THEIR RELATIONS TO SELECTED ENVIRONMENTAL FACTORS

Water-Resources Investigations Report 02-4210

U.S. Department of the Interior
U.S. Geological Survey

A

B

C

On the cover:

A - Buffalo River near Boxley, Arkansas

B - Rocks with periphyton removed from circular sampling area

C - *Cymbella delicatula*, a diatom indicative of low nutrient concentrations (courtesy of the Phycology Section of the Academy of Natural Sciences Patrick Center for Environmental Research in Philadelphia, Pennsylvania)

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By James C. Petersen and Suzanne R. Femmer

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National Water-Quality Assessment Program

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FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources. (http://www.usgs.gov/). Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity and quality, even more critical to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy. (http://water.usgs.gov/nawqa/). Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units. (http://water.usgs.gov/nawqa/nawqamap.html). Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings. (http://water.usgs.gov/nawqa/natsyn.html).

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Associate Director for Water

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ILLUSTRATIONS

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CONVERSION FACTORS

Multiply	By	To obtain
square kilometer (km^2)	0.3861	square mile
meter (m)	3.281	foot
square meter (m^2)	10.76	square foot
cubic meter (m^3)	35.31	cubic foot
centimeter (cm)	0.3937	inch
cubic centimeter (cm^3)	0.0610	cubic inch
degree Celsius (° C)	1.8 x ° C + 32	degree Fahrenheit

Abbreviated units used in this report:

mg/L, milligram per liter

mg, milligram

mL, milliliter

PERIPHYTON COMMUNITIES IN STREAMS OF THE OZARK PLATEAUS AND THEIR RELATIONS TO SELECTED ENVIRONMENTAL FACTORS

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ABSTRACT

During August through September of 1993-95, 83 periphyton samples were collected at 51 stream sites in the Ozark Plateaus. These sites were categorized into six land-use categories (20 forest, 18 agriculture, 10 mining, 1 urban, 1 urban/mining, and 1 mix), based on land-use percentages in the basin upstream from the site.

Results indicate that periphyton communities of riffles of Ozark streams are affected by natural and land-use related factors. These factors include nutrients, dissolved organic carbon, alkalinity, canopy shading, suspended sediment, embeddedness, stream morphometry, and velocity. For several measures of periphyton communities, statistically significant ($p<0.05$) differences were found among sites assigned to agriculture, forest, and mining categories. Blue-green algae biovolume, relative abundance of blue-green algae, relative biovolume of diatoms, relative abundance of oligotrophic algae, relative abundance of tolerant taxa, and condition index values were among the measures that differed among land-use categories.

Although no environmental factors were significantly correlated with total biovolume, several factors were significantly correlated with biovolume of blue-green algae or biovolume of diatoms. Biovolume of blue-green algae was correlated with percent agriculture land use. Biovolume of diatoms was correlated with orthophosphate, total phosphorus, alkalinity, velocity, embeddedness, and dissolved organic carbon.

Diatoms often composed the largest percentage of the biovolume (relative biovolume). Diatom relative biovolume was much higher at mining sites (generally 75 to 90 percent of the total biovolume) than at forest or agriculture sites (generally 15 to 80 percent) and was correlated with several factors, including many land-use related factors. The diatoms *Cymbella affinis* and *Cymbella delicatula* and the blue-green algae *Calothrix* often were the most common (relative abundance and relative biovolume) algae in samples.

Detrended correspondence analysis (DCA) and hierarchical cluster analyses results indicated differences among land-use category sites. The DCA results were correlated with a number of land-use related factors and channel morphometry.

Grazers (specifically, snails and stonerollers) are related to periphyton biovolume and community composition. Total periphyton and diatom biovolume typically were highest at sites where snail density was lowest. Lower relative abundances of diatoms usually occurred at sites with higher snail densities and stoneroller relative abundances.

INTRODUCTION

During 1993-95, a study of the Ozark Plateaus was conducted as part of the National Water -Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS), which uses an integrated, multidisciplinary approach (physical, chemical, and biological) to assess water quality on a basinwide (or larger) scale (Gurtz, 1994). NAWQA was initiated in 20 of the 60 planned study units in 1991 with a goal of describing the status and trends in the quality of the Nation’s water resources. The Ozark Plateaus study unit was one of these initial 20 study units. One objective of the

NAWQA biological studies is to characterize benthic invertebrate (Cuffney and others, 1993), algal (Porter and others, 1993), and fish communities (Meador and others, 1993a), and related instream and riparian habitats (Meador and others, 1993b) and their relations to water quality.

A better understanding of the relation between periphyton communities of the Ozark Plateaus and environmental factors is of interest to many, including the National Park Service, which administers several parks in the Ozark Plateaus. To contribute to this understanding (as well as to understanding of similar relations across the Nation), the NAWQA Program and the National Park Service/USGS Water-Quality Monitoring and Assessment Partnership collaborated to complete a study of periphyton communities in the Ozark Plateaus. Studies conducted as part of the Water-Quality Monitoring and Assessment Partnership are designed to contribute information that would enhance the understanding of National Park Service water-quality management issues.

Purpose and Scope

The purpose of this report is to present relations between periphyton (within this report defined as attached benthic algae, including blue-green algae or cyanobacteria) community characteristics, and physical, chemical, and biological factors for representative sections (reaches) of selected Ozark Plateaus (Ozark) streams. A limited discussion of macroalgae (primarily attached or floating filaments) abundance and distribution among Ozark streams is included in this report. The emphasis of the NAWQA Program is water quality; hence, the relation of periphyton communities to water quality is an important focus of this report. However, periphyton community characteristics related to water quality must be considered in conjunction with differences in other physical and biological factors because these factors are known to affect periphyton communities in streams. To determine the relations between water quality and periphyton community characteristics, periphyton communities were sampled from reaches of streams that differed in environmental setting (land-use, basin size, and physiographic section). To evaluate temporal variability, some reaches were sampled for multiple years (1993, 1994, and 1995). To evaluate spatial variability, multiple (and adjacent) reaches of three streams were sampled. Evaluation of temporal and spatial variability provides some insight into the natural variability of periphyton communities in Ozark streams and can be compared with the variability between communities at sites chosen to represent selected environmental settings. The study included the collection of periphyton community, water-quality, and habitat (measures of stream size, riparian vegetation and shading, velocity, upstream land use, and embeddedness) data associated with 83 samples from 57 reaches at 51 sites (fig. 1, table 1) during the study period (August through September of 1993-95). The periphyton communities of most reaches were sampled in 1994.

Acknowledgments

Sample collection and chemical or biological analysis were conducted as part of the NAWQA Program. The statistical analysis, interpretation of the results, and report preparation were conducted as part of the National Park Service-USGS Water Quality Assessment and Monitoring Program and the NAWQA Program. The assistance of the National Park Service (and particularly David Mott, hydrologist at Buffalo National River) is gratefully acknowledged. Stephen Porter of the USGS provided valuable guidance and assistance during the data analysis phase of the study. We also thank private landowners and public agencies for permission to access and sample many of these sites.

DESCRIPTION OF STUDY AREA AND PREVIOUS STUDIES

The Ozark Plateaus study unit (fig. 1) has an area of about 123,000 km^2 and includes parts of Arkansas, Kansas, Missouri, and Oklahoma. Most of the study unit is within the Springfield and Salem Plateaus and the Boston Mountains physiographic sections (fig. 1); these three sections compose the Ozark Plateaus physiographic province (Fenneman, 1938). These sections closely correspond with the Ozark Highlands and Boston Mountains ecoregions (Omernik and Gallant, 1987). Part of the study unit is within the Osage Plains physiographic section; this section closely corresponds with the Central Irregular Plains ecoregion (Fenneman, 1938; Omernik and Gallant, 1987). The environmental and hydrologic setting of the study unit is described in more detail in Adamski and others (1995), Femmer (1995), and Petersen and others (1998).

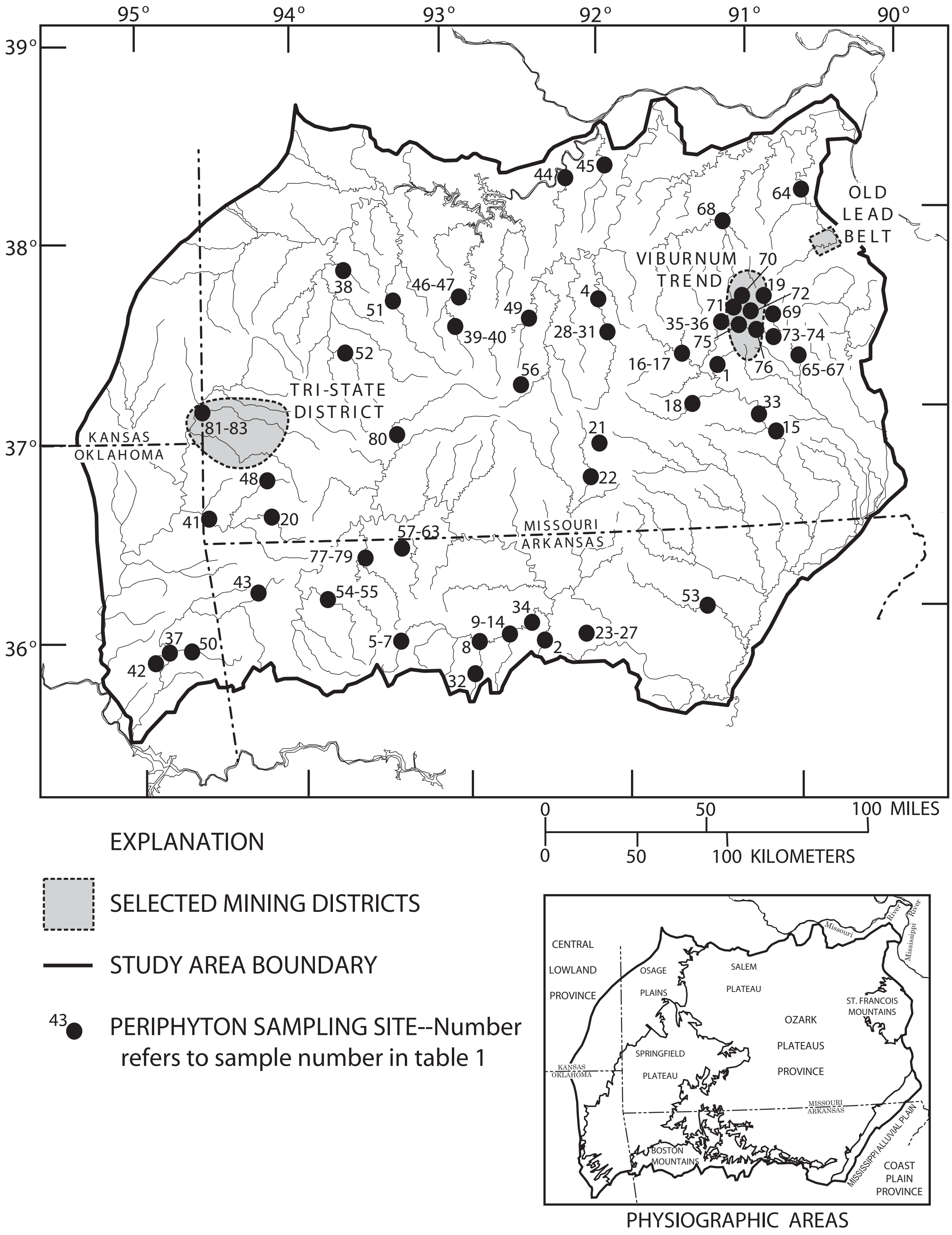

Figure 1. Location of study area and periphyton sampling sites.

Table 1. Sample numbers and associated site characteristics

[Land-use percentages may not sum to 100 because of rounding; km^2, square kilometer; lower, middle, and upper are reach designations; split designates a second sample collected at a site]

Sample number (see fig. 1)	Site name	Year sampled	Land-use category	Land use (percent)			Basin area (km^2)
				Forest	Agriculture	Urban	
1	Big Creek at Mauser Mill, Mo.	1994	Forest	95	5	0.5	108
2	Big Creek near Big Flat, Ark.	1994	Forest	64	36	0.5	232
3	Big Creek near Rat, Mo.	1995	Forest	91	7	2.0	18
4	Big Piney River near Big Piney, Mo.	1994	Forest	64	36	0.5	1,427
5	Buffalo River near Boxley, Ark.	1993	Forest	96	4	0.0	149
6	Buffalo River near Boxley, Ark.	1994	Forest	96	4	0.0	149
7	Buffalo River near Boxley, Ark.	1995	Forest	96	4	0.0	149
8	Buffalo River near Eula, Ark.	1994	Forest	88	12	0.0	1,562
9	Buffalo River near St. Joe, Ark. (lower)	1993	Forest	86	13	0.5	2,147
10	Buffalo River near St. Joe, Ark. (lower)	1994	Forest	86	13	0.5	2,147
11	Buffalo River near St. Joe, Ark. (lower)	1995	Forest	86	13	0.5	2,147
12	Buffalo River near St. Joe, Ark. (middle)	1994	Forest	86	13	0.5	2,147
13	Buffalo River near St. Joe, Ark. (upper)	1994	Forest	86	13	0.5	2,147
14	Buffalo River near St. Joe, Ark. (upper) (split)	1994	Forest	86	13	0.5	2,147
15	Current River at Van Buren, Mo.	1995	Forest	83	17	0.5	4,318
16	Current River below Akers, Mo.	1994	Forest	74	26	0.5	761
17	Current River below Akers, Mo. (split)	1994	Forest	74	26	0.5	761
18	Jacks Fork River at Alley Spring, Mo.	1994	Forest	78	22	0.5	790
19	Middle Fork Black River at Redmondville, Mo.	1995	Forest	97	1	2.0	58
20	Mikes Creek at Powell, Mo.	1994	Forest	72	28	0.0	167
21	Noblett Creek near Willow Springs, Mo.	1994	Forest	91	9	0.0	53
22	North Fork White River near Dora, Mo.	1994	Forest	71	29	0.5	1,046
23	North Sylamore Creek near Fifty Six, Ark. (lower)	1993	Forest	97	3	0.0	150
24	North Sylamore Creek near Fifty Six, Ark. (lower)	1994	Forest	97	3	0.0	150
25	North Sylamore Creek near Fifty Six, Ark. (lower)	1995	Forest	97	3	0.0	150
26	North Sylamore Creek near Fifty Six, Ark. (middle)	1993	Forest	97	3	0.0	150
27	North Sylamore Creek near Fifty Six, Ark. (upper)	1993	Forest	97	3	0.0	150
28	Paddy Creek above Slabtown Spring, Mo.	1994	Forest	90	10	0.5	89
29	Paddy Creek above Slabtown Spring, Mo. (split)	1994	Forest	90	10	0.5	89
30	Paddy Creek above Slabtown Spring, Mo.	1995	Forest	90	10	0.5	89
31	Paddy Creek above Slabtown Spring, Mo. (split)	1995	Forest	90	10	0.5	89
32	Richland Creek near Witts Springs, Ark.	1994	Forest	97	3	0.5	174
33	Rogers Creek near Van Buren, Mo.	1994	Forest	100	1	0.0	46
34	Water Creek near Evening Star, Ark.	1994	Forest	72	28	0.0	100
35	West Fork Black River near Greeley, Mo.	1995	Forest	87	13	0.0	107
36	West Fork Black River near Greeley, Mo. (split)	1995	Forest	87	13	0.0	107
37	Baron Fork at Eldon, Okla..	1994	Agriculture	52	46	1.0	808
38	Brush Creek above Collins, Mo.	1994	Agriculture	37	62	2.0	143
39	Dousinbury Creek near Wall Street, Mo.	1994	Agriculture	40	59	0.5	106
40	Dousinbury Creek near Wall Street, Mo.	1995	Agriculture	40	59	0.5	106
41	Elk River near Tiff City, Mo.	1994	Agriculture	51	47	2.0	2,258

Table 1. Sample numbers and associated site characteristics--Continued

[Land-use percentages may not sum to 100 because of rounding; km^2, square kilometer; lower, middle, and upper are reach designations; split designates a second sample collected at a site]

Sample number (see fig. 1)	Site name	Year sam-pled	Land-use category	Land use (percent) Forest	Agriculture	Urban	Basin area (km^2)
42	Illinois River near Tahlequah, Okla.	1994	Agriculture	36	59	5.0	2,484
43	Little Osage Creek near Healing Spring, Ark.	1994	Agriculture	6	91	3.0	102
44	Little Tavern Creek near St. Elizabeth, Mo.	1994	Agriculture	50	50	0.0	124
45	Maries River near Freeburg, Mo.	1994	Agriculture	59	40	0.5	482
46	Niangua River near Windyville, MO	1994	Agriculture	42	56	1.0	875
47	Niangua River near Windyville, Mo. (split)	1994	Agriculture	42	56	1.0	875
48	North Indian Creek near Wanda, Mo.	1994	Agriculture	5	94	1.0	121
49	Osage Fork near Russ, Mo.	1994	Agriculture	48	51	0.5	909
50	Peacheater Creek at Christie, Okla.	1994	Agriculture	42	57	0.5	61
51	Pomme de Terre near Polk, Mo.	1994	Agriculture	28	71	0.5	715
52	Sac River near Dadeville, Mo.	1994	Agriculture	15	83	2.0	666
53	Strawberry River near Poughkeepsie, Ark.	1994	Agriculture	57	41	1.0	1,225
54	War Eagle Creek near Hindsville, Ark.	1994	Agriculture	61	38	0.5	689
55	War Eagle Creek near Hindsville, Ark. (split)	1994	Agriculture	61	38	0.5	689
56	Woods Fork near Hartville, Mo.	1994	Agriculture	43	57	0.0	118
57	Yocum Creek near Oak Grove, Ark. (lower)	1993	Agriculture	22	76	2.0	137
58	Yocum Creek near Oak Grove, Ark. (middle)	1993	Agriculture	22	76	2.0	137
59	Yocum Creek near Oak Grove, Ark. (middle)	1994	Agriculture	22	76	2.0	137
60	Yocum Creek near Oak Grove, Ark. (middle) (split)	1994	Agriculture	22	76	2.0	137
61	Yocum Creek near Oak Grove, Ark. (middle)	1995	Agriculture	22	76	2.0	137
62	Yocum Creek near Oak Grove, Ark. (middle) (split)	1995	Agriculture	22	76	2.0	137
63	Yocum Creek near Oak Grove, Ark. (upper)	1993	Agriculture	22	76	2.0	137
64	Big River near Richwoods, Mo.	1994	Mining	64	31	1.0	1,904
65	Black River near Lesterville, Mo.	1993	Mining	93	6	0.5	1,242
66	Black River near Lesterville, Mo.	1994	Mining	93	6	0.5	1,242
67	Black River near Lesterville, Mo.	1995	Mining	93	6	0.5	1,242
68	Huzzah Creek near Scotia, Mo.	1994	Mining	86	12	0.5	1,258
69	Middle Fork Black River at Black, Mo.	1995	Mining	94	5	0.5	284
70	Neals Creek near Goodland, Mo.	1995	Mining	96	4	0.5	43
71	Strother Creek near Oates, Mo.	1995	Mining	99	1	0.5	23
72	Strother Creek near Redmondville, Mo.	1995	Mining	94	5	0.5	94
73	West Fork Black River at Centerville, Mo.	1995	Mining	92	8	0.5	356
74	West Fork Black River at Centerville, Mo. (split)	1995	Mining	92	8	0.5	356
75	West Fork Black River at West Fork, Mo.	1995	Mining	90	10	0.5	187
76	West Fork Black River near Centerville, Mo.	1995	Mining	91	9	0.5	237
77	Kings River near Berryville, Ark.	1993	Mix	68	32	0.5	1,365
78	Kings River near Berryville, Ark.	1994	Mix	68	32	0.5	1,365
79	Kings River near Berryville, Ark.	1995	Mix	68	32	0.5	1,365
80	James River near Boaz, Mo.	1994	Urban	21	68	10.0	1,202
81	Center Creek near Smithfield, Mo.	1993	Urban/mining	17	77	3.0	761
82	Center Creek near Smithfield, Mo.	1994	Urban/mining	17	77	3.0	761
83	Center Creek near Smithfield, Mo.	1995	Urban/mining	17	77	3.0	761

Land use in the study unit primarily is forest and agriculture (U.S. Geological Survey, 1990; Petersen and others, 1998). Therefore, forestry practices and agriculture (primarily pasture land) may affect water quality over relatively large areas. Mining, urban land use, and discharges from industrial and municipal sources also can affect water quality over smaller areas (Petersen and others, 1998). Poultry, cattle, and swine production is contributing to elevated nutrient concentrations in many streams (Petersen, 1988; Giese and others, 1990; Missouri Department of Natural Resources, 1990; Petersen, 1992; Kurklin, 1993; Davis and others, 1995; Davis and Bell, 1998; Petersen and others, 1998). Median nutrient concentrations reported by Davis and Bell (1998) at sites downstream from urban areas typically were similar or higher than concentrations at sites in agricultural areas. Nitrite plus nitrate (as nitrogen) concentrations typically are less than 0.1-0.2 milligrams per liter (mg/L) in forested areas of the Springfield Plateau and Salem Plateau, whereas concentrations typically range from about 0.4-2.0 mg/L in agricultural areas. Total phosphorus concentrations in agricultural areas are less elevated relative to forested areas than those for nitrite plus nitrate, except in the Springfield Plateau where total phosphorus concentrations are about 0.01 mg/L in forested areas and about 0.1-0.2 mg/L in agricultural areas. Suspended solids concentrations also are different in areas of differing land use, ranging from about 3-6 mg/L in forested areas to about 8 mg/L in agricultural areas (Davis and others, 1995); however, Davis and Bell (1998) did not find a significant relation between land use and suspended sediment concentration (medians ranged from 3-28 mg/L) to be as close as between land use and nutrients. Davis and Bell (1998) summarized nutrient, bacteria, organic carbon, and suspended sediment data for the periphyton-sampling sites in this report.

Canopy shading (an indirect measure of the amount of light reaching a stream) also appears to be related to land use. Femmer (1997) reported that canopies at sites in basins with predominantly agricultural land use were more open (i.e., less canopy shading) than canopies in more forested basins. Riparian canopy also was more open at larger stream sites, both in forested and agricultural basins.

The interaction of nutrient concentrations and canopy shading appears to have increased the relative abundance of stonerollers (*Campostoma*) in Ozark streams affected by agricultural and urban land use (Petersen, 1998). Stonerollers are an important grazer of algae in Ozark streams. Presumably, the increase in relative abundance of stonerollers indicates an increase in density of stonerollers in these streams, and the increase in density of stonerollers probably is the result of increased periphyton production. The abundance of invertebrate periphyton grazers (such as snails) also may be influenced by periphyton production, nutrient concentrations, and canopy shading.

Lead and zinc have been mined in parts of the Ozark Plateaus (fig. 1). The most important ore deposits were near Joplin, Mo., and in areas near the northern part of the eastern boundary of the study unit (Petersen and others, 1998). Concentrations of lead and zinc are elevated in water, bed sediment, and fish or clam tissue of some streams in these areas (Petersen and others, 1998).

SUMMARY OF MAJOR FACTORS EXPECTED TO INFLUENCE PERIPHYTON COMMUNITIES

Periphyton in Ozark streams are subject to numerous factors affecting their growth and community structure. Several of these factors are essential to their survival, whereas other factors have detrimental effects. Light duration and intensity, diurnal and temporal temperature fluctuations, nutrients, grazing pressures, and disturbances are some of the critical factors affecting periphyton communities. Several studies in the Ozarks and surrounding area have shown that nutrients and grazing have significant effects on periphyton communities.

Light is essential for periphyton to photosynthesize inorganic materials into organic, living biomass. Variations in light availability and intensity can account for considerable differences in the physiology, growth, and community structure of periphyton populations. Algal biomass often decreases as the amount of riparian vegetation, and thus shading, increases. For Missouri Ozark streams, Smart and others (1985) found that periphyton biomass (as measured by chlorophyll *a* concentration) in small forest streams was significantly lower than in small urban or agriculture streams. The urban and agriculture streams generally had no canopy cover and higher nutrient concentrations than forest streams.

Spatial and temporal variations in water temperature can affect rates of metabolism and species composition of periphyton communities. Riparian canopy cover over a stream channel can result in lower mean and maximum summer temperatures and less diurnal variation (DeNicola, 1996). Local ground-water discharge to streams, which is a major factor in the Ozarks, can have substantial effects on ambient water temperature. The continuous discharge of ground water contributes to stable streamflow and cooler water temperatures in the summer, and to warmer water temperatures during the winter.

The relation between nutrients and periphyton is not completely understood. Although nutrient enrichment studies have documented that increases in nitrogen and phosphorus concentrations can stimulate growth of periphyton in streams, algal responses to nutrient concentrations make it difficult to show a clear relation (Stockner and Shortreed, 1978; Lohman and others, 1991; Lohman and Priscu, 1992). The responses of periphyton to different nutrient conditions can be unpredictable. Nitrogen and phosphorus can be limiting to the growth of benthic algal communities (Borchardt, 1996). Because optimum nutrient ratios apparently differ among species (Borchardt, 1996), the concept of a single nutrient limiting the growth of a community is not valid in heterogeneous communities. Lohman and others (1991) cited the common occurrence of total nitrogen to total phosphorus ratios of less than 20:1 in northern Ozark streams during low flow conditions to support the theory that northern Ozark streams are nitrogen limited. Other studies of Ozark streams have suggested phosphorus limitation (Toetz and others, 1999), phosphorus and nitrogen limitation varying with time and location (Jones and others, 1984), or a predominance of limitation by phosphorus or co-limitation by phosphorus and nitrogen (Jones and others, 1984; Matlock and others, 1999).

Mining activities in areas of hard-rock mining, such as in the Old Lead Belt, Viburnum Trend, and Tri-State mining districts (fig. 1), can affect the chemistry and aquatic communities of streams as a result of toxicity. In the Ozarks, the heavy metals contributed by hard-rock mining most often are lead and zinc. Some changes in periphyton community structure do occur as a result of heavy metals (Klerks and Weis, 1987). Exposure to the inorganic stress can place pressure on a population and result in a decrease in the abundance of pollution-sensitive species and an increase or no change in abundance of pollution-tolerant species (Genter, 1996). The relative abundance of specific diatom species has been shown to be a useful variable in multivariate models to indicate high or low metal concentrations in streams (Rushforth and others, 1981). Differences in the abundance of certain diatom taxa among sites can indicate differences in water quality. For example, Hill and others (2000) found in their study of mining-impacted streams in central Colorado that *Fragilaria* dominated the periphyton community at less impacted sites, whereas *Achnanthes* was predominant at impacted sites.

The grazing of algae by herbivores can have a substantial effect on the biomass and diversity of a periphyton community. Feminella and Hawkins (1995) described interactions between stream herbivores and periphyton based on the results of 89 experimental studies. In those studies, grazing usually decreased periphyton biomass and altered the structure of periphyton communities. Intensive grazing can substantially reduce periphyton biomass and number of taxa in a community (Power and others, 1985; Lowe and Hunter, 1988; Gelwick and Matthews, 1992). Power and others (1985) documented that populations of the herbivorous central stoneroller (*Campostoma anomalum)* and algal abundances were negatively correlated during late summer and fall. Feeding preferences also can alter the taxonomic structure of algal communities by substantially reducing specific taxa. Matthews and others (1987) described observations and experiments in Ozark streams that indicate that *Campostoma* grazing results in "algal lawns" consisting largely of tightly attached blue-green algae (notably *Calothrix*).

Physical disturbances such as floods, droughts, and instream gravel removal can periodically scour periphyton from the streambed. The frequency, type, magnitude, timing, and season of the disturbances can have substantial effects on the biomass and structure of periphyton communities. These effects generally are of short duration and the algal community recovers fairly rapidly within 2 to 4 weeks (Lohman and others, 1992). In a study of periphyton in streams of the northern Ozarks of Missouri (Lohman and others, 1992), flooding resulting from 30 to 40 cm of rainfall within a 2-week period was sufficient to remove most or all of the periphyton (chlorophyll *a* <0.1 mg/m^2) from rocks.

Physical, chemical, and biological factors interact to construct spatial and temporal heterogeneity of periphyton communities. A combination of many factors such as light, temperature, nutrients, grazers, and disturbances contribute to the periphyton community's biomass and species composition.

FIELD AND LABORATORY METHODS

Streams were sampled during the summers of 1993-95. The location of the 51 sites selected for study are shown in figure 1 and described in table 1. At each site, water-quality samples were collected as described by Shelton (1994) no more than 30 days preceding periphyton sampling. Reach level habitat features were measured once during the summer of 1993, 1994, or 1995 in accordance with NAWQA protocols (Meador and others, 1993b). Results of this and other sampling are reported by Bell and others (1997), Femmer (1997), Davis and Bell (1998), and Petersen and others (1998). Single reaches were sampled except at two sites in 1993 and one site in 1994. At each of the three "multiple-reach" sites, three adjacent reaches were sampled for periphyton and habitat.

Reaches where periphyton communities were sampled ranged from about 150 to 550 m in length. Lengths of the reaches were determined based upon stream geomorphology (so that there were at least two occurrences of two of the three geomorphological units—riffles, runs, and pools), channel width, and a minimum-maximum length criterion (Meador and others, 1993a).

The environmental setting and habitat of each reach were characterized using a spatially hierarchical approach (Meador and others, 1993b). Maps, GIS (geographic information system) data, and field-collected data were used to characterize the sampling reach at the basin, segment (section of stream between two tributaries), reach, and microhabitat levels. These data include drainage area, land use, channel morphometry, substrate size, substrate embeddedness, canopy shading, riparian vegetation, discharge, and velocity. Substrate size, substrate embeddedness, and velocity were measured at the microhabitat level. Depth was measured at the reach and microhabitat levels. Measurements at the microhabitat level were made on the day of periphyton collection, within 0.5 m of the locations where the periphyton samples were collected.

The periphyton communities were sampled in August and September of 1993-95 using methods described in Porter and others (1993). Semi-quantitative samples from cobble-sized rocks from riffles and pools, and qualitative samples from throughout the reach, were collected at each site. Periphyton samples from the riffles are the focus of this report, although some aspects of the qualitative samples are discussed. Samples from riffles were collected using a SG-92 sampling device (an O-ring cemented to the flanged end of the barrel of a 30-mL syringe). The SG-92 was firmly sealed to the collected rocks (placed in a shallow tray filled with water) by pressing the O-ring against the rocks. A brush was then used to remove the attached periphyton contained within the circular sampling area of approximately 1.8 to 2.0 cm. The periphyton-water mixture was withdrawn from the SG-92 with a hand pipettor and dispensed into a sample container.

The periphyton sample consisted of the periphyton-water mixture collected from five rocks collected from each of five (occasionally six) locations in riffles within the sampling reach. The five or six locations in the riffles were chosen to represent the range of the most common depths and velocities in the riffles. At each location, five rocks with periphyton representative of conditions in the reach were selected for sampling.

Mixtures retained for identification and enumeration were placed in three to four small vials. Typically, 20 to 22 mL of mixture was measured and placed in each vial. The mixtures were then preserved with a measured amount of full strength buffered formalin, sufficient to constitute a 3- to 5-percent concentration of formalin in the sample.

Qualitative multihabitat samples also were collected using methods described in Porter and others (1993). If macroalgae (algae with morphology visible to the eye) were encountered, samples of the macroalgae were placed in a separate sample container and preserved using similar methods to those described above. Because the samples were not collected from a specific area of known size, results are in terms of taxa presence in the sample.

Samples were analyzed by the Phycology Section of the Academy of Natural Sciences Patrick Center for Environmental Research in Philadelphia, Pennsylvania (ANSP) using protocols described by Charles and others (2002). Diatoms were identified to the species or variety level. Other taxa were identified to genus or family. Relative abundance data were provided for each sample. Density (cells/cm^2) and biovolume data were provided by the ANSP for samples with unambiguous sample area and volume data. Voucher specimens of algae are deposited at the ANSP.

STATISTICAL METHODS

Several statistical methods were used to describe and compare the periphyton communities and selected physical, chemical, and biological factors. The relations of the communities to these factors also were described and compared statistically.

Sites were placed in six land-use categories (termed agriculture, forest, mining, urban, urban/mining, and mix) by land use (table 1), generally as described by Davis and Bell (1998). Sites with greater than 40 percent agricultural land use in the basin upstream from the site generally were classified as agriculture sites; however, War Eagle Creek near Hindsville, Ark., (38 percent agricultural land use) was classified as an agriculture site because of major nutrient concentration differences from forest sites. Urban, mining, urban/mining, and mix (mixture of forest and agricultural land use, influence from upstream wastewater-treatment plant, instream gravel mining at and near the site) site classifications were based on presence of the pertinent land use upstream from the site.

Environmental factors and periphyton community characteristics of samples from sites in these land-use classifications were compared graphically and statistically using boxplots of untransformed data and Tukey's multiple comparison test of rank-transformed data (Helsel and Hirsch, 1992, p. 196). The multiple comparison test was not applied to the urban, urban/mining, or mix classifications because of the small number of sites in those classifications.

Spearman correlations (rho) were used to examine relations between relative abundance and biovolume and environmental factors for the two major algal taxa (diatoms and blue-green algae) and selected individual taxa. Spearman correlations also were used to examine relations between environmental factors and taxa richness, diversity, condition index values, autecological guilds, and detrended correspondence analysis results.

The Shannon-Wiener diversity index, *H'* (Shannon and Weaver, 1949; Washington, 1984), which is a measure of taxa richness (the number of taxa in the community) and the evenness of the taxa distribution was calculated using the equation:

$$H' = \sum_{i=1}^{s} (P_i)(lnP_i) \qquad (1)$$

Where *s* is equal to the total number of taxa in the sample, P_i equals the proportion of each taxon in the sample and lnP_i is the natural log of that proportion value for each taxon.

Pearson's correlation coefficient and the percentage similarity index were used to measure the amount of correlation and similarity between samples collected in 1994 and between samples collected at single sites at multiple reaches or in multiple years. For the 1994 data, each site was compared with all other sites by calculating the Pearson's correlation coefficient *(r)* of the x-y pairs of relative abundances for all taxa collected at any site sampled in 1994. Relative abundance data for samples from sites that were sampled at multiple reaches or during each of the 3 years were compared by reach and year using Pearson's correlation and the percentage similarity index (*PSC*) (Whittaker, 1952; Whittaker and Fairbanks, 1958).

$$PSC = 100 - 0.5 \sum_{i=1}^{K} |a - b| \qquad (2)$$

where *a* and *b* are (for each taxon) percentages of the total individuals in community A and community B, respectively, and *K* is the total number of species in the two samples.

The taxonomic composition of the communities in each reach was analyzed using two types of multivariate analysis (ordination and classification). Detrended correspondence analysis (DCA) (Hill, 1979), which is an ordination technique, was used to examine relations between reaches (samples) based on their taxa composition (relative abundance and biovolume). A samples-by-taxa data matrix was analyzed using the computer program MVSP Plus (Kovach, 1998). Rare taxa (those without a relative abundance of at least 1 percent in at least five samples) were not included in the DCA of the relative abundance data. All biovolume data were log (base 10) transformed and included in the biovolume DCA.

Hierarchical cluster analysis of the relative abundance data was used to group sites with similar community structure. Hierarchical clustering links the two closest objects (or communities) as a cluster and continues in a step-wise manner joining objects until all are combined and displays the results as a dendrogram. For this report, the data were analyzed using Ward's linkage (Ward, 1963) and the Pearson distance methods. The linkage is the type of joining algorithm used to join clusters. Ward's method averages all distances between pairs of objects in different clusters, with adjustments for covariances, to decide how far apart the clusters are (SPSS, Inc., 2000). The Pearson distance method was used for this analysis. The Pearson distances are computed using 1 minus the Pearson product-moment correlation coefficient for each pair of objects and are used for quantitative variables.

A condition index (similar to an index described in Cuffney and others, 1997) of periphyton communities of Ozark streams was determined by categorizing taxa as tolerant, intolerant, or moderately tolerant (hereafter termed "cosmopolitan") of elevated nutrient concentrations. Taxa were categorized as tolerant if a positive correlation (Spearman's rho >0.30) was found between the taxon relative abundance and nitrate, orthophosphate, or total phosphorus concentration. Taxa were categorized as intolerant if a negative correlation (negative Spearman's rho > 0.30) was found between the taxon and the nutrients. All other taxa were considered cosmopolitan. A sample score was calculated by multiplying the relative abundance (as a decimal) of the tolerant taxa by 1, cosmopolitan taxa by 5, and intolerant taxa by 10 and then summing the scores to produce a sample score that could range from 1 (all tolerant taxa) to 10 (all intolerant taxa). The sample scores were adjusted by subtracting a value of 1 and dividing by the average of similarly calculated scores for appropriate "reference" sites (sites with high percentages of forest land use and no nearby mining, of similar drainage area and physiographic section).

COMPARISON OF HABITAT AND WATER CHEMISTRY BY LAND-USE CATEGORY

During August through September of 1993-95, 83 samples were collected at 51 sites in the Ozark Plateaus (table 20 at back of this report, fig. 1). These sites are categorized into six land-use categories (forest, agriculture, mining, urban, urban/mining, and mix) (table 1), based on land-use information. Several sites were sampled (for periphyton and water quality) two or three times during 1993 through 1995 and three sites (Buffalo River near St. Joe, North Sylamore Creek near Fifty Six, and Yocum Creek near Oak Grove) were each sampled at three immediately adjacent reaches in 1993 or 1994.

In general (and except for land-use percentage, measurements of nutrients, canopy shading, and trace elements in bed sediment, and other factors related to the land use), most characteristics of sites in these categories were similar (tables 1, 2, 20; fig. 2). However, the three urban, urban/mining, and mix sites were larger (drainage area, reach width, and reach depth) than most other sites. Median velocities at actual periphyton collection locations did not differ significantly ($p>0.05$) among the agriculture, forest, and mining site categories, but were slightly higher in mining streams (fig. 2). Dissolved nitrite plus nitrate concentrations (hereafter referred to as nitrate concentrations) did not differ significantly among the agriculture, forest, and mining site categories (fig. 2). Dissolved orthophosphate concentrations were significantly lower at forest and mining sites than at agriculture sites (fig. 2). Ratios of nitrate to orthophosphate (table 20) generally were highest at urban/mining, mining, and agriculture sites. Dissolved organic carbon concentrations (table 20) generally were lowest at forest and mining sites and highest at urban, mix, and urban/mining sites. The lower dissolved organic carbon concentrations at forest and mining sites were significantly different from concentrations at agriculture sites (table 2). Concentrations of triazine herbicides (table 20) generally were highest at urban, urban/mining, agriculture, and mix sites. Concentrations of suspended sediment (table 20) generally were slightly elevated at all types of sites relative to concentrations at forest sites and concentrations at mining sites were higher and significantly different from concentrations at agriculture and forest sites (table 2). Forested sites often were more shaded than other sites; however, agriculture, forest, and mining sites did not differ significantly from each other (fig. 2).

ANTECEDENT HYDROLOGIC CONDITIONS

Because of potential scouring of periphyton resulting from increased water velocities, samples typically were not collected after recent, large flood events. For example, samples were not collected at several sites during 1993 because of flooding in much of the western and northern parts of the study area. However, some samples were collected at sites following minor to moderate increases in streamflow.

Antecedent hydrologic conditions for 36 samples collected at 20 sites with continuous-recording streamflow gages are summarized in table 3. Of these samples, 11 were collected within 30 days of an antecedent high flow event (defined as a flow five times higher than the background flow—typically the flow at the time of sampling) and 6 were collected within 14 days of an antecedent high flow event. A comparison of the relation between periphyton biovolumes (blue-

Table 2. Summary of site characteristic and environmental factor differences among land-use categories

[= indicates that values associated with land-use categories are not significantly different (p<0.05), > indicates that values associated with the preceding land-use category are significantly different (p<0.05) and larger than the second category]

Site characteristics and environmental factors	Comparison among land-use categories
Reach width	Agriculture=Forest=Mining
Velocity	Agriculture=Forest=Mining
Canopy shading	Agriculture=Forest=Mining
Woody vegetation density	Agriculture=Forest=Mining
Embeddedness	Agriculture=Forest=Mining
Nitrite plus nitrate	Agriculture=Forest=Mining
Total triazines	Agriculture=Forest=Mining
Total alkalinity	Agriculture=Forest=Mining
Orthophosphate	Agriculture>Forest=Mining
Dissolved organic carbon	Agriculture>Forest=Mining
Suspended sediment	Mining>Agriculture=Forest
Lead in bed sediment	Mining>Forest>Agriculture
Zinc in bed sediment	Mining>Agriculture, Mining=Forest, Agriculture=Forest

green algae and diatoms) and percent forest land use in the drainage basin (fig. 3) does not indicate that biovolumes for samples collected within 14 days of an antecedent high flow event were substantially lower than would be expected for a given percent of forest land use. Therefore, it appears that the antecedent high flow events typically were of low enough magnitude or occurred sufficiently prior to sampling to have relatively little effect on biovolume.

PERIPHYTON COMMUNITY CHARACTERISTICS OF OZARK STREAMS AND RELATIONS TO ENVIRONMENTAL FACTORS

Periphyton communities can be characterized relative to biomass or biovolume, structure (species composition and richness), and tolerance to environmental (chemical and physical) factors (autecological guilds). Characteristics of periphyton communities in riffles of Ozark streams differ among and within groups of sites classified by land use and are related to environmental factors.

Biovolume

The biomass of periphyton frequently is of interest to water-resource managers and the public because nuisance growths of attached algae provide visible evidence of eutrophication and water-quality degradation. Periphyton biovolume (table 4) is an estimate of total algal biomass based on the volume of predominant algal cells in the sample. Assuming slightly greater than unit density, periphyton biovolume of 3 cm^3/m^2 is equivalent to a total algal biomass of roughly 3 grams/m^2. By comparison, measurements of periphyton ash-free dry mass (AFDM) for the same sample would be expected to be larger because of non-algal sources of carbon in periphyton mats. Total biovolume values of agriculture, forest, and mining sites were not significantly different from each other (fig. 4). These results are consistent with results of Jones and others (1984) where nutrient concentrations were not significantly correlated with benthic chlorophyll *a* concentrations in Ozark streams. However, Lohman and others (1992) found that benthic chlorophyll *a* was highly correlated with nutrient concentration in Ozark streams.

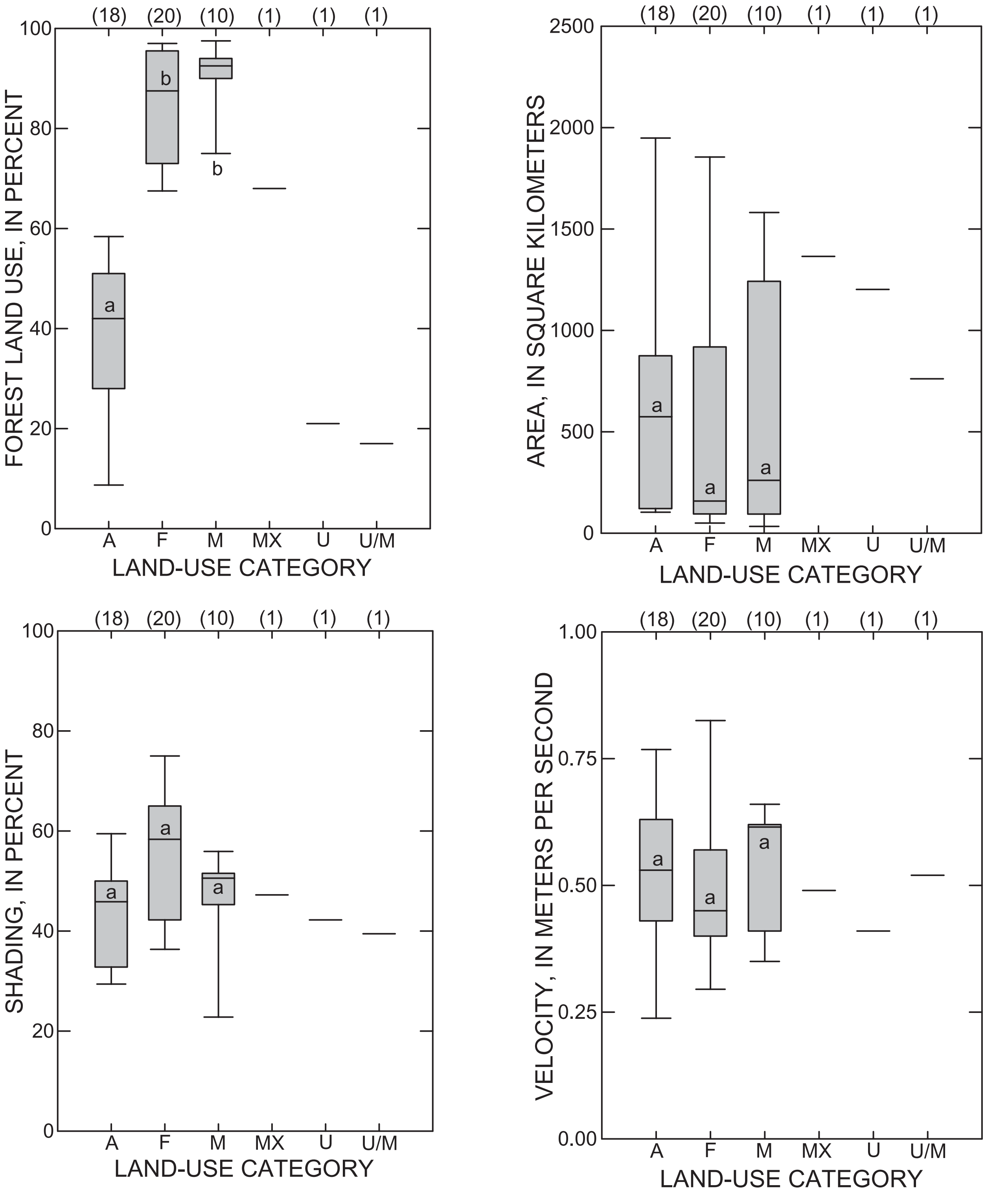

Figure 2. Distribution of values of selected environmental factors by land-use category.

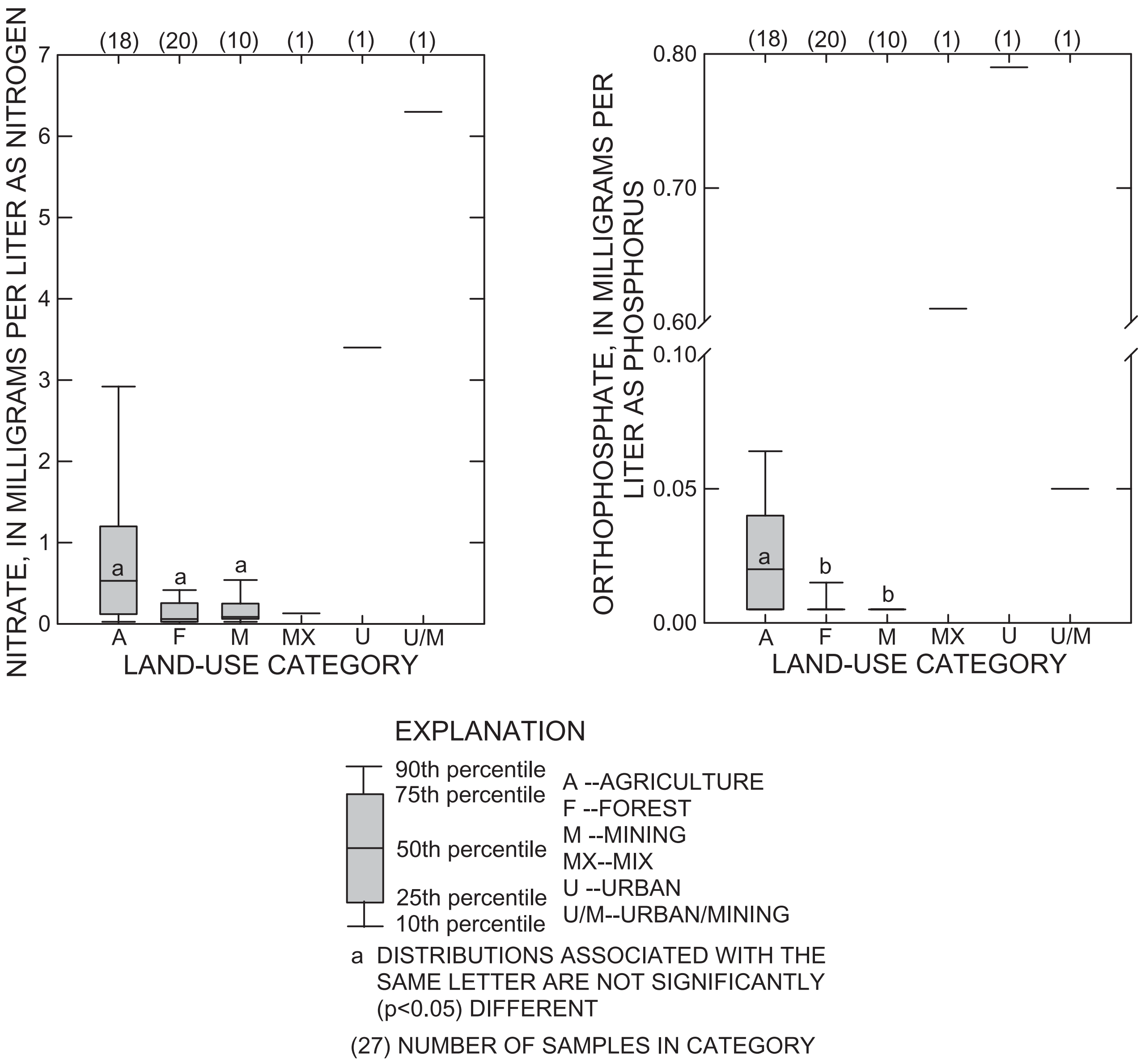

Figure 2. Distribution of values of selected environmental factors by land-use category—Continued.

Table 3. Antecedent (June through September) hydrologic conditions for selected sites

[High flow is defined as a flow that exceeds the background flow by a factor of five. Background flow is the flow at time of sampling or preceding an increase in flow near time of sampling. ft^3/s, cubic foot per second; NA, not applicable]

Sample number (see fig. 1)	Site name	Sample date	Date of high flow event	Background flow (ft^3/s)	High flow (ft^3/s)	Days elapsed	Comments
4	Big Piney River near Big Piney, Mo.	9/13/94	9/06/94	244	1,500	7	
5	Buffalo River near Boxley, Ark.	9/24/93	9/15/93	7.8	61	9	Flow during 30 days preceding 9/15 typically ranged from 0.1 to 0.2 ft^3/s
6	Buffalo River near Boxley, Ark.	9/12/94	8/21/94	2.8	52	22	
7	Buffalo River near Boxley, Ark.	9/05/95	7/05/95	0.75	17	62	731 ft^3/s on 6/11
9	Buffalo River near St. Joe, Ark.	9/16/93	6/27/93	62	501	81	
10,12-14	Buffalo River near St. Joe, Ark.	9/12-14/94	6/10/94	58	2,130	95	
11	Buffalo River near St. Joe, Ark.	9/06/95	7/05/95	32	267	63	
15	Current River at Van Buren, Mo.	8/21/95	6/11/95	1,090	8,710	71	
18	Jacks Fork River at Alley Spring, Mo.	9/20/94	6/03/94	77	430	109	334 ft^3/s on 9/6
23, 26, 27	North Sylamore Creek near Fifty Six, Ark.	9/14-21/93	6/13/93	14	72	93-100	
24	North Sylamore Creek near Fifty Six, Ark.	8/30/94	6/10/94	4.8	33	81	
25	North Sylamore Creek near Fifty Six, Ark.	9/07/95	6/12/95	2.1	158	87	
28	Paddy Creek above Slabtown Spring, Mo.	9/12/94	6/07/94	2.2	33	97	
30, 31	Paddy Creek above Slabtown Spring, Mo.	8/24/95	7/03/95	0.8	130	52	
37	Baron Fork at Eldon, Okla.	9/06/94	7/27/94	61	205	41	Minimum flow during summer was 44 ft^3/s on 7/6
39	Dousinbury Creek near Wall Street, Mo.	9/01/94	8/30/94	20	367	2	
40	Dousinbury Creek near Wall Street, Mo.	8/23/95	8/08/95	1.8	10	15	Three high flows of 23 to 43 ft^3/s between 6/24 and 8/8. 1,200 ft^3/s on 6/10
41	Elk River near Tiff City, Mo.	9/01/94	6/10/94	178	463	83	
42	Illinois River near Tahlequah, Okla.	9/09/94	6/06/94	217	1,150	95	
46, 47	Niangua River near Windyville, Mo.	9/07/94	8/31/94	133	1,580	7	
50	Peacheater Creek at Christie, Okla.	9/07/94	7/28/94	3.2	17	41	
51	Pomme de Terre near Polk, Mo.	9/21/94	8/31/94	9.1	996	21	
53	Strawberry River near Poughkeepsie, Ark.	8/29/94	7/28/94	60	662	32	
57, 58, 63	Yocum Creek near Oak Grove, Ark.	9/22-23/93	7/06/93	20	504	78-79	
59	Yocum Creek near Oak Grove, Ark.	9/13/94	6/08/94	8.4	46	97	
61, 62	Yocum Creek near Oak Grove, Ark.	8/31/95	6/10/95	27	706	82	
64	Big River near Richwoods, Mo.	8/24/94	6/28/94	126	647	57	
65	Black River near Lesterville, Mo.	9/23/93	8/13/93	313	2,950	41	Flow measured at Black River below Annapolis, Mo.
66	Black River near Lesterville, Mo.	8/25/94	7/03/94	168	1,100	53	Flow measured at Black River below Annapolis, Mo.
67	Black River near Lesterville, Mo.	8/22/95	7/04/95	177	1,080	49	Flow measured at Black River below Annapolis, Mo.
77	Kings River near Berryville, Ark.	10/26/93	10/21/93	333	945	5	Background flow in late August was about 30 to 60 ft^3/s. Two high flows in September of about 2,000 ft^3/s.
78	Kings River near Berryville, Ark.	9/14/94	8/20/94	32	210	25	
79	Kings River near Berryville, Ark.	8/30/95	7/28/95	13	66	33	298 ft^3/s on 7/7
81	Center Creek near Smithfield, Mo.	9/21/93	9/15/93	421	879	6	Background flow in mid-September was about 160 ft^3/s
82	Center Creek near Smithfield, Mo.	9/19/94	NA	56	NA	>110	225 ft^3/s on 6/1
83	Center Creek near Smithfield, Mo.	8/29/95	8/04/95	82	501	25	

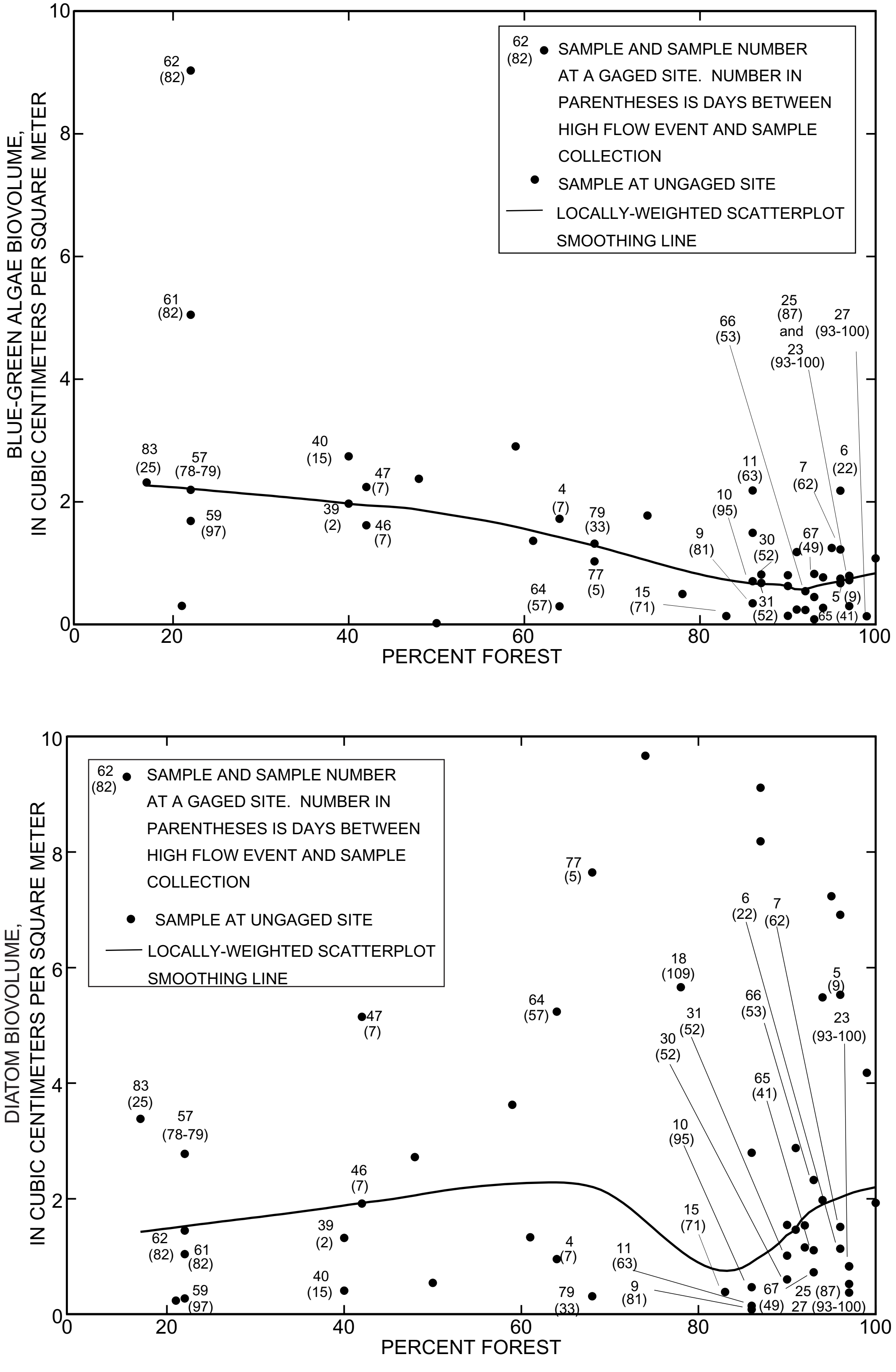

Figure 3. Relation between biovolume and percent forest land use at sites with differing antecedent hydrologic conditions.

Table 4. Periphyton biovolume associated with sampling sites

[cm^3/m^2, cubic centimeters per square meter; lower, middle, and upper are reach designations; split designates a second sample collected at a site]

Sample number (see fig. 1)	Site name	Year	Land-use category	Biovolume (cm^3/m^2)			Blue-green algae biovolume (percent)
				Total	Blue-green algae	Diatoms	
1	Big Creek at Mauser Mill, Mo.	1994	Forest	8.48	1.25	7.24	14.7
3	Big Creek near Rat, Mo.	1995	Forest	2.65	1.18	1.46	44.7
4	Big Piney River near Big Piney, Mo.	1994	Forest	2.68	1.72	0.96	64.3
5	Buffalo River near Boxley, Ark.	1993	Forest	6.20	0.67	5.53	10.8
6	Buffalo River near Boxley, Ark.	1994	Forest	3.32	2.18	1.13	65.9
7	Buffalo River near Boxley, Ark.	1995	Forest	2.74	1.22	1.51	44.7
9	Buffalo River near St. Joe, Ark. (lower)	1993	Forest	0.43	0.35	0.08	80.5
11	Buffalo River near St. Joe, Ark. (lower)	1995	Forest	2.33	2.18	0.15	93.8
14	Buffalo River near St. Joe, Ark. (upper) (split)	1994	Forest	1.17	0.70	0.47	60.2
15	Current River at Van Buren, Mo.	1995	Forest	0.52	0.14	0.39	26.1
17	Current River below Akers, Mo. (split)	1994	Forest	11.44	1.78	9.67	15.5
18	Jacks Fork River at Alley Spring, Mo.	1994	Forest	6.15	0.50	5.66	8.1
19	Middle Fork Black River at Redmondville, Mo.	1995	Forest	1.62	0.79	0.83	48.9
23	North Sylamore Creek near Fifty Six, Ark. (lower)	1993	Forest	1.56	0.72	0.83	46.5
25	North Sylamore Creek near Fifty Six, Ark. (lower)	1995	Forest	1.32	0.79	0.53	60.0
27	North Sylamore Creek near Fifty Six, Ark. (upper)	1993	Forest	0.67	0.30	0.37	44.4
30	Paddy Creek above Slabtown Spring, Mo.	1995	Forest	1.40	0.80	0.60	57.1
31	Paddy Creek above Slabtown Spring, Mo. (split)	1995	Forest	1.64	0.63	1.02	38.1
33	Rogers Creek near Van Buren, Mo.	1994	Forest	3.01	1.08	1.93	35.9
35	West Fork Black River near Greeley, Mo.	1995	Forest	8.86	0.68	8.18	7.7
36	West Fork Black River near Greeley, Mo. (split)	1995	Forest	9.93	0.82	9.11	8.2
39	Dousinbury Creek near Wall Street, Mo.	1994	Agriculture	3.29	1.97	1.32	59.9
40	Dousinbury Creek near Wall Street, Mo.	1995	Agriculture	3.15	2.74	0.41	87.0
44	Little Tavern Creek near St. Elizabeth, Mo.	1994	Agriculture	0.57	0.02	0.54	4.0
45	Maries River near Freeburg, Mo.	1994	Agriculture	6.53	2.90	3.62	44.5
46	Niangua River near Windyville, Mo.	1994	Agriculture	3.53	1.62	1.91	45.8
47	Niangua River near Windyville, Mo. (split)	1994	Agriculture	7.39	2.24	5.15	30.3
49	Osage Fork near Russ, Mo.	1994	Agriculture	5.09	2.37	2.72	46.6
54	War Eagle Creek near Hindsville, Ark.	1994	Agriculture	2.69	1.36	1.33	50.6

Table 4. Periphyton biovolume associated with sampling sites--Continued

[cm^3/m^2, cubic centimeters per square meter; lower, middle, and upper are reach designations; split designates a second sample collected at a site]

Sample number (see fig. 1)	Site name	Year	Land-use category	Biovolume (cm^3/m^2) Total	Blue-green algae	Diatoms	Blue-green algae biovolume (percent)
57	Yocum Creek near Oak Grove, Ark. (lower)	1993	Agriculture	4.97	2.19	2.78	44.1
59	Yocum Creek near Oak Grove, Ark. (middle)	1994	Agriculture	1.96	1.69	0.28	86.0
61	Yocum Creek near Oak Grove, Ark. (middle)	1995	Agriculture	6.09	5.05	1.04	82.9
62	Yocum Creek near Oak Grove, Ark. (middle) (split)	1995	Agriculture	10.48	9.03	1.45	86.2
64	Big River near Richwoods, Mo.	1994	Mining	5.53	0.30	5.24	5.4
65	Black River near Lesterville, Mo.	1993	Mining	1.19	0.08	1.11	7.0
66	Black River near Lesterville, Mo.	1994	Mining	2.77	0.45	2.32	16.1
67	Black River near Lesterville, Mo.	1995	Mining	1.55	0.82	0.73	53.1
68	Huzzah Creek near Scotia, Mo.	1994	Mining	4.29	1.49	2.80	34.8
69	Middle Fork Black River at Black, Mo.	1995	Mining	5.76	0.27	5.49	4.7
70	Neals Creek near Goodland, Mo.	1995	Mining	7.66	0.75	6.91	9.8
71	Strother Creek near Oates, Mo.	1995	Mining	4.31	0.13	4.18	3.1
72	Strother Creek near Redmondville, Mo.	1995	Mining	2.74	0.77	1.97	28.1
73	West Fork Black River at Centerville, Mo.	1995	Mining	2.08	0.54	1.54	26.1
74	West Fork Black River at Centerville, Mo. (split)	1995	Mining	1.39	0.24	1.16	17.1
75	West Fork Black River at West Fork, Mo.	1995	Mining	1.68	0.14	1.54	8.4
76	West Fork Black River near Centerville, Mo.	1995	Mining	3.12	0.24	2.88	7.8
77	Kings River near Berryville, Ark.	1993	Mix	8.68	1.03	7.65	11.8
79	Kings River near Berryville, Ark.	1995	Mix	1.63	1.32	0.31	80.9
80	James River near Boaz, Mo.	1994	Urban	0.54	0.30	0.24	56.2
83	Center Creek near Smithfield, Mo.	1995	Urban/mining	5.69	2.31	3.38	40.7

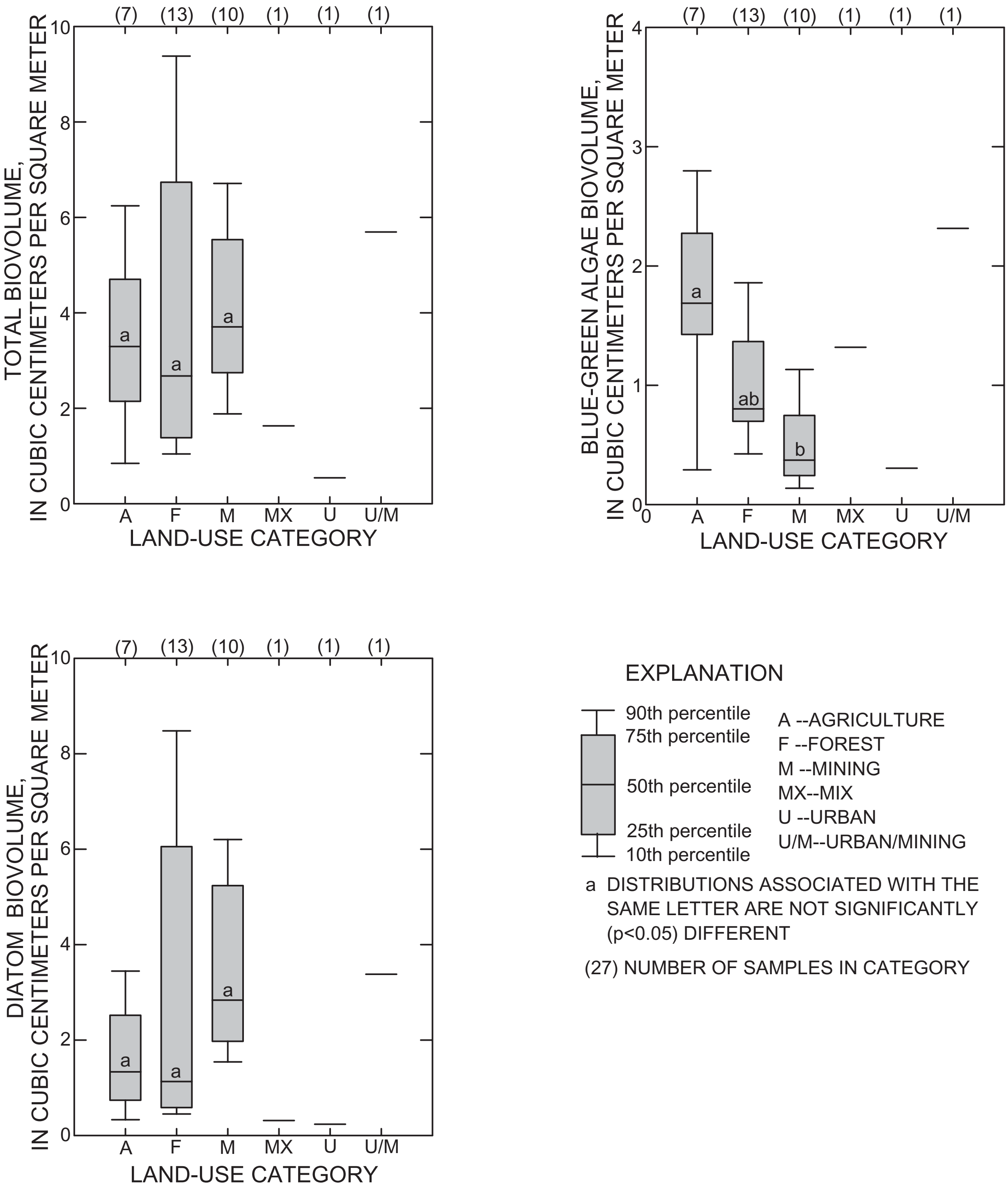

Figure 4. Distribution of total biovolume, blue-green algae biovolume, and diatom biovolume by land-use category.

Biovolume of blue-green algae generally was higher at agriculture sites (fig. 4) and lower at forest and mining sites. Biovolume of blue-green algae at agriculture sites was statistically different ($p < 0.05$) from biovolume at mining sites.

Median diatom biovolume did not differ statistically among land-use categories (fig. 4). Although median biovolumes were not significantly different, higher values (greater than 3.5 cm^3/cm^2) were more likely to occur at forest and mining sites.

Only embeddedness was correlated significantly with total biovolume (table 5). The strongest correlations with total biovolume were the negative correlation with embeddedness and a positive correlation with alkalinity. Although the lack of relation between biovolume and nutrients (fig. 5), velocity, and basin size is consistent with findings of Jones and others (1984), Lohman and others (1992) demonstrated a significant

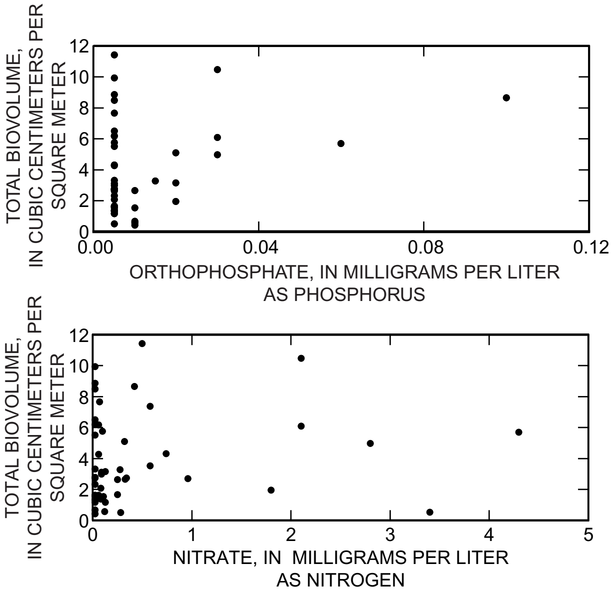

Figure 5. Relation between total biovolume and nutrient concentrations.

Table 5. Correlation between biovolume and environmental factors

[rho, Spearman's rank correlation coefficient; p, probability of greater absolute value of rho; NO3:TP, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and total phosphorus; NO3:PO4, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and dissolved orthophosphate; <, less than]

	Total		**Blue-green algae**		**Diatoms**	
	rho	**p**	**rho**	**p**	**rho**	**p**
Area	-0.12	0.494	0.04	0.823	-0.15	0.396
Reach width	-0.04	0.814	0.24	0.176	-0.13	0.446
Reach depth	-0.23	0.200	0.08	0.658	-0.28	0.107
Width:depth	0.17	0.339	0.24	0.180	0.11	0.519
Sample depth	0.16	0.356	-0.20	0.257	0.28	0.109
Percent forest	0.06	0.725	-0.34	0.055	0.21	0.228
Percent agriculture	-0.06	0.738	0.35	0.049	-0.22	0.221
Percent urban	-0.09	0.593	0.12	0.500	-0.10	0.558
Velocity	0.21	0.246	-0.02	0.929	0.27	0.122
Percent canopy shading	0.15	0.390	0.01	0.944	0.13	0.462
Woody vegetation density	-0.06	0.714	-0.14	0.443	0.02	0.922
Embeddedness	-0.36	0.040	0.21	0.229	-0.41	0.021
Nitrate	-0.09	0.617	0.09	0.593	-0.11	0.548
Orthophosphate	-0.22	0.206	0.34	0.054	-0.40	0.022
Total phosphorus	-0.22	0.210	0.30	0.085	-0.38	0.031
NO3:TP	0.11	0.546	-0.02	0.894	0.18	0.319
NO3:PO4	0.08	0.662	0.01	0.951	0.14	0.426
Dissolved organic carbon	-0.24	0.175	0.32	0.074	-0.40	0.023
Total triazines	-0.06	0.791	0.24	0.254	-0.10	0.642
Suspended sediment	-0.09	0.623	-0.31	0.085	<0.01	0.999
Alkalinity	0.32	0.079	-0.10	0.584	0.38	0.032
Cadmium in bed sediment	<0.01	0.991	-0.22	0.332	0.15	0.514
Lead in bed sediment	0.23	0.313	-0.36	0.112	0.41	0.064
Zinc in bed sediment	0.13	0.563	-0.24	0.284	0.29	0.198

relation between mean periphyton chlorophyll *a* and total nitrogen and phosphorus in Ozark streams.

A few factors were significantly correlated with the biovolume of blue-green algae and diatoms (table 5). Biovolume of blue-green algae was significantly and positively correlated with percent agriculture land use. Correlations of biovolume of blue-green algae with percent forest land use and orthophosphate concentration were relatively strong but not quite statistically significant. Biovolume of diatoms was significantly and positively correlated with alkalinity and significantly and negatively correlated with embeddedness, orthophosphate, total phosphorus, and dissolved organic carbon.

In general, the biovolume results indicate that total biovolume decreases as siltation (embeddedness) increases and increases as alkalinity increases. Also, blue-green algae biovolume increases and diatom biovolume decreases as nutrient and dissolved organic carbon concentrations increase.

Detrended correspondence analysis (DCA) was used to compare the community structure on a biovolume basis from 50 biovolume samples collected from 33 sites. The first two axes of the biovolume data (fig. 6) explained approximately 33 percent of the variation in the biovolume data. Axis 1 (eigenvalue 0.25, 23.5 percent of variation) separated most of a group of agriculture, mix, urban, and urban/mining sites from a group of forest and mining sites. No separation by land-use category along axis 2 (eigenvalue 0.10, 9.6 percent of variation) was evident.

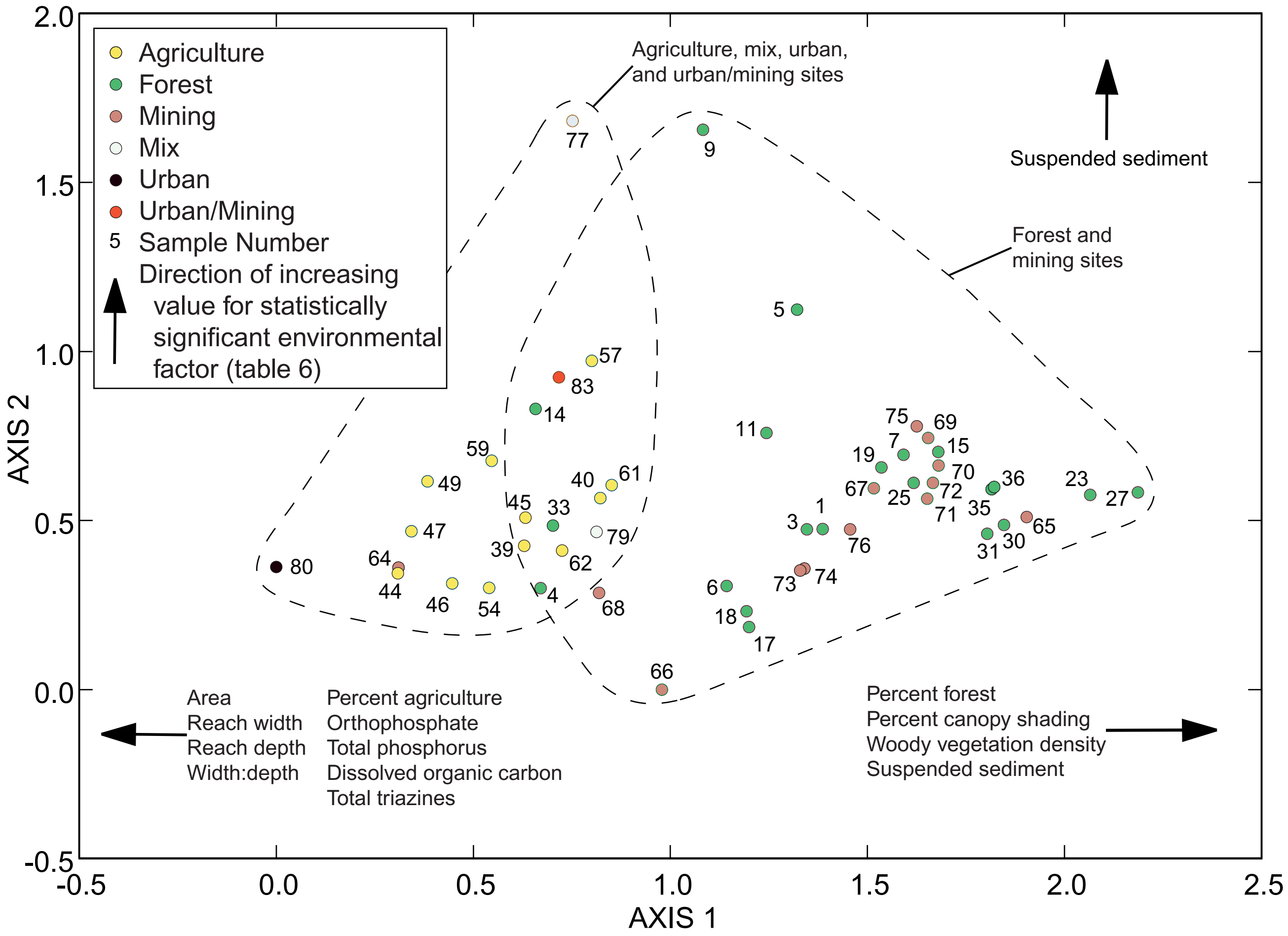

Figure 6. Detrended correspondence analysis (DCA) site scores for biovolume data.

Several environmental factors (most associated with agricultural land use) were significantly ($p<0.05$) correlated with axis 1 values, and suspended sediment was significantly correlated with axis 2 values (table 6). Percent forest, percent canopy shading, woody vegetation density, and suspended sediment concentration were positively correlated with axis 1 values. Percent agriculture, concentrations of orthophosphate, total phosphorus, dissolved organic carbon, and triazines, and several factors associated with stream size were negatively correlated with axis 1 values.

Biovolume of periphyton taxa in Ozark streams appears to be influenced by stream size and land use. Community structure changes primarily along a gradient of agricultural land-use intensity, as reflected by nutrient and herbicide (triazine) concentrations, indicators of organic enrichment (dissolved organic carbon) and land disturbance (suspended sediment). Riparian shading also plays a role.

Table 6. Correlation between biovolume data detrended correspondence analysis axis values and environmental factors

[rho, Spearman’s rank correlation coefficient; p, probability of greater absolute value of rho; NO3:TP, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and total phosphorus; NO3:PO4, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and dissolved orthophosphate; <, less than]

	Axis 1		Axis 2	
	rho	**p**	**rho**	**p**
Area	-0.44	0.012	-0.24	0.168
Reach width	-0.54	0.002	-0.31	0.078
Reach depth	-0.36	0.043	-0.23	0.201
Width:depth	-0.40	0.020	-0.27	0.120
Sample depth	-0.21	0.232	-0.34	0.051
Percent forest	0.70	<0.001	0.14	0.432
Percent agriculture	-0.69	<0.001	-0.13	0.458
Percent urban	-0.26	0.146	0.13	0.460
Velocity	-0.29	0.101	-0.23	0.185
Percent canopy shading	0.39	0.028	0.02	0.930
Woody vegetation density	0.38	0.030	0.03	0.849
Embeddedness	0.01	0.936	0.06	0.753
Nitrate	-0.26	0.147	0.07	0.692
Orthophosphate	-0.61	<0.001	-0.03	0.885
Total phosphorus	-0.50	0.005	0.04	0.830
NO3:TP	0.21	0.229	0.17	0.340
NO3:PO4	0.18	0.322	0.20	0.259
Dissolved organic carbon	-0.65	<0.001	-0.19	0.274
Total triazines	-0.52	0.014	0.25	0.245
Suspended sediment	0.40	0.027	0.42	0.018
Alkalinity	-0.04	0.812	-0.09	0.610
Cadmium in bed sediment	-0.04	0.859	0.31	0.163
Lead in bed sediment	0.16	0.473	0.04	0.860
Zinc in bed sediment	0.14	0.532	0.32	0.152

Composition Measurements

A second way of comparing periphyton communities is based on the composition and abundance of species in the communities. Composition differences can be assessed using measures such as diversity indices, differences in taxa relative abundance, and differences in relative biovolume of taxa.

Shannon-Wiener Diversity

One measure of the number of taxa and the evenness of the abundance of the taxa in the community is the Shannon-Wiener diversity index (Shannon and Weaver, 1949; Washington, 1984). Shannon-Wiener diversity index values can range from 0, where all individuals are the same taxon, to a maximum value that is dependent on the number of taxa in the sample. Using the natural log form of the equation, maximum values for samples composed of 25, 50, and 100 taxa would be 3.2, 3.9, and 4.6, respectively.

Shannon-Wiener values (table 7) may be somewhat influenced by land use, but values did not differ significantly among agriculture, forest, and mining sites (fig. 7). Diversity values generally were larger at mining sites than at agricultural or forest sites, and approximately 90 percent of the values at mining sites exceeded the agriculture and forest site medians (fig. 7).

Table 7. Shannon-Wiener diversity; relative abundance of blue-green algae, diatoms, and green algae; and taxa

Sample number (see fig. 1)	Site name	Year	Land use	Shannon-Wiener diversity	Relative abundance (percent)		
					Blue-green algae	Dia-toms	Green algae
1	Big Creek at Mauser Mill, Mo.	1994	Forest	1.72	74.1	25.9	0.0
2	Big Creek near Big Flat, Ark.	1994	Forest	0.96	99.0	0.6	0.0
3	Big Creek near Rat, Mo.	1995	Forest	1.40	87.7	12.3	0.0
4	Big Piney River near Big Piney, Mo.	1994	Forest	1.20	95.2	3.7	0.2
5	Buffalo River near Boxley, Ark.	1993	Forest	1.50	88.4	11.0	0.6
6	Buffalo River near Boxley, Ark.	1994	Forest	0.71	98.6	1.0	0.0
7	Buffalo River near Boxley, Ark.	1995	Forest	1.11	94.0	5.8	0.1
8	Buffalo River near Eula, Ark.	1994	Forest	1.12	99.2	0.5	0.0
9	Buffalo River near St. Joe, Ark. (lower)	1993	Forest	1.01	98.5	0.9	0.2
10	Buffalo River near St. Joe, Ark. (lower)	1994	Forest	1.07	98.1	1.4	0.0
11	Buffalo River near St. Joe, Ark. (lower)	1995	Forest	0.33	99.4	0.5	0.1
12	Buffalo River near St. Joe, Ark. (middle)	1994	Forest	1.11	98.6	1.3	0.0
13	Buffalo River near St. Joe, Ark. (upper)	1994	Forest	1.20	96.8	2.8	0.2
14	Buffalo River near St. Joe, Ark. (upper) (split)	1994	Forest	1.12	95.7	3.0	0.2
15	Current River at Van Buren, Mo.	1995	Forest	1.22	82.7	16.5	0.8
16	Current River below Akers, Mo.	1994	Forest	1.86	70.8	29.0	0.3
17	Current River below Akers, Mo. (split)	1994	Forest	1.72	75.5	22.8	1.7
18	Jacks Fork River at Alley Spring, Mo.	1994	Forest	1.81	64.3	34.9	0.7
19	Middle Fork Black River at Redmondville, Mo.	1995	Forest	1.23	94.9	5.1	0.0
20	Mikes Creek at Powell, Mo.	1994	Forest	1.53	92.9	6.4	0.0
21	Noblett Creek near Willow Springs, Mo.	1994	Forest	1.53	81.3	18.3	0.0
22	North Fork White River near Dora, Mo.	1994	Forest	1.60	85.5	14.1	0.4
23	North Sylamore Creek near Fifty Six, Ark. (lower)	1993	Forest	1.20	95.9	3.9	0.0
24	North Sylamore Creek near Fifty Six, Ark. (lower)	1994	Forest	1.21	92.7	6.0	0.2
25	North Sylamore Creek near Fifty Six, Ark. (lower)	1995	Forest	0.92	96.0	3.5	0.1
26	North Sylamore Creek near Fifty Six, Ark. (middle)	1993	Forest	1.04	95.6	4.3	0.0
27	North Sylamore Creek near Fifty Six, Ark. (upper)	1993	Forest	1.23	96.8	3.0	0.0
28	Paddy Creek above Slabtown Spring, Mo.	1994	Forest	1.48	87.8	10.9	0.0
29	Paddy Creek above Slabtown Spring, Mo. (split)	1994	Forest	1.58	86.0	13.5	0.3
30	Paddy Creek above Slabtown Spring, Mo.	1995	Forest	1.09	96.7	2.8	0.0
31	Paddy Creek above Slabtown Spring, Mo. (split)	1995	Forest	1.17	94.6	4.3	0.0
32	Richland Creek near Witts Springs, Ark.	1994	Forest	0.97	98.9	0.8	0.0
33	Rogers Creek near Van Buren, Mo.	1994	Forest	1.62	79.4	20.0	0.0
34	Water Creek near Evening Star, Ark.	1994	Forest	1.07	94.1	5.4	0.0
35	West Fork Black River near Greeley, Mo.	1995	Forest	1.38	74.2	25.8	0.0
36	West Fork Black River near Greeley, Mo. (split)	1995	Forest	1.42	73.6	26.2	0.2
37	Baron Fork at Eldon, Okla.	1994	Agriculture	0.71	97.6	1.8	0.6
38	Brush Creek above Collins, Mo.	1994	Agriculture	1.60	85.6	12.2	2.2
39	Dousinbury Creek near Wall Street, Mo.	1994	Agriculture	1.02	97.7	2.2	0.0
40	Dousinbury Creek near Wall Street, Mo.	1995	Agriculture	0.53	98.3	1.4	0.3
41	Elk River near Tiff City, Mo.	1994	Agriculture	0.46	98.7	1.0	0.1
42	Illinois River near Tahlequah, Okla.	1994	Agriculture	0.45	97.2	2.1	0.4
43	Little Osage Creek near Healing Spring, Ark.	1994	Agriculture	0.57	99.3	0.5	0.0
44	Little Tavern Creek near St. Elizabeth, Mo.	1994	Agriculture	2.70	46.7	43.0	10.3

richness of blue-green algae, diatoms, and green algae associated with sampling sites

Taxa richness					
Blue-green algae	**Diatoms**	**Green algae**	**Total**	**Sample number**	**Site name**
4	13	0	17	1	Big Creek at Mauser Mill, Mo.
5	24	0	29	2	Big Creek near Big Flat, Ark.
5	14	0	19	3	Big Creek near Rat, Mo.
5	21	1	27	4	Big Piney River near Big Piney, Mo.
4	18	3	25	5	Buffalo River near Boxley, Ark.
4	28	0	32	6	Buffalo River near Boxley, Ark.
4	25	1	30	7	Buffalo River near Boxley, Ark.
4	34	1	39	8	Buffalo River near Eula, Ark.
3	34	4	41	9	Buffalo River near St. Joe, Ark. (lower)
4	37	0	41	10	Buffalo River near St. Joe, Ark. (lower)
4	43	0	47	11	Buffalo River near St. Joe, Ark. (lower)
4	36	0	40	12	Buffalo River near St. Joe, Ark. (middle)
4	29	2	35	13	Buffalo River near St. Joe, Ark. (upper)
4	36	1	42	14	Buffalo River near St. Joe, Ark. (upper) (split)
4	37	2	43	15	Current River at Van Buren, Mo.
3	21	1	25	16	Current River below Akers, Mo.
4	16	3	23	17	Current River below Akers, Mo. (split)
4	14	2	20	18	Jacks Fork River at Alley Spring, Mo.
4	17	0	21	19	Middle Fork Black River at Redmondville, Mo.
5	14	0	19	20	Mikes Creek at Powell, Mo.
4	15	0	19	21	Noblett Creek near Willow Springs, Mo.
4	20	3	27	22	North Fork White River near Dora, Mo.
4	15	0	19	23	North Sylamore Creek near Fifty Six, Ark. (lower)
3	32	1	36	24	North Sylamore Creek near Fifty Six, Ark. (lower)
5	15	1	21	25	North Sylamore Creek near Fifty Six, Ark. (lower)
4	9	0	13	26	North Sylamore Creek near Fifty Six, Ark. (middle)
5	25	0	30	27	North Sylamore Creek near Fifty Six, Ark. (upper)
4	23	0	28	28	Paddy Creek above Slabtown Spring, Mo.
4	17	1	23	29	Paddy Creek above Slabtown Spring, Mo. (split)
5	18	0	24	30	Paddy Creek above Slabtown Spring, Mo.
5	20	0	26	31	Paddy Creek above Slabtown Spring, Mo. (split)
4	27	0	31	32	Richland Creek near Witts Springs, Ark.
5	13	0	18	33	Rogers Creek near Van Buren, Mo.
3	21	0	24	34	Water Creek near Evening Star, Ark.
3	19	0	22	35	West Fork Black River near Greeley, Mo.
4	17	1	22	36	West Fork Black River near Greeley, Mo. (split)
4	17	1	22	37	Baron Fork at Eldon, Okla.
3	41	2	46	38	Brush Creek above Collins, Mo.
5	19	0	24	39	Dousinbury Creek near Wall Street, Mo.
5	27	3	35	40	Dousinbury Creek near Wall Street, Mo.
4	23	2	29	41	Elk River near Tiff City, Mo.
4	15	3	22	42	Illinois River near Tahlequah, Okla.
4	27	0	31	43	Little Osage Creek near Healing Spring, Ark.
4	39	5	48	44	Little Tavern Creek near St. Elizabeth, Mo.

Table 7. Shannon-Wiener diversity; relative abundance of blue-green algae, diatoms, and green algae; and taxa

					Relative abundance (percent)		
Sample number (see fig. 1)	Site name	Year	Land use	Shannon-Wiener diversity	Blue-green algae	Dia-toms	Green algae
45	Maries River near Freeburg, Mo.	1994	Agriculture	0.69	98.3	1.6	0.1
46	Niangua River near Windyville, MO	1994	Agriculture	1.47	93.1	6.9	0.0
47	Niangua River near Windyville, Mo. (split)	1994	Agriculture	1.43	93.2	6.8	0.0
48	North Indian Creek near Wanda, Mo.	1994	Agriculture	1.93	65.1	32.0	0.0
49	Osage Fork near Russ, MO	1994	Agriculture	1.45	92.2	7.7	0.2
50	Peacheater Creek at Christie, Okla.	1994	Agriculture	0.63	97.6	2.0	0.3
51	Pomme de Terre near Polk, Mo.	1994	Agriculture	1.86	79.7	20.3	0.0
52	Sac River near Dadeville, Mo.	1994	Agriculture	2.41	64.0	36.0	0.0
53	Strawberry River near Poughkeepsie, Ark.	1994	Agriculture	1.79	83.2	14.7	1.7
54	War Eagle Creek near Hindsville, Ark.	1994	Agriculture	1.21	96.3	3.6	0.0
55	War Eagle Creek near Hindsville, Ark. (split)	1994	Agriculture	1.08	97.4	2.6	0.0
56	Woods Fork near Hartville, Mo.	1994	Agriculture	0.94	98.0	2.0	0.0
57	Yocum Creek near Oak Grove, Ark. (lower)	1993	Agriculture	1.07	95.8	4.1	0.0
58	Yocum Creek near Oak Grove, Ark. (middle)	1993	Agriculture	0.82	97.9	1.9	0.1
59	Yocum Creek near Oak Grove, Ark. (middle)	1994	Agriculture	1.18	98.2	0.7	0.1
60	Yocum Creek near Oak Grove, Ark. (middle) (split)	1994	Agriculture	1.13	99.2	0.5	0.0
61	Yocum Creek near Oak Grove, Ark. (middle)	1995	Agriculture	0.32	98.9	1.1	0.0
62	Yocum Creek near Oak Grove, Ark. (middle) (split)	1995	Agriculture	0.42	98.9	1.0	0.0
63	Yocum Creek near Oak Grove, Ark. (upper)	1993	Agriculture	1.03	98.5	0.6	0.9
64	Big River near Richwoods, Mo.	1994	Mining	1.92	75.8	23.8	0.4
65	Black River near Lesterville, Mo.	1993	Mining	1.83	65.3	32.7	0.0
66	Black River near Lesterville, Mo.	1994	Mining	1.72	80.0	18.1	0.1
67	Black River near Lesterville, Mo.	1995	Mining	0.93	90.0	9.5	0.0
68	Huzzah Creek near Scotia, Mo.	1994	Mining	1.47	85.7	13.4	0.5
69	Middle Fork Black River at Black, Mo.	1995	Mining	1.91	59.2	40.8	0.0
70	Neals Creek near Goodland, Mo.	1995	Mining	1.57	65.7	34.3	0.0
71	Strother Creek near Oates, Mo.	1995	Mining	2.54	41.2	51.8	6.6
72	Strother Creek near Redmondville, Mo.	1995	Mining	1.08	83.6	16.4	0.1
73	West Fork Black River at Centerville, Mo.	1995	Mining	1.82	77.9	21.7	0.2
74	West Fork Black River at Centerville, Mo. (split)	1995	Mining	1.88	72.5	26.8	0.4
75	West Fork Black River at West Fork, Mo.	1995	Mining	2.01	60.9	38.9	0.1
76	West Fork Black River near Centerville, Mo.	1995	Mining	1.81	60.6	37.6	0.9
77	Kings River near Berryville, Ark.	1993	Mix	1.38	79.8	17.5	2.5
78	Kings River near Berryville, Ark.	1994	Mix	1.23	91.7	7.1	1.2
79	Kings River near Berryville, Ark.	1995	Mix	1.12	95.6	3.1	1.3
80	James River near Boaz, Mo.	1994	Urban	1.81	61.8	33.8	0.0
81	Center Creek near Smithfield, Mo.	1993	Urban/mining	1.55	32.0	66.9	1.1
82	Center Creek near Smithfield, Mo.	1994	Urban/mining	1.89	65.7	33.5	0.9
83	Center Creek near Smithfield, Mo.	1995	Urban/mining	1.26	71.0	20.3	8.7

richness of blue-green algae, diatoms, and green algae associated with sampling sites

Taxa richness					
Blue-green algae	Diatoms	Green algae	Total	Sample number	Site name
4	31	1	36	45	Maries River near Freeburg, Mo.
5	31	0	36	46	Niangua River near Windyville, MO
5	27	0	32	47	Niangua River near Windyville, Mo. (split)
4	28	0	32	48	North Indian Creek near Wanda, Mo.
5	24	1	30	49	Osage Fork near Russ, MO
4	21	2	27	50	Peacheater Creek at Christie, Okla.
3	32	0	35	51	Pomme de Terre near Polk, Mo.
3	43	0	46	52	Sac River near Dadeville, Mo.
5	38	6	49	53	Strawberry River near Poughkeepsie, Ark.
5	31	0	36	54	War Eagle Creek near Hindsville, Ark.
4	21	0	25	55	War Eagle Creek near Hindsville, Ark. (split)
5	19	0	24	56	Woods Fork near Hartville, Mo.
5	16	0	21	57	Yocum Creek near Oak Grove, Ark. (lower)
5	20	1	26	58	Yocum Creek near Oak Grove, Ark. (middle)
5	27	1	33	59	Yocum Creek near Oak Grove, Ark. (middle)
5	30	0	35	60	Yocum Creek near Oak Grove, Ark. (middle) (split)
5	19	0	24	61	Yocum Creek near Oak Grove, Ark. (middle)
3	29	0	32	62	Yocum Creek near Oak Grove, Ark. (middle) (split)
4	20	2	26	63	Yocum Creek near Oak Grove, Ark. (upper)
3	33	1	37	64	Big River near Richwoods, Mo.
4	23	0	27	65	Black River near Lesterville, Mo.
4	20	1	25	66	Black River near Lesterville, Mo.
4	10	1	15	67	Black River near Lesterville, Mo.
3	22	5	30	68	Huzzah Creek near Scotia, Mo.
5	11	0	16	69	Middle Fork Black River at Black, Mo.
3	15	0	18	70	Neals Creek near Goodland, Mo.
3	24	6	35	71	Strother Creek near Oates, Mo.
3	14	0	17	72	Strother Creek near Redmondville, Mo.
5	20	0	25	73	West Fork Black River at Centerville, Mo.
5	22	2	29	74	West Fork Black River at Centerville, Mo. (split)
4	21	1	26	75	West Fork Black River at West Fork, Mo.
4	17	1	22	76	West Fork Black River near Centerville, Mo.
3	22	2	27	77	Kings River near Berryville, Ark.
4	22	4	30	78	Kings River near Berryville, Ark.
6	34	6	46	79	Kings River near Berryville, Ark.
2	33	0	36	80	James River near Boaz, Mo.
5	14	1	20	81	Center Creek near Smithfield, Mo.
5	16	2	23	82	Center Creek near Smithfield, Mo.
3	11	9	23	83	Center Creek near Smithfield, Mo.

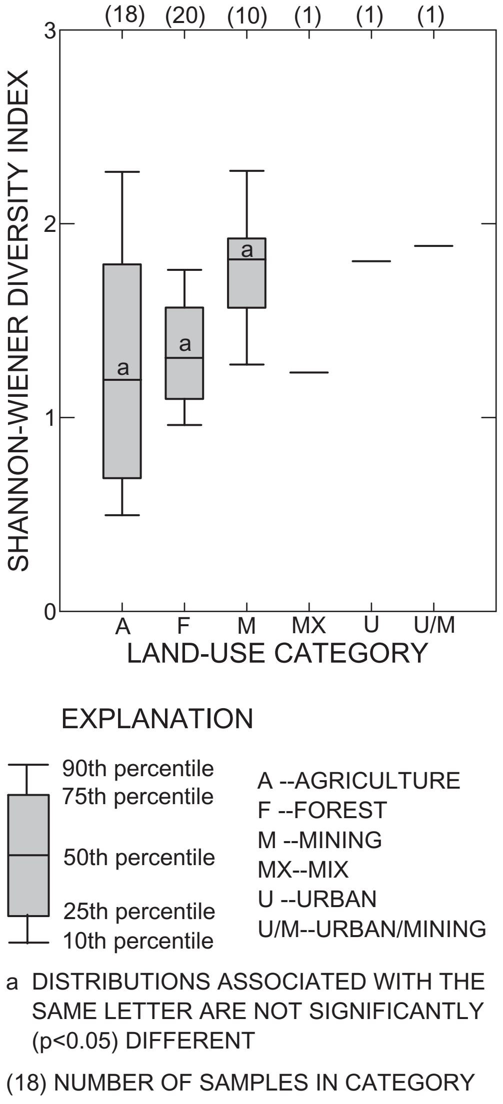

Figure 7. Distribution of values of Shannon-Weiner diversity by land-use category.

Table 8. Correlation between Shannon-Weiner diversity and environmental factors

[rho, Spearman's rank correlation coefficient; p, probability of greater absolute value of rho; NO3:TP, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and total phosphorus; NO3:PO4, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and dissolved orthophosphate; <, less than]

	rho	**p**
Area	-0.03	0.854
Reach width	-0.13	0.353
Reach depth	-0.13	0.370
Width:depth	-0.06	0.668
Sample depth	0.16	0.249
Percent forest	0.08	0.550
Percent agriculture	-0.09	0.526
Percent urban	0.04	0.765
Velocity	-0.21	0.130
Percent canopy shading	0.12	0.383
Woody vegetation density	0.19	0.170
Embeddedness	-0.16	0.261
Nitrate	<0.01	0.967
Orthophosphate	-0.17	0.234
Total phosphorus	-0.14	0.316
NO3:TP	0.10	0.488
NO3:PO4	0.09	0.533
Dissolved organic carbon	-0.03	0.850
Total triazines	-0.11	0.492
Suspended sediment	0.26	0.066
Alkalinity	0.39	0.006
Cadmium in bed sediment	0.23	0.237
Lead in bed sediment	0.08	0.662
Zinc in bed sediment	0.31	0.110

In general, diversity was greatest at sites with greater alkalinity and suspended sediment concentrations. A statistically significant correlation was found between diversity and alkalinity (table 8).

Taxa Relative Abundance

In all but two samples (Center Creek near Smithville, Mo. in 1993, sample 71; and Strother Creek near Oates, Mo., sample 71), blue-green algae composed the largest percentage of the periphyton community (cells/cm^2); diatoms were the next most common component (table 7). The relative abundance of blue-green algae generally was greater than 60 percent of the periphyton community (fig. 8); the highest relative abundances generally were at agriculture and forest sites and the lowest were at mining sites. The relative abundance of blue-green algae at mining sites was significantly different ($p<0.05$) from relative abundance at agriculture and forest sites. Diatoms generally composed 5 to 40 percent of the periphyton community (fig. 8); highest relative abundances generally were at mining sites. As with blue-green algae, the relative abundance of diatoms at mining sites was significantly different from relative abundance at agriculture and forest sites. Green algae were the next most common algal division, but the relative abundance of green algae generally was less than 1 percent.

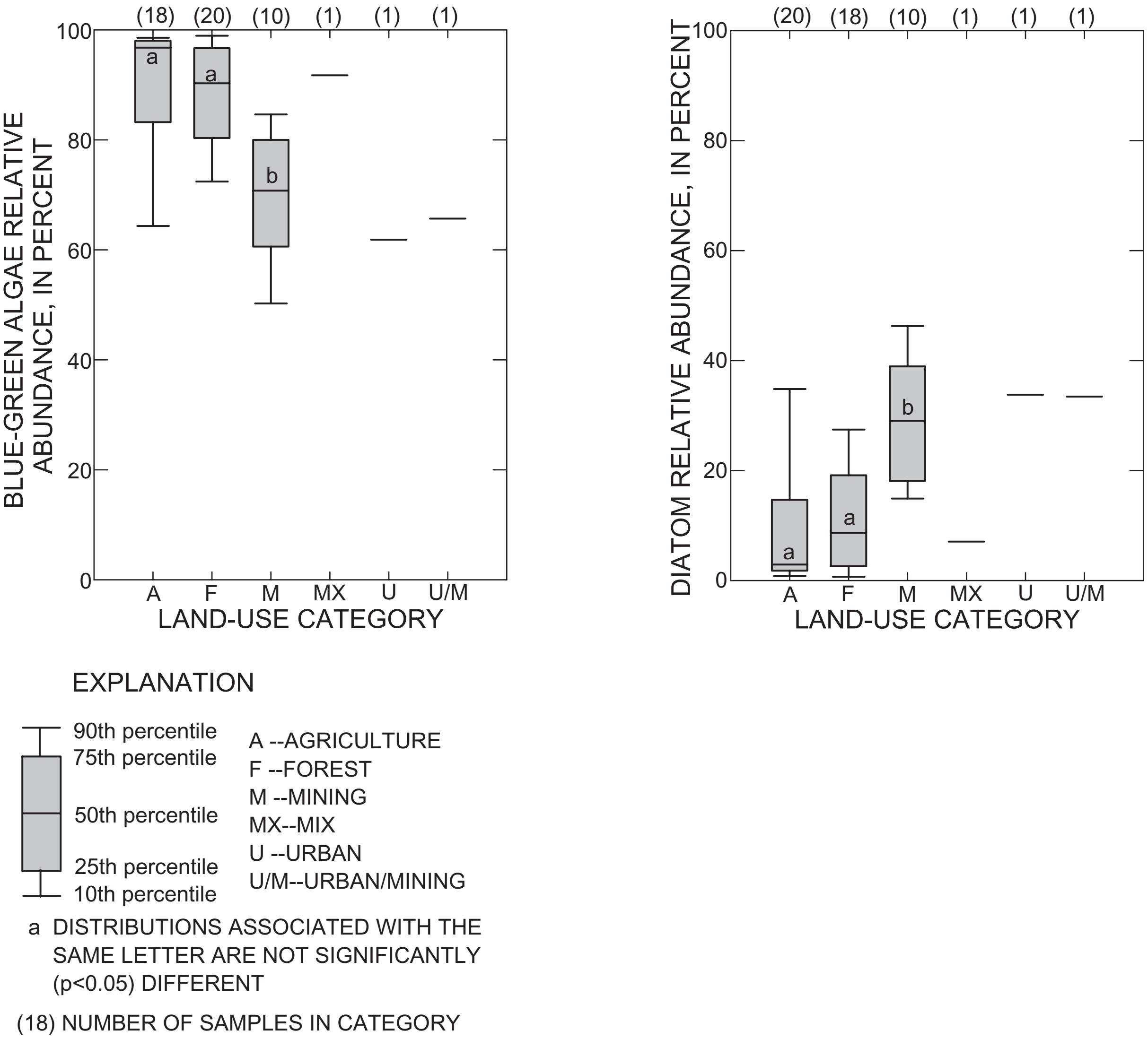

Figure 8. Distribution of blue-green algae and diatom relative abundance by land-use category.

Some historic information from the mid-1970s indicates a shift in the composition of periphyton communities of the Buffalo River. The high relative abundance of blue-green algae in NAWQA samples from sites on the Buffalo River (usually exceeding 90 percent and typical of forest sites) contrasts with information from the mid-1970s. Rippey (1976, p. 72) describes the diatoms as "...by far the most abundant and diverse algal taxon represented on the river...," apparently referring to relative abundance. This description apparently applied to all seasons, with the possible exception of late summer when blooms of unattached *Spirogyra* occurred.

Higher relative abundance of blue-green algae (and therefore lower relative abundance of diatoms) was significantly and negatively correlated with alkalinity, suspended sediment, woody vegetation density, and total triazines and positively correlated with embeddedness (table 9). Nutrient concentrations are substantially less correlated with blue-green algae relative abundance (table 9) than with blue-green algae biovolume (table 5).

Calothrix, a nitrogen-fixing, filamentous blue-green algal taxon (Prescott, 1968), was abundant and nearly ubiquitous in Ozark streams, with a median relative abundance of 42 percent. *Calothrix* was absent in only 3 of 83 samples: Kings River (1993), North Indian Creek, and the James River. Matthews and others (1987) reported that grazing by stonerollers *(Campostoma)* resulted in periphyton communities consisting largely of tightly attached blue-green algae (notably *Calothrix*). In this study, *Calothrix* often was abundant at agriculture sites (fig. 9), the type of sites where stonerollers are a large percentage of the fish community (Petersen, 1998). Although, the relative abundance of *Calothrix* did not differ significantly among land uses, the highest relative abundances of *Calothrix* occurred at agriculture sites.

Table 9. Correlation between diatom and blue-green algae relative abundance and environmental factors

[rho, Spearman's rank correlation coefficient; p, probability of greater absolute value of rho; NO3:TP, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and total phosphorus; NO3:PO4, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and dissolved orthophosphate; <, less than]

	Blue-green algae		Diatoms	
	rho	**p**	**rho**	**p**
Area	0.10	0.464	-0.12	0.411
Reach width	0.15	0.280	-0.15	0.303
Reach depth	0.21	0.131	-0.22	0.117
Width:depth	<0.01	0.988	0.01	0.921
Sample depth	-0.16	0.251	0.16	0.248
Percent forest	-0.16	0.268	0.17	0.222
Percent agriculture	0.16	0.248	-0.18	0.204
Percent urban	<0.01	0.960	-0.01	0.919
Velocity	-0.18	0.199	0.19	0.189
Percent canopy shading	-0.10	0.487	0.09	0.517
Woody vegetation density	-0.32	0.024	0.33	0.021
Embeddedness	0.29	0.037	-0.31	0.029
Nitrate	-0.04	0.772	0.03	0.838
Orthophosphate	0.17	0.216	-0.20	0.166
Total phosphorus	0.12	0.398	-0.13	0.345
NO3:TP	-0.12	0.391	0.12	0.381
NO3:PO4	-0.12	0.382	0.13	0.370
Dissolved organic carbon	0.18	0.201	-0.17	0.230
Total triazines	-0.31	0.031	0.32	0.022
Suspended sediment	-0.34	0.020	0.34	0.017
Alkalinity	-0.47	0.001	0.48	<0.001
Cadmium in bed sediment	-0.23	0.223	0.24	0.204
Lead in bed sediment	-0.22	0.248	0.22	0.241
Zinc in bed sediment	-0.37	0.053	0.39	0.044

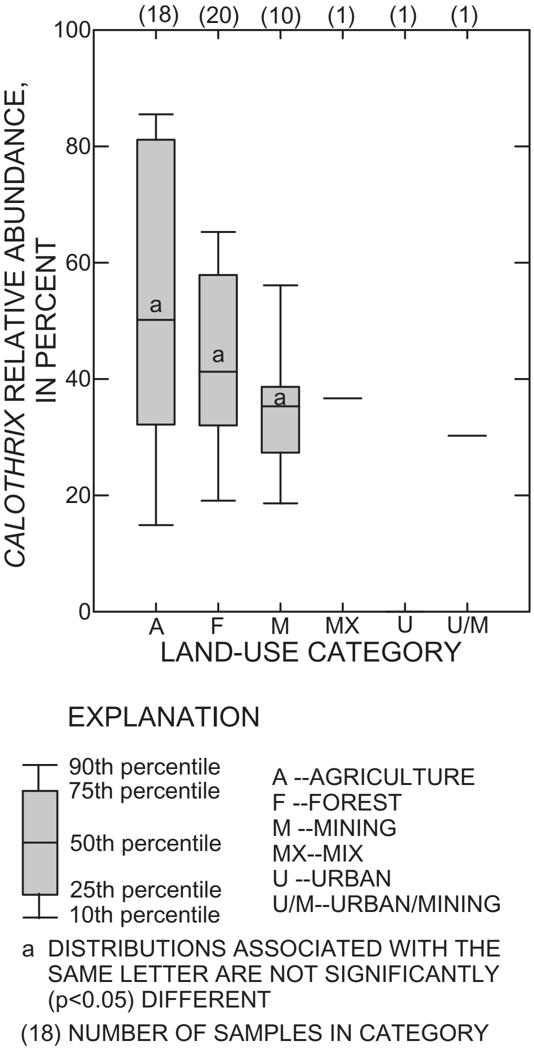

Figure 9. Distribution of *Calothrix* relative abundance by land-use category.

Two other filamentous genera, *Lyngbya* and *Oscillatoria*, were the only other common blue-green algae in these samples. These generally are cosmopolitan and do not fix nitrogen (S.D. Porter, U.S. Geological Survey, written commun., 2001). *Lyngbya* was found in 75 samples, with a median relative abundance of 15 percent. *Oscillatoria* was found in 79 samples, with a median relative abundance of 10 percent.

Diatom relative abundance was much higher at mining sites (generally 20 to 40 percent relative abundance) than at forest or agriculture sites (generally 5 to 15 percent). The most common diatoms were *Achnanthidium minutissimum* (76 samples), *Cymbella affinis* (72 samples), *Cocconeis placentula var. euglypta* (71 samples), an unidentified *Gomphonema* species (69 samples), *Rossithidium pusillum* (68 samples), and *Reimeria sinuata* (65 samples). Gale (1992) reported that *Cymbella*, *Gomphonema*, *Asterionella*, *Tabellaria*, *Fragilaria*, and *Navicula* were prominent diatoms at sites on streams in the West Fork of the Black River Basin.

Achnanthidium minutissimum (15 of 16 mining and urban/mining samples, mean of 2.7 percent from the 16 samples), *Rossithidium pusillum* (13 of 16 samples, mean of 3.3 percent), *Cymbella delicatula* (12 of 16 samples, mean of 6.1 percent) *Cymbella affinis* (12 of 16 samples, mean of 5.2 percent), and *Navicula minima* (7 of 16 samples, mean of 5.4 percent) were substantially more common and abundant than other diatoms in samples from mining sites. *N. minima* was abundant (16 to 53 percent relative abundance) at the urban/mining site (Center Creek near Smithfield, Mo.) but not at the mining sites that do not have a substantial urban influence. *C. affinis* and *C. delicatula* and *R. pusillum* typically were absent at the urban/mining site.

Diatom relative abundance was correlated with alkalinity and other factors (table 9). Diatom relative abundance did not exceed 15 percent at sites with alkalinity concentrations less than about 125 mg/L (fig. 10). At sites with higher alkalinity concentrations, diatom relative abundance frequently exceeded 25 percent, particularly at mining, urban/mining, and forest sites. Diatom relative abundance also was correlated with embeddedness, woody vegetation density, suspended sediment, total triazines, and zinc in bed sediment.

Detrended correspondence analysis (DCA) was used to compare the community structure of 83 relative abundance samples collected from 51 sites. In a preliminary ordination of the relative abundance data, scores for two samples were distinctly different from scores for all other samples. These two samples (from sites with major urban influences were James River near Boaz, Mo., sample 80; and Center Creek near Smithville, Mo., 1993, sample 81) were omitted from the final analyses of the relative abundance data.

The first two axes of the final DCA of the relative abundance data (fig. 11) explained about 35 percent of the variation in the relative abundance data. Axis 1 (eigenvalue of 0.22, 18.7 percent of variation) did not consistently separate sites by land-use category. However, some of the lowest axis 1 values and some of the highest axis 1 values were associated with agriculture sites, and many of the intermediate values on axis 1 were associated with mining and forest sites. These two groups of agriculture sites do not appear to differ from each other in terms of drainage area, physiographic area, or year of sample collection. Axis 2 (eigenvalue of 0.18, 15.7 percent of variation) separated a group of mining sites (sites in the Black River Basin downstream from mines being operated in 1993-95) from most of the agriculture, forest, urban/mining, and mix sites.

Axis 2 scores and axis 1 scores were significantly correlated with four and zero chemical and physical environmental factors, respectively (table 10). Axis 2 scores were positively correlated with nitrogen to phosphorus ratios and suspended sediment concentrations and negatively correlated with dissolved organic carbon concentrations. The lead-zinc mining sites are characterized by somewhat elevated concentrations of nitrate (usually greater than 0.05 mg/L) and total phosphorus concentrations of less than 0.010 mg/L. Axis 1 scores were most strongly correlated with alkalinity and lead concentrations in bed sediment.

Table 10. Correlation between relative abundance data detrended correspondence analysis axis values and environmental factors

[rho, Spearman's rank correlation coefficient; p, probability of greater absolute value of rho; NO3:TP, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and total phosphorus; NO3:PO4, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and dissolved orthophosphate; <, less than]

	Axis 1		Axis 2	
	rho	p	rho	p
Area	0.11	0.429	-0.18	0.206
Reach width	0.10	0.465	-0.13	0.350
Reach depth	0.09	0.524	-0.14	0.317
Width:depth	-0.03	0.835	-0.03	0.830
Sample depth	0.19	0.169	0.16	0.264
Percent forest	0.01	0.970	0.21	0.146
Percent agriculture	-0.02	0.914	-0.21	0.143
Percent urban	-0.06	0.658	0.04	0.804
Velocity	0.23	0.110	0.19	0.176
Percent canopy shading	0.20	0.156	0.04	0.792
Woody vegetation density	-0.05	0.726	0.25	0.084
Embeddedness	-0.07	0.602	-0.11	0.457
Nitrate	-0.01	0.924	0.24	0.093
Orthophosphate	-0.06	0.697	-0.26	0.066
Total phosphorus	-0.09	0.531	-0.21	0.144
NO3:TP	0.03	0.836	0.44	0.002
NO3:PO4	-0.03	0.846	0.43	0.002
Dissolved organic carbon	0.19	0.185	-0.55	<0.001
Total triazines	-0.15	0.340	0.01	0.928
Suspended sediment	0.01	0.932	0.43	0.003
Alkalinity	0.28	0.059	0.13	0.380
Cadmium in bed sediment	0.07	0.725	0.13	0.507
Lead in bed sediment	-0.27	0.154	0.19	0.313
Zinc in bed sediment	0.13	0.508	0.24	0.216

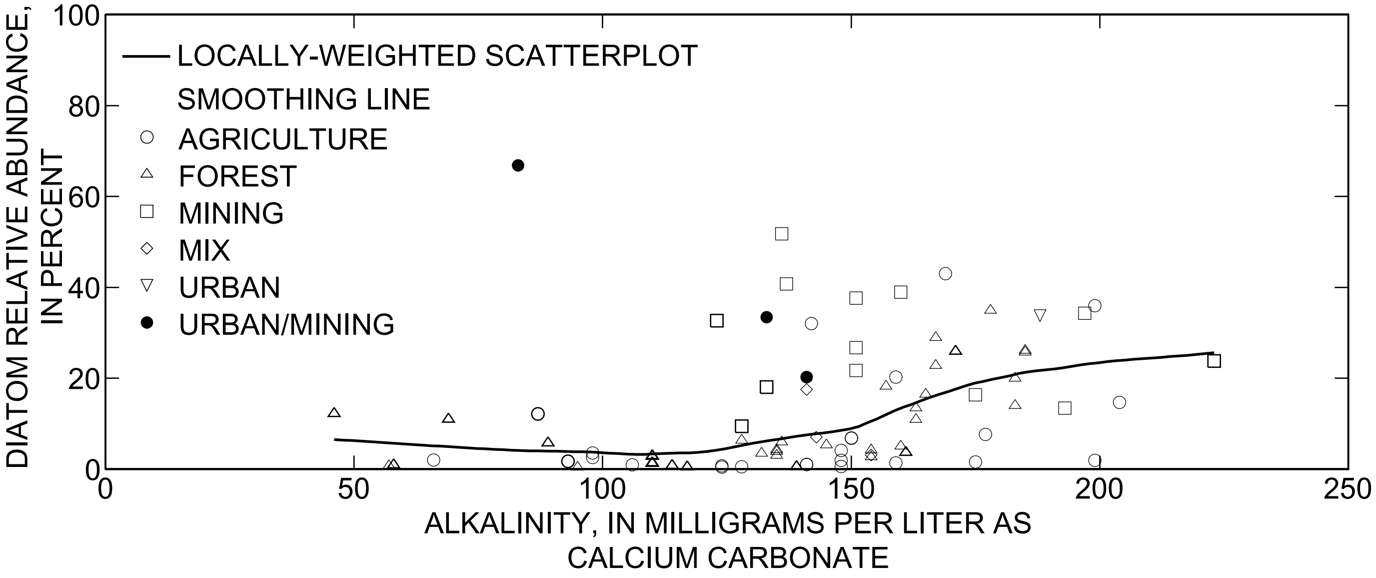

Figure 10. Relations between diatom relative abundance, alkalinity, and land use.

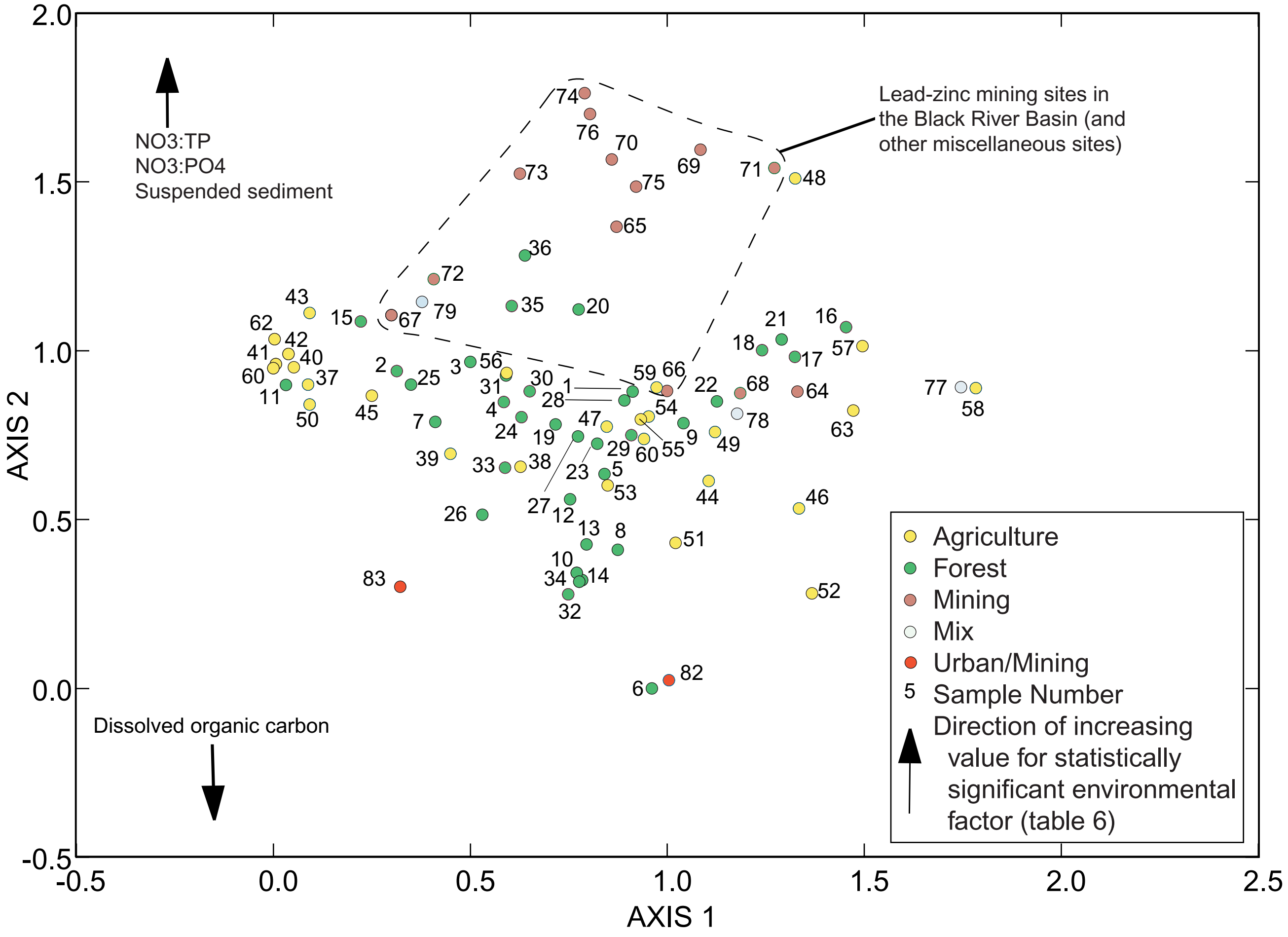

Figure 11. Detrended correspondence analysis (DCA) site scores for relative abundance data.

Hierarchical cluster analysis also was used to group sites sampled in 1994-95 with similar community structure (fig. 12). In general, sites with like land use and drainage size showed similarity in community structure.

Most of the sites with mining as the dominant land use grouped together (Set A, fig. 12), indicating similarity in community composition. These mining sites (except for Center Creek) are located in the Viburnum Trend in the Black River Basin. Two mining land-use sites that were not in Set A, Big River and Huzzah Creek, are located in different basins. Although Strother Creek near Oates is located in the Black River Basin, this site is immediately downstream of a large tailings lake and exhibits some lake type species causing this site to differ from the other mining sites in the Black River Basin. West Fork Black River near Greeley is located in the Black River Basin upstream from mining activities and also is in Set A, although the Middle Fork Black River at Redmondville, a Black River Basin nonmining site, is grouped in Set B with similar forested land-use sites.

Set B is composed of similar forested land-use sites located in different smaller drainage basins. Algal communities found at North Sylamore and Paddy Creek show relatively high similarity.

Many agriculture land-use sites of differing drainage area size are grouped in Set C. Two forest land-use sites with small drainage basins also are in this group. These agriculture land-use sites have the closest relation of the data set, illustrated by the small Pearson distances among the sites. A short horizontal line indicates a strong similarity. The Maries River, Illinois River, and Peacheater Creek sites had very similar algal community compositions, relative to the other sites.

The sites in Set D are all forest land use with the exception of the Strawberry River. Water Creek and Buffalo River at St. Joe appear to have very similar algal community structure, indicated by the short Pearson distances connecting the two sites. These two sites do not appear to have many traits in common other than forest land use and similar algal communities.

The sites in Set E represent a variety of land uses. The James River algal community is not similar to any other site sampled. This probably is because of urban influences on the James River. None of the sites in Set E have very similar algal communities as indicated by the lengths of the Pearson distance lines connecting the sites. The Big River near Richwoods and Huzzah River sites are located in mining land-use basins. The Big River is located in an historical mining area and there are some current and historical mining operations in the Huzzah River Basin. Strother Creek near Oates is located in the Black River mining area but drains a large tailings lake, which the other mining sites do not.

The forested and agricultural land-use sites are evenly distributed between Sets F and G. The majority of the mining land-use sites are grouped in Set F. The sites in Set G tend to be from a variety of physiographic sections, whereas sites in Set F tend to be located either in the Salem Plateau or Springfield Plateau physiographic sections.

The relative abundance data also were analyzed using the percent similarity (PSC) index. This method is used to measure the degree of similarity in species abundance data between two sites. For this report, PSC values greater than 70 percent were considered to be "strongly similar."

A comparison of median PSC similarity among agriculture, forest, and mining category sites and between sites in all land-use categories indicates that forest and mining sites typically are more similar to forest and mining sites, respectively, and that the urban site was substantially less similar than sites in any other category to agriculture, forest, and mining sites (table 11). The median similarities of forest sites with other forest sites (61 percent) and mining sites with other mining sites (59 percent) were somewhat higher (by 5 to 7 percent) than similarities with other sites in the agriculture, forest, and mining categories. The median similarities of agriculture sites with agriculture sites, forest sites, and mining sites ranged from 51 to 54 percent. The median similarities of the single site in the urban land-use category with sites in the agriculture, forest, and mining categories ranged from 14 to 18 percent. The median similarities of mixed, urban, and urban/mining sites (all sites with some urban influence) with agriculture, forest, and mining sites were all lower than median similarities among the agriculture, forest, and mining sites.

Table 11. Comparison of median percent similarity index values among land-use categories

	Agriculture	Forest	Mining	Mix[1]	Urban[1]	Urban/ mining[1]
Agriculture	51	54	54	48	17	35
Forest	54	61	54	50	18	47
Mining	54	54	59	51	14	41

[1] One site available for analysis.

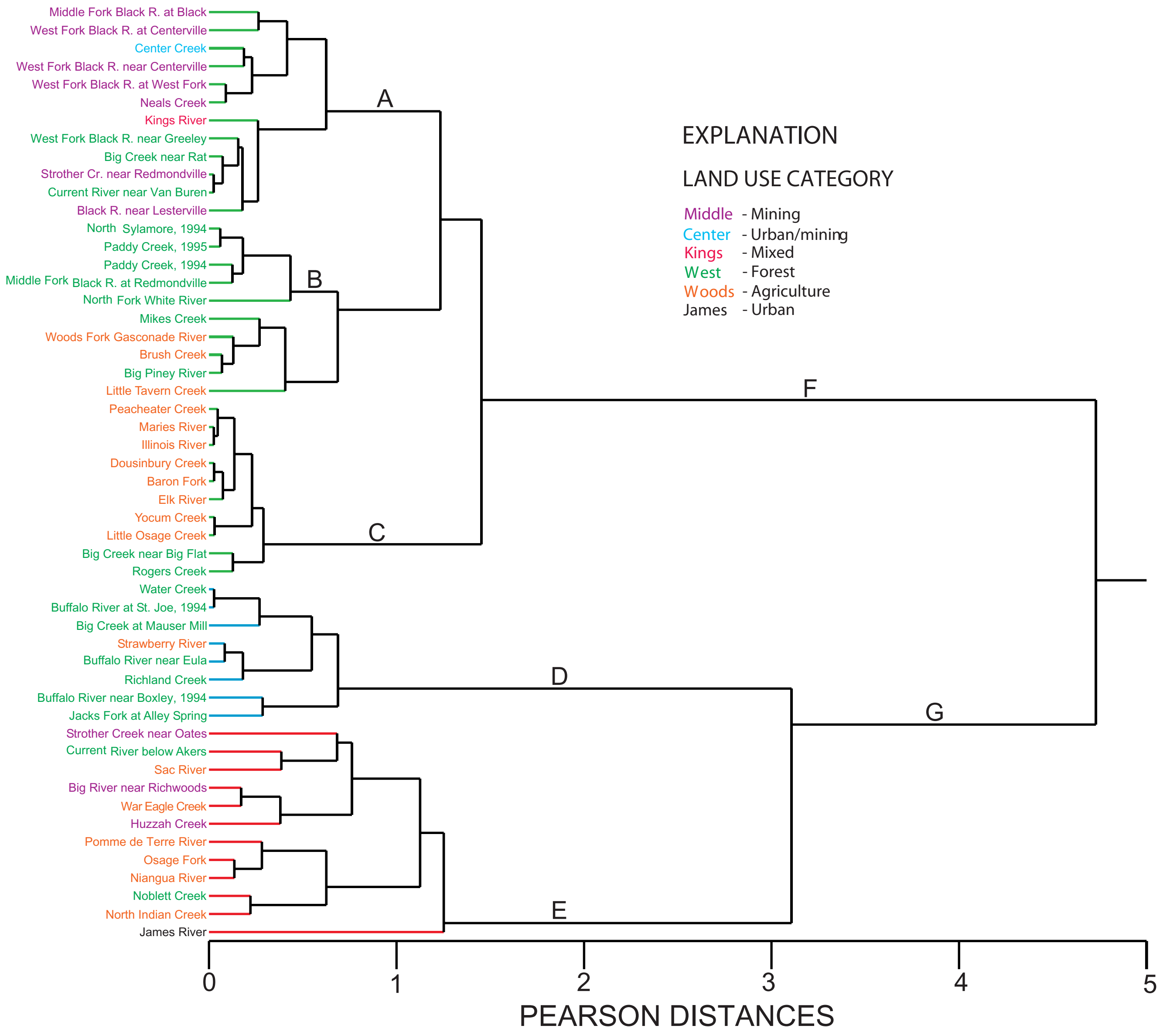

Figure 12. Cluster dendrogram of sites sampled in 1994-1995.

Samples from North Indian Creek, Little Tavern Creek, Sac River, Strother Creek near Oates, James River, and Center Creek were not strongly similar (PSC < 69 percent) to samples from other sites for this study. Of all samples, the samples from the James River near Boaz, Mo., were the least similar to other samples (PSC < 34 percent). These dissimilar algal communities may be attributed to natural or anthropogenic conditions or both. Strother Creek near Oates drains a lead-zinc mining tailings lake, James River drains a large urban area, and Center Creek drains an area with substantial urban influences and historic lead-zinc mining.

Samples from many sites that drain agricultural land-use areas correlated reasonably well (typically PSC ranged from 35 to 70 percent) with other agriculture sites. Little Osage River, Elk River, Baron Fork, Peacheater Creek, Yocum Creek, and Dousinbury Creek were strongly similar to each other. As a group (and with the exception of the single sites in the mix, urban, and urban/mining categories), samples from agriculture sites tended to be most dissimilar to the samples from sites in other land-use categories. However, there were exceptions and samples from Brush Creek and Pomme de Terre Creek (two other agriculture sites) generally were more correlated and similar to samples from other land-use categories than other agricultural samples were to samples from other categories. Woods Fork Gasconade River, an agriculture site, was similar (typically PSC = 50 to 85 percent) to sites located in forested land-use basins.

Sites within forested basins typically were less similar than sites within agricultural basins, and often were comparable to agriculture sites. However, North Sylamore Creek, Current River at Van Buren, and Paddy Creek were strongly similar only to other forest sites. Paddy Creek, which has a small forested basin in the Salem Plateau, was strongly similar (PSC=89 percent) to its counterpart in the Springfield Plateau physiographic section, North Sylamore Creek.

The sites located in the Viburnum Trend of Missouri, an area of active lead-zinc mining, exhibited strong similarity only with other sites in the same area. Neals Creek, West Fork Black River near West Fork, West Fork Black River near Centerville, West Fork Black River at Centerville, and the Middle Fork Black River near Black, did not demonstrate any substantial similarity with sites outside of the Black River Basin. The Middle Fork Black River near Redmondville, and the West Fork Black River near Greeley, sites in the same basin but upstream of mining activities, did not show a strong similarity to the sites downstream.

Taxa Relative Biovolume

Blue-green algae almost always composed the largest percentage of periphyton cells (i.e., relative abundance, fig. 8), whereas, diatoms often composed the largest percentage of the biovolume (relative biovolume) (fig. 13). Diatoms almost always composed the largest percentage of the biovolume in samples from mining sites. The highest relative biovolumes generally were at mining sites and the lowest were at agriculture sites. The relative biovolume of diatoms at mining sites was significantly different from relative biovolume at agriculture sites (fig. 13). Relative biovolume of green algae was always less than 1 percent.

Diatom relative biovolume was much higher at mining sites (generally 75 to 90 percent of the total biovolume) than at forest or agriculture sites (generally 15 to 80 percent). Diatoms species comprising the largest percentage of the biovolume at mining sites were *Cymbella affinis* (generally about 25 to 60 percent) (fig. 13), *Cymbella delicatula* (generally about 5 to 50 percent) (fig. 13), and *Rossithidium pusillum* (generally about 2 to 7 percent). *Cymbella affinis* was a cosmopolitan species except that it was not found in samples from sites with an urban influence (mix, urban, and urban/mining). *Cymbella delicatula* appears to be a good indicator of nutrient enrichment because it was absent or rare in samples from agriculture, mix, urban, and urban/mining sites. In a national dataset of NAWQA periphyton and water-quality data, *C. delicatula* has been found to have very low optima for both total phosphorus and total nitrogen and to prefer a calcium carbonate water chemistry (Marina Potapova, The Academy of Natural Sciences, written commun., 2002). *Navicula minima* (a eutrophic species) composed nearly 40 percent of the biovolume at the urban/mining site (Center Creek near Smithfield, Mo.), but less than 1 percent of the biovolume at the mining sites that do not have a substantial urban influence.

At forest and agriculture sites, the largest percentages of diatom biovolume generally were of *Cymbella affinis* (generally about 1 to 50 percent) (fig. 13), *Cymbella delicatula* (generally about 1 to 50 percent—at forest sites only) (fig. 13), *Gomphonema* sp. (generally 1 to 5 percent), *Achnanthidium minutissimum*, *Rossithidium pusillum,* and *Cymbella turgidula* (each generally less than 5 percent). However, several other diatoms (notably *Epithemia sorex*, *Epithemia tur-*

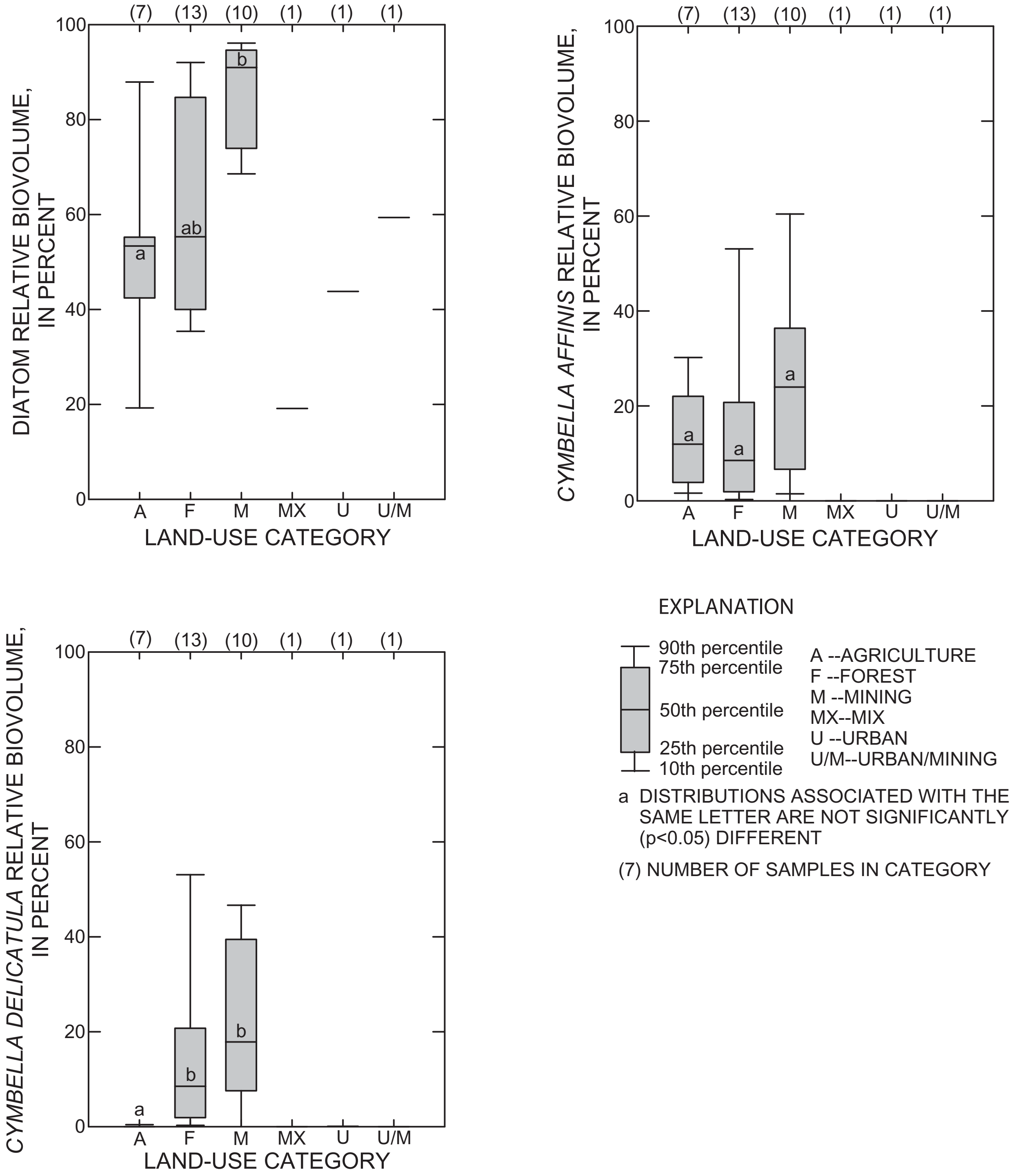

Figure 13. Distribution of diatom, *Cymbella affinis,* and *Cymbella delicatula* relative biovolume by land-use category.

gida, *Epithemia reichelti*, *Gomphonema apuncto*, and *Reimeria sinuata var. antiqua*) made up a large percentage (greater than 10 percent) of the biovolume at some sites. *Epithemia* spp. are nitrogen fixers which tend to be favored by nitrogen limitation (Borchardt, 1996).

Higher relative biovolume of diatoms (and therefore lower relative biovolume of blue-green algae) was significantly and positively correlated with sample depth, lead in bed sediment, and alkalinity and was significantly and negatively correlated with embeddedness, orthophosphate, total phosphorus, and dissolved organic carbon (table 12). A visual examination of plots showing the relation between orthophosphate and total phosphorus concentrations with diatom relative biovolume indicated that the correlation may have little ecological meaning and is the result of a wide range of relative biovolume values at low concentrations and moderate biovolume values for the three samples associated with phosphorus concentrations that exceed 0.2 mg/L.

Table 12. Correlation between relative biovolume of diatoms and environmental factors

[rho, Spearman's rank correlation coefficient; p, probability of greater absolute value of rho; NO3:TP, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and total phosphorus; NO3:PO4, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and dissolved orthophosphate; <, less than]

	rho	p
Area	-0.16	0.369
Reach width	-0.25	0.149
Reach depth	-0.23	0.189
Width:depth	-0.10	0.575
Sample depth	0.39	0.027
Percent forest	0.26	0.134
Percent agriculture	-0.27	0.120
Percent urban	-0.16	0.350
Velocity	0.29	0.097
Percent canopy shading	<0.01	0.995
Woody vegetation density	0.10	0.579
Embeddedness	-0.51	0.004
Nitrate	-0.03	0.862
Orthophosphate	-0.43	0.015
Total phosphorus	-0.36	0.041
NO3:TP	0.16	0.356
NO3:PO4	0.18	0.308
Dissolved organic carbon	-0.44	0.014
Total triazines	0.03	0.901
Suspended sediment	0.21	0.234
Alkalinity	0.37	0.040
Cadmium in bed sediment	0.23	0.308
Lead in bed sediment	0.57	0.011
Zinc in bed sediment	0.38	0.093

The relative biovolume of *Calothrix*, a nitrogen-fixing, filamentous blue-green algae, usually exceeded 10 percent at agriculture and forest sites (fig. 14). Relative biovolume of *Calothrix* was substantially lower, usually was less than 10 percent, at mining sites; however, these differences were not statistically significant among land-use categories.

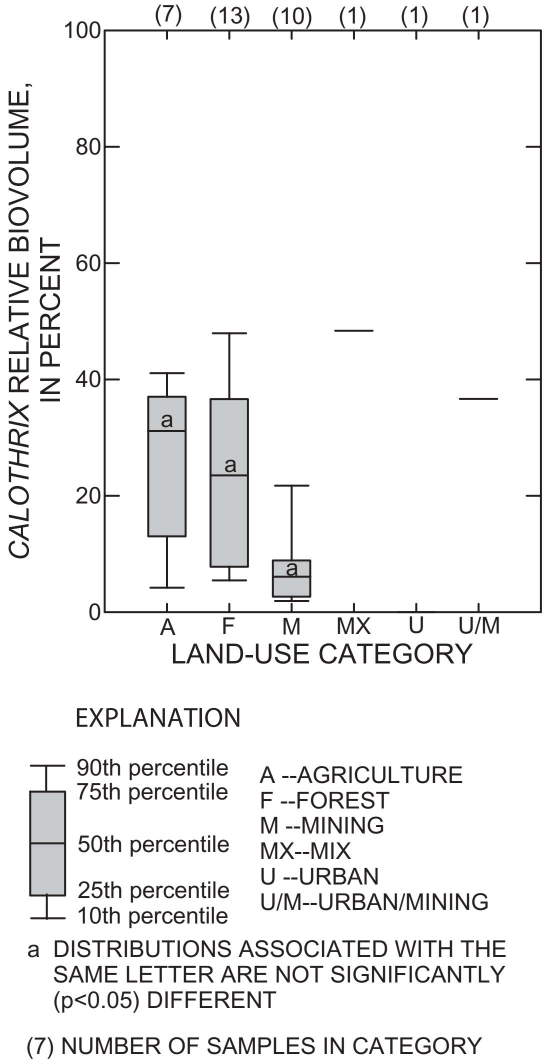

Figure 14. Distribution of *Calothrix* relative biovolume by land-use category.

Three other filamentous taxa, *Hydrocoleum brebissonii*, *Lyngbya*, and *Oscillatoria*, were the only other blue-green algae with relative biovolumes commonly greater than 1 percent. With the exception of *Lyngbya*, these three taxa generally composed less than 1 percent of the biovolume at mining sites.

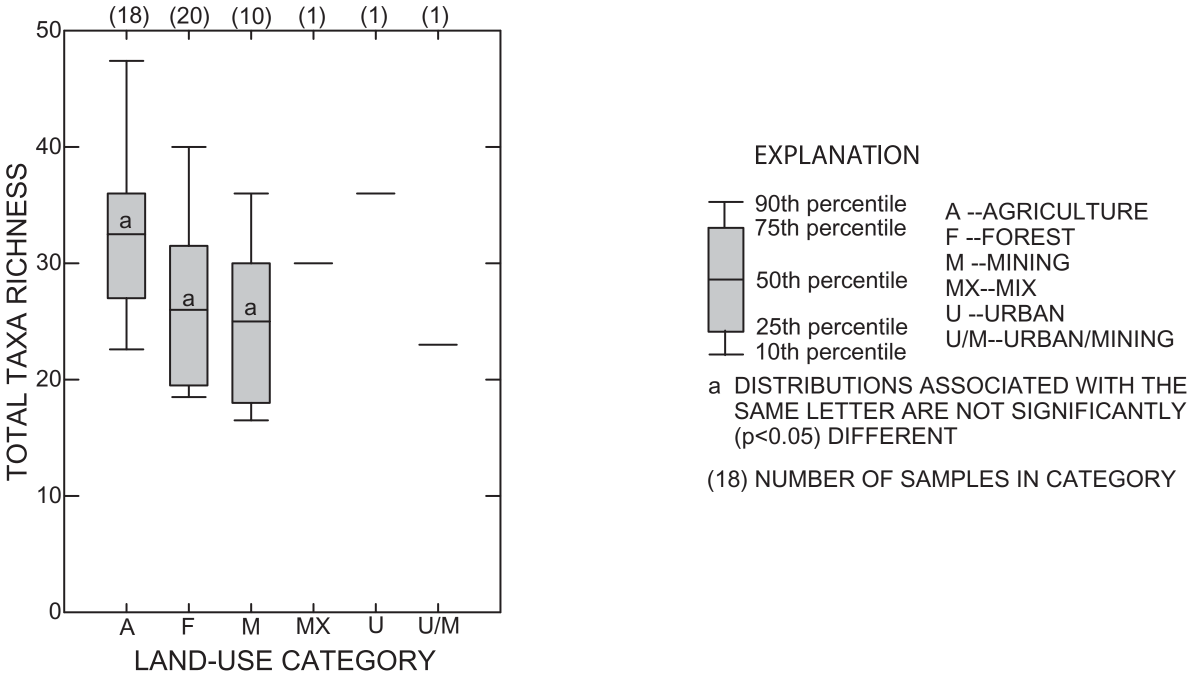

Figure 15. Distribution of values of taxa richness by land-use category.

Richness Measurements

Although more taxa often were found in samples from riffles at agriculture sites than at other types of sites, these differences were not statistically significant (fig. 15). Taxa richness ranged from 13 in sample 26 from North Sylamore Creek near Fifty Six, Ark., to 49 in sample 53 from the Strawberry River near Poughkeepsie, Ark. (table 7).

In general, total taxa richness was greater in larger agriculture streams with less riparian vegetation, lower nitrogen to phosphorus ratios, and higher dissolved organic carbon concentrations. Taxa richness was significantly and positively correlated with dissolved organic carbon, two measures of stream size (area, reach depth), and percent agriculture, and significantly and negatively correlated with percent forest, and nitrogen to phosphorus ratios (table 13).

Most taxa at most sites were diatoms, and most of the remaining taxa were blue-green algae. Diatom richness ranged from 9 in sample 26 from North Sylamore Creek near Fifty Six, Ark., to 43 in sample 11 from the Buffalo River near St. Joe, Ark., and sample 52 from the Sac River near Dadeville, Mo (table 7). Blue-green algae richness (with the exception of two sites) ranged from three to five taxa. Because most taxa were diatoms, correlations between diatom richness and environmental factors were very similar to correlations between taxa richness and environmental factors (table 13). Very little correlation was found between the number of blue-green alga taxa and the environmental factors (table 13).

Tolerance of Nutrient Enrichment

Periphyton often are used as a measure of nutrient conditions of streams (Barbour and others, 1999). A condition index based on the correlation of taxa relative abundance to nutrient concentrations (compared to reference sites) was used to rank the relative condition (the tolerance to elevated nutrient concentrations) of periphyton communities of Ozark streams. Because the condition index values reported here are based on reference sites from the Ozarks, these index values probably can not be used for direct comparison with index values from other regions.

Taxa that positively correlated (Spearman's rho values greater than 0.30) with nitrate, orthophosphate, or total phosphorus (table 14) were considered tolerant of elevated nutrient concentrations. All of the tolerant taxa were diatoms.

Taxa that negatively correlated (negative Spearman's rho values less than -0.30) with nitrate, orthophosphate, or total phosphorus (table 14) were considered intolerant of elevated nutrient concentrations. With the exception of *Oscillatoria* and *Oedogonium,* all of these intolerant taxa were diatoms.

The relative abundances of most taxa were weakly correlated with nutrient concentrations (table 14), and these taxa were considered cosmopolitan. These taxa also include a large number of diatoms, and almost all blue-green and green algal taxa found in samples.

The percentages of tolerant, intolerant, and cosmopolitan taxa at sites were compared to one or more reference sites of similar size and physiographic location (Richland Creek near Witt Springs, Ark., Buffalo River near Boxley, Ark., Buffalo River near St. Joe, Ark., Buffalo River near Eula, Ark., Paddy Creek near Slabtown Spring, Mo., Big Creek at Mauser Mill, Mo., Noblett Creek near Willow Springs, Mo., North Sylamore Creek near Fifty Six, Ark., Jacks Fork River at Alley Spring, Mo., and Current River at Van Buren, Mo.) and used to calculate the condition index. Condition index values ranged from 0.22 to 1.63.

Table 13. Correlation between taxa richness and environmental factors

[rho, Spearman’s rank correlation coefficient; p, probability of greater absolute value of rho; NO3:TP, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and total phosphorus; NO3:PO4, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and dissolved orthophosphate; <, less than]

	Total		Blue-green algae		Diatoms	
	rho	p	rho	p	rho	p
Area	0.41	0.004	0.03	0.841	0.36	0.011
Reach width	0.24	0.092	0.14	0.340	0.19	0.170
Reach depth	0.36	0.011	0.11	0.424	0.31	0.030
Width:depth	-0.08	0.591	0.10	0.467	-0.08	0.551
Sample depth	0.08	0.571	-0.10	0.475	0.06	0.648
Percent forest	-0.40	0.005	-0.10	0.463	-0.39	0.006
Percent agriculture	0.39	0.005	0.11	0.425	0.39	0.006
Percent urban	0.16	0.252	<0.01	0.992	0.14	0.311
Velocity	0.01	0.912	0.17	0.226	-0.03	0.849
Percent canopy shading	-0.19	0.189	-0.10	0.480	-0.16	0.246
Woody vegetation density	-0.25	0.080	-0.16	0.259	-0.22	0.116
Embeddedness	0.11	0.445	0.10	0.474	0.12	0.377
Nitrate	-0.04	0.765	0.20	0.148	-0.07	0.598
Orthophosphate	0.26	0.068	0.03	0.856	0.26	0.068
Total phosphorus	0.25	0.074	0.11	0.454	0.23	0.109
NO3:TP	-0.28	0.048	0.16	0.271	-0.29	0.044
NO3:PO4	-0.28	0.050	0.28	0.049	-0.31	0.028
Dissolved organic carbon	0.59	<0.001	<0.01	0.958	0.55	<0.001
Total triazines	<0.01	0.967	0.06	0.677	-0.27	0.055
Suspended sediment	0.03	0.816	-0.15	0.304	0.05	0.754
Alkalinity	-0.05	0.750	-0.23	0.106	-0.04	-0.762
Cadmium in bed sediment	-0.17	0.384	-0.21	0.276	-0.15	0.440
Lead in bed sediment	-0.16	0.398	-0.06	0.749	-0.15	0.412
Zinc in bed sediment	-0.36	0.058	-0.16	0.413	-0.34	0.073

Table 14. Autecological guild and correlation between taxa relative abundance and nutrient concentrations

[Taxa are listed in order of decreasing positive correlation with total phosphorus. Shading denotes nutrient tolerant (positive rho values exceeding 0.30) and intolerant (negative rho values exceeding 0.30) taxa; rho, Spearman's rank correlation coefficient; Autecological guilds: E, eutrophic; NH, nitrogen heterotrophs; C, cosmopolitan; NF, nitrogen fixer; O, oligotrophic. For some subspecies, an assignment to an autecological guild is based on information for the species or for another subspecies. Literature sources: 1, Lowe (1974); 2, Bahls (1992); 3, Van Dam and others (1994); 4, Cuffney and others (1997); 5, Anderson and Carpenter (1998)]

Taxa	rho			Autecological guild from literature	Literature sources
	Total phosphorus	Ortho-phosphate	Nitrate		
Navicula minima	0.64	0.57	0.40	E,NH	1,3,4,5
Nitzschia amphibia	0.62	0.66	0.35	E,NH	1,3,4,5
Luticola mutica	0.44	0.41	0.23	E	4
Gomphonema parvulum	0.43	0.42	0.25	E,NH	3,4,5
Navicula salinarum intermedia	0.42	0.28	0.25	E	3,5
Rhoicosphenia abbreviata	0.39	0.39	0.32	--	--
Sellaphora seminulum	0.39	0.40	0.14	E	4
Hydrocoleum brebissonii	0.38	0.38	0.42	--	--
Cyclotella meneghiniana	0.33	0.32	0.09	E	4,5
Diadesmis confervacea	0.33	0.27	0.06	--	--
Navicula tantula	0.31	0.29	0.04	--	--
Stigeoclonium lubricum	0.31	0.32	0.27	--	--
Amphora perpusilla	0.31	0.30	0.07	NH,E	5
Nitzschia dissipata	0.30	0.18	0.16	E	1,3,4,5
Reimeria sinuata antiqua	0.30	0.26	0.00	E	4,5
Navicula rhynchocephala germaini	0.30	0.27	0.11	E	1,3
Cocconeis placentula lineata	0.29	0.28	0.16	E	3,5
Achnanthes pinnata	0.29	0.18	0.11	--	--
Navicula tripunctata	0.29	0.29	0.32	E	1,3,4
Cocconeis placentula euglypta	0.28	0.16	0.08	C	4
Amphora submontana	0.27	0.27	0.16	O	2
Scenedesmus acuminatus	0.27	0.21	0.18	E	4
Synedra rumpens familiaris	0.27	0.28	0.29	C	4
Planothidium lanceolatum	0.26	0.23	0.18	--	--
Nitzschia frustulum perminuta	0.26	0.25	-0.02	E,NH	1,3
Nitzschia kuetzingiana	0.26	0.33	0.26	E	1,4
Navicula biconica	0.26	0.25	0.16	--	--
Fallacia subhamulata	0.26	0.26	-0.03	--	--
Nitzschia palea	0.24	0.26	0.16	E,NH	1,3,4,5
Scenedesmus sp.	0.24	0.20	-0.08	E	4
Cyanophyta	0.24	0.12	0.32	--	--
Gomphoneis olivacea	0.23	0.24	0.12	E	1,4,5
Psammothidium subatomoides	0.22	0.22	0.22	--	--
Navicula lanceolata	0.21	0.19	0.18	E	1,3,4
Navicula tripunctata schizonemoides	0.21	0.16	0.00	E	3,4
Anabaena sp.	0.20	0.18	-0.08	NF	5
Nitzschia sinuata delognei	0.19	0.19	0.11	E	3

Table 14. Autecological guild and correlation between taxa relative abundance and nutrient concentrations--Continued

[Taxa are listed in order of decreasing positive correlation with total phosphorus. Shading denotes nutrient tolerant (positive rho values exceeding 0.30) and intolerant (negative rho values exceeding 0.30) taxa; rho, Spearman's rank correlation coefficient; Autecological guilds: E, eutrophic; NH, nitrogen heterotrophs; C, cosmopolitan; NF, nitrogen fixer; O, oligotrophic. For some subspecies, an assignment to an autecological guild is based on information for the species or for another subspecies. Literature sources: 1, Lowe (1974); 2, Bahls (1992); 3, Van Dam and others (1994); 4, Cuffney and others (1997); 5, Anderson and Carpenter (1998)]

Taxa	**rho**			**Autecological guild from literature**	**Literature sources**
	Total phosphorus	**Ortho-phosphate**	**Nitrate**		
Pediastrum duplex	0.19	0.19	-0.14	--	--
Melosira varians	0.19	0.08	0.00	E,NH	1,3,4,5
Navicula mutica stigma	0.18	0.19	0.08	E	4
Cocconeis pediculus	0.17	0.08	-0.01	E	4,5
Cymbella tumida	0.17	0.10	-0.08	C	4
Planothidium dubium	0.16	0.17	0.07	--	--
Oocystis sp.	0.16	0.16	0.11	--	--
Fragilaria capucina mesolepta	0.16	0.13	0.01	E	1
Navicula symmetrica	0.15	0.20	0.14	--	--
Kirchneriella sp.	0.15	0.12	0.07	--	--
Nitzschia romana	0.15	0.12	0.01	O	2
Scenedesmus ecornis	0.15	0.02	0.11	E	4
Ankistrodesmus falcatus	0.15	0.10	0.18	--	--
Pinnularia obscura	0.15	0.15	0.17	--	--
Cosmarium botrytis	0.15	0.16	0.17	--	--
Cladophora sp.	0.13	0.00	0.04	E	4
Surirella angusta	0.13	0.05	0.02	C	4
Gomphonema mexicanum	0.13	0.12	0.15	--	--
Gyrosigma scalproides	0.13	0.15	0.12	C	4
Reimeria sinuata	0.13	0.04	0.11	E	4,5
Gomphonema affine	0.13	0.06	-0.06	--	--
Bacillaria paxillifer	0.12	0.12	-0.01	--	--
Navicula sp.	0.12	0.14	0.02	--	--
Nitzschia frustulum subsalina	0.12	0.05	0.07	E,NH	1,3
Gomphonema gracile	0.11	0.04	0.02	--	--
Navicula cryptocephala	0.11	0.11	0.15	E	1
Scenedesmus acutus	0.10	0.27	0.16	E	4
Navicula gysingensis	0.10	-0.05	0.15	--	--
Eunotia pectinalis minor	0.10	0.07	0.02	--	--
Navicula pseudolanceolata	0.10	0.07	0.02	O	2
Sellaphora mutata	0.10	0.07	0.02	--	--
Amphora ovalis	0.10	0.07	0.02	E	3
Nitzschia intermediopsis	0.10	0.07	0.02	--	--
Navicula contenta biceps	0.10	0.10	0.06	--	--
Navicula viridula linearis	0.10	-0.02	0.06	E	3,4
Cocconeis placentula	0.10	0.15	0.19	E	5
Geissleria decussis	0.09	0.08	-0.01	--	--
Scenedesmus spinosus	0.07	0.03	0.02	E	4
Calothrix sp.	0.07	0.01	-0.15	NF	5

Table 14. Autecological guild and correlation between taxa relative abundance and nutrient concentrations--Continued

[Taxa are listed in order of decreasing positive correlation with total phosphorus. Shading denotes nutrient tolerant (positive rho values exceeding 0.30) and intolerant (negative rho values exceeding 0.30) taxa; rho, Spearman's rank correlation coefficient; Autecological guilds: E, eutrophic; NH, nitrogen heterotrophs; C, cosmopolitan; NF, nitrogen fixer; O, oligotrophic. For some subspecies, an assignment to an autecological guild is based on information for the species or for another subspecies. Literature sources: 1, Lowe (1974); 2, Bahls (1992); 3, Van Dam and others (1994); 4, Cuffney and others (1997); 5, Anderson and Carpenter (1998)]

Taxa	rho			Autecological guild from literature	Literature sources
	Total phosphorus	Ortho-phosphate	Nitrate		
Gomphonema sp.	0.06	0.16	0.24	--	--
Pediastrum biradiatum	0.05	0.07	-0.09	--	--
Navicula gregaria	0.05	0.07	0.02	E	3
Mougeotia sp.	0.05	0.06	0.10	C	4
Achnanthes hauckiana rostrata	0.04	-0.09	-0.14	--	--
Pseudostaurosira brevistriata inflata	0.03	0.13	-0.09	--	--
Nitzschia sinuata tabellaria	0.03	-0.07	-0.18	--	--
Navicula menisculus	0.03	0.13	-0.07	E	3,5
Staurastrum sp.	0.03	-0.09	-0.14	--	--
Amphora ovalis pediculus	0.02	0.11	-0.09	C	4
Audouinella hermanii	0.02	-0.08	-0.18	O	4
Synedra rumpens meneghiniana	0.02	-0.04	-0.01	C	4
Fragilaria construens pumila	0.02	0.03	-0.12	E	5
Caloneis bacillum	0.01	0.08	-0.18	O	5
Cymbella turgidula	0.01	-0.07	-0.08	C	4
Cosmarium granatum	0.01	0.02	0.15	--	--
Gomphosphenia lingulatiformis	0.01	0.04	0.02	--	--
Gomphonema angustatum	0.01	-0.01	-0.18	E	1,5
Gomphonema grunowii	0.00	-0.03	-0.06	--	--
Gomphonema truncatum	-0.01	0.00	0.14	C	4
Gomphonema intricatum	-0.01	0.04	-0.02	C	4
Staurosirella leptostauron	-0.02	-0.19	0.14	--	--
Navicula cryptocephala veneta	-0.02	0.10	0.07	E,NH	1,5
Pseudostaurosira brevistriata	-0.02	0.07	0.01	--	--
Tetraedron minimum	-0.02	-0.06	-0.05	E	4
Sellaphora pupula	-0.02	-0.07	-0.04	--	--
Cymbella sp.	-0.03	0.08	-0.12	--	--
Achnanthidium exiguum	-0.04	-0.12	-0.26	O	5
Lyngbya sp.	-0.04	-0.04	0.01	--	--
Kirchneriella lunaris	-0.04	-0.02	0.01	--	--
Navicula cryptocephala exilis	-0.04	-0.16	-0.10	E,NH	1,5
Scenedesmus quadricauda	-0.04	-0.12	-0.13	E	4
Epithemia sorex	-0.05	0.09	-0.27	NF,E	1,3,4,5
Gomphonema truncatum capitatum	-0.05	-0.13	-0.20	C	4
Encyonema prostratum	-0.05	-0.13	-0.06	E	4
Gomphonema angustatum intermedia	-0.05	0.13	-0.21	E	1,5
Cosmarium subcrenatum	-0.06	-0.02	-0.08	--	--
Cymbella affinis	-0.07	-0.29	0.09	E	3,5
Diatoma vulgare	-0.08	-0.12	0.04	E	1,4,5

Table 14. Autecological guild and correlation between taxa relative abundance and nutrient concentrations--Continued

[Taxa are listed in order of decreasing positive correlation with total phosphorus. Shading denotes nutrient tolerant (positive rho values exceeding 0.30) and intolerant (negative rho values exceeding 0.30) taxa; rho, Spearman's rank correlation coefficient; Autecological guilds: E, eutrophic; NH, nitrogen heterotrophs; C, cosmopolitan; NF, nitrogen fixer; O, oligotrophic. For some subspecies, an assignment to an autecological guild is based on information for the species or for another subspecies. Literature sources: 1, Lowe (1974); 2, Bahls (1992); 3, Van Dam and others (1994); 4, Cuffney and others (1997); 5, Anderson and Carpenter (1998)]

Taxa	rho			Autecological guild from literature	Literature sources
	Total phosphorus	Ortho-phosphate	Nitrate		
Nitzschia frustulum	-0.08	0.11	-0.16	E,NH	1,3,4,5
Navicula radiosa	-0.08	-0.13	-0.15	C	4
Staurosirella pinnata	-0.09	-0.03	-0.11	E	4,5
Achnanthidium affine	-0.10	-0.19	-0.10	O	2
Karayevia clevei	-0.11	-0.06	-0.29	--	--
Rhopalodia gibba	-0.11	-0.16	-0.24	NF,E	1,3,4,5
Trachelomonas volvocina	-0.11	-0.09	-0.14	--	--
Caloneis ventricosa truncatula	-0.11	-0.09	-0.14	--	--
Gyrosigma acuminatum	-0.11	-0.09	-0.14	E	1,3
Sellaphora pupula rectangularis	-0.11	-0.09	-0.14	--	--
Tetraedron caudatum	-0.11	-0.09	-0.14	E	4
Cosmarium regnesi	-0.11	-0.09	-0.02	--	--
Synedra acus	-0.11	-0.09	0.00	E	1
Merismopedia tenuissima	-0.11	-0.09	0.01	--	--
Pyrrophyta	-0.11	-0.09	0.11	--	--
Trachelomonas hispida	-0.11	-0.09	0.11	--	--
Nitzschia bacata	-0.11	-0.09	0.11	E	1
Cosmarium sp.	-0.11	-0.09	0.11	--	--
Chamaesiphon incrustans	-0.11	0.07	-0.14	--	--
Golenkinia paucispina	-0.11	0.07	-0.14	--	--
Closterium sp.	-0.11	0.07	-0.14	--	--
Cyclotella aliquantula	-0.11	0.17	-0.14	--	--
Diploneis puella	-0.11	0.17	-0.14	--	--
Scenedesmus denticulatus	-0.12	-0.16	-0.10	E	4
Chlamydomonas sp.	-0.12	-0.11	-0.14	E	4
Fragilaria vaucheriae	-0.12	-0.10	0.00	E	1,5
Brachysira vitrea	-0.12	-0.10	0.17	--	--
Amphipleura pellucida	-0.15	-0.19	-0.28	C	4
Epithemia turgida	-0.15	-0.14	-0.36	NF	3,4,5
Gomphonema sphaerophorum	-0.15	-0.05	-0.21	--	--
Synedra fasciculata truncata	-0.16	-0.13	-0.20	--	--
Achnanthidium microcephalum	-0.16	-0.13	-0.20	O	2
Gomphonema mehleri	-0.17	-0.27	-0.16	--	--
Synedra rumpens	-0.18	-0.17	0.06	C	4
Chlorophyta	-0.19	-0.23	-0.07	--	--
Epithemia adnata	-0.19	-0.02	-0.32	NF	3,4,5
Navicula radiosa parva	-0.19	-0.20	-0.28	C	4
Synedra ulna oxyrhynchus	-0.20	-0.17	0.05	E	4,5
Navicula festiva	-0.20	-0.16	-0.24	--	--

Table 14. Autecological guild and correlation between taxa relative abundance and nutrient concentrations--Continued

[Taxa are listed in order of decreasing positive correlation with total phosphorus. Shading denotes nutrient tolerant (positive rho values exceeding 0.30) and intolerant (negative rho values exceeding 0.30) taxa; rho, Spearman’s rank correlation coefficient; Autecological guilds: E, eutrophic; NH, nitrogen heterotrophs; C, cosmopolitan; NF, nitrogen fixer; O, oligotrophic. For some subspecies, an assignment to an autecological guild is based on information for the species or for another subspecies. Literature sources: 1, Lowe (1974); 2, Bahls (1992); 3, Van Dam and others (1994); 4, Cuffney and others (1997); 5, Anderson and Carpenter (1998)]

Taxa	rho			Autecological guild from literature	Literature sources
	Total phosphorus	Ortho-phosphate	Nitrate		
Navicula grimmii	-0.20	-0.16	-0.17	--	--
Fragilaria pinnata lancettula	-0.20	-0.16	-0.11	O	2
Encyonema silesiacum	-0.23	-0.15	-0.31	--	--
Synedra tenera	-0.23	-0.19	0.06	--	--
Epithemia reichelti	-0.25	0.02	-0.40	NF	4,5
Staurosira construens	-0.26	-0.22	-0.07	E	4
Oedogonium sp.	-0.26	-0.14	-0.32	--	--
Synedra ulna	-0.26	-0.25	-0.16	E	1,4,5
Navicula minuscula	-0.27	-0.22	-0.30	O	3
Oscillatoria sp.	-0.27	-0.14	-0.36	--	--
Gomphonema apuncto	-0.28	-0.21	-0.44	--	--
Achnanthidium minutissimum	-0.30	-0.45	-0.17	C	4
Denticula elegans	-0.31	-0.26	-0.12	--	--
Navicula stroemii	-0.31	-0.26	0.09	--	--
Fragilaria crotonensis	-0.32	-0.35	0.05	E	1
Encyonema minutum	-0.35	-0.34	-0.19	E,NH	5
Encyonopsis microcephala	-0.40	-0.37	-0.19	--	--
Rossithidium pusillum	-0.41	-0.53	0.00	--	--
Cymbella cistula	-0.44	-0.40	-0.48	E	3
Cymbella hustedtii	-0.46	-0.16	-0.47	--	--
Achnanthes deflexa	-0.52	-0.60	-0.25	O	2
Cymbella delicatula	-0.64	-0.57	-0.44	O	2

Condition index values generally were highest in forest and mining streams and lowest in mix, urban, and urban/mining streams (fig.16, table 15). Index values for forest streams were significantly different from values for agriculture sites. In addition to nutrient values (which were used to derive the index values), index values were significantly correlated only with percent land use (forest, agriculture, and urban) (table 16). Condition index values increased with percent forest land use within the drainage area upstream from a site (Spearman's rho=0.49) (fig. 17). However, considerable variability in index values exists even when the percentage of forest exceeded 80 percent. The relation between index values and percent forest in the Salem Plateau differs from that in the Springfield Plateau. Where percent forest was less than about 85 percent, index values tend to be higher at sites in the Salem Plateau than at sites in the Springfield Plateau. Index values in the Salem Plateau appear to decrease very little as percent forest decreases. In the Springfield Plateau, values decrease as percent forest decreases below about 85 percent. These differences in condition values may indicate that agricultural practices (and possibly other factors) generally are more intensive (i.e., may introduce more nutrients, sediment, and pesticides and remove more riparian vegetation) in the Springfield Plateau than in the Salem Plateau. Davis and Bell (1998) reported higher nitrite plus nitrate concentrations in the Springfield Plateau than in the Salem Plateau for a given percentage of agricultural land use.

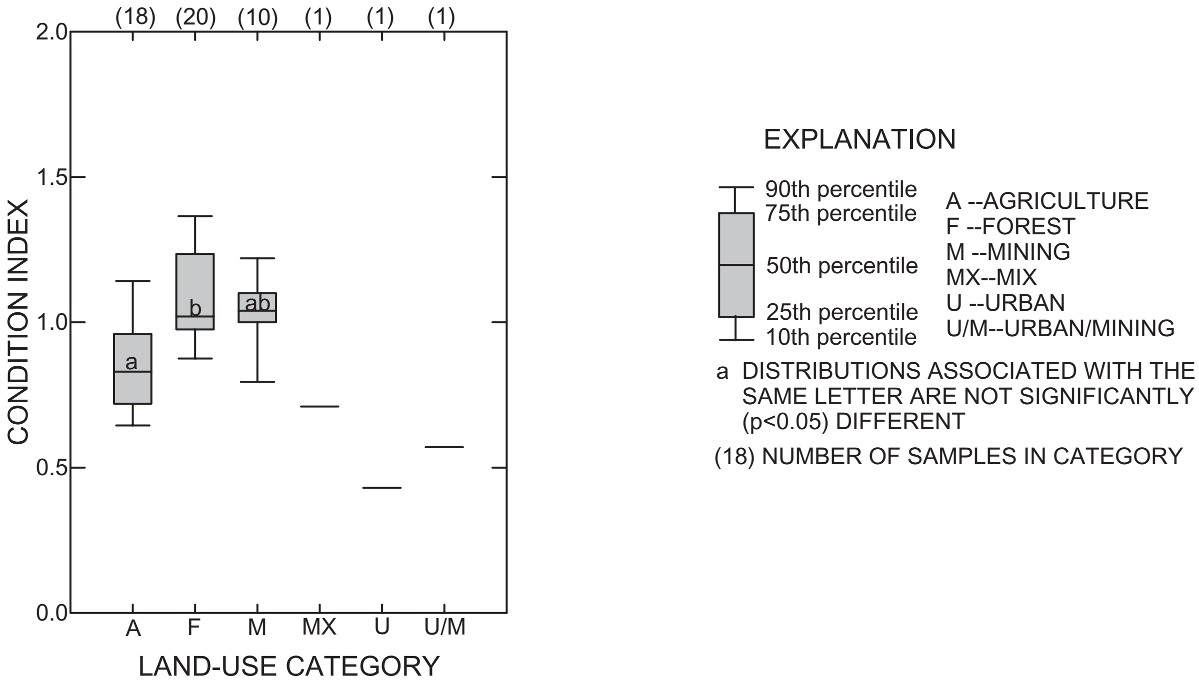

Figure 16. Distribution of condition index values by land-use category.

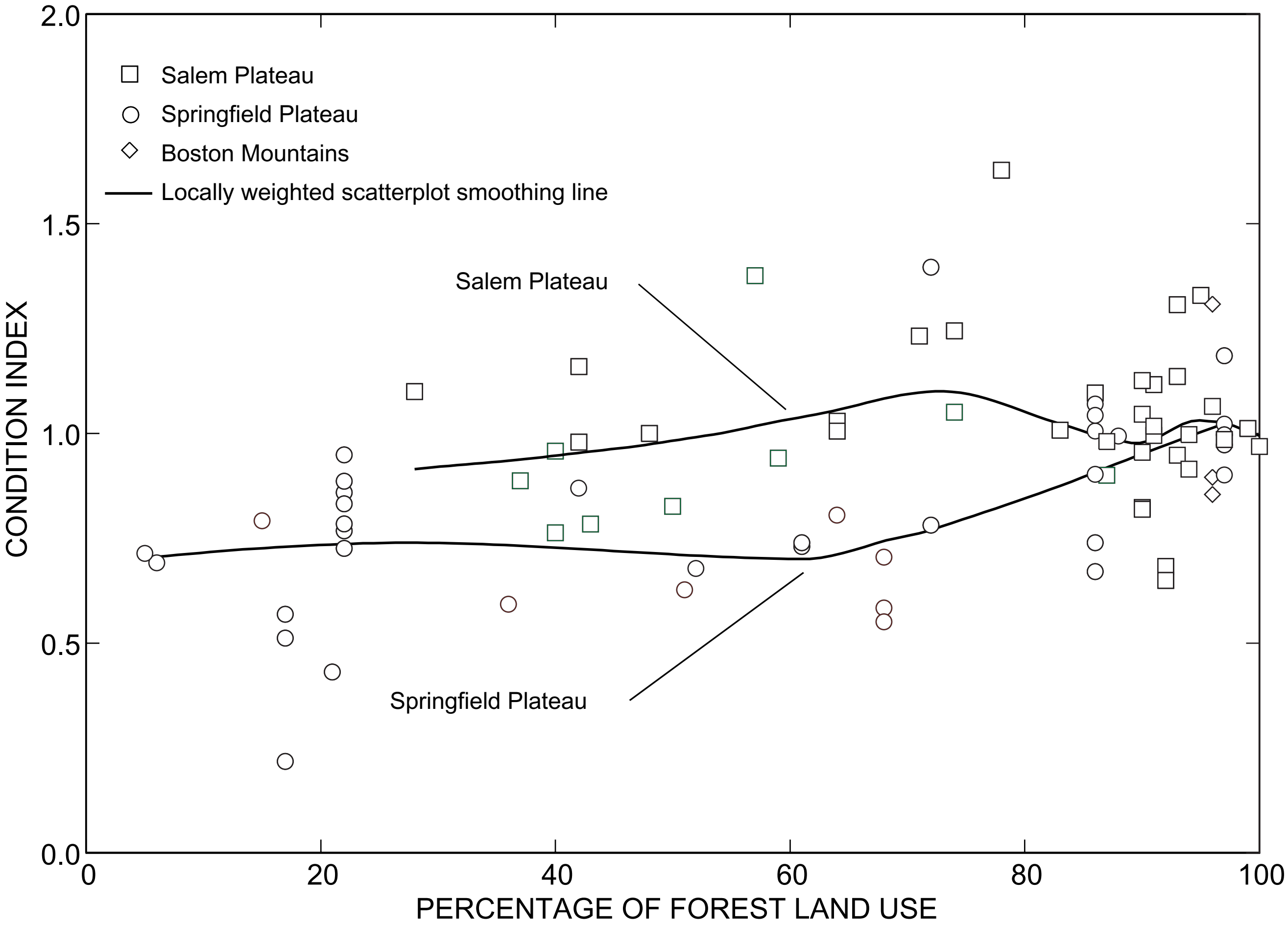

Figure 17. Relations between condition index, percent forest, and physiographic section.

Table 15. Percent intolerant, percent tolerant, and percent cosmopolitan taxa, and condition index values from relative abundance samples

[Taxa are assigned to intolerant, tolerant, and cosmopolitan categories based on correlations between relative abundance and nutrient concentration; see table 13. Therefore, intolerant taxa are associated with lower nutrient concentrations and tolerant taxa are associated with higher nutrient concentrations]

Sample number	Land use	Site name	Year	Intolerant taxa (percent)	Tolerant taxa (percent)	Cosmopolitan taxa (percent)	Condition index value	Reference sites
1	Forest	Big Creek at Mauser Mill, Mo.	1994	56.1	0.6	43.4	1.33	Paddy, Big (Mauser Mill), Noblett
2	Forest	Big Creek near Big Flat, Ark.	1994	7.3	10.6	82.1	0.80	North Sylamore
3	Forest	Big Creek near Rat, Mo.	1995	26.0	5.6	68.4	1.00	Paddy, Big (Mauser Mill), Noblett
4	Forest	Big Piney River near Big Piney, Mo.	1994	14.4	4.7	80.9	1.03	Jacks, Current (Van Buren)
5	Forest	Buffalo River near Boxley, Ark.	1993	25.4	1.8	72.8	0.90	Buffalo (Boxley), Richland
6	Forest	Buffalo River near Boxley, Ark.	1994	74.3	3.1	22.6	1.31	Buffalo (Boxley), Richland
7	Forest	Buffalo River near Boxley, Ark.	1995	22.6	4.3	73.2	0.85	Buffalo (Boxley), Richland
8	Forest	Buffalo River near Eula, Ark.	1994	40.5	1.6	57.9	0.99	Buffalo (Eula, St. Joe)
9	Forest	Buffalo River near St. Joe, Ark. (lower)	1993	9.0	0.4	90.6	0.74	Buffalo (Eula, St. Joe)
10	Forest	Buffalo River near St. Joe, Ark. (lower)	1994	46.7	1.8	51.5	1.04	Buffalo (Eula, St. Joe)
11	Forest	Buffalo River near St. Joe, Ark. (lower)	1995	2.2	2.2	95.6	0.67	Buffalo (Eula, St. Joe)
12	Forest	Buffalo River near St. Joe, Ark. (middle)	1994	28.5	0.2	71.3	0.90	Buffalo (Eula, St. Joe)
13	Forest	Buffalo River near St. Joe, Ark. (upper)	1994	41.4	0.9	57.7	1.01	Buffalo (Eula, St. Joe)
14	Forest	Buffalo River near St. Joe, Ark. (upper) (split)	1994	48.6	0.2	51.2	1.07	Buffalo (Eula, St. Joe)
15	Forest	Current River at Van Buren, Mo.	1995	12.7	5.0	82.3	1.01	Jacks, Current (Van Buren)
16	Forest	Current River below Akers, Mo.	1994	31.4	2.3	66.3	1.24	Jacks, Current (Van Buren)
17	Forest	Current River below Akers, Mo. (split)	1994	15.8	4.1	80.1	1.05	Jacks, Current (Van Buren)
18	Forest	Jacks Fork River at Alley Spring, Mo.	1994	68.1	6.0	25.9	1.63	Jacks, Current (Van Buren)
19	Forest	Middle Fork Black River at Redmondville, Mo.	1995	21.9	1.8	76.3	0.99	Paddy, Big (Mauser Mill), Noblett
20	Forest	Mikes Creek at Powell, Mo.	1994	12.9	20.5	66.6	0.78	North Sylamore
21	Forest	Noblett Creek near Willow Springs, Mo.	1994	34.2	0.4	65.4	1.12	Paddy, Big (Mauser Mill), Noblett
22	Forest	North Fork White River near Dora, Mo.	1994	29.5	1.3	69.2	1.23	Jacks, Current (Van Buren)
23	Forest	North Sylamore Creek near Fifty Six, Ark. (lower)	1993	20.5	0.5	79.0	1.02	North Sylamore
24	Forest	North Sylamore Creek near Fifty Six, Ark. (lower)	1994	15.7	0.4	83.9	0.97	North Sylamore
25	Forest	North Sylamore Creek near Fifty Six, Ark. (lower)	1995	11.0	3.3	85.7	0.90	North Sylamore
26	Forest	North Sylamore Creek near Fifty Six, Ark. (middle)	1993	36.6	0.5	62.9	1.19	North Sylamore
27	Forest	North Sylamore Creek near Fifty Six, Ark. (upper)	1993	19.3	1.9	78.8	1.00	North Sylamore
28	Forest	Paddy Creek above Slabtown Spring, Mo.	1994	18.7	1.6	79.7	0.95	Paddy, Big (Mauser Mill), Noblett
29	Forest	Paddy Creek above Slabtown Spring, Mo. (split)	1994	27.5	1.1	71.4	1.05	Paddy, Big (Mauser Mill), Noblett
30	Forest	Paddy Creek above Slabtown Spring, Mo.	1995	6.6	3.3	90.1	0.82	Paddy, Big (Mauser Mill), Noblett
31	Forest	Paddy Creek above Slabtown Spring, Mo. (split)	1995	7.8	5.2	87.0	0.82	Paddy, Big (Mauser Mill), Noblett

Table 15. Percent intolerant, percent tolerant, and percent cosmopolitan taxa, and condition index values from relative abundance samples--Continued

[Taxa are assigned to intolerant, tolerant, and cosmopolitan categories based on correlations between relative abundance and nutrient concentration; see table 13. Therefore, intolerant taxa are associated with lower nutrient concentrations and tolerant taxa are associated with higher nutrient concentrations]

Sample number	Land use	Site name	Year	Intolerant taxa (percent)	Tolerant taxa (percent)	Cosmopolitan taxa (percent)	Condition index value	Reference sites
32	Forest	Richland Creek near Witts Springs, Ark.	1994	50.3	1.0	48.8	1.12	Buffalo (Boxley), Richland
33	Forest	Rogers Creek near Van Buren, Mo.	1994	31.6	15.9	52.5	0.97	Paddy, Big (Mauser Mill), Noblett
34	Forest	Water Creek near Evening Star, Ark.	1994	57.0	0.1	42.9	1.40	North Sylamore
35	Forest	West Fork Black River near Greeley, Mo.	1995	20.1	0.0	79.9	0.98	Paddy, Big (Mauser Mill), Noblett
36	Forest	West Fork Black River near Greeley, Mo. (split)	1995	13.0	1.4	85.6	0.90	Paddy, Big (Mauser Mill), Noblett
37	Agriculture	Baron Fork at Eldon, Okla.	1994	8.2	8.6	83.2	0.68	Buffalo (Eula, St. Joe)
38	Agriculture	Brush Creek above Collins, Mo.	1994	14.7	5.3	80.1	0.89	Paddy, Big (Mauser Mill), Noblett
39	Agriculture	Dousinbury Creek near Wall Street, Mo.	1994	19.5	2.2	78.2	0.96	Paddy, Big (Mauser Mill), Noblett
40	Agriculture	Dousinbury Creek near Wall Street, Mo.	1995	2.6	5.9	91.5	0.76	Paddy, Big (Mauser Mill), Noblett
41	Agriculture	Elk River near Tiff City, Mo.	1994	2.0	8.5	89.4	0.63	Buffalo (Eula, St. Joe)
42	Agriculture	Illinois River near Tahlequah, Okla.	1994	1.1	12.3	86.6	0.59	Buffalo (Eula, St. Joe)
43	Agriculture	Little Osage Creek near Healing Spring, Ark.	1994	2.6	18.5	79.0	0.69	North Sylamore
44	Agriculture	Little Tavern Creek near St. Elizabeth, Mo.	1994	12.9	10.8	76.2	0.83	Paddy, Big (Mauser Mill), Noblett
45	Agriculture	Maries River near Freeburg, Mo.	1994	4.4	1.9	93.7	0.94	Jacks, Current (Van Buren)
46	Agriculture	Niangua River near Windyville, MO	1994	27.2	6.5	66.3	1.16	Jacks, Current (Van Buren)
47	Agriculture	Niangua River near Windyville, Mo. (split)	1994	12.3	7.7	80.0	0.98	Jacks, Current (Van Buren)
48	Agriculture	North Indian Creek near Wanda, Mo.	1994	23.2	41.4	35.5	0.72	North Sylamore
49	Agriculture	Osage Fork near Russ, MO	1994	12.8	6.0	81.2	1.00	Jacks, Current (Van Buren)
50	Agriculture	Peacheater Creek at Christie, Okla.	1994	9.5	5.4	85.1	0.87	North Sylamore
51	Agriculture	Pomme de Terre near Polk, Mo.	1994	24.3	9.4	66.4	1.10	Jacks, Current (Van Buren)
52	Agriculture	Sac River near Dadeville, Mo.	1994	30.0	18.8	51.2	0.79	Buffalo (Eula, St. Joe)
53	Agriculture	Strawberry River near Poughkeepsie, Ark.	1994	43.4	2.8	53.8	1.38	Jacks, Current (Van Buren)
54	Agriculture	War Eagle Creek near Hindsville, Ark.	1994	9.6	2.5	87.9	0.73	Buffalo (Eula, St. Joe)
55	Agriculture	War Eagle Creek near Hindsville, Ark. (split)	1994	9.2	0.7	90.1	0.74	Buffalo (Eula, St. Joe)
56	Agriculture	Woods Fork near Hartville, Mo.	1994	3.0	3.8	93.2	0.78	Paddy, Big (Mauser Mill), Noblett
57	Agriculture	Yocum Creek near Oak Grove, Ark. (lower)	1993	3.9	10.9	85.2	0.77	North Sylamore
58	Agriculture	Yocum Creek near Oak Grove, Ark. (middle)	1993	11.3	8.9	79.8	0.86	North Sylamore
59	Agriculture	Yocum Creek near Oak Grove, Ark. (middle)	1994	7.7	7.7	84.7	0.83	North Sylamore
60	Agriculture	Yocum Creek near Oak Grove, Ark. (middle) (split)	1994	15.2	2.7	82.1	0.95	North Sylamore
61	Agriculture	Yocum Creek near Oak Grove, Ark. (middle)	1995	0.9	5.0	94.2	0.78	North Sylamore
62	Agriculture	Yocum Creek near Oak Grove, Ark. (middle) (split)	1995	0.0	11.1	88.9	0.73	North Sylamore
63	Agriculture	Yocum Creek near Oak Grove, Ark. (upper)	1993	12.6	7.2	80.2	0.89	North Sylamore

Table 15. Percent intolerant, percent tolerant, and percent cosmopolitan taxa, and condition index values from relative abundance samples--Continued

[Taxa are assigned to intolerant, tolerant, and cosmopolitan categories based on correlations between relative abundance and nutrient concentration; see table 13. Therefore, intolerant taxa are associated with lower nutrient concentrations and tolerant taxa are associated with higher nutrient concentrations]

Sample number	Land use	Site name	Year	Intolerant taxa (percent)	Tolerant taxa (percent)	Cosmopolitan taxa (percent)	Condition index value	Reference sites
64	Mining	Big River near Richwoods, Mo.	1994	13.0	5.7	81.3	1.01	Jacks, Current (Van Buren)
65	Mining	Black River near Lesterville, Mo.	1993	22.5	3.1	74.4	1.14	Jacks, Current (Van Buren)
66	Mining	Black River near Lesterville, Mo.	1994	35.6	0.7	63.7	1.31	Jacks, Current (Van Buren)
67	Mining	Black River near Lesterville, Mo.	1995	10.0	8.2	81.8	0.95	Jacks, Current (Van Buren)
68	Mining	Huzzah Creek near Scotia, Mo.	1994	16.6	0.2	83.2	1.10	Jacks, Current (Van Buren)
69	Mining	Middle Fork Black River at Black, Mo.	1995	28.3	8.2	63.5	1.00	Paddy, Big (Mauser Mill), Noblett
70	Mining	Neals Creek near Goodland, Mo.	1995	30.9	2.9	66.2	1.06	Paddy, Big (Mauser Mill), Noblett
71	Mining	Strother Creek near Oates, Mo.	1995	27.3	5.1	67.6	1.01	Paddy, Big (Mauser Mill), Noblett
72	Mining	Strother Creek near Redmondville, Mo.	1995	15.6	2.8	81.6	0.91	Paddy, Big (Mauser Mill), Noblett
73	Mining	West Fork Black River at Centerville, Mo.	1995	12.9	29.0	58.1	0.68	Paddy, Big (Mauser Mill), Noblett
74	Mining	West Fork Black River at Centerville, Mo. (split)	1995	16.2	37.4	46.4	0.65	Paddy, Big (Mauser Mill), Noblett
75	Mining	West Fork Black River at West Fork, Mo.	1995	35.8	1.1	63.1	1.13	Paddy, Big (Mauser Mill), Noblett
76	Mining	West Fork Black River near Centerville, Mo.	1995	32.4	10.8	56.8	1.02	Paddy, Big (Mauser Mill), Noblett
77	Mix	Kings River near Berryville, Ark.	1993	8.4	22.9	68.6	0.58	Buffalo (Eula, St. Joe)
78	Mix	Kings River near Berryville, Ark.	1994	7.6	3.7	88.8	0.71	Buffalo (Eula, St. Joe)
79	Mix	Kings River near Berryville, Ark.	1995	5.0	23.6	71.4	0.55	Buffalo (Eula, St. Joe)
80	Urban	James River near Boaz, Mo.	1994	18.1	58.0	23.9	0.43	Buffalo (Eula, St. Joe)
81	Urban/mining	Center Creek near Smithfield, Mo.	1993	5.4	74.1	20.5	0.22	Buffalo (Eula, St. Joe)
82	Urban/mining	Center Creek near Smithfield, Mo.	1994	16.2	34.9	48.9	0.57	Buffalo (Eula, St. Joe)
83	Urban/mining	Center Creek near Smithfield, Mo.	1995	5.1	29.5	65.4	0.51	Buffalo (Eula, St. Joe)

Table 16. Correlation between condition index and environmental factors

[rho, Spearman's rank correlation coefficient; p, probability of greater absolute value of rho; NO3:TP, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and total phosphorus; NO3:PO4, molar ratio of nitrogen to phosphorus in dissolved nitrite plus nitrate and dissolved orthophosphate; <, less than]

	rho	p
Area	-0.02	0.879
Reach width	0.06	0.649
Reach depth	-0.15	0.284
Width:depth	0.19	0.172
Sample depth	0.21	0.142
Percent forest	0.49	<0.001
Percent agriculture	-0.50	<0.001
Percent urban	-0.35	0.014
Velocity	-0.03	0.860
Percent canopy shading	0.22	0.127
Woody vegetation density	0.07	0.623
Embeddedness	-0.06	0.668
Nitrate	-0.52	<0.001
Orthophosphate	-0.52	<0.001
Total phosphorus	-0.57	<0.001
NO3:TP	-0.10	0.468
NO3:PO4	-0.20	0.149
Dissolved organic carbon	-0.16	0.248
Total triazines	-0.24	0.090
Suspended sediment	-0.25	0.078
Alkalinity	0.19	0.178
Cadmium in bed sediment	-0.08	0.668
Lead in bed sediment	0.32	0.090
Zinc in bed sediment	-0.14	0.471

The relative abundance of tolerant taxa usually was highest at sites with the greatest urban influence (urban, urban/mining, mix) (figs. 18-19) and ranged (at all sites) from a relative abundance of about 2 to 75 percent. Relative to these urban-influenced sites, communities of agriculture, forest, and mining sites generally were composed of substantially smaller relative abundances of tolerant periphyton. The relative abundance of tolerant taxa at forest sites was significantly lower than at agriculture sites (fig. 18), however, median abundance of tolerant taxa at mining sites did not differ statistically from forest or agriculture sites.

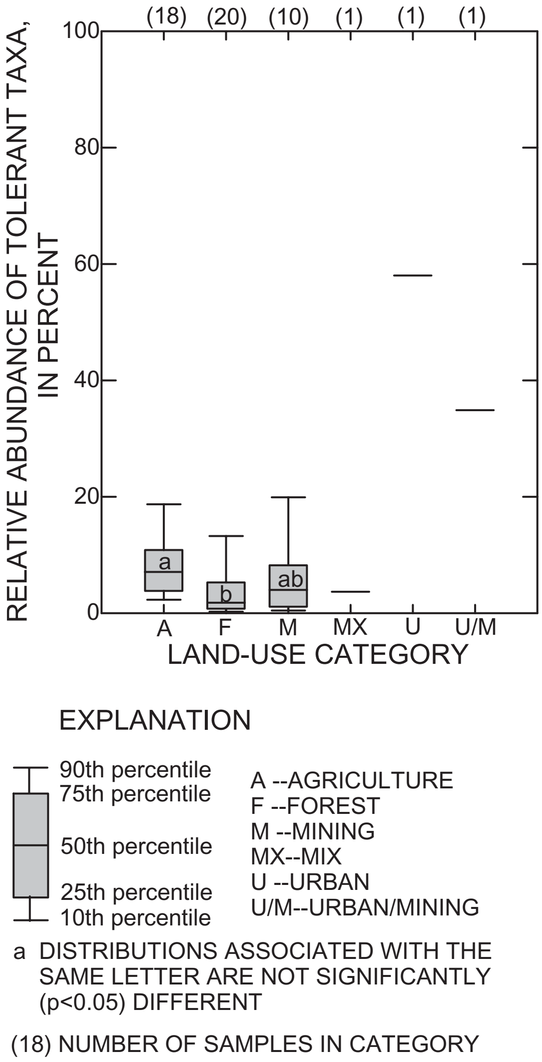

Figure 18. Distribution of relative abundance of tolerant taxa by land-use category.

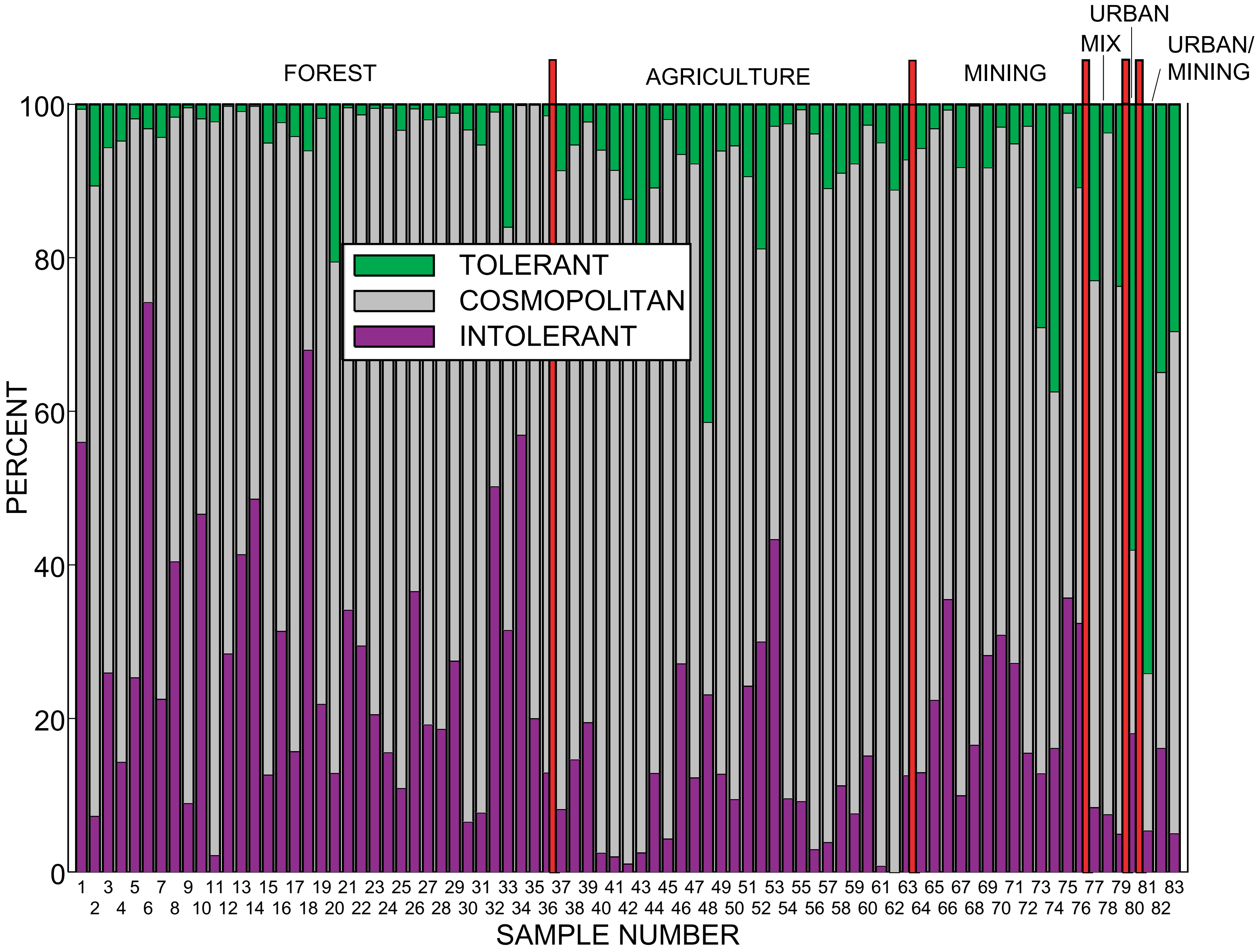

Figure 19. Relative abundance of intolerant, cosmopolitan, and tolerant taxa at individual sites.

Within many land-use classifications, the relative abundance of tolerant taxa at one or more sites was substantially higher than most other sites in the classification (fig. 19); these higher abundance values often could be associated with high (relative to other sites in the classification) nutrient concentrations. Among the forest sites, the highest percentage of tolerant taxa and the highest nitrate concentration occurred at Mikes Creek at Powell, Mo. (sample 20). Relatively high percentages of tolerant taxa and nitrate concentrations also occurred at Rogers Creek near Van Buren, Mo. (sample 33), and Big Creek near Big Flat, Ark. (sample 2). Among the agriculture sites, the highest percentage of tolerant taxa and highest nitrate concentration were associated with North Indian Creek near Wanda, Mo. (sample 48). Of the three samples from the urban/mining site (Center Creek near Smithfield, Mo.), the highest percentage of tolerant taxa (sample 81) was associated with the highest concentrations of orthophosphate and total phosphorus. Among the mining sites, the highest percentages of tolerant taxa (mostly *Hydrocoleum brebissonii* and unidentified Cyanophyta taxa) were associated with two samples (samples 73 and 74) from the West Fork Black River near Centerville, Mo. However, nutrient concentrations at this site were not high relative to other mining sites indicating that elevated amounts of nutrients are being delivered to the stream and being removed by the periphyton. The differences in relative abundance of tolerant taxa (which were identified as part of the condition index derivation process) among land-use classifications (figs. 18-19) and the concurrence of “anomalous” relative abundances of tolerant taxa within a land-use classification with high (relative to other sites within the land-use classification) nutrient concentrations indicate that elevated nutrient concentrations are likely to cause shifts in periphyton community composition.

Tolerance of elevated nutrient concentrations also was evaluated using autecological guilds determined from the literature (Lowe, 1974; Fairchild and others, 1985; Bahls, 1992; Van Dam and others, 1994; also see Cuffney and others, 1997; Anderson and Carpenter, 1998). The relative abundance of autecological guilds (eutrophic, nitrogen heterotrophic, nitrogen fixing, cosmopolitan, and oligotrophic) appears to be affected by land use (table 17). Despite the prevalent occurrence of taxa with unknown or uncertain autecology in many samples, significant differences were detected in the abundance of taxa that, collectively, comprise autecological guilds as defined in this report.

Table 17. Autecological guild relative abundance

[Autecological guilds from Lowe, 1974; Fairchild and others, 1985; Bahls, 1992; Van Dam and others, 1994; Cuffney and others, 1997; Anderson and Carpenter, 1998. Lower, middle, and upper are reach designations; split designates a second aliquot from a sample collected at a site]

				Relative abundance (percent) of taxa in autecological guilds				
Sample number	Site name	Year	Land-use category	Nitrogen fixers	Oligotrophic	Eutrophic	Nitrogen heterotrophs	Cosmopolitan
1	Big Creek at Mauser Mill, Mo.	1994	Forest	32.1	7.0	2.9	0.0	9.6
2	Big Creek near Big Flat, Ark.	1994	Forest	70.6	0.0	0.2	0.1	0.1
3	Big Creek near Rat, Mo.	1995	Forest	58.8	4.6	0.7	0.5	4.4
4	Big Piney River near Big Piney, Mo.	1994	Forest	60.0	0.0	0.8	0.1	0.2
5	Buffalo River near Boxley, Ark.	1993	Forest	41.7	0.8	2.1	0.6	7.2
6	Buffalo River near Boxley, Ark.	1994	Forest	21.0	0.2	0.2	0.0	0.1
7	Buffalo River near Boxley, Ark.	1995	Forest	65.3	0.5	0.2	0.0	2.5
8	Buffalo River near Eula, Ark.	1994	Forest	39.0	0.1	0.1	0.0	0.1
9	Buffalo River near St. Joe, Ark. (lower)	1993	Forest	44.0	0.0	0.6	0.2	0.1
10	Buffalo River near St. Joe, Ark. (lower)	1994	Forest	41.0	0.2	0.2	0.1	0.7
11	Buffalo River near St. Joe, Ark. (lower)	1995	Forest	92.5	0.1	0.2	0.1	0.1
12	Buffalo River near St. Joe, Ark. (middle)	1994	Forest	50.1	0.3	0.2	0.1	0.7
13	Buffalo River near St. Joe, Ark. (upper)	1994	Forest	42.5	0.5	0.5	0.2	1.5
14	Buffalo River near St. Joe, Ark. (upper) (split)	1994	Forest	40.0	0.3	0.3	0.1	2.1
15	Current River at Van Buren, Mo.	1995	Forest	72.9	3.6	3.9	0.4	5.4
16	Current River below Akers, Mo.	1994	Forest	17.2	0.1	13.0	2.4	2.1

Table 17. Autecological guild relative abundance--Continued

[Autecological guilds from Lowe, 1974; Fairchild and others, 1985; Bahls, 1992; Van Dam and others, 1994; Cuffney and others, 1997; Anderson and Carpenter, 1998. Lower, middle, and upper are reach designations; split designates a second aliquot from a sample collected at a site]

Sample number	Site name	Year	Land-use category	Relative abundance (percent) of taxa in autecological guilds				
				Nitrogen fixers	Oligotrophic	Eutrophic	Nitrogen heterotrophs	Cosmopolitan
17	Current River below Akers, Mo. (split)	1994	Forest	24.1	0.2	17.6	2.2	2.6
18	Jacks Fork River at Alley Spring, Mo.	1994	Forest	7.5	11.3	9.8	0.0	5.9
19	Middle Fork Black River at Redmondville, Mo.	1995	Forest	53.8	1.5	0.9	0.0	0.3
20	Mikes Creek at Powell, Mo.	1994	Forest	39.5	0.1	2.4	0.3	0.5
21	Noblett Creek near Willow Springs, Mo.	1994	Forest	22.9	11.5	0.2	0.2	2.0
22	North Fork White River near Dora, Mo.	1994	Forest	31.9	0.7	4.5	1.1	4.7
23	North Sylamore Creek near Fifty Six, Ark. (lower)	1993	Forest	48.9	2.4	0.1	0.0	0.1
24	North Sylamore Creek near Fifty Six, Ark. (lower)	1994	Forest	59.8	2.0	1.2	0.5	1.0
25	North Sylamore Creek near Fifty Six, Ark. (lower)	1995	Forest	73.0	2.3	0.1	0.0	0.7
26	North Sylamore Creek near Fifty Six, Ark. (middle)	1993	Forest	55.7	2.3	0.0	0.0	0.1
27	North Sylamore Creek near Fifty Six, Ark. (upper)	1993	Forest	51.2	1.9	0.2	0.0	0.1
28	Paddy Creek above Slabtown Spring, Mo.	1994	Forest	48.9	1.7	1.9	0.4	1.8
29	Paddy Creek above Slabtown Spring, Mo. (split)	1994	Forest	48.5	2.5	1.4	0.0	0.3
30	Paddy Creek above Slabtown Spring, Mo.	1995	Forest	60.0	0.6	0.2	0.0	0.0
31	Paddy Creek above Slabtown Spring, Mo. (split)	1995	Forest	60.4	1.6	0.3	0.1	0.3
32	Richland Creek near Witts Springs, Ark.	1994	Forest	41.5	0.1	0.0	0.0	0.3
33	Rogers Creek near Van Buren, Mo.	1994	Forest	45.5	1.6	7.9	6.7	5.1
34	Water Creek near Evening Star, Ark.	1994	Forest	37.8	3.7	0.3	0.1	0.4
35	West Fork Black River near Greeley, Mo.	1995	Forest	57.0	6.7	16.7	0.0	0.5
36	West Fork Black River near Greeley, Mo. (split)	1995	Forest	57.8	6.9	16.2	0.0	1.0
37	Baron Fork at Eldon, Okla.	1994	Agriculture	82.7	0.0	0.7	0.2	0.8
38	Brush Creek above Collins, Mo.	1994	Agriculture	54.5	0.0	8.7	1.4	2.8
39	Dousinbury Creek near Wall Street, Mo.	1994	Agriculture	66.1	0.0	1.0	0.2	0.8
40	Dousinbury Creek near Wall Street, Mo.	1995	Agriculture	88.3	0.0	0.6	0.2	0.9
41	Elk River near Tiff City, Mo.	1994	Agriculture	88.7	0.0	0.8	0.5	0.0
42	Illinois River near Tahlequah, Okla.	1994	Agriculture	86.0	0.0	1.6	1.6	0.3
43	Little Osage Creek near Healing Spring, Ark.	1994	Agriculture	78.5	0.0	0.2	0.1	0.0
44	Little Tavern Creek near St. Elizabeth, Mo.	1994	Agriculture	25.8	0.3	30.7	8.1	16.5
45	Maries River near Freeburg, Mo.	1994	Agriculture	81.8	0.1	1.1	0.2	0.3
46	Niangua River near Windyville, Mo.	1994	Agriculture	20.2	0.0	4.1	3.0	0.6
47	Niangua River near Windyville, Mo. (split)	1994	Agriculture	46.8	0.0	4.3	0.7	0.4
48	North Indian Creek near Wanda, Mo.	1994	Agriculture	0.0	0.7	12.7	9.3	1.1
49	Osage Fork near Russ, Mo.	1994	Agriculture	35.3	0.0	4.0	2.7	1.2

Table 17. Autecological guild relative abundance--Continued

[Autecological guilds from Lowe, 1974; Fairchild and others, 1985; Bahls, 1992; Van Dam and others, 1994; Cuffney and others, 1997; Anderson and Carpenter, 1998. Lower, middle, and upper are reach designations; split designates a second aliquot from a sample collected at a site]

				Relative abundance (percent) of taxa in autecological guilds				
Sample number	**Site name**	**Year**	**Land-use category**	**Nitrogen fixers**	**Oligo-trophic**	**Eutro-phic**	**Nitrogen heterotrophs**	**Cosmo-politan**
50	Peacheater Creek at Christie, Okla.	1994	Agriculture	84.4	0.0	1.3	0.8	0.1
51	Pomme de Terre near Polk, Mo.	1994	Agriculture	32.2	0.0	10.7	7.4	1.8
52	Sac River near Dadeville, Mo.	1994	Agriculture	13.2	0.5	24.8	11.7	2.5
53	Strawberry River near Poughkeepsie, Ark.	1994	Agriculture	33.8	3.7	5.4	0.4	4.7
54	War Eagle Creek near Hindsville, Ark.	1994	Agriculture	46.3	0.0	2.1	0.9	1.0
55	War Eagle Creek near Hindsville, Ark. (split)	1994	Agriculture	48.9	0.0	1.7	0.6	1.0
56	Woods Fork near Hartville, Mo.	1994	Agriculture	64.7	0.0	0.8	0.2	1.2
57	Yocum Creek near Oak Grove, Ark. (lower)	1993	Agriculture	18.2	0.0	3.6	0.7	0.1
58	Yocum Creek near Oak Grove, Ark. (middle)	1993	Agriculture	3.0	0.0	1.8	0.3	0.0
59	Yocum Creek near Oak Grove, Ark. (middle)	1994	Agriculture	41.8	0.0	0.5	0.2	0.0
60	Yocum Creek near Oak Grove, Ark. (middle) (split)	1994	Agriculture	44.8	0.0	0.3	0.1	0.0
61	Yocum Creek near Oak Grove, Ark. (middle)	1995	Agriculture	92.7	0.0	0.7	0.2	0.1
62	Yocum Creek near Oak Grove, Ark. (middle) (split)	1995	Agriculture	88.0	0.0	0.6	0.2	0.1
63	Yocum Creek near Oak Grove, Ark. (upper)	1993	Agriculture	18.3	0.0	0.7	0.0	0.0
64	Big River near Richwoods, Mo.	1994	Mining	24.0	0.2	14.9	4.4	4.9
65	Black River near Lesterville, Mo.	1993	Mining	40.5	11.7	14.8	0.4	4.0
66	Black River near Lesterville, Mo.	1994	Mining	34.1	5.8	4.4	0.2	4.6
67	Black River near Lesterville, Mo.	1995	Mining	72.2	1.6	1.2	0.0	6.3
68	Huzzah Creek near Scotia, Mo.	1994	Mining	32.8	0.1	12.1	0.7	0.9
69	Middle Fork Black River at Black, Mo.	1995	Mining	27.3	10.5	19.2	0.0	3.9
70	Neals Creek near Goodland, Mo.	1995	Mining	42.1	19.9	2.5	0.3	1.5
71	Strother Creek near Oates, Mo.	1995	Mining	13.2	5.2	9.2	0.3	10.7
72	Strother Creek near Redmondville, Mo.	1995	Mining	70.1	6.7	0.6	0.3	2.6
73	West Fork Black River at Centerville, Mo.	1995	Mining	38.6	4.8	9.4	0.1	4.3
74	West Fork Black River at Centerville, Mo. (split)	1995	Mining	25.0	5.8	11.5	0.4	4.8
75	West Fork Black River at West Fork, Mo.	1995	Mining	36.5	18.6	3.7	0.5	3.2
76	West Fork Black River near Centerville, Mo.	1995	Mining	36.9	20.8	7.6	0.0	1.9
77	Kings River near Berryville, Ark.	1993	Mix	0.0	0.1	13.5	6.3	1.1
78	Kings River near Berryville, Ark.	1994	Mix	36.7	0.0	3.1	2.4	3.5
79	Kings River near Berryville, Ark.	1995	Mix	60.3	0.0	2.0	1.1	1.5
80	James River near Boaz, Mo.	1994	Urban	0.0	4.6	16.4	10.5	1.8
81	Center Creek near Smithfield, Mo.	1993	Urban/mining	12.7	1.0	65.1	63.8	0.1
82	Center Creek near Smithfield, Mo.	1994	Urban/mining	30.2	0.1	31.1	30.1	0.2
83	Center Creek near Smithfield, Mo.	1995	Urban/mining	62.7	0.0	20.7	19.2	0.1

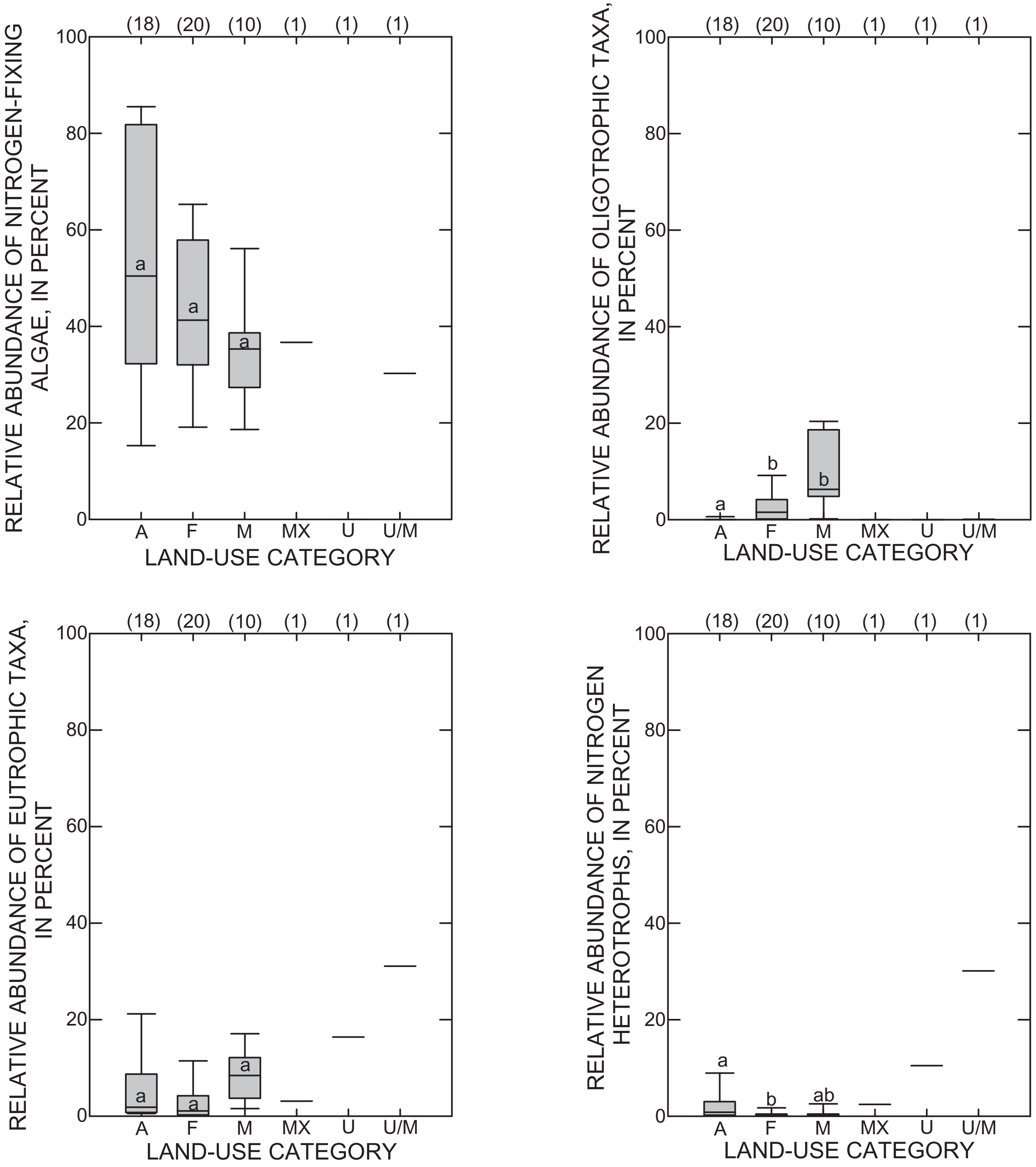

Figure 20. Distribution of relative abundance of taxa in selected autecological guilds by land-use category.

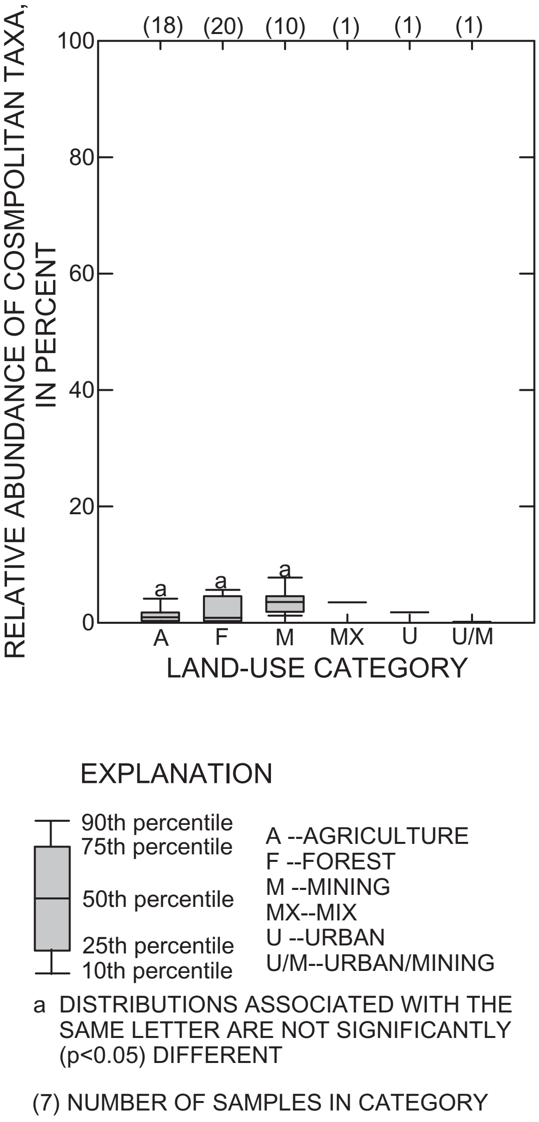

Figure 20. Distribution of relative abundance of taxa in selected autecological guilds by land-use category—Continued.

At most sites, nitrogen-fixing algae (which are able to use atmospheric nitrogen as a nutrient source) were the numerically dominant guild. Nitrogen-fixing algae frequently are abundant when dissolved nitrogen concentrations are low (Cuffney and others, 1997). Nitrogen fixing blue-green algae (*Calothrix* and *Anabaena)* were not strongly associated with low nitrogen concentrations; however five nitrogen-fixing diatoms (*Epithemia reichelti, E. turgida, E. adnata, E. sorex,* and *Rhopalodia gibba*) were strongly associated with low nitrogen concentrations (table 14). The median relative abundance of nitrogen-fixing algae exceeded 40 percent at sites in the agriculture and forest land-use categories (fig. 20); however, results did not differ significantly among categories. Nitrogen-fixing algae were somewhat less abundant at the mining, mix, and urban/mining sites, and substantially lower at the urban site. The relative abundances of nitrogen-fixing algae in samples from agriculture, forest, and mining sites were not statistically different.

The relative abundances of oligotrophic algae, which have a preference for low nutrient conditions, almost always were less than 10 percent at agriculture and forest sites and usually greater than 10 percent at mining sites (fig. 20). The relative abundance of oligotrophic algae at forest and mining sites was significantly different from the relative abundance at agriculture sites. The relative abundance of oligotrophic algae at mix, urban, and urban/mining sites was less than 1 percent.

The relative abundance of eutrophic algae, which have a requirement for elevated nutrient conditions, usually was less than 20 percent (fig. 20); however, the abundance of eutrophic algae did not differ statistically among agriculture, forest, and mining sites. In contrast, the relative abundance of eutrophic algae ranged from 16 to 65 percent at the urban and urban/mining sites (table 17). *Navicula minima* and *Nitzschia amphibia* were predominant taxa at both sites.

The distribution of facultative nitrogen heterotrophs, which are indicative of elevated organic nitrogen concentrations because they have the ability to use organic compounds as an energy source to supplement photosynthesis, was similar to eutrophic algae. Relative abundances of nitrogen heterotrophs almost always were less than 10 percent, but tended to be lowest at forest and mining sites. Relative abundances at agriculture and forest sites were statistically different from each other (fig. 20). Relative abundances of nitrogen heterotrophs ranged from 10 to 64 percent (table 17) at the urban and urban/mining sites; the heterotrophs *Navicula minima* and *Nitzschia amphibia* were dominant taxa at both sites.

The relative abundance of cosmopolitan algae (those designated cosmopolitan in the literature—see table 14) generally was less than 10 percent (fig. 20). The relative abundance of taxa that were designated as cosmopolitan because of weak correlation with nutrient concentrations (tables 14-15) were substantially higher (table 15, fig. 23) and typically exceeded 50 percent.

Effects of Grazers on Periphyton Communities

Several studies have indicated that grazers frequently affect the biomass (biovolume), taxonomic composition, species richness, and species diversity of periphyton communities (see a review of this topic in Steinman, 1996). Periphyton biomass frequently decreases in the presence of grazers. Changes in algal-species composition, richness, and diversity are less predictable.

Snails (*Elimia* and *Ferrissia* are two common genera) and stonerollers (*Campostoma anomalum* and *C. pullum*) are two groups of organisms that are major grazers of periphyton in Ozark streams. Estimates of snail density and stoneroller relative abundance are available for many of the periphyton-sample collection sites described in this report. Snail densities are from benthic macroinvertebrate samples collected at locations adjacent (within 1 m) to the periphyton sample collection locations. Stoneroller relative abundances are from collections from about 150- to 550-m reaches that included the periphyton sample collection locations.

Total periphyton biovolume typically was highest at sites where snail density was lowest (less than 150 snails per m^2), although biovolume often was low at sites with low snail densities (fig. 21). A similar relation exists between diatom biovolume and snail density (fig. 31); however, blue-green algae biovolume was not affected by snail density (fig. 21).

Unlike the biovolume and snail density relation, little relation was seen between total biovolume and stoneroller relative abundance (fig. 22). It may be that stoneroller relative abundance is not correlated closely enough with stoneroller density to effectively use relative abundance to examine stoneroller grazing effects. Another explanation may be that even relatively low relative abundances (equals densities?) of stonerollers can substantially affect periphyton biovolumes.

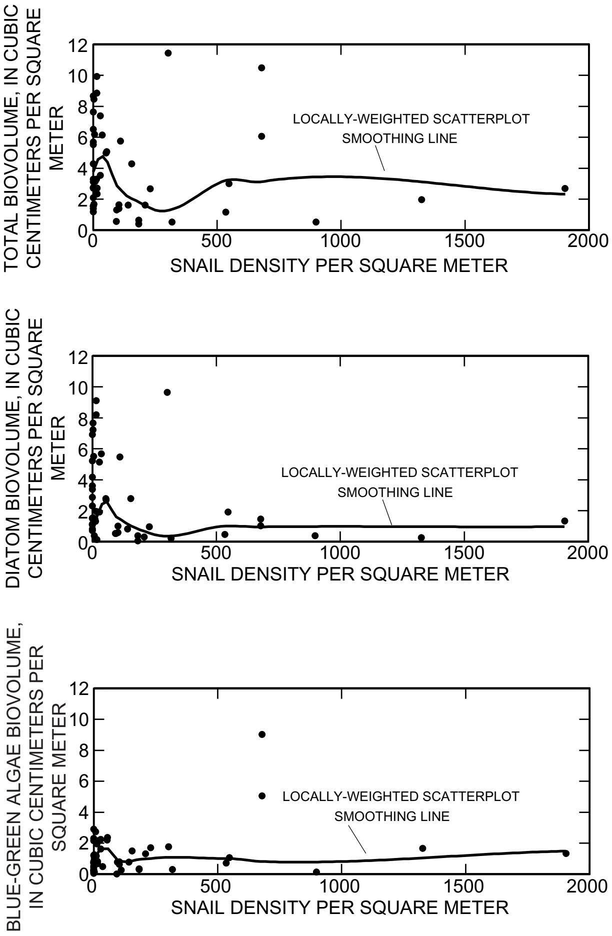

Figure 21. Relation between total biovolume, diatom biovolume, and blue-green algae biovolume and snail density.

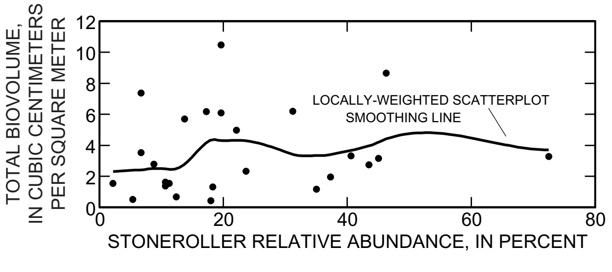

Figure 22. Relation between total biovolume and stoneroller relative abundance.

Snail density and stoneroller relative abundance both seem related to periphyton community composition. At sites where snail densities were less than about 400 snails per m^2, diatom relative abundance ranged from about 0 to 50 percent (fig. 23). At sites with greater snail densities, diatom relative abundances generally were less than 10 percent. Similar differences occurred between sites with stoneroller relative abundance values of less than 20 percent and the remaining sites (fig. 24). Any relation between diatom relative biovolume (and therefore blue-green algae biovolume, because almost all biovolume was contributed by diatoms or blue-green algae) and snail density or stoneroller relative abundance was less consistent (figs. 25 and 26). However, the highest diatom relative biovolumes occurred at the lowest snail densities and diatom relative biovolume almost always exceeded 40 percent where stoneroller relative abundance was less than 15 percent.

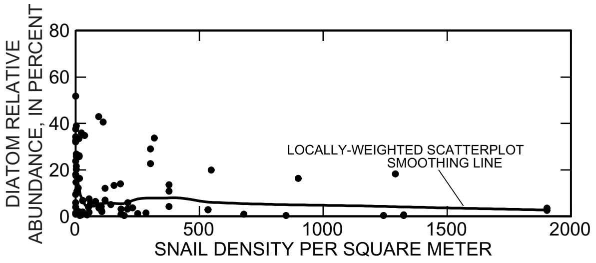

Figure 23. Relation between diatom relative abundance and snail density.

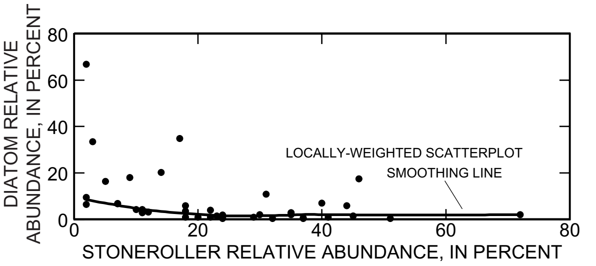

Figure 24. Relation between diatom relative abundance and stoneroller relative abundance.

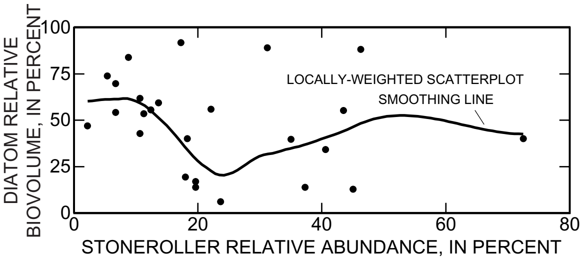

Figure 25. Relation between diatom relative biovolume and snail density.

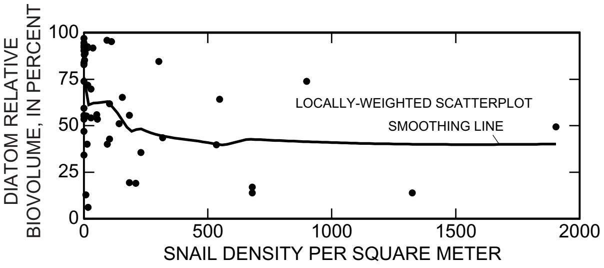

Figure 26. Relation between diatom relative biovolume and stoneroller relative abundance.

These results are somewhat consistent with findings by previous researchers. Using wooden troughs that effectively excluded snails (and presumably stonerollers) and that were placed in streams in the northern Ozarks, Lohman and others (1991) found that 85 to 97 percent of the biovolume was contributed by diatoms. Matthews and others (1987) reported a diatom-dominated community on tiles placed in troughs in the Baron Fork in northeastern Oklahoma and that when tiles were removed from the troughs, placed into the stream, and grazed upon by stonerollers, the community became dominated by blue-green algae (primarily *Calothrix, Phormidium*, and *Oscillatoria*).

Macroalgae

Qualitative samples collected throughout the sampling reach at each site also were analyzed. Because the samples were not collected from a specific area of known size, results are in terms of "presence" or "absence" of taxa. Qualitative samples were of two types—microalgae and macroalgae. The macroalgae samples primarily contained algae that were observed as attached or floating filaments.

Two genera of filamentous green algae, *Spirogyra* and *Oedogonium*, were the most commonly collected taxa in the macroalgae samples. *Spirogyra* was present in 26 of 80 (32 percent) macroalgae samples—30 percent of samples from agriculture sites, 40 percent of forest site samples, 31 percent of mining site samples, and 0 percent of other types of samples. *Oedogonium* was present in 19 of 80 (24 percent) samples—26 percent of agriculture site samples, 30 percent of forest site samples, 15 percent of mining site samples, and 0 percent of other types of samples. These data do not directly reflect the abundance of these two genera, but their presence in the macroalgae component of the qualitative samples indicates that these taxa were sufficiently abundant to form easily visible masses of algal material.

Although not restricted to these rivers (for example, see Gale, 1992), blooms of filamentous algae (which sometimes are extensive enough to be considered a nuisance by visitors to the rivers) have been reported from the three major rivers (Buffalo River, Current River, and Jacks Fork River) of the Buffalo National River and Ozark National Scenic Riverways. *Spirogyra* has been previously reported to occur as periphyton or as dense, floating masses of material in pools of the middle to lower parts of the Buffalo River, generally sometime during July through September (Rippey, 1976; Meyer and others, 1977; Meyer and Woomer, 1978). *Spirogyra* seems to occur most often in still areas of pools at the downstream edge of large point bars of gravel and in shallow areas along margins of pools (David Mott, National Park Service, oral commun., 2000). Its abundance in these areas may simply be associated with lower water velocity and higher water temperature in these areas, or may indicate higher nutrient concentrations in water flowing out of the gravel bars. *Spirogyra* was found in 60 percent of the macroalgae samples from sites on the mainstem of the Buffalo River. Blooms of filamentous algae also have been reported from the Current and Jacks Fork Rivers (Mike Gossett, National Park Service, written commun., 2000). Unlike blooms on the Buffalo River, blooms on the Current and Jacks Fork Rivers generally occur in the spring and seem to coincide with clear water conditions and low intensity rains.

Spirogyra and *Oedogonium* were absent or rare in the quantitative samples from riffles (and also pools) that are the subject of this report. *Spirogyra* was never detected in samples from riffles and only rarely detected in the samples from pools. One of the two detections from pools was in a sample from the Buffalo River near St. Joe, Ark., in 1995.

Under some circumstances, blooms of *Spirogyra* can be controlled by stoneroller grazing. In a study conducted in a small stream (stream width 2 to 5 m at base flow, base flow discharge of 0.01-0.02 m^3/s; Gelwick and Matthews, 1992) in south-central Oklahoma, Power and others (1985) manipulated distributions of stonerollers in a shallow pool (maximum depth 36 to 37 cm). Stonerollers were added to one side of a longitudinally-fenced pool that had been devoid of stonerollers. The stonerollers were able to control a bloom of *Spirogyra* that occurred on the side of the pool without stonerollers. Natural presence or absence of stonerollers in individual pools of this stream largely was determined by presence or absence of largemouth and spotted bass; stonerollers typically were not found in pools that contained bass. The pools of this stream typically are separated by long, shallow (often only 2 to 3 cm deep) riffles that can keep bass from moving between pools during low flow. This segregation of bass and stonerollers probably does not occur in larger streams of the Ozarks because of deeper riffles and possibly different feeding patterns of smallmouth bass, which are a more common Ozark black bass (Matthews and others, 1987; Power and others, 1985).

MULTIPLE-REACH AND MULTIPLE-YEAR COMPARISONS

Algal community data were collected during three consecutive years at seven sites to compare possible year-to-year changes in community structure. Results varied from little difference to substantial difference between years (table 18). Yocum Creek near Oak Grove, Ark., had the greatest variability in correlation values and the least correlation from year to year. Comparing the 1993 sample to the 1995 sample resulted in a negative correlation (Pearson method). Samples from Yocum Creek were not strongly correlated from year to year (r=-0.03 to 0.69, PSC=10 to 54 percent). The 1993 sample from Center Creek near Smithfield, Mo., was collected 6 days after a high streamflow event (table 2). This may have been the cause of the 1993 sample being substantially different from the 1994 and 1995 samples (r= 0.31 and 0.49, PSC=41 and 54 percent, respectively). The 1994 and 1995 samples were more similar, particularly as measured by Pearson correlation (r=0.85, PSC=57 percent). Algal community data from Buffalo River near Boxley, Ark., and Kings River near Berryville, Ark., also exhibited dissimilarities from year to year but to a lesser degree than the Yocum Creek and Center Creek data. Samples from North Sylamore Creek, Black River near Lesterville, Mo., and Buffalo River near St. Joe, Ark., showed substantial similarities among sampling years and exhibited little variability.

Table 18. Similarity and correlation of periphyton communities from multiple reaches during a single year and multiple years at a single reach

[U, upper; M, middle; L, lower]

Site	Percent similarity index					
	U-M	U-L	M-L	1993-1994	1993-1995	1994-1995
Yocum Creek	82	90	81	54	10	46
Buffalo River near Boxley	--	--	--	47	44	70
Center Creek	--	--	--	54	41	57
Kings River	--	--	--	60	29	53
Buffalo River near St. Joe	86	92	80	60	49	56
North Sylamore Creek	76	96	76	85	72	82
Black River	--	--	--	73	60	52
	Pearson correlation					
Site	**U-M**	**U-L**	**M-L**	**1993-1994**	**1993-1995**	**1994-1995**
Yocum Creek	0.97	0.99	0.96	0.69	-0.03	0.68
Buffalo River near Boxley	--	--	--	0.58	0.89	0.45
Center Creek	--	--	--	0.49	0.31	0.85
Kings River	--	--	--	0.97	0.53	0.32
Buffalo River near St. Joe	0.88	1.0	0.87	0.85	0.69	0.84
North Sylamore Creek	0.96	0.99	0.92	0.97	0.91	0.98
Black River	--	--	--	0.84	0.91	0.75

Data were collected from multiple reaches to determine longitudinal variability in community composition. Differences in substrate material, velocity, and canopy shading can have substantial effects on algal communities. Multiple reach samples were collected in 1993 at Yocum Creek and North Sylamore Creek, and in 1994 at the Buffalo River near St. Joe. Comparison of reach-to-reach data at each site indicated little variability in species composition (table 18).

Periphyton communities in adjacent stream reaches in a given year seem to be much more similar than communities at a given stream reach in different years. For example, PSC values for samples collected at adjacent reaches typically ranged from about 75 to 90 percent, whereas PSC values for samples collected in different years typically ranged from about 40 to 70 percent (table 18). This indicates that many factors important in determining periphyton community structure (such as antecedent hydrologic conditions, nutrient concentrations, velocity) vary more from year-to-year than from reach-to-reach.

POTENTIAL EFFECTS OF DIFFERENCES IN PERIPHYTON COMMUNITIES

Although an evaluation of the effects of differences in periphyton communities of Ozark streams on human uses and ecosystems was beyond the scope of this report, an overview of potential effects follows. Quinn (1991) lists several potential nuisance effects of excessive periphyton growth related to water supply, aesthetic appeal, recreation, and ecosystem protection. These include blockage of intake screens and filters of water supplies. Reduced clarity and altered color due to sloughed material, increased presence of floating mats, and slippery substrates that make wading more difficult are potential effects related to aesthetics and recreation. For example, anglers, floaters, and other visitors to Buffalo National River and Ozark National Scenic Riverways sometimes express concern about the presence of undesirable amounts of filamentous algae in the Buffalo, Current, and Jacks Fork Rivers during certain periods of most years (Dave Mott, National Park Service, oral commun., 2000; Mike Gossett, National Park Service, written commun., 2000). Diurnal fluctuations in pH or dissolved oxygen may stress sensitive species of invertebrates or fish, and dense mats covering the stream-bed may reduce intergravel flow and habitat quality for invertebrates and fish.

Lamberti (1996), in a review of the role of periphyton in benthic food webs, stated that studies of the chemical composition of algae indicate that the food quality of living algae is high compared to that of detritus. Colonial green algae appear to be especially nutritious and blue-green algae contain the highest nitrogen content. Based on biochemical considerations, the food value of blue-green algae is good but secondary chemicals may limit the palatability of blue-green algae to benthic grazers. Diatoms generally are considered to be a good food, but this is not indicated by the biochemical analyses. However, if ingestion and assimilation rates for diatoms are high, then low nutritive value may not be important.

Changes in the distribution of various algal growth forms (such as prostrate, stalked, or filamentous) also may be important. Some herbivores are less able to harvest periphyton with certain growth forms (Steinman, 1996). Changes in amounts or types of algal growth forms also may affect the availability of cover for invertebrates.

Matthews and others (1987) suggest communities dominated by *Calothrix* and other blue-green algae may alter nitrogen-cycling characteristics because of nitrogen fixation of atmospheric nitrogen. However, most diatoms (which flourish when stonerollers are excluded from grazing of periphyton; Matthews and others, 1987) do not fix nitrogen.

IMPLICATIONS FOR WATER-QUALITY ASSESSMENT

In general, use of periphyton communities in water-quality assessments has several advantages (Lowe and Pan, 1996; Barbour and others, 1999). Because algae are primary producers they are most directly affected by physical and chemical factors. Periphyton communities can be sensitive to concentrations of some contaminants (for example, nutrients) that may not noticeably affect other organisms. Sampling is relatively inexpensive because it does not require a large field crew and is relatively easy. Multiple measures of periphyton community structure and function can be used (such as biomass or biovolume, chlorophyll, taxa relative abundance, and autecological measures) to assess water quality based on several lines of evidence.

The relations between land use, water chemistry, other environmental factors, and periphyton communities discussed in this report have implications for water-quality assessments of Ozark streams. Periphyton communities can serve as a tool to indicate water-quality changes and, if water-quality changes are substantial, communities may change enough to have detrimental effects on human uses and stream ecology.

Autecological information based on correlations between nutrient concentrations and taxa relative abundances for samples from Ozark streams collected as part of the NAWQA program contributes information that should be useful for future investigations related to nutrients in Ozark streams. For example, the absence or low abundance of *Cymbella delicatula* in nutrient-enriched streams indicates that it would be a good species to use as an indicator of non-enriched conditions. Several other taxa were found to be correlated with nutrient concentrations in Ozark streams.

In Ozark streams, several water-quality factors were found to be important in determining periphyton communities. Among the most consistent of these were land use, nutrient concentration, and alkalinity. Other factors that can be important include canopy shading, velocity, stream morphometry, and grazing by stream fauna such as fish, snails, and aquatic insects.

The combined DCA results (i.e., relative abundance and biovolume data) indicated that periphyton taxa relative abundance values and taxa biovolume both are important in assessing differences in periphyton communities resulting from differences in water chemistry and other environmental factors. However, relative abundance was important for separating mining sites from sites in other land-use categories, while taxa biovolumes were more important in separating agriculture, urban/mining, and urban sites (sites that generally are nutrient enriched and receive more sunlight) from sites in other land-use categories.

Many of the periphyton community measures and analysis methods provided complementary results. For example, measures of community structure and function based on correlations between relative abundances of Ozark stream taxa and nutrient concentrations (the condition index) and on autecological guilds from the literature varied similarly among land-use categories. Biovolume DCA results and comparison of biovolume among land-use categories both indicated that nutrient-enriched sites and other sites support different periphyton communities.

The results also complement and are consistent with results from other components of NAWQA studies of water quality in the Ozarks. For example, Davis and Bell (1998) reported nutrient differences among streams in different land-use settings and Petersen (1998) reported fish community differences among many of the same streams. A consistent difference in fish communities was the larger relative abundance of algae-grazing stonerollers at sites in agricultural basins.

Periphyton communities of streams placed in agriculture, forest, and mining classifications exhibited general differences in characteristics related to biovolume, relative abundance, autecology, and nutrient preferences. Multivariate analyses (detrended correspondence analysis) also indicated differences in periphyton communities among the land-use classifications.

Results indicate that communities in agricultural streams generally will be characterized by higher (relative to communities from streams in forested basins or in forested basins with historical or on-going lead-zinc mining) relative abundances of taxa tolerant of nutrient enrichment, higher relative abundances of nitrogen heterotrophs, lower relative abundances of oligotrophic taxa, lower relative biovolume of *Cymbella delicatula* (which is a potential indicator species for low nutrient concentrations in Ozark streams), and lower values of the condition index derived from the data described in this report. Detrended correspondence analysis (DCA) based on relative biovolume data separated sites in a manner that generally was consistent with the *a priori* land-use classifications. Most agriculture streams (as well as other streams with nutrient enrichment) were separated from most forest and mining streams (which had lower nutrient concentrations). These findings are consistent with significantly higher nitrate, phosphorus, and dissolved organic carbon concentrations typical of these agricultural streams, indicative of nutrient and organic enrichment.

Results also indicate that communities from streams in forested basins associated with lead-zinc mining generally will be characterized by lower (relative to communities from streams in forested basins or agricultural basins) relative abundances of blue-green algae and higher relative abundances and relative biovolume of diatoms. DCA based on relative abundance data separated sites in a manner that also indicated that communities of streams in basins with on-going lead-zinc mining were different from communities in other basins. These findings suggest that trace-element concentrations directly or indirectly are causing a shift toward communities dominated by diatoms.

Results indicate that total biovolume, blue-green algae biovolume, and diatom biovolume often will not be larger in agricultural streams than in forest or mining streams; however, diatom biovolume was significantly and negatively correlated with orthophosphate, total phosphorus, and dissolved organic carbon concentrations. Grazing by stonerollers, snails, and aquatic insects probably is an important factor in determining periphyton biovolume in Ozark streams and maintaining biovolume from streams with nutrient and organic enrichment at levels more similar to biovolume of non-enriched streams than if grazing did not occur.

SUMMARY

During August through September of 1993-95, 83 periphyton samples were collected at 51 stream sites in the Ozark Plateaus. These sites were classified into six land-use categories (forest, agriculture, mining, urban, urban/mining, and mix), based on land-use percentages in the basin upstream from the site.

Results indicate that periphyton communities of riffles in Ozark streams are affected by both natural and human factors. These factors include nutrients, dissolved organic carbon, alkalinity, canopy shading, suspended sediment, embeddedness, stream morphometry, and velocity.

For several measures of periphyton communities, statistically significant differences were found among groups of sites assigned to agriculture, forest, and mining land-use categories (table 19). For several other measures of periphyton communities, differences among the site groups were not significantly different.

Relative biovolume of *Cymbella delicatula* and relative abundance of oligotrophic algae were significantly different and lower at agriculture sites than at forest and mining sites. Relative abundances of nitrogen heterotrophs (higher at agriculture sites) and tolerant taxa (higher) and condition index values (lower) were significantly different between agriculture and forest sites. Mining sites were associated with higher relative abundance of diatoms and lower relative abundance of blue-green algae compared to agriculture and mining sites. Relative biovolume of diatoms was greater at mining sites than at agriculture sites.

Table 19. Summary of effects of land use on periphyton community characteristics and environmental factors

[= signifies that values associated with land-use categories are not significantly different (p<0.05), > signifies that values associated with the preceding land-use category are significantly different (p<0.05) and larger than the second category, < signifies that values associated with the preceding land-use category are significantly different (p<0.05) and smaller than the second category)

Periphyton community characteristic	Comparison among land-use categories
Total biovolume	Agriculture=Forest=Mining
Diatom biovolume	Agriculture=Forest=Mining
Shannon-Wiener diversity	Agriculture=Forest=Mining
Calothrix relative abundance	Agriculture=Forest=Mining
Calothrix relative biovolume	Agriculture=Forest=Mining
Cymbella affinis relative biovolume	Agriculture=Forest=Mining
Richness	Agriculture=Forest=Mining
Nitrogen fixers relative abundance	Agriculture=Forest=Mining
Eutrophic algae relative abundance	Agriculture=Forest=Mining
Cosmopolitan algae relative abundance	Agriculture=Forest=Mining
Cymbella delicatula relative biovolume	Agriculture<Forest=Mining
Oligotrophic algae relative abundance	Agriculture<Forest=Mining
Blue-green algae biovolume	Agriculture>Mining, Agriculture=Forest, Forest=Mining
Nitrogen heterotrophs relative abundance	Agriculture>Forest, Forest=Mining, Agriculture=Mining
Tolerant taxa relative abundance	Agriculture>Forest, Forest=Mining, Agriculture=Mining,
Condition index	Forest>Agriculture, Agriculture=Mining, Forest=Mining
Blue-green algae relative abundance	Mining<Agriculture=Forest
Diatom relative abundance	Mining>Agriculture=Mining
Diatom relative biovolume	Mining>Agriculture, Agriculture=Forest, Forest=Mining

Periphyton biomass (or biovolume) frequently is a characteristic of interest to water-resources managers and others. Total algal biovolumes did not differ statistically among agriculture, forest, and mining sites. Biovolume of blue-green algae often was highest at agriculture sites and lower at forest and mining sites. However, biovolume of blue-green algae at agriculture sites was significantly different only from mining sites. No statistical differences in diatom biovolumes were found among land-use categories.

Although no environmental factors were significantly correlated with total biovolume, biovolume of diatoms was significantly and positively correlated with alkalinity and negatively correlated with embeddedness, orthophosphate, total phosphorus, and dissolved organic carbon.

Diatoms often composed the largest percentage of the biovolume (relative biovolume). Diatoms almost always composed the largest percentages of the biovolume in samples from mining sites. The highest relative biovolumes of diatoms generally were at mining sites and the lowest were at agriculture sites. Diatom relative biovolume was much higher at mining sites (generally 75 to 90 percent of the total biovolume) than at forest or agriculture sites (generally 15 to 80 percent).

Relative biovolume of diatoms was correlated with several factors, including many land-use related factors. Relative biovolume of diatoms was significantly and positively correlated with sample depth, lead in bed sediment, and alkalinity, and negatively correlated with embeddedness, orthophosphate, total phosphorus, and dissolved organic carbon.

At forest and agriculture sites the largest percentages of diatom biovolume generally were of *Cymbella affinis*, *Cymbella delicatula* (at forest sites only), *Gomphonema* sp., *Achnanthidium minutissimum*, *Rossithidium pusillum*, and *Cymbella turgidula*. Several other diatom species (notably *Epithemia sorex, Epithemia turgida, Epithemia reichelti, Gomphonema apuncto,* and *Reimeria sinuata antiqua*) made up a large percentage of the biovolume at some sites.

Diatom species comprising the largest percentage of the biovolume at mining sites were *Cymbella affinis*, *Cymbella delicatula*, and *Rossithidium pusillum*. *Navicula minima* (a eutrophic species) composed nearly 40 percent of the biovolume at the urban/mining site (Center Creek near Smithfield, Mo.) but less than 1 percent of the biovolume at the mining sites that do not have a substantial urban influence.

The relative biovolume of *Calothrix*, a nitrogen-fixing, filamentous blue-green algae, usually exceeded 10 percent at agriculture and forest sites. Relative biovolume of *Calothrix* was substantially lower, usually less than 10 percent, at mining sites.

Blue-green algal cells almost always comprised the largest percentage (relative abundance) of the periphyton community; diatoms were the next most common component. In terms of relative abundance, blue-green algae generally accounted for greater than 60 percent of the periphyton community. Diatoms generally composed 5 to 40 percent of the periphyton; highest relative abundances generally were at mining, urban/mining, and urban sites. Green algae were the next most common algae, but the relative abundance of green algae generally was less than 1 percent.

Calothrix, a nitrogen-fixing, filamentous blue-green algae, appears to be abundant and nearly ubiquitous in Ozark streams, with a median relative abundance of 42 percent. Two other filamentous genera, *Lyngbya* and *Oscillatoria*, were the only other common blue-green algae in these samples.

Among all samples, the most common diatoms (based on relative abundance) were *Achnanthidium minutissimum, Cymbella affinis, Cocconeis placentula euglypta*, an unidentified *Gomphonema* species, *Rossithidium pusillum*, and *Reimeria sinuata*. *Achnanthidium minutissimum, Rossithidium pusillum, Cymbella delicatula, Cymbella affinis*, and *Navicula minima* were substantially more common and abundant than other diatoms in samples from mining or urban/mining sites. *N. minima (*a eutrophic species) was abundant at the urban/mining site but not at the mining sites that do not have a substantial urban influence. *C. affinis* and *C. delicatula* and *R. pusillum* typically were absent at the urban/mining site.

Several other measures of periphyton community structure (including diversity, relative abundance of blue-green algae or diatoms, condition index, and relative abundance of autecological guilds), as well as results of multivariate analyses, were correlated with natural and land-use related factors or were significantly different among land-use categories. For example, diversity was greatest at sites with greater alkalinity. Relative abundance of blue-green algae was significantly and negatively correlated with alkalinity, woody vegetation density, total triazines, percent canopy shading, and suspended sediment and positively correlated with embeddedness. Condition index values were significantly correlated with nutrients and percent land use. Eutrophic and nitrogen heterotrophic algae relative abundances in samples from the urban and urban/mining sites were substantially higher than in most samples from other land-use categories. Detrended correspondence analysis results (biovolume or relative abundance) were correlated with a number of factors including nutrients, land-use percentages, dissolved organic carbon, triazines, canopy shading, channel morphometry, and suspended sediment. Hierarchical cluster analysis yielded differences by land-use category.

Periphyton communities in adjacent stream reaches in a single year seem to be much more similar than communities in the same stream reach in different years. For example, percentage similarity index (PSC) values for samples collected at adjacent reaches typically ranged from about 75 to 90 percent, whereas PSC values for samples collected in different years typically ranged from about 40 to 70 percent. This indicates that many factors important in determining periphyton community structure (such as antecedent hydrologic conditions, nutrient concentrations, and velocity) vary more from year-to-year than from reach-to-reach.

Grazers (specifically, snails and stonerollers) are related to periphyton biovolume and community composition. Total periphyton and diatom biovolume typically was highest at sites where snail density was lowest (less than 150 snails per m^2), although biovolume often was low at sites with low snail densities. Unlike the biovolume and snail density relation, little relation was seen between biovolume and stoneroller relative abundance.

Periphyton community composition appears related to snail density and stoneroller relative abundance. At sites where snail densities were less than about 400 snails per m^2, diatom relative abundance ranged from about 0 to 50 percent. Diatom relative abundances generally were less than 10 percent at sites with greater snail densities. Similar differences occurred between sites with less than 20 percent relative abundance of stonerollers and remaining sites.

Filamentous green algae rarely were detected in samples from riffles (or pools), but two genera of filamentous green algae, *Spirogyra* and *Oedogonium*, commonly were collected taxa in qualitative macroalgae samples. *Spirogyra* was present in 26 of 80 (32 percent) macroalgae samples.

The relations between land use, water chemistry, other environmental factors, and periphyton communities discussed in this report have implications for water-quality assessments of Ozark streams. Periphyton communities can serve as a tool to indicate water-quality changes and can potentially change enough to have detrimental effects on human uses and stream ecology. Autecological information based on samples from Ozark streams collected as part of the National Water-Quality Assessment program contributes information that should be useful for future investigations related to nutrients in Ozark streams. Periphyton communities of streams placed in agriculture, forest, and mining classifications exhibited general differences in several characteristics. Results indicate that communities from agricultural streams generally will be characterized by periphyton communities consistent with significantly higher nitrate, phosphorus, and dissolved organic carbon concentrations typical of these agricultural streams. Results also indicate that communities from streams in forested basins associated with lead-zinc mining generally will be characterized by communities different from communities in other basins. These findings indicate that trace-element concentrations directly or indirectly are causing a shift toward communities dominated by diatoms. Results indicate that total biovolume, blue-green algae biovolume, and diatom biovolume often will not be larger in agricultural streams than in forest or mining streams; however, diatom biovolume was significantly and negatively correlated with orthophosphate, total phosphorus, and dissolved organic carbon concentrations. Grazing by stonerollers, snails, and aquatic insects probably is an important factor in determining periphyton biovolume in Ozark streams.

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Table 20. Sample numbers, site characteristics, and associated environmental factors

[km^2, square kilometer; lower, middle, and upper are reach designations; split designates a second sample collected at a site; m^2, square meter; estimated value assuming a phosphorus concentration of 0.005 mg/L; µg/g, micrograms per gram; <, less than; --, no data]

Sample number	Site name	Year	Land-use category	Reach width (meters)	Reach depth (meters)	Width to depth (ratio)	Sample depth (meters)
1	Big Creek at Mauser Mill, Mo.	1994	Forest	20.3	0.30	68.4	0.50
2	Big Creek near Big Flat, Ark.	1994	Forest	8.6	0.28	30.6	0.20
3	Big Creek near Rat, Mo.	1995	Forest	4.8	0.14	34.3	0.13
4	Big Piney River near Big Piney, Mo.	1994	Forest	41.7	0.64	65.5	0.51
5	Buffalo River near Boxley, Ark.	1993	Forest	27.4	0.62	44.3	0.21
6	Buffalo River near Boxley, Ark.	1994	Forest	27.4	0.62	44.3	0.07
7	Buffalo River near Boxley, Ark.	1995	Forest	27.4	0.62	44.3	0.07
8	Buffalo River near Eula, Ark.	1994	Forest	14.2	0.59	24.1	0.28
9	Buffalo River near St. Joe, Ark. (lower)	1993	Forest	24.6	0.82	29.9	0.27
10	Buffalo River near St. Joe, Ark. (lower)	1994	Forest	24.6	0.82	29.9	0.24
11	Buffalo River near St. Joe, Ark. (lower)	1995	Forest	24.6	0.82	29.9	0.19
12	Buffalo River near St. Joe, Ark. (middle)	1994	Forest	24.6	0.71	34.8	0.23
13	Buffalo River near St. Joe, Ark. (upper)	1994	Forest	29.8	0.60	50.0	0.23
14	Buffalo River near St. Joe, Ark. (upper) (split)	1994	Forest	29.8	0.60	50.0	0.23
15	Current River at Van Buren, Mo.	1995	Forest	97.0	1.30	74.6	0.36
16	Current River below Akers, Mo.	1994	Forest	35.3	0.44	79.5	0.46
17	Current River below Akers, Mo. (split)	1994	Forest	35.3	0.44	79.5	0.46
18	Jacks Fork River at Alley Spring, Mo.	1994	Forest	23.7	0.29	80.6	0.28
19	Middle Fork Black River at Redmondville, Mo.	1995	Forest	9.4	0.21	44.8	0.14
20	Mikes Creek at Powell, Mo.	1994	Forest	11.4	0.56	20.4	0.19
21	Noblett Creek near Willow Springs, Mo.	1994	Forest	14.3	0.26	54.6	0.18
22	North Fork White River near Dora, Mo.	1994	Forest	23.2	0.45	51.6	0.17
23	North Sylamore Creek near Fifty Six, Ark. (lower)	1993	Forest	9.1	0.32	28.4	0.14
24	North Sylamore Creek near Fifty Six, Ark. (lower)	1994	Forest	9.1	0.32	28.4	0.14
25	North Sylamore Creek near Fifty Six, Ark. (lower)	1995	Forest	9.1	0.32	28.4	0.08
26	North Sylamore Creek near Fifty Six, Ark. (middle)	1993	Forest	11.5	0.40	28.5	0.17
27	North Sylamore Creek near Fifty Six, Ark. (upper)	1993	Forest	12.4	0.42	29.5	0.29
28	Paddy Creek above Slabtown Spring, Mo.	1994	Forest	7.3	0.38	19.1	0.21
29	Paddy Creek above Slabtown Spring, Mo. (split)	1994	Forest	7.3	0.38	19.1	0.21

mg/L, milligrams per liter; µg/L, micrograms per liter; $CaCO_3$, calcium carbonate; E, indicates that nitrogen to phosphorus ratio is an

Velocity (meters per second)	Canopy shading (percent)	Woody vegetation density (individuals per 100 m^2)	Embedded-ness (percent)	Substrate	Site name	Sample number
0.52	54	26.61	51-75	gravel/cobble	Big Creek at Mauser Mill, Mo.	1
0.53	61	6.44	5-25	cobble	Big Creek near Big Flat, Ark.	2
0.43	66	20.20	26-50	boulder	Big Creek near Rat, Mo.	3
0.84	46	8.66	5-25	gravel	Big Piney River near Big Piney, Mo.	4
0.35	62	8.00	26-50	cobble/boulder	Buffalo River near Boxley, Ark.	5
0.30	62	8.00	5-25	cobble	Buffalo River near Boxley, Ark.	6
0.15	62	8.00	5-25	boulder	Buffalo River near Boxley, Ark.	7
0.51	18	0.39	5-25	cobble	Buffalo River near Eula, Ark.	8
0.50	41	2.76	5-25	cobble/boulder	Buffalo River near St. Joe, Ark. (lower)	9
0.70	41	2.76	5-25	cobble	Buffalo River near St. Joe, Ark. (lower)	10
0.73	41	2.76	51-75	gravel/boulder	Buffalo River near St. Joe, Ark. (lower)	11
0.64	38	6.80	<5	boulder	Buffalo River near St. Joe, Ark. (middle)	12
0.64	36	6.30	5-25	cobble	Buffalo River near St. Joe, Ark. (upper)	13
0.64	36	6.30	5-25	cobble	Buffalo River near St. Joe, Ark. (upper) (split)	14
0.42	39	14.90	26-50	cobble	Current River at Van Buren, Mo.	15
0.86	43	13.31	26-50	cobble	Current River below Akers, Mo.	16
0.86	43	13.31	26-50	cobble	Current River below Akers, Mo. (split)	17
0.81	36	6.78	26-50	cobble	Jacks Fork River at Alley Spring, Mo.	18
0.47	47	19.40	5-25	gravel	Middle Fork Black River at Redmondville, Mo.	19
0.41	67	8.82	5-25	cobble	Mikes Creek at Powell, Mo.	20
0.46	83	8.23	5-25	cobble	Noblett Creek near Willow Springs, Mo.	21
0.39	65	12.25	5-25	cobble	North Fork White River near Dora, Mo.	22
0.59	56	22.50	5-25	cobble	North Sylamore Creek near Fifty Six, Ark. (lower)	23
0.29	56	22.50	5-25	cobble	North Sylamore Creek near Fifty Six, Ark. (lower)	24
0.28	56	22.50	5-25	cobble	North Sylamore Creek near Fifty Six, Ark. (lower)	25
0.52	59	14.80	26-50	cobble	North Sylamore Creek near Fifty Six, Ark. (middle)	26
0.38	58	10.10	5-25	cobble	North Sylamore Creek near Fifty Six, Ark. (upper)	27
0.42	75	23.20	26-50	cobble	Paddy Creek above Slabtown Spring, Mo.	28
0.42	75	23.20	26-50	cobble	Paddy Creek above Slabtown Spring, Mo. (split)	29

Table 20. Sample numbers, site characteristics, and associated environmental factors--Continued

[km^2, square kilometer; lower, middle, and upper are reach designations; split designates a second sample collected at a site; m^2, square meter; estimated value assuming a phosphorus concentration of 0.005 mg/L; µg/g, micrograms per gram; <, less than; --, no data]

Sample number	Site name	Year	Land-use category	Reach width (meters)	Reach depth (meters)	Width to depth (ratio)	Sample depth (meters)
30	Paddy Creek above Slabtown Spring, Mo.	1995	Forest	7.3	0.38	19.1	0.18
31	Paddy Creek above Slabtown Spring, Mo. (split)	1995	Forest	7.3	0.38	19.1	0.18
32	Richland Creek near Witts Springs, Ark.	1994	Forest	15.9	0.33	48.6	0.25
33	Rogers Creek near Van Buren, Mo.	1994	Forest	6.4	0.11	60.4	0.11
34	Water Creek near Evening Star, Ark.	1994	Forest	7.7	0.18	42.1	0.18
35	West Fork Black River near Greeley, Mo.	1995	Forest	7.0	0.27	26.0	0.20
36	West Fork Black River near Greeley, Mo. (split)	1995	Forest	7.0	0.27	26.0	0.20
37	Baron Fork at Eldon, Okla.	1994	Agriculture	15.0	0.65	23.1	0.31
38	Brush Creek above Collins, Mo.	1994	Agriculture	4.9	0.28	17.4	0.06
39	Dousinbury Creek near Wall Street, Mo.	1994	Agriculture	23.6	0.52	45.0	0.18
40	Dousinbury Creek near Wall Street, Mo.	1995	Agriculture	23.6	0.52	45.0	0.13
41	Elk River near Tiff City, Mo.	1994	Agriculture	60.8	0.75	81.1	0.38
42	Illinois River near Tahlequah, Okla.	1994	Agriculture	51.3	0.70	73.7	0.20
43	Little Osage Creek near Healing Spring, Ark.	1994	Agriculture	11.6	0.47	24.8	0.18
44	Little Tavern Creek near St. Elizabeth, Mo.	1994	Agriculture	11.1	0.44	25.3	0.32
45	Maries River near Freeburg, Mo.	1994	Agriculture	31.3	0.29	107.6	0.13
46	Niangua River near Windyville, MO	1994	Agriculture	21.9	0.61	36.1	0.38
47	Niangua River near Windyville, Mo. (split)	1994	Agriculture	21.9	0.61	36.1	0.38
48	North Indian Creek near Wanda, Mo.	1994	Agriculture	10.4	0.31	34.1	0.21
49	Osage Fork near Russ, Mo.	1994	Agriculture	60.8	0.44	138.5	0.29
50	Peacheater Creek at Christie, Okla.	1994	Agriculture	5.4	0.35	15.6	0.10
51	Pomme de Terre near Polk, Mo.	1994	Agriculture	18.1	0.30	60.5	0.13
52	Sac River near Dadeville, Mo.	1994	Agriculture	10.7	0.50	21.4	0.13
53	Strawberry River near Poughkeepsie, Ark.	1994	Agriculture	25.2	0.32	79.2	0.21
54	War Eagle Creek near Hindsville, Ark.	1994	Agriculture	27.3	0.69	39.5	0.16
55	War Eagle Creek near Hindsville, Ark. (split)	1994	Agriculture	27.3	0.69	39.5	0.16
56	Woods Fork near Hartville, Mo.	1994	Agriculture	20.3	0.22	90.6	0.13
57	Yocum Creek near Oak Grove, Ark. (lower)	1993	Agriculture	13.7	0.49	27.9	0.20
58	Yocum Creek near Oak Grove, Ark. (middle)	1993	Agriculture	13.0	0.45	29.0	0.21
59	Yocum Creek near Oak Grove, Ark. (middle)	1994	Agriculture	13.0	0.45	29.0	0.09

mg/L, milligrams per liter; µg/L, micrograms per liter; $CaCO_3$, calcium carbonate; E, indicates that nitrogen to phosphorus ratio is an

Velocity (meters per second)	Canopy shading (percent)	Woody vegetation density (individuals per 100 m^2)	Embeddedness (percent)	Substrate	Site name	Sample number
0.19	75	23.20	26-50	cobble	Paddy Creek above Slabtown Spring, Mo.	30
0.19	75	23.20	26-50	cobble	Paddy Creek above Slabtown Spring, Mo. (split)	31
0.30	65	2.14	26-50	boulder	Richland Creek near Witts Springs, Ark.	32
0.44	74	21.34	51-75	gravel	Rogers Creek near Van Buren, Mo.	33
0.19	62	6.60	5-25	boulder/cobble	Water Creek near Evening Star, Ark.	34
0.61	61	30.50	51-75	cobble	West Fork Black River near Greeley, Mo.	35
0.61	61	30.50	51-75	cobble	West Fork Black River near Greeley, Mo. (split)	36
0.78	50	2.75	26-50	cobble	Baron Fork at Eldon, Okla.	37
0.18	52	10.42	5-25	cobble	Brush Creek above Collins, Mo.	38
0.52	25	6.40	26-50	bedrock	Dousinbury Creek near Wall Street, Mo.	39
0.27	25	6.40	26-50	cobble	Dousinbury Creek near Wall Street, Mo.	40
0.69	29	25.00	5-25	cobble	Elk River near Tiff City, Mo.	41
0.55	33	5.45	5-25	cobble	Illinois River near Tahlequah, Okla.	42
0.47	35	3.02	5-25	cobble	Little Osage Creek near Healing Spring, Ark.	43
0.74	37	12.54	51-75	sand/gravel	Little Tavern Creek near St. Elizabeth, Mo.	44
0.35	46	8.22	26-50	cobble	Maries River near Freeburg, Mo.	45
0.85	46	10.80	26-50	cobble	Niangua River near Windyville, MO	46
0.85	46	10.80	26-50	cobble	Niangua River near Windyville, Mo. (split)	47
0.59	81	5.43	5-25	cobble	North Indian Creek near Wanda, Mo.	48
0.58	31	19.30	26-50	sand/gravel	Osage Fork near Russ, Mo.	49
0.40	43	4.06	26-50	cobble	Peacheater Creek at Christie, Okla.	50
0.43	31	6.54	5-25	boulder	Pomme de Terre near Polk, Mo.	51
0.46	63	5.45	5-25	cobble	Sac River near Dadeville, Mo.	52
0.54	47	2.52	5-25	cobble	Strawberry River near Poughkeepsie, Ark.	53
0.63	46	4.22	26-50	cobble	War Eagle Creek near Hindsville, Ark.	54
0.63	46	4.22	26-50	cobble	War Eagle Creek near Hindsville, Ark. (split)	55
0.19	52	5.94	5-25	cobble	Woods Fork near Hartville, Mo.	56
0.66	53	5.64	26-50	cobble	Yocum Creek near Oak Grove, Ark. (lower)	57
0.66	49	3.22	26-50	gravel	Yocum Creek near Oak Grove, Ark. (middle)	58
0.50	49	3.22	5-25	gravel	Yocum Creek near Oak Grove, Ark. (middle)	59

Table 20. Sample numbers, site characteristics, and associated environmental factors--Continued

[km^2, square kilometer; lower, middle, and upper are reach designations; split designates a second sample collected at a site; m^2, square meter; estimated value assuming a phosphorus concentration of 0.005 mg/L; µg/g, micrograms per gram; <, less than; --, no data]

Sample number	Site name	Year	Land-use category	Reach width (meters)	Reach depth (meters)	Width to depth (ratio)	Sample depth (meters)
60	Yocum Creek near Oak Grove, Ark. (middle) (split)	1994	Agriculture	13.0	0.45	29.0	0.09
61	Yocum Creek near Oak Grove, Ark. (middle)	1995	Agriculture	13.0	0.45	29.0	0.12
62	Yocum Creek near Oak Grove, Ark. (middle) (split)	1995	Agriculture	13.0	0.45	29.0	0.12
63	Yocum Creek near Oak Grove, Ark. (upper)	1993	Agriculture	13.6	0.42	32.2	0.21
64	Big River near Richwoods, Mo.	1994	Mining	48.8	0.72	67.6	0.94
65	Black River near Lesterville, Mo.	1993	Mining	29.8	0.64	46.7	0.43
66	Black River near Lesterville, Mo.	1994	Mining	29.8	0.64	46.7	0.77
67	Black River near Lesterville, Mo.	1995	Mining	29.8	0.64	46.7	0.29
68	Huzzah Creek near Scotia, Mo.	1994	Mining	23.2	0.69	33.5	0.54
69	Middle Fork Black River at Black, Mo.	1995	Mining	12.6	0.59	21.5	0.21
70	Neals Creek near Goodland, Mo.	1995	Mining	7.9	0.18	43.9	0.12
71	Strother Creek near Oates, Mo.	1995	Mining	4.2	0.28	15.0	0.23
72	Strother Creek near Redmondville, Mo.	1995	Mining	8.2	0.26	31.4	0.27
73	West Fork Black River at Centerville, Mo.	1995	Mining	20.0	0.41	48.8	0.19
74	West Fork Black River at Centerville, Mo. (split)	1995	Mining	20.0	0.41	48.8	0.19
75	West Fork Black River at West Fork, Mo.	1995	Mining	13.8	0.62	22.3	0.20
76	West Fork Black River near Centerville, Mo.	1995	Mining	13.5	0.24	56.3	0.18
77	Kings River near Berryville, Ark.	1993	Mix	28.2	0.80	35.3	0.57
78	Kings River near Berryville, Ark.	1994	Mix	28.2	0.80	35.3	0.19
79	Kings River near Berryville, Ark.	1995	Mix	28.2	0.80	35.3	0.13
80	James River near Boaz, Mo.	1994	Urban	49.8	0.43	116.1	0.29
81	Center Creek near Smithfield, Mo.	1993	Urban/mining	20.2	0.52	38.7	0.50
82	Center Creek near Smithfield, Mo.	1994	Urban/mining	20.2	0.52	38.7	0.16
83	Center Creek near Smithfield, Mo.	1995	Urban/mining	20.2	0.52	38.7	0.24

mg/L, milligrams per liter; µg/L, micrograms per liter; $CaCO_3$, calcium carbonate; E, indicates that nitrogen to phosphorus ratio is an

Velocity (meters per second)	Canopy shading (percent)	Woody vegetation density (individuals per 100 m^2)	Embedded-ness (percent)	Substrate	Site name	Sample number
0.50	49	3.22	5-25	gravel	Yocum Creek near Oak Grove, Ark. (middle) (split)	60
0.46	49	3.22	26-50	gravel	Yocum Creek near Oak Grove, Ark. (middle)	61
0.46	49	3.22	26-50	gravel	Yocum Creek near Oak Grove, Ark. (middle) (split)	62
0.70	27	23.00	51-75	gravel	Yocum Creek near Oak Grove, Ark. (upper)	63
0.62	51	6.87	51-75	gravel	Big River near Richwoods, Mo.	64
0.69	51	6.87	51-75	cobble	Black River near Lesterville, Mo.	65
0.41	51	6.87	5-25	gravel	Black River near Lesterville, Mo.	66
0.26	51	6.87	51-75	boulder	Black River near Lesterville, Mo.	67
0.62	57	5.38	5-25	cobble/gravel/sand	Huzzah Creek near Scotia, Mo.	68
0.62	47	4.40	26-50	cobble	Middle Fork Black River at Black, Mo.	69
0.31	56	8.60	26-50	cobble	Neals Creek near Goodland, Mo.	70
0.66	54	10.10	51-75	cobble	Strother Creek near Oates, Mo.	71
0.57	44	14.10	26-50	cobble	Strother Creek near Redmondville, Mo.	72
0.66	23	16.40	5-25	gravel	West Fork Black River at Centerville, Mo.	73
0.66	23	16.40	5-25	gravel	West Fork Black River at Centerville, Mo. (split)	74
0.61	47	6.85	5-25	cobble	West Fork Black River at West Fork, Mo.	75
0.39	46	17.65	5-25	cobble	West Fork Black River near Centerville, Mo.	76
0.76	47	8.55	26-50	gravel	Kings River near Berryville, Ark.	77
0.49	47	8.55	26-50	cobble	Kings River near Berryville, Ark.	78
0.46	47	8.55	5-25	gravel	Kings River near Berryville, Ark.	79
0.41	42	13.63	26-50	gravel	James River near Boaz, Mo.	80
0.96	39	3.70	5-25	cobble	Center Creek near Smithfield, Mo.	81
0.52	39	3.70	5-25	cobble	Center Creek near Smithfield, Mo.	82
0.66	39	3.70	5-25	gravel	Center Creek near Smithfield, Mo.	83

Table 20. Sample numbers, site characteristics, and associated environmental factors--Continued

[km^2, square kilometer; lower, middle, and upper are reach designations; split designates a second sample collected at a site; m^2, square meter; estimated value assuming a phosphorus concentration of 0.005 mg/L; µg/g, micrograms per gram; <, less than; --, no data]

					Molar nitrogen to phosphorus ratio	
Sample number	Site name	Dissolved nitrite plus nitrate as nitrogen (mg/L)	Dissolved orthophosphorus as phosphorus (mg/L)	Total phosphorus as phosphorus (mg/L)	Nitrate to total phosphorus	Nitrate to dissolved orthophosphorus
1	Big Creek at Mauser Mill, Mo.	0.025	<0.010	<0.010	E11.1	E11.1
2	Big Creek near Big Flat, Ark.	0.190	0.020	0.020	21.0	21.0
3	Big Creek near Rat, Mo.	0.250	<0.010	<0.010	E110.7	E110.7
4	Big Piney River near Big Piney, Mo.	0.330	0.010	0.010	73.1	73.1
5	Buffalo River near Boxley, Ark.	0.025	<0.010	0.010	5.5	E11.1
6	Buffalo River near Boxley, Ark.	0.025	<0.010	<0.010	E11.1	E11.1
7	Buffalo River near Boxley, Ark.	0.025	<0.010	0.020	2.8	E11.1
8	Buffalo River near Eula, Ark.	0.025	<0.010	<0.010	E11.1	E11.1
9	Buffalo River near St. Joe, Ark. (lower)	0.025	0.010	<0.010	E11.1	5.5
10	Buffalo River near St. Joe, Ark. (lower)	0.025	<0.010	<0.010	E11.1	E11.1
11	Buffalo River near St. Joe, Ark. (lower)	0.025	<0.010	<0.010	E11.1	E11.1
12	Buffalo River near St. Joe, Ark. (middle)	0.025	<0.010	<0.010	E11.1	E11.1
13	Buffalo River near St. Joe, Ark. (upper)	0.025	<0.010	<0.010	E11.1	E11.1
14	Buffalo River near St. Joe, Ark. (upper) (split)	0.025	<0.010	<0.010	E11.1	E11.1
15	Current River at Van Buren, Mo.	0.280	<0.010	0.020	31.0	E124.0
16	Current River below Akers, Mo.	0.500	<0.010	<0.010	E221.4	E221.4
17	Current River below Akers, Mo. (split)	0.500	<0.010	<0.010	E221.4	E221.4
18	Jacks Fork River at Alley Spring, Mo.	0.060	<0.010	<0.010	E26.6	E26.6
19	Middle Fork Black River at Redmondville, Mo.	0.060	<0.010	<0.010	E26.6	E26.6
20	Mikes Creek at Powell, Mo.	0.550	<0.010	<0.010	E243.6	E243.6
21	Noblett Creek near Willow Springs, Mo.	0.088	<0.010	<0.010	E39.0	E39.0
22	North Fork White River near Dora, Mo.	0.260	<0.010	0.100	5.8	E115.1
23	North Sylamore Creek near Fifty Six, Ark. (lower)	0.025	0.010	<0.010	E11.1	5.5
24	North Sylamore Creek near Fifty Six, Ark. (lower)	0.025	0.100	<0.010	E11.1	0.6
25	North Sylamore Creek near Fifty Six, Ark. (lower)	0.025	<0.010	<0.010	E11.1	E11.1
26	North Sylamore Creek near Fifty Six, Ark. (middle)	0.025	0.010	<0.010	E11.1	5.5
27	North Sylamore Creek near Fifty Six, Ark. (upper)	0.025	0.010	<0.010	E11.1	5.5
28	Paddy Creek above Slabtown Spring, Mo.	0.025	<0.010	<0.010	E11.1	E11.1
29	Paddy Creek above Slabtown Spring, Mo. (split)	0.025	<0.010	<0.010	E11.1	E11.1

mg/L, milligrams per liter; µg/L, micrograms per liter; $CaCO_3$, calcium carbonate; E, indicates that nitrogen to phosphorus ratio is an

Dissolved organic carbon (mg/L)	Total triazines (µg/L)	Suspended sediment (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	Cadmium in bed sediment (µg/g)	Lead in bed sediment (µg/g)	Zinc in bed sediment (µg/g)	Site name	Sample number
0.5	<0.001	2	171	0.5	26	74	Big Creek at Mauser Mill, Mo.	1
0.6	<0.001	5	139	--	--	--	Big Creek near Big Flat, Ark.	2
0.7	--	15	46	--	--	--	Big Creek near Rat, Mo.	3
1.2	0.006	2	161	--	--	--	Big Piney River near Big Piney, Mo.	4
0.6	<0.001	93	69	1.0	28	160	Buffalo River near Boxley, Ark.	5
0.6	<0.001	1	58	1.0	28	160	Buffalo River near Boxley, Ark.	6
0.8	<0.001	23	89	1.0	28	160	Buffalo River near Boxley, Ark.	7
1.2	<0.001	3	117	--	--	--	Buffalo River near Eula, Ark.	8
0.9	<0.001	86	114	1.1	19	130	Buffalo River near St. Joe, Ark. (lower)	9
0.7	<0.001	1	110	1.1	19	130	Buffalo River near St. Joe, Ark. (lower)	10
0.9	0.005	25	95	1.1	19	130	Buffalo River near St. Joe, Ark. (lower)	11
0.7	<0.001	1	110	1.1	19	130	Buffalo River near St. Joe, Ark. (middle)	12
0.7	<0.001	1	110	1.1	19	130	Buffalo River near St. Joe, Ark. (upper)	13
0.7	<0.001	1	110	1.1	19	130	Buffalo River near St. Joe, Ark. (upper) (split)	14
0.6	0.002	32	165	0.3	24	61	Current River at Van Buren, Mo.	15
0.4	<0.001	1	167	--	--	--	Current River below Akers, Mo.	16
0.4	<0.001	1	167	--	--	--	Current River below Akers, Mo. (split)	17
0.6	<0.001	1	178	0.4	24	64	Jacks Fork River at Alley Spring, Mo.	18
0.5	--	22	160	0.8	80	180	Middle Fork Black River at Redmondville, Mo.	19
0.6	0.005	12	128	--	--	--	Mikes Creek at Powell, Mo.	20
1.0	0.003	3	157	--	--	--	Noblett Creek near Willow Springs, Mo.	21
0.9	<0.001	3	183	--	--	--	North Fork White River near Dora, Mo.	22
0.9	<0.001	49	135	0.4	20	54	North Sylamore Creek near Fifty Six, Ark. (lower)	23
0.8	<0.001	10	136	0.4	20	54	North Sylamore Creek near Fifty Six, Ark. (lower)	24
0.8	<0.001	24	132	0.4	20	54	North Sylamore Creek near Fifty Six, Ark. (lower)	25
0.9	<0.001	49	135	0.4	20	54	North Sylamore Creek near Fifty Six, Ark. (middle)	26
0.9	<0.001	49	135	0.4	20	54	North Sylamore Creek near Fifty Six, Ark. (upper)	27
0.8	<0.001	1	163	0.2	27	54	Paddy Creek above Slabtown Spring, Mo.	28
0.8	<0.001	1	163	0.2	27	54	Paddy Creek above Slabtown Spring, Mo. (split)	29

Table 20. Sample numbers, site characteristics, and associated environmental factors--Continued

[km^2, square kilometer; lower, middle, and upper are reach designations; split designates a second sample collected at a site; m^2, square meter; estimated value assuming a phosphorus concentration of 0.005 mg/L; µg/g, micrograms per gram; <, less than; --, no data]

					Molar nitrogen to phosphorus ratio	
Sample number	**Site name**	**Dissolved nitrite plus nitrate as nitrogen (mg/L)**	**Dissolved orthophosphorus as phosphorus (mg/L)**	**Total phosphorus as phosphorus (mg/L)**	**Nitrate to total phosphorus**	**Nitrate to dissolved orthophosphorus**
30	Paddy Creek above Slabtown Spring, Mo.	0.025	<0.010	0.020	2.8	E11.1
31	Paddy Creek above Slabtown Spring, Mo. (split)	0.025	<0.010	0.020	2.8	E11.1
32	Richland Creek near Witts Springs, Ark.	0.050	0.010	<0.010	E22.1	11.1
33	Rogers Creek near Van Buren, Mo.	0.087	<0.010	0.020	9.6	E38.5
34	Water Creek near Evening Star, Ark.	0.060	<0.010	<0.010	E26.6	E26.6
35	West Fork Black River near Greeley, Mo.	0.025	<0.010	0.020	2.8	E11.1
36	West Fork Black River near Greeley, Mo. (split)	0.025	<0.010	0.020	2.8	E11.1
37	Baron Fork at Eldon, Okla.	0.480	0.030	0.050	21.3	35.4
38	Brush Creek above Collins, Mo.	0.025	<0.010	0.020	2.8	E11.1
39	Dousinbury Creek near Wall Street, Mo.	0.279	0.015	0.020	30.9	41.2
40	Dousinbury Creek near Wall Street, Mo.	0.130	0.020	0.030	9.6	14.4
41	Elk River near Tiff City, Mo.	0.630	0.050	0.060	23.3	27.9
42	Illinois River near Tahlequah, Okla.	0.660	0.070	0.090	16.2	20.9
43	Little Osage Creek near Healing Spring, Ark.	3.400	0.020	0.030	251.0	376.4
44	Little Tavern Creek near St. Elizabeth, Mo.	0.120	0.010	0.030	8.9	26.6
45	Maries River near Freeburg, Mo.	0.025	<0.010	0.020	2.8	E11.1
46	Niangua River near Windyville, Mo.	0.580	0.270	0.280	4.6	4.8
47	Niangua River near Windyville, Mo. (split)	0.580	0.270	0.280	4.6	4.8
48	North Indian Creek near Wanda, Mo.	3.700	0.040	0.040	204.8	204.8
49	Osage Fork near Russ, Mo.	0.320	0.020	0.030	23.6	35.4
50	Peacheater Creek at Christie, Okla.	1.500	0.030	0.020	166.1	110.7
51	Pomme de Terre near Polk, Mo.	0.065	0.030	0.040	3.6	4.8
52	Sac River near Dadeville, Mo.	1.200	0.050	0.050	53.1	53.1
53	Strawberry River near Poughkeepsie, Ark.	0.025	<0.010	<0.010	E11.1	E11.1
54	War Eagle Creek near Hindsville, Ark.	0.960	<0.010	0.020	106.3	E425.1
55	War Eagle Creek near Hindsville, Ark. (split)	0.960	<0.010	0.020	106.3	E425.1
56	Woods Fork near Hartville, Mo.	0.140	<0.010	0.030	10.3	E62.0
57	Yocum Creek near Oak Grove, Ark. (lower)	2.800	0.030	0.050	124.0	206.7
58	Yocum Creek near Oak Grove, Ark. (middle)	2.800	0.030	0.050	124.0	206.7

mg/L, milligrams per liter; µg/L, micrograms per liter; $CaCO_3$, calcium carbonate; E, indicates that nitrogen to phosphorus ratio is an

Dissolved organic carbon (mg/L)	Total triazines (µg/L)	Sus- pended sediment (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	Cadmium in bed sediment (µg/g)	Lead in bed sediment (µg/g)	Zinc in bed sediment (µg/g)	Site name	Sample number
0.9	<0.001	40	154	--	--	--	Paddy Creek above Slabtown Spring, Mo.	30
0.9	<0.001	40	154	--	--	--	Paddy Creek above Slabtown Spring, Mo. (split)	31
0.8	<0.001	2	57	1.2	25	140	Richland Creek near Witts Springs, Ark.	32
0.5	<0.001	0	183	--	--	--	Rogers Creek near Van Buren, Mo.	33
0.8	<0.001	6	145	--	--	--	Water Creek near Evening Star, Ark.	34
0.4	--	29	185	0.5	33	150	West Fork Black River near Greeley, Mo.	35
0.4	--	29	185	0.5	33	150	West Fork Black River near Greeley, Mo. (split)	36
0.5	<0.001	2	93	--	--	--	Baron Fork at Eldon, Okla.	37
3.0	<0.001	3	87	--	--	--	Brush Creek above Collins, Mo.	38
1.6	0.003	--	--	0.2	20	50	Dousinbury Creek near Wall Street, Mo.	39
1.5	0.002	24	159	0.2	20	50	Dousinbury Creek near Wall Street, Mo.	40
1.0	0.007	4	106	0.4	19	71	Elk River near Tiff City, Mo.	41
0.8	0.153	15	---	0.3	19	62	Illinois River near Tahlequah, Okla.	42
0.9	0.007	41	128	0.6	15	65	Little Osage Creek near Healing Spring, Ark.	43
1.2	0.014	5	169	--	--	--	Little Tavern Creek near St. Elizabeth, Mo.	44
1.7	0.015	3	175	--	--	--	Maries River near Freeburg, Mo.	45
3.8	0.011	31	150	0.2	25	60	Niangua River near Windyville, Mo.	46
3.8	0.011	31	150	0.2	25	60	Niangua River near Windyville, Mo. (split)	47
0.6	<0.001	24	142	--	--	--	North Indian Creek near Wanda, Mo.	48
1.1	0.049	10	177	--	--	--	Osage Fork near Russ, Mo.	49
0.5	0.021	--	66	--	--	--	Peacheater Creek at Christie, Okla.	50
3.1	<0.001	11	159	0.2	22	43	Pomme de Terre near Polk, Mo.	51
1.2	0.017	34	199	--	--	--	Sac River near Dadeville, Mo.	52
1.0	<0.001	11	204	0.2	20	44	Strawberry River near Poughkeepsie, Ark.	53
1.2	<0.001	4	98	--	--	--	War Eagle Creek near Hindsville, Ark.	54
1.2	<0.001	4	98	--	--	--	War Eagle Creek near Hindsville, Ark. (split)	55
1.1	<0.001	4	199	--	--	--	Woods Fork near Hartville, Mo.	56
0.7	<0.001	42	148	0.5	22	68	Yocum Creek near Oak Grove, Ark. (lower)	57
0.7	<0.001	42	148	0.5	22	68	Yocum Creek near Oak Grove, Ark. (middle)	58

Table 20. Sample numbers, site characteristics, and associated environmental factors--Continued

[km^2, square kilometer; lower, middle, and upper are reach designations; split designates a second sample collected at a site; m^2, square meter; estimated value assuming a phosphorus concentration of 0.005 mg/L; µg/g, micrograms per gram; <, less than; --, no data]

					Molar nitrogen to phosphorus ratio	
Sample number	**Site name**	**Dissolved nitrite plus nitrate as nitrogen (mg/L)**	**Dissolved orthophosphorus as phosphorus (mg/L)**	**Total phosphorus as phosphorus (mg/L)**	**Nitrate to total phosphorus**	**Nitrate to dissolved orthophosphorus**
59	Yocum Creek near Oak Grove, Ark. (middle)	1.800	0.020	0.020	199.3	199.3
60	Yocum Creek near Oak Grove, Ark. (middle) (split)	1.800	0.020	0.020	199.3	199.3
61	Yocum Creek near Oak Grove, Ark. (middle)	2.100	0.030	0.030	155.0	155.0
62	Yocum Creek near Oak Grove, Ark. (middle) (split)	2.100	0.030	0.030	155.0	155.0
63	Yocum Creek near Oak Grove, Ark. (upper)	2.800	0.030	0.050	124.0	206.7
64	Big River near Richwoods, Mo.	0.025	<0.010	<0.010	E11.1	E11.1
65	Black River near Lesterville, Mo.	0.130	<0.010	<0.010	E57.6	E57.6
66	Black River near Lesterville, Mo.	0.025	<0.010	<0.010	E11.1	E11.1
67	Black River near Lesterville, Mo.	0.110	<0.010	0.010	24.4	E48.7
68	Huzzah Creek near Scotia, Mo.	0.061	<0.010	<0.010	E27.0	E27.0
69	Middle Fork Black River at Black, Mo.	0.100	<0.010	<0.010	E44.3	E44.3
70	Neals Creek near Goodland, Mo.	0.070	<0.010	<0.010	E31.0	E31.0
71	Strother Creek near Oates, Mo.	0.740	<0.010	<0.010	E327.7	E327.7
72	Strother Creek near Redmondville, Mo.	0.340	<0.010	<0.010	E150.6	E150.6
73	West Fork Black River at Centerville, Mo.	0.080	<0.010	<0.010	E35.4	E35.4
74	West Fork Black River at Centerville, Mo. (split)	0.080	<0.010	<0.010	E35.4	E35.4
75	West Fork Black River at West Fork, Mo.	0.250	<0.010	<0.010	E110.7	E110.7
76	West Fork Black River near Centerville, Mo.	0.090	<0.010	<0.010	E39.9	E39.9
77	Kings River near Berryville, Ark.	0.420	0.100	0.100	9.3	9.3
78	Kings River near Berryville, Ark.	0.130	0.610	0.620	0.5	0.5
79	Kings River near Berryville, Ark.	0.025	0.800	0.800	0.1	0.1
80	James River near Boaz, Mo.	3.400	0.790	0.780	9.7	9.5
81	Center Creek near Smithfield, Mo.	2.200	0.190	0.250	19.5	25.6
82	Center Creek near Smithfield, Mo.	6.300	0.050	0.060	232.5	279.0
83	Center Creek near Smithfield, Mo.	4.300	0.060	0.060	158.7	158.7

mg/L, milligrams per liter; μg/L, micrograms per liter; $CaCO_3$, calcium carbonate; E, indicates that nitrogen to phosphorus ratio is an

Dissolved organic carbon (mg/L)	Total triazines (μg/L)	Sus-pended sediment (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	Cadmium in bed sediment (μg/g)	Lead in bed sediment (μg/g)	Zinc in bed sediment (μg/g)	Site name	Sample number
0.6	<0.001	3	124	0.5	22	68	Yocum Creek near Oak Grove, Ark. (middle)	59
0.6	<0.001	3	124	0.5	22	68	Yocum Creek near Oak Grove, Ark. (middle) (split)	60
0.6	<0.001	86	141	0.5	22	68	Yocum Creek near Oak Grove, Ark. (middle)	61
0.6	<0.001	86	141	0.5	22	68	Yocum Creek near Oak Grove, Ark. (middle) (split)	62
0.7	<0.001	42	148	0.5	22	68	Yocum Creek near Oak Grove, Ark. (upper)	63
1.1	<0.001	38	223	12.0	2,300	670	Big River near Richwoods, Mo.	64
0.7	<0.001	20	123	0.6	84	91	Black River near Lesterville, Mo.	65
0.6	<0.001	1	133	0.6	84	91	Black River near Lesterville, Mo.	66
0.5	<0.001	19	128	0.6	84	91	Black River near Lesterville, Mo.	67
0.8	<0.001	4	193	--	--	--	Huzzah Creek near Scotia, Mo.	68
0.4	--	40	137	0.8	100	210	Middle Fork Black River at Black, Mo.	69
0.5	--	20	197	--	--	--	Neals Creek near Goodland, Mo.	70
1.1	--	51	136	--	--	--	Strother Creek near Oates, Mo.	71
0.5	--	42	175	2.2	200	1,200	Strother Creek near Redmondville, Mo.	72
0.4	--	36	151	0.6	100	120	West Fork Black River at Centerville, Mo.	73
0.4	--	36	151	0.6	100	120	West Fork Black River at Centerville, Mo. (split)	74
0.5	--	20	160	3.3	950	460	West Fork Black River at West Fork, Mo.	75
0.5	--	19	151	1.0	170	200	West Fork Black River near Centerville, Mo.	76
1.2	0.003	19	141	0.3	28	84	Kings River near Berryville, Ark.	77
1.7	0.003	10	143	0.3	28	84	Kings River near Berryville, Ark.	78
2.1	<0.001	38	154	0.3	28	84	Kings River near Berryville, Ark.	79
2.0	0.062	18	188	1.1	44	170	James River near Boaz, Mo.	80
4.6	0.020	136	83	42.0	370	5,600	Center Creek near Smithfield, Mo.	81
1.3	0.020	9	133	42.0	370	5,600	Center Creek near Smithfield, Mo.	82
1.3	0.039	42	141	42.0	370	5,600	Center Creek near Smithfield, Mo.	83