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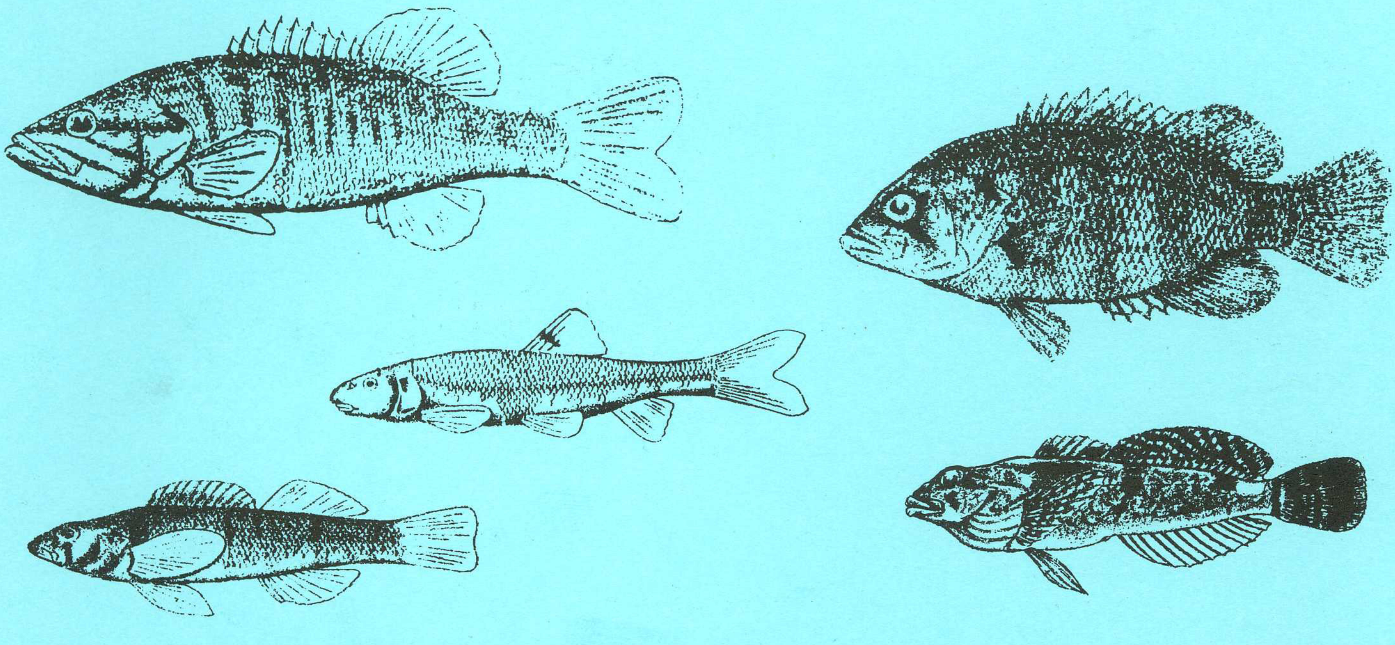
WATER-QUALITY ASSESSMENT OF THE OZARK PLATEAUS STUDY UNIT, ARKANSAS, KANSAS, MISSOURI, AND OKLAHOMA—FISH COMMUNITIES IN STREAMS AND THEIR RELATIONS TO SELECTED ENVIRONMENTAL FACTORS

Water-Resources Investigations Report 98-4155



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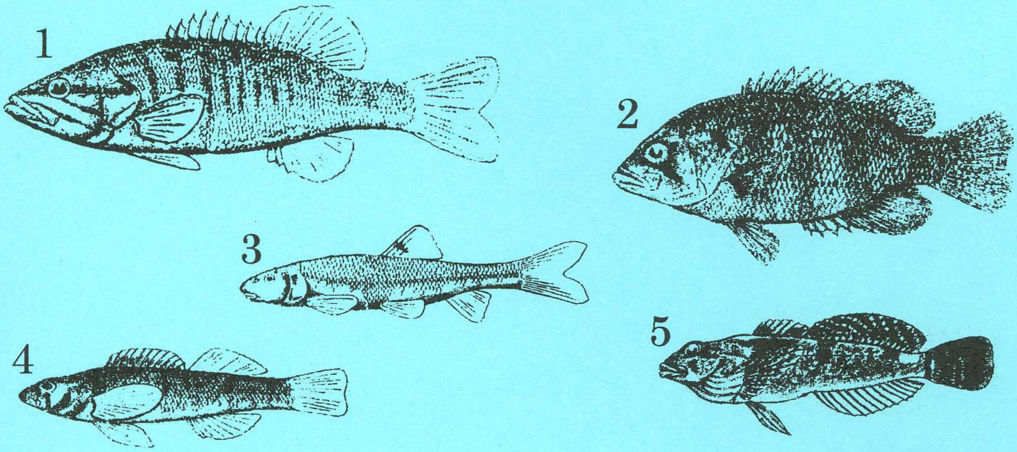

1—Smallmouth bass
2—Ozark bass
3—Central stoneroller
4—Yoke darter
5—Ozark sculpin

The smallmouth bass is an important Ozark gamefish. Stonerollers are found in most Ozark streams. The Ozark bass, yoke darter, and Ozark sculpin are found only in the Ozark Plateaus. (Illustrations from "The Fishes of Missouri." Copyright 1997 by the Conservation Commission of the State of Missouri. Used with permission.)

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By James C. Petersen

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National Water-Quality Assessment Program

U.S. DEPARTMENT OF THE INTERIOR

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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ILLUSTRATIONS

TABLES

CONVERSION FACTORS

Multiply	By	To obtain
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
square kilometer (km^2)	0.3861	square mile
square meter (m^2)	10.76	square foot
cubic meter (m^3)	35.31	cubic foot

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ABSTRACT

Fish communities from 22 reaches at 18 stations in the Ozark Plateaus were sampled in 1993, 1994, and 1995. The 18 stations were chosen to represent selected combinations of major environmental factors (geology/physiographic area, land use, and basin size). Additional physical, chemical, and biological factors also were measured for each of the 22 reaches and the influence of these factors upon the fish communities was investigated.

Fish community samples collected at the 22 reaches identified differences in these communities that can be attributed to differences in land use and related water-quality and habitat characteristics. Communities from agriculture reaches tended to have more species, increased relative abundance of stonerollers and members of the sucker family, and decreased relative abundance of members of the sunfish and darter families. Several groups of environmental factors (concentrations of nutrients, organic carbon, suspended sediment, and dissolved oxygen; measures related to ionic strength; measures related to riparian vegetation; measures related to substrate; and measures related to stream size) appear to be related to land-use differences and fish community differences.

Three multivariate analysis techniques (two ordination techniques and a classification technique) yielded similar results when applied to the fish community data. Fish communities from reaches with more similar land use in their basins and with similar drainage areas generally were grouped closer together in the analysis. Water quality, substrate, stream morphology, and riparian measures appear to be affecting fish communities at these reaches.

The relations between land use, stream size, and fish communities have implications for water-quality assessments of Ozark streams. Compared to other parts of the United States, many fish species live in the Ozark Plateaus. At least 19 of these species are endemic to the Ozarks area. Many of these species are intolerant of habitat or water-chemistry degradation. This characteristic makes fish a useful tool for assessing water-chemistry and other habitat conditions of streams.

Several environmental factors can contribute to differences in fish communities. Elevated nutrient concentrations and greater canopy angles can increase periphyton production. Greater canopy angles can raise water temperatures and, if they reflect less woody vegetation along the banks of streams, can be associated with greater streambank erosion. Elevated suspended sediment concentrations and finer and more embedded substrates can reduce benthic macroinvertebrate populations, decrease spawning success of many fish species, and decrease protection of benthic fish from water velocities and predators.

INTRODUCTION

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 basin-wide (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).

Purpose and Scope

The purpose of this report is to relate fish community characteristics of representative sections (reaches) of selected Ozark Plateaus (Ozark) streams to physical, chemical, and biological factors. The emphasis of the NAWQA Program is water quality, hence the relation of fish communities to water quality is an important focus of this report. However, fish 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 fish community structure in Ozark streams. To determine the relation between water quality and fish community characteristics, fish communities were sampled from reaches of streams that differed in environmental setting (land use, basin size, and physiographic section). Although differences in fish communities of physiographic sections (or ecoregions) are known (see Giese and others, 1987, for differences between the Springfield-Salem Plateaus and the Boston Mountains), many of these differences were minimized by the analysis techniques used in preparation of this report. Therefore, results do not show major or consistent differences in fish communities attributable to physiographic section, and physiographic section effects on communities will not be discussed. To evaluate temporal variability, reaches were sampled for multiple years (1993, 1994, 1995). To evaluate spatial variability, multiple (and adjacent) reaches of two similar-sized streams (but differing in basin land use) in the Springfield Plateau were sampled. To evaluate spatial variability at a larger scale, multiple stations were sampled within some of the environmental settings. Evaluation of temporal and spatial variability provides some insight into the natural variability of fish communities in Ozark streams to compare with the variability between communities at stations chosen to represent selected environmental settings.

The study included the collection of fish-community, water-quality, and habitat data associated with 22 reaches at 18 stations during the study period (April 1993 through October 1995). The fish communities of most reaches were sampled in 1993, 1994, and 1995. Most of the 1994 data are not analyzed in this report. Some reaches were only sampled in one year.

Acknowledgments

Substantial assistance was provided by several agencies, organizations, and universities during the planning and implementation of the work described in this report. I especially thank personnel of the Arkansas Department of Pollution Control and Ecology (Bill Keith, Bob Singleton, and Jim Wise), Arkansas Game and Fish Commission (Steve Filipek, Brian Wagner, and April Layher), Missouri Department of Conservation (Craig Fuller, Dave Mayer, and Bob Schultz), Missouri Cooperative Fish and Wildlife Research Unit (Eric Nelson and Martin Smale), Oklahoma Cooperative Fish and Wildlife Research Unit (Paul Balkenbush, Bruce Corley, Bill Fisher, and others), Pittsburg State University (Jim Triplett), the former National Biological Service (Bill Layher), and the U.S. Department of Agriculture Forest Service (Jean Ayers, Jerry Gott, Craig Hilburn, Dwayne Rambo, and Karen Tinkle) for field assistance. Bill Keith, Jim Wise, Steve Filipek, Brian Wagner, Craig Fuller, Martin Smale, Jim Triplett, Bill Layher, Craig Hilburn, and Dwayne Rambo assisted by identifying fish at many of the stations. Fish also were identified at several stations by Nick Ashbaugh (Stillwater, Okla.), Geff Lutrell (Stillwater, Okla.), and James T. Peterson (Columbia, Mo.) under contract to the U.S. Geological Survey. The Missouri Department of Conservation provided an electrofishing boat and crew for the sampling of the Current River and the Oklahoma Cooperative Fish and Wildlife Research Unit provided an electrofishing boat and crew for the sampling of the Illinois River. The National Park Service provided partial funding for sampling of the Current River. I also thank private landowners and public agencies for permission to access and sample many of these stations.

DESCRIPTION OF STUDY AREA

The Ozark Plateaus study unit (fig. 1) has an area of about 123,000 km^2 and includes parts of Arkansas,

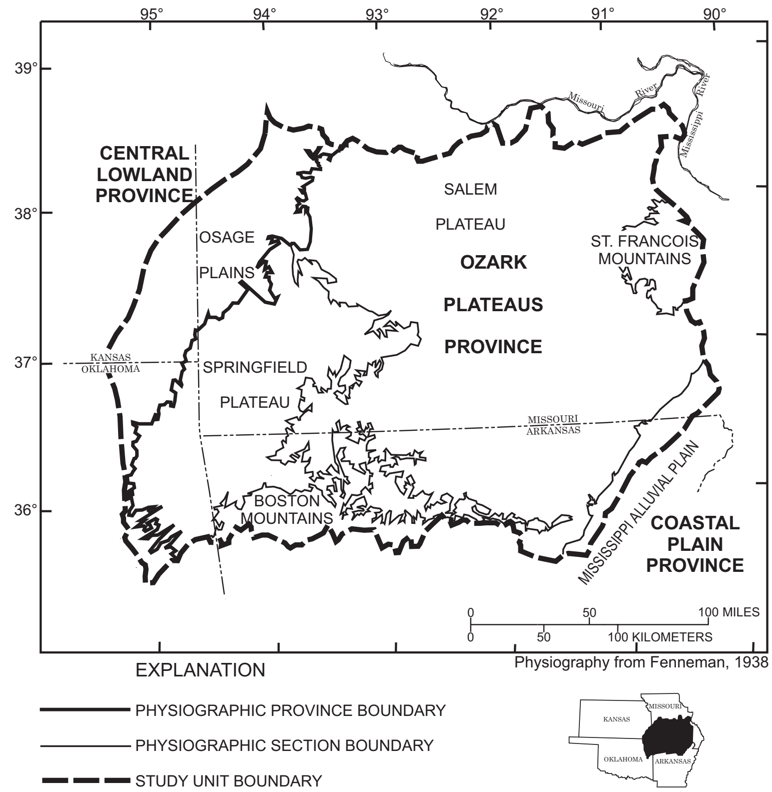

Figure 1. Physiographic subdivisions of the Ozark Plateaus study unit and adjacent areas.

Kansas, Missouri, and Oklahoma. Most of the study unit is within the Springfield and Salem Plateaus and the Boston Mountains physiographic sections (fig. 1); it is these three sections that compose the Ozark Plateaus physiographic province (Fenneman, 1938). These sections correspond closely 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 corresponds closely 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).

The Ozark Plateaus study unit (and the Ozark Plateaus physiographic province, particularly) has a rich fish fauna. Approximately 175 species (including introduced species) occur within the study unit in the Ozark Plateaus province (Miller and Robison, 1973; Robison and Buchanan, 1988; Pflieger, 1997); at least 19 species (10 darters, 4 minnows, 2 madtoms, 1 sunfish, 1 sculpin, and 1 cavefish) are found only in the Ozark Plateaus and small areas immediately adjacent (Robison and Buchanan, 1988; Pflieger, 1997; Ceas and Page, 1997).

Land use in the study unit is primarily forest and agriculture (U.S. Geological Survey, 1990). 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; Petersen and others, 1998). Nitrite plus nitrate (as nitrogen) concentrations typically are 0.1-0.2 milligrams per liter (mg/L) in forested areas of the Springfield Plateau and Salem Plateau, while concentrations in animal production areas typically range from about 0.4-2.0 mg/L. Total phosphorus concentrations are less elevated than the nitrite plus nitrate, except in the Springfield Plateau where concentrations are about 0.01 mg/L in forested areas and about 0.1-0.2 mg/L in animal production 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 animal production areas (Davis and others, 1995).

FIELD METHODS

Streams were sampled between the spring of 1993 and the fall of 1995. The location of the 18 stations selected for study are shown in figure 2. These stations were placed into 1 of 12 categories, based upon the basin land use, physiographic and geologic setting of each station and drainage area (table 1); for example a station might be a "small, Springfield Plateau, agriculture station" or a "small, Springfield Plateau, forest station." At most of the 18 stations water-quality samples were collected at least monthly (Shelton, 1994), fine-grained bed sediment was sampled once for trace elements and organic compounds (Shelton and Capel, 1994), habitat was measured once, and the fish community was sampled annually. At four stations (Big Creek, Mikes Creek, Little Osage Creek, and Peacheater Creek), water quality was sampled three times (spring and summer of 1994, spring of 1995), habitat was measured once, and the fish community was sampled once. Results of this 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 stations in 1993; at each of the two "multiple-reach" stations (North Sylamore Creek and Yocum Creek), three adjacent reaches were sampled (fish and habitat) in 1993. Thus, 22 reaches were sampled.

Reaches where fish communities were sampled ranged from about 150 to 550 meters 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). In most cases, the reach length was determined based upon the multiple geomorphological units, which occurred within a distance meeting the minimum-maximum length criterion (150 to 300 m for wadeable streams, 300 to 1,000 m for nonwadeable streams). In other cases, a reach length of about 20 times the channel width and meeting the minimum-maximum length criterion was selected.

The environmental setting and habitat of each reach were characterized using a spatially hierarchical

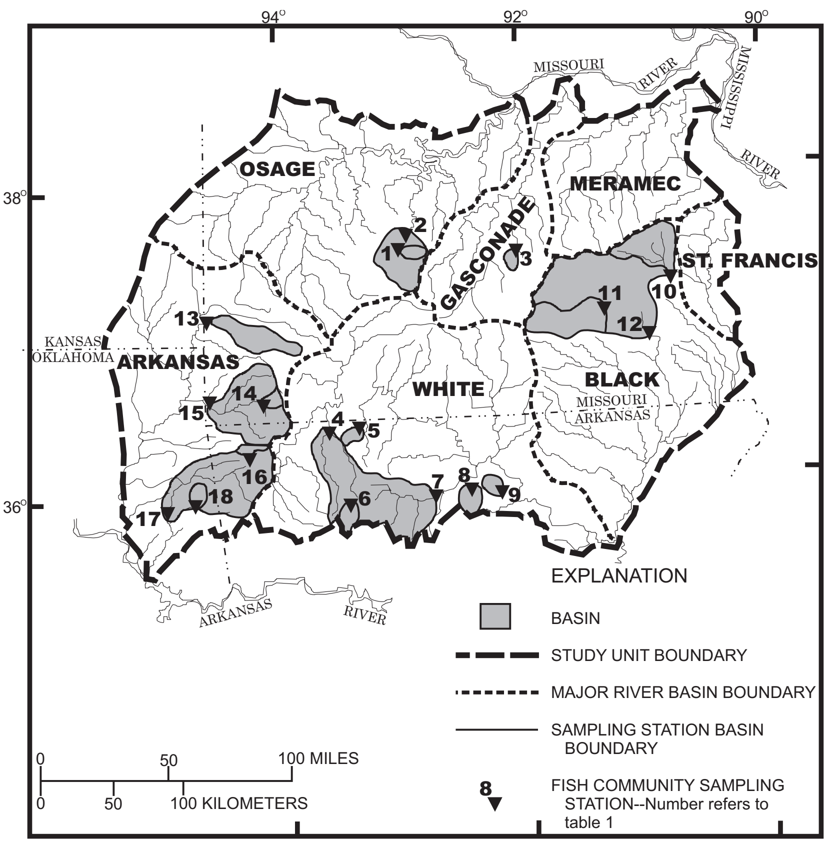

Figure 2. Location of sampling stations.

Table 1. General basin and reach characteristics of stations

[km^2, square kilometers; A, agricultural; F, forested; M, mixture of agricultural and forested land use, wastewater treatment plant effects, and instream gravel mining; P, lead-zinc mining; S, small, L, large; Salem, Salem Plateau; Springfield, Springfield Plateau; OH, Ozark Highlands; BM, Boston Mountains; CIP, Central Irregular Plains]

Map number (figure 2)	Station identification number	Name	Land use category	Percent agriculture	Size category	Drainage area (km^2)	Stream order	Physiographic category	Ecoregion
1	06923150	Dousinbury Creek on JJ near Wall Street, Mo.	A	59	S	106	3	Salem	OH
2	06923250	Niangua River at Windyville, Mo.	A[1]	56	L	875	5	Salem	OH
3	06929315	Paddy Creek above Slabtown Springs, Mo.	F	10	S	79	2	Salem	OH
4	07050500	Kings River near Berryville, Ark.	M[1,2]	32	L	1,365	6	Salem	OH
5	07053250	Yocum Creek near Oak Grove, Ark.	A	76	S	137	4	Springfield	OH
6	07055646	Buffalo River near Boxley, Ark.	F	4	S	149	4	Boston	BM
7	07056000	Buffalo River near St. Joe, Ark.	F	13	L	2,147	6	Springfield	BM
8	07057100	Big Creek near Big Flat, Ark.	F	36	S	232	5	Springfield	OH
9	07060710	North Sylamore Creek near Fifty Six, Ark.	F	3	S	150	4	Springfield	OH
10	07061400	Black River near Lesterville, Mo.	P	6	L	1,114	5	Salem	OH
11	07065495	Jacks Fork River at Alley Springs, Mo.	F	22	L	790	5	Salem	OH
12	07067000	Current River at Van Buren, Mo.	F	17	L	4,318	6	Salem	OH
13	07186480	Center Creek near Smithfield, Mo.	P[1,2]	77	L	761	5	Springfield	CIP
14	07188660	Mikes Creek at Powell, Mo.	F	28	S	167	5	Springfield	OH
15	07189000	Elk River near Tiff City, Mo.	A[1]	47	L	2,258	5	Springfield	OH
16	07194947	Little Osage Creek at Healing Springs, Ark.	A	91	S	102	4	Springfield	OH
17	07196500	Illinois River near Tahlequah, Okla.	A[1]	59	L	2,484	6	Springfield	BM
18	07196973	Peacheater Creek at Christie, Okla.	A	57	S	61	4	Springfield	CIP

[1]Municipal wastewater-treatment plant source with discharge greater than 0.5 million gallons per day upstream of station (Davis and Bell, 1998)
[2]Industrial or municipal wastewater-treatment plant source considered the major source of nitrate or phosphorus at the station.

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, stream segment (section of stream between two tributaries), reach, and microhabitat levels. This information includes such measures as drainage area, land use, channel sinuosity (a measure of meandering), stream order (an indirect indication of stream size), channel morphometry, substrate size, substrate embeddedness, canopy angle, riparian vegetation, discharge, and velocity.

The fish communities were sampled from late July to mid-August of 1993-1995 using methods described in Meador and others (1993a). Backpack or towed electrofishing gear (direct current) was used at most stations; at two stations (Center Creek and Niangua River) electrofishing was not used because of the possible presence of federally-listed threatened species. At these two stations, the community was sampled using a 10 m $\times$ 2 m $\times$ 6.4 mm seine. At the smaller streams, one electrofishing pass progressing from the downstream end of the sampling reach was used to collect fish. Two passes were used at the larger streams. Riffles also were sampled by separate kick seining efforts in conjunction with electrofishing. Two stations (Illinois and Current Rivers) were partially sampled using an electrofishing boat, in addition to use of the towed barge and kick seining. After each sampling effort, fish were identified, weighed, measured, and examined for external anomalies. Fish that were identified in the field were released. Fish that could not be positively identified in the field were preserved for later identification. Specimens of selected species were retained for verification of field identification and reference. A voucher collection will be retained at the office of the USGS in Little Rock, Arkansas, pending transfer to a biological museum.

STATISTICAL METHODS

Several statistical methods were used to describe and compare the fish communities and selected physical, chemical, and biological factors. The relations of the communities to these factors also were described and compared statistically. The conservative, nonparametric Wilcoxon rank sum test was used to investigate the relation between these habitat variables and selected reach groupings.

For each species, relative abundances were calculated as the proportion of the number of individuals of that species to the total number of individuals in the

sample. Relative abundances also were aggregated into taxa groups for the purpose of comparing the relative abundances of these groups at reaches. These groups are: stonerollers (*Campostoma*), other minnows (Cyprinidae), suckers (Catostomidae), madtoms (*Noturus*), sunfish (Centrarchidae, includes the black bass), darters (Percidae), and all other species.

The similarity of selected community samples was measured using the percentage similarity index (Whittaker, 1952; Whittaker and Fairbanks, 1958). This index (PSC) is:

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

where a and b are (for a given species) 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 compositions (relative abundances of species) of the communities at each reach were analyzed using two types of multivariate analysis techniques: ordination and classification. A samples-by-species data matrix was input into the computer program CANOCO (Ter Braak, 1988) which is designed for data analysis in community ecology using a class of techniques known as canonical ordination. Two ordination techniques, detrended correspondence analysis (DCA) (Hill, 1979a) and canonical correspondence analysis (CCA) (Ter Braak, 1986), were used to group reaches (samples) by their species composition (relative abundances). Two-way indicator species analysis (TWINSPAN) (Hill, 1979b), a classification technique, also was used to distinguish reaches. In the TWINSPAN analysis, pseudospecies (created by separating true species into entities defined by the true species and the relative abundance of that species) were created. Creating one or more pseudospecies from a true species allows relative abundance to influence TWINSPAN results. Pseudospecies with relative abundances of 20 percent or greater were given more weight (doubled) in the analysis. TWINSPAN also produces lists of "preferential species" (pseudospecies and species that are at least twice as likely to occur in samples in a given classification group as in the alternate classification group).

Relations between fish community and environmental factors were evaluated using several statistical methods. DCA results were compared to several environmental factors using Spearman correlations. TWINSPAN results were evaluated using the Wilcoxon rank sum test to test for differences between selected groups of sites. CCA differs from DCA and TWINSPAN because it is a direct gradient analysis technique—species composition is displayed along gradients of environmental factors as part of the analysis. Environmental factors used in the CCA were chosen using principal components analysis (PCA).

Some data editing steps were used to modify the reach-by-species matrix prior to multivariate analysis. Relative abundances of several species were combined because of difficulty of identification in the field (*Campostoma* spp.); because of zoogeographical separation of similar species (for example, in the Ozarks the redspot chub is restricted to the Arkansas River system while the hornyhead chub occurs in all other stream systems); or to minimize the influence, on the multivariate analysis results, of species that are not widely distributed across the Ozarks. Relative abundances were combined for the central and largescale stonerollers (*Campostoma anomalum* and *C. oligolepis)*; the hornyhead chub (*Nocomis biguttatus*) and redspot chub (*N. asper*); the duskystripe shiner (*Luxilus pilsbryi*), bleeding shiner (*L. zonatus*), and cardinal shiner (*L. cardinalis*); the gravel chub (*Hybopsis x-punctata)* and Ozark chub (*Erimystax harryi*); the shadow bass (*Ambloplites ariommus)*, Ozark bass (*A. constellatus)*, and rock bass (*A. rupestris)*. In addition, relative abundances for all the darters (*Etheostoma* and *Percina*) were combined.

ENVIRONMENTAL FACTORS

Several environmental factors were determined or measured for each reach or station (Meador and others, 1993b) during this study. A subset of these factors was selected for inclusion in analysis of the fish community data. These factors include basin-level factors (such as drainage area and land use), segment-level factors (such as stream gradient and sinuosity), reach-level factors (such as measures of stream morphometry, streamflow characteristics, mean velocity, mean substrate embeddedness, substrate size, canopy angle, and density of riparian woody vegetation), and water-quality measures (including median pH and specific conductance and median dissolved nitrite-plus-nitrate, total phosphorus, dissolved organic carbon, and suspended sediment concentrations). The values for selected factors are listed in table 2.

Statistically significant ($p<0.10$, two-sided test) differences in some environmental factors were detected between reaches in the agriculture and forest land-use categories (table 3). Differences in percent agricultural land use, dissolved nitrite plus nitrate (in text, hereafter referred to as “nitrate”), total phosphorus, and canopy angle were detected. Although p-values are not shown in table 3, Wilcoxon rank sum tests for differences in environmental factors between land use categories, but within a size category, were performed. These results generally were similar to the results shown in table 3, except that woody vegetation density differs by land-use category within the small basin category, and canopy angle does not differ by land-use category within the large basin category. Therefore, in general, forest reaches have lower concentrations of nitrite plus nitrate and total phosphorus, and are more shaded.

Statistically significant ($p<0.10$, two-sided test) differences in some environmental factors were detected between reaches in the small and large basin-size categories (table 3). Differences in drainage area, stream order, suspended-sediment concentration, velocity, canopy angle, and several measures of channel morphometry (width, depth, width-to-depth ratio, streambed gradient, and sinuosity) were detected. Results of rank sum tests for differences by size category, but within land-use category, generally agreed with the results shown in table 3. However, results did indicate that canopy angles at forest reaches are more affected by basin size (an indicator of channel width) than are canopy angles at agriculture reaches. Therefore, large-size category reaches usually have higher concentrations of suspended sediment, are wider, deeper, less steep, more sinuous, and less shaded, and have higher water velocities than small-size category reaches.

Concentrations of lead and zinc in water and bed sediment at the two lead-zinc mining stations (Black River and Center Creek) and two nearby non-mining stations are shown in table 4 (see Petersen and others, 1998, for additional information). Lead was not detectable in water at any of these four stations. Concentrations of lead and zinc in bed sediment at Center Creek are substantially greater than concentrations at the other stations. Concentrations of lead and zinc in bed sediment at the Black River are somewhat higher than

Table 2. Chemical, physical, and biological factors associated with reaches, 1993-95

[Much of this information is from Femmer (1997) and Davis and Bell (1998). Reaches are grouped by land-use category within basin-size categories. A, agricultural; F, forested; P, lead-zinc mining; M, mixture of land uses, wastewater- treatment plant effects, and instream gravel mining; S, small basin; L, large basin; N, nitrogen, P, phosphorus; C, carbon; $CaCO_3$, calcium carbonate; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; m^3/s, cubic meter per second; m, meters; m^2, square meter. Width is of wetted width of stream at low discharge. Sinuosity is a measure of meandering. Embeddedness is the percent a larger substrate is buried in silt, clay, or sand. Phi is a measure of particle sizes and is defined as the negative base-2 logarithm of the particle size diameter in millimeters; more negative values correspond with larger particle sizes. Canopy angle is formed by the angles from the midpoint of the stream channel to the visible horizon, lower values of canopy angle indicate taller trees, hills, or bluffs adjacent to the stream]

Abbreviated reach name	Land use and size category	Median dissolved nitrite plus nitrate, as N (mg/L)	Median total phosphorus, as P (mg/L)	Median dissolved organic carbon, as C (mg/L)	Median suspended sediment (mg/L)	Median alkalinity, as $CaCO_3$ (mg/L)	Median specific conductance (µS/cm)	Median pH (units)	Dissolved oxygen, 5th percentile (mg/L)	Mean width (m)	Mean depth (m)
Dousinbury Creek	A-S	0.36	0.03	1.6	11.5	138	291	8.1	7.4	23.6	0.524
Yocum Creek-Upper	A-S	2.6	.04	.70	13.0	144	331	7.9	6.9	13.6	.406
Yocum Creek-Middle	A-S	2.6	.04	.70	13.0	144	331	7.9	6.9	13.0	.449
Yocum Creek-Lower	A-S	2.6	.04	.70	13.0	144	331	7.9	6.9	13.7	.491
Little Osage Creek	A-S	4.6	.03	.90	17.0	105	274	8.2	--	11.6	.467
Peacheater Creek	A-S	2.3	.02	.90	5.0	49	148	7.7	--	5.4	.347
Paddy Creek	F-S	.02	.004	1.1	7.0	118	234	7.9	6.3	7.3	.382
Buffalo River-Boxley	F-S	.03	.009	.70	13.0	28	63	7.6	5.2	27.4	.619
Big Creek	F-S	.23	.02	2.0	2.0	146	304	8.3	--	8.6	.281
North Sylamore Creek-Upper	F-S	.06	.005	1.0	16.0	133	262	8.1	6.7	12.4	.421
North Sylamore Creek-Middle	F-S	.06	.005	1.0	16.0	133	262	8.1	6.7	11.4	.403
North Sylamore Creek-Lower	F-S	.06	.005	1.0	16.0	133	262	8.1	6.7	9.1	.320
Mikes Creek	F-S	.52	.005	.60	12.0	128	220	7.8	--	11.4	.559
Niangua River	A-L	.32	.04	1.8	23.5	163	336	8.0	5.4	21.9	.606
Elk River	A-L	1.6	.05	.90	24.0	127	273	8.0	5.0	60.8	.750
Illinois River	A-L	1.6	.01	.70	24.0	85	230	8.0	5.4	51.3	.696
Buffalo River-St. Joe	F-L	.06	.004	.95	22.5	94	207	7.8	6.6	24.6	.823
Jacks Fork	F-L	.15	.003	.80	12.0	160	297	8.1	7.4	23.7	.294
Current River	F-L	.23	.005	.90	26.0	140	272	8.2	8.7	97.0	1.332
Kings River	M-L	.42	.10	1.4	18.5	113	243	8.0	6.0	28.2	.800
Black River	P-L	.10	.002	.70	2.6	111	241	8.0	7.2	29.8	.638
Center Creek	P-L[1]	3.1	.05	1.2	23.0	131	349	8.0	7.3	20.2	.522

[1]Center Creek is also downstream of municipal and industrial point sources.

Table 2. Chemical, physical, and biological factors associated with reaches, 1993-95--Continued

[Much of this information is from Femmer (1997) and Davis and Bell (1998). Reaches are grouped by land-use category within basin-size categories. A, agricultural; F, forested; P, lead-zinc mining; M, mixture of land uses, wastewater- treatment plant effects, and instream gravel mining; S, small basin; L, large basin; N, nitrogen, P, phosphorus; C, carbon; $CaCO_3$, calcium carbonate; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; m^3/s, cubic meter per second; m, meters; m^2, square meter. Width is of wetted width of stream at low discharge. Sinuosity is a measure of meandering. Embeddedness is the percent a larger substrate is buried in silt, clay, or sand. Phi is a measure of particle sizes and is defined as the negative base-2 logarithm of the particle size diameter in millimeters; more negative values correspond with larger particle sizes. Canopy angle is formed by the angles from the midpoint of the stream channel to the visible horizon, lower values of canopy angle indicate taller trees, hills, or bluffs adjacent to the stream]

Abbreviated reach name	Width-to-depth ratio	Stream-bed gradient (m/100 m)	Segment sinuosity	Median discharge (m^3/s)	Discharge, coefficient of variation (percent)	Mean velocity (m/sec)	Modal embeddedness (percent)	Modal dominant substrate	Mean phi	Mean canopy angle (degrees)	Woody vegetation density (individuals/100 m^2)
Dousinbury Creek	45.0	0.770	1.23	1.48	376	0.174	26-50	Bedrock	-5.5	135	6.40
Yocum Creek-Upper	33.5	.370	1.24	1.65	138	.383	26-50	Cobble	--	91	13.2
Yocum Creek-Middle	29.0	.370	1.24	1.65	138	.453	5-25	Cobble	-4.6	91	3.22
Yocum Creek-Lower	27.9	.370	1.24	1.65	138	.485	5-25	Cobble	--	84	5.18
Little Osage Creek	24.8	.443	1.14	--	--	.121	5-25	Cobble	--	117	3.02
Peacheater Creek	15.6	.434	1.07	--	--	.193	26-50	Gravel	--	103	4.06
Paddy Creek	19.1	.420	1.08	.84	444	.070	26-50	Cobble	-5.2	45	23.2
Buffalo River-Boxley	44.3	.582	1.27	2.41	177	.158	26-50	Cobble	-6.2	69	8.00
Big Creek	30.6	.195	1.45	--	--	.522	5-25	Cobble	--	70	6.44
North Sylamore Creek-Upper	29.4	.304	1.52	1.41	253	.341	5-25	Gravel	--	76	4.88
North Sylamore Creek-Middle	28.5	.304	1.52	1.41	253	.146	0-5	Cobble	--	75	10.2
North Sylamore Creek-Lower	28.4	.304	1.52	1.41	253	.287	5-25	Cobble	-5.5	80	22.6
Mikes Creek	20.4	.263	1.45	--	--	.123	5-25	Gravel	--	60	8.82
Niangua River	36.1	.410	1.90	15.3	274	.550	5-25	Cobble	-5.5	98	10.8
Elk River	81.1	.062	1.23	40.7	167	.385	26-50	Cobble	-5.6	128	25.0
Illinois River	73.7	.108	3.00	37.6	138	.523	26-50	Gravel	-5.0	121	5.45
Buffalo River-St. Joe	29.9	.188	1.50	36.0	217	.334	5-25	Cobble	-5.0	106	2.76
Jacks Fork	80.6	.223	1.36	10.5	294	.144	5-25	Cobble	-4.9	115	6.78
Current River	72.8	.081	1.43	81.2	125	.724	26-50	Cobble	-5.5	110	14.9
Kings River	35.2	.030	2.69	19.7	157	.696	5-25	Cobble	-4.6	95	8.55
Black River	46.7	.429	1.51	22.9	265	.778	5-25	Cobble	-5.4	111	5.53
Center Creek	38.7	.156	1.38	14.3	230	.602	5-25	Cobble	-5.4	109	3.70

Table 3. Probabilities that selected environmental factors do not differ between land-use and basin-size categories

[p-values are two-sided values from Wilcoxon rank sum test. The data do not include data for the lead-zinc mining reaches, the mixed-effects reach, or the second and third reaches at the multiple-reach stations]

Environmental factor	p-value	
	By land-use category	**By basin-size category**
Drainage area	0.60	0.002
Stream order	.59	.004
Percent agriculture land use	.002	.86
Dissolved nitrite plus nitrate	.003	.86
Total phosphorus	.003	.81
Dissolved organic carbon	1.0	.95
Suspended sediment	.48	.009
Alkalinity	.86	.52
Specific conductance	.27	.68
pH	.95	.68
Dissolved oxygen (5th percentile)	.27	.58
Width	.86	.008
Depth	.68	.04
Width-to-depth ratio	.78	.01
Streambed gradient	.61	.02
Segment sinuosity	.44	.09
Coefficient of variation of discharge	.65	.36
Discharge	.65	.008
Velocity	.45	.05
Embeddedness	.50	.89
Dominant substrate	.20	.49
Phi	1.0	.78
Canopy angle	.03	.07
Woody vegetation density	.27	.68

Table 4. Lead and zinc concentrations at the lead-zinc mining and nearby reaches

[Black River and Center Creek are lead-zinc mining reaches. µg/L, micrograms per liter;
µg/g, micrograms per gram; <, less than]

Abbreviated reach name	Median dissolved lead (µg/L)	Lead in bed sediment (µg/g)	Median dissolved zinc (µg/L)	Zinc in bed sediment (µg/g)
Black River	<10	84	2.1	91
Jacks Fork	<10	24	1.0	64
Center Creek	<10	370	160	5,600
Elk River	<10	19	4.0	71

at the two non-mining reaches. Although mining does not presently occur in the Center Creek Basin, extensive mining occurred in the past and piles of tailings are located immediately adjacent to the creek about 3 river km upstream of the sampling reach. Active mines are greater than 25 km upstream of the sampling reach in the Black River Basin.

COMMUNITY STRUCTURE

A total of 88 species were collected for the fish community samples described in this report. These species are listed in the appendix at the back of this report.

Fish community structure in Ozark streams may be affected by a number of factors. These factors include biotic factors such as competition (Matthews, 1982), predator-prey interactions (Matthews and others, 1987), and periphyton abundance (Matthews and others, 1987). In addition, many species are restricted to a specific stream system. For example, the duskystripe shiner is limited to the White River system (exclusive of the Black River drainage), while its congeners, the cardinal shiner and bleeding shiner, are found in the Arkansas River system and in the Black River drainage of the White River system plus the remainder of the Ozark Plateaus, respectively. Other factors include physical factors such as altitude, water temperature, substrate, geology, stream width and order, channel morphometry, water depth, water velocity, shading, and water quality (Felley and Hill, 1983; Matthews and others, 1987; Matthews and Robison, 1988; Brown and Lyttle, 1992; Matthews and others, 1992; Rabeni and Jacobson, 1993).

Fish communities can be characterized using several criteria—number of species (richness), taxa relative abundance, and feeding group (trophic guild) abundance, for example. Fish communities at different locations can be compared using these criteria or similar measures.

Species and Taxa Richness

In general, communities from larger rivers (larger basins, higher stream order, and higher streamflow) appear to be composed of more species (tables 5 and 6). The number of species in samples from the larger rivers ranged from 15 to 42. The number of species from the small rivers ranged from 10 to 25. A comparison of sites by size category within land-use categories (table 6) indicated that overall species richness and richness of species in the minnow, darter, and sunfish families generally were greater at sites in larger basins. Differences between small and large basins were statistically significant ($p<0.10$, two-sided test) except for richness of darters and sunfish in agriculture basins. This increase in species richness with increasing basin size and stream order is predictable (Vannote and others, 1980) and has been reported in Ozark streams (Pflieger, 1989; Smale and others, 1995). Also, several of the reaches on larger rivers are relatively close to farm ponds or downstream reservoirs, which can contribute additional species (including largemouth bass, bluegill, and gizzard shad) not commonly found in these streams.

Species richness generally was greater at agriculture reaches (tables 5 and 7). The number of species ranged from 19 to 36 at agriculture reaches, and from 10 to 38 at forest reaches. A comparison of reaches by land-use category within size categories (table 7) indicated that basin size is a factor affecting differences in species and taxa richness between land-use categories. Species and taxa richness were not significantly different at reaches in large agriculture and forest basins. Species richness and richness of darters and sunfish of agriculture and forest reaches were significantly different ($p<0.001$) in small basins. Some of the additional species may be coming from nearby farm ponds and reservoirs.

Relative Abundance of Taxonomic Groups

The relative abundances of selected taxa (stonerollers, all other minnows, sunfish, darters, madtoms, suckers, and all remaining fish) at each reach were calculated. Relative abundance differences were observed between some of the categories of reaches. The magnitude, consistency, and statistical significance of the differences varied.

At most reaches, most individuals were members of the minnow family. Stonerollers, duskystripe shiners, bleeding shiners, or cardinal shiners generally were more abundant than other fish species. Both of these situations are common in the Springfield and Salem Plateaus and Boston Mountain streams (Pflieger, 1997; Rohm and others, 1987; Matthews and others, 1978; Giese and others, 1987; Robison and Buchanan, 1988, Pflieger, 1989; Arkansas Department of Pollution Control and Ecology, 1995; Smale and others, 1995). Sunfish, darters, and sculpins also were abundant.

To evaluate temporal variability and multiple-reach spatial variability, samples were collected at most reaches in 1993-95 (only the 1993, 1995, and selected 1994 data are presented here). The relative abundances of the selected taxa were relatively consistent at a specific reach between 1993 and 1995 (fig. 3). Two additional reaches were sampled at two of the stations to evaluate spatial variability of multiple reaches. The three multiple reaches at the two stations were usually quite similar (fig. 3), and appeared to have less variation than in the temporal comparison.

Land-use differences seem to affect the relative abundance of several taxa. The relative abundance of stonerollers, sunfish, darters, and suckers is significantly different ($p<0.10$) in samples from forest and agriculture reaches (table 8 and fig. 3). Relative abundances of stonerollers and suckers generally were smaller and the relative abundances of sunfish and darters generally were larger at forest reaches. The largest difference is between median relative abundances of stonerollers at forest and agriculture reaches. The median relative abundance of stonerollers at forest reaches was 14 percent (range 2 to 44 percent); the median relative abundance of stonerollers at agriculture reaches was 35 percent (range 3 to 51 percent). The median relative abundance of sunfish at forest reaches was 11 percent (range 3 to 40 percent); the median relative abundance of sunfish at agriculture reaches was 4 percent (range 2 to 28 percent). The median relative abundance of darters at forest reaches was 14 percent (range 8 to 26 percent); the median

Table 5. Species richness by reach

[Richness numbers do not include both species of stonerollers; A, agriculture; S, small basin; L, large basin; F, forest; P, lead-zinc mining; M, mixture of land uses, wastewater-treatment plant effects and instream gravel mining]

Abbreviated reach name	Land use and size category	Year	Species richness	Taxa richness		
				Minnows	Darters	Sunfish
Dousinbury Creek	A-S	1993	24	8	4	6
Dousinbury Creek	A-S	1995	25	8	4	5
Yocum Creek - Upper	A-S	1993	21	3	6	5
Yocum Creek - Middle	A-S	1993	20	4	5	6
Yocum Creek - Middle	A-S	1994	20	3	5	5
Yocum Creek - Middle	A-S	1995	21	4	5	6
Yocum Creek - Lower	A-S	1993	19	3	5	6
Little Osage Creek	A-S	1995	24	7	6	5
Peacheater Creek	A-S	1995	19	6	4	5
Niangua River	A-L	1993	20	6	4	4
Niangua River	A-L	1995	32	11	6	7
Elk River	A-L	1993	26	8	4	8
Elk River	A-L	1995	32	9	5	8
Illinois River	A-L	1993	34	9	5	5
Illinois River	A-L	1995	36	10	4	7
Paddy Creek	F-S	1993	10	3	1	4
Paddy Creek	F-S	1995	14	3	3	4
Buffalo River - Boxley	F-S	1993	16	6	3	3
Buffalo River - Boxley	F-S	1995	19	8	4	4
Big Creek	F-S	1995	16	3	4	3
North Sylamore Creek - Upper	F-S	1993	14	4	2	4
North Sylamore Creek - Middle	F-S	1993	14	4	3	4
North Sylamore Creek - Lower	F-S	1993	16	6	2	4
North Sylamore Creek - Lower	F-S	1994	18	5	3	4
North Sylamore Creek - Lower	F-S	1995	18	6	2	5
Mikes Creek	F-S	1995	13	4	3	3
Buffalo River - St. Joe	F-L	1993	32	12	7	5
Buffalo River - St. Joe	F-L	1995	38	13	8	5
Jacks Fork	F-L	1995	20	7	3	4
Current River	F-L	1995	29	7	5	5
Black River	P-L	1993	22	6	5	5
Black River	P-L	1995	18	4	4	5
Center Creek	P-L	1993	15	6	1	4
Center Creek	P-L	1995	29	8	5	8
Kings River	M-L	1993	42	15	6	8

Table 6. Comparison of taxa richness of reaches in small and large basins

[p-values are two-sided values from Wilcoxon rank sum test]

Characteristic	Agriculture basins			Forest basins		
	Small basin median	Large basin median	p-value	Small basin median	Large basin median	p-value
Species richness	21	32	0.02	16	30.5	0.005
Minnow richness	4	9	.01	4	9.5	.01
Darter richness	5	4.5	.61	3	6	.02
Sunfish richness	5	7	.18	4	5	.03

Table 7. Comparison of taxa richness of reaches in agriculture and forest basins

[p-values are two-sided values from Wilcoxon rank sum test]

Characteristic	Small basins			Large basins		
	Forest basin median	Agriculture basin median	p-value	Forest basin median	Agriculture basin median	p-value
Species richness	16	21	<0.001	30.5	32	1.0
Minnow richness	4	4	.81	9.5	9	.75
Darter richness	3	5	<.001	6	4.5	.44
Sunfish richness	4	5	<.001	5	7	.15

Table 8. Probabilities that relative abundances of selected taxonomic groups do not differ between the forest and agriculture land-use categories

[p-values are two-sided values from Wilcoxon rank sum test. The data are for 1995 and do not include data for the lead-zinc mining reaches, or the mixed-effects reach. RA, relative abundance]

Taxonomic group	p-value	
	Stonerollers included in RA calculation	Stonerollers not included in RA calculation
Stonerollers	0.07	--
Other minnows	.77	0.45
Sunfish	.09	.18
Darters	.07	.15
Madtoms	.77	.52
Suckers	.06	.06

relative abundance of darters at agriculture reaches was 4 percent (range 1 to 23 percent). The median relative abundance of suckers at forest reaches was 0.4 percent (range 0.0 to 12 percent); the median relative abundance of suckers at agriculture reaches was 1.2 percent (range 0.6 to 3.3 percent).

Much of the decrease in the relative abundances of sunfish and darters at forest reaches is the result of the increase in the relative abundance of stonerollers. When the stonerollers collected at a reach were not included in the calculation of relative abundance values, no statistical difference in the relative abundances of minnows, sunfish, darters, or madtoms between the forest and agriculture reaches was detected (table 8). The relative abundance of suckers remained significantly different. However, although not statistically different, the relative abundances of sunfish and darters generally remained greater at forest reaches (medians of 26 percent sunfish and 18 percent darters) than at agriculture reaches (medians of 6 percent sunfish and 8 percent darters).

The higher relative abundance of stonerollers and lower relative abundance of darters at agriculture reaches are consistent with the results of a study by the Arkansas Department of Pollution Control and Ecology (1995). In that study, fish communities of several sites in the upper White River Basin in Arkansas were

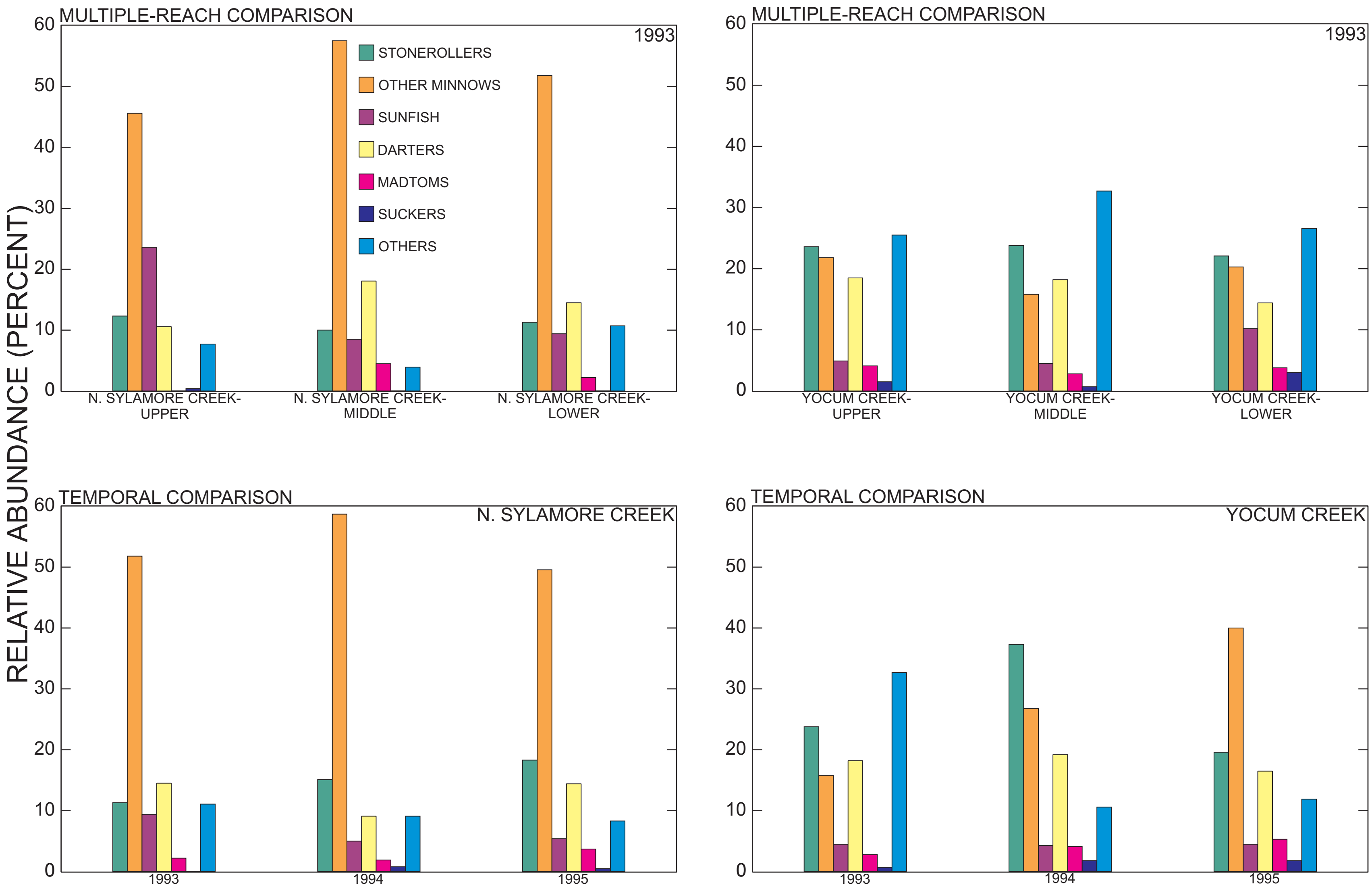

Figure 3. Relative abundance of selected taxa at individual reaches (page 1 of 3).

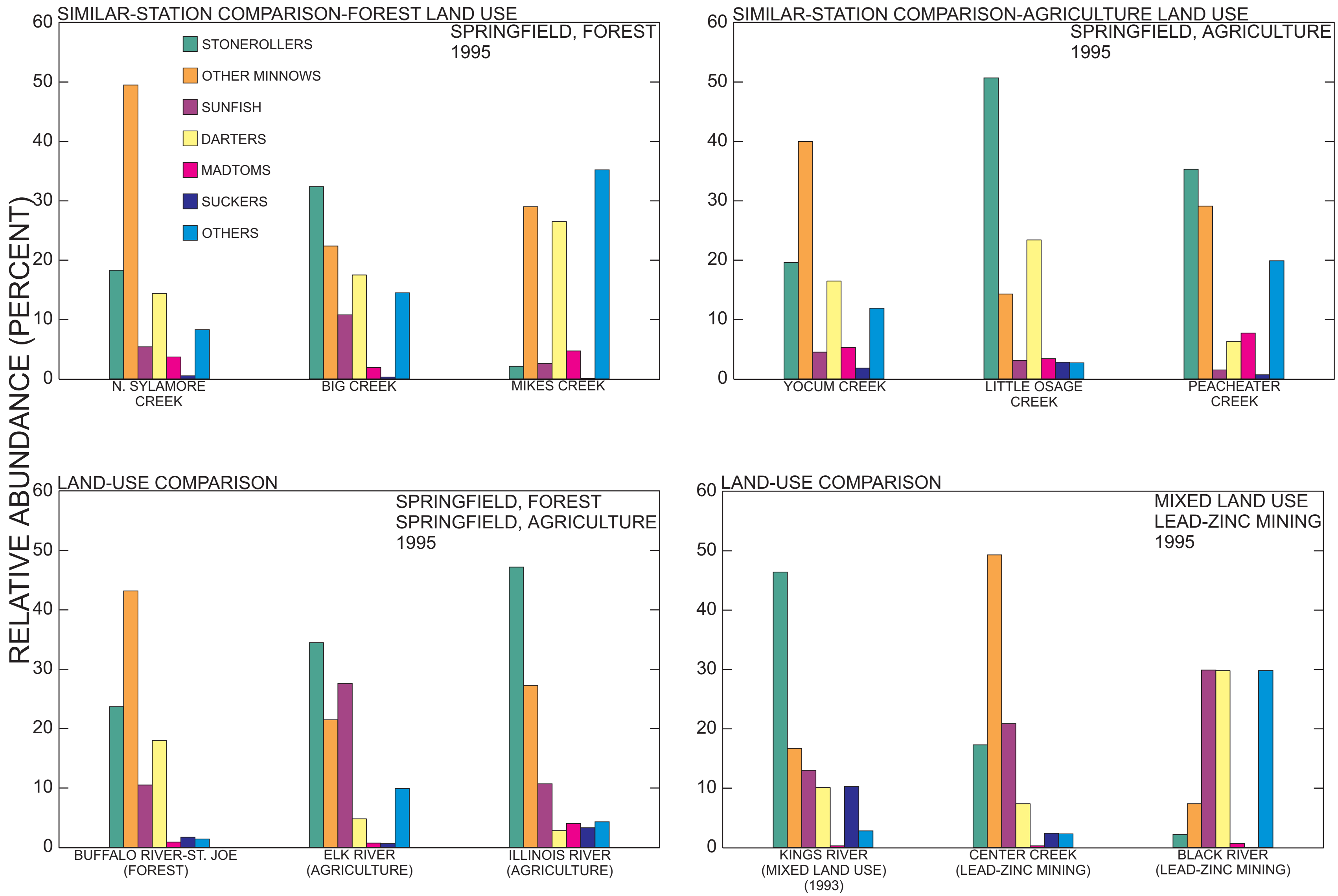

Figure 3. Relative abundance of selected taxa at individual reaches (page 2 of 3).

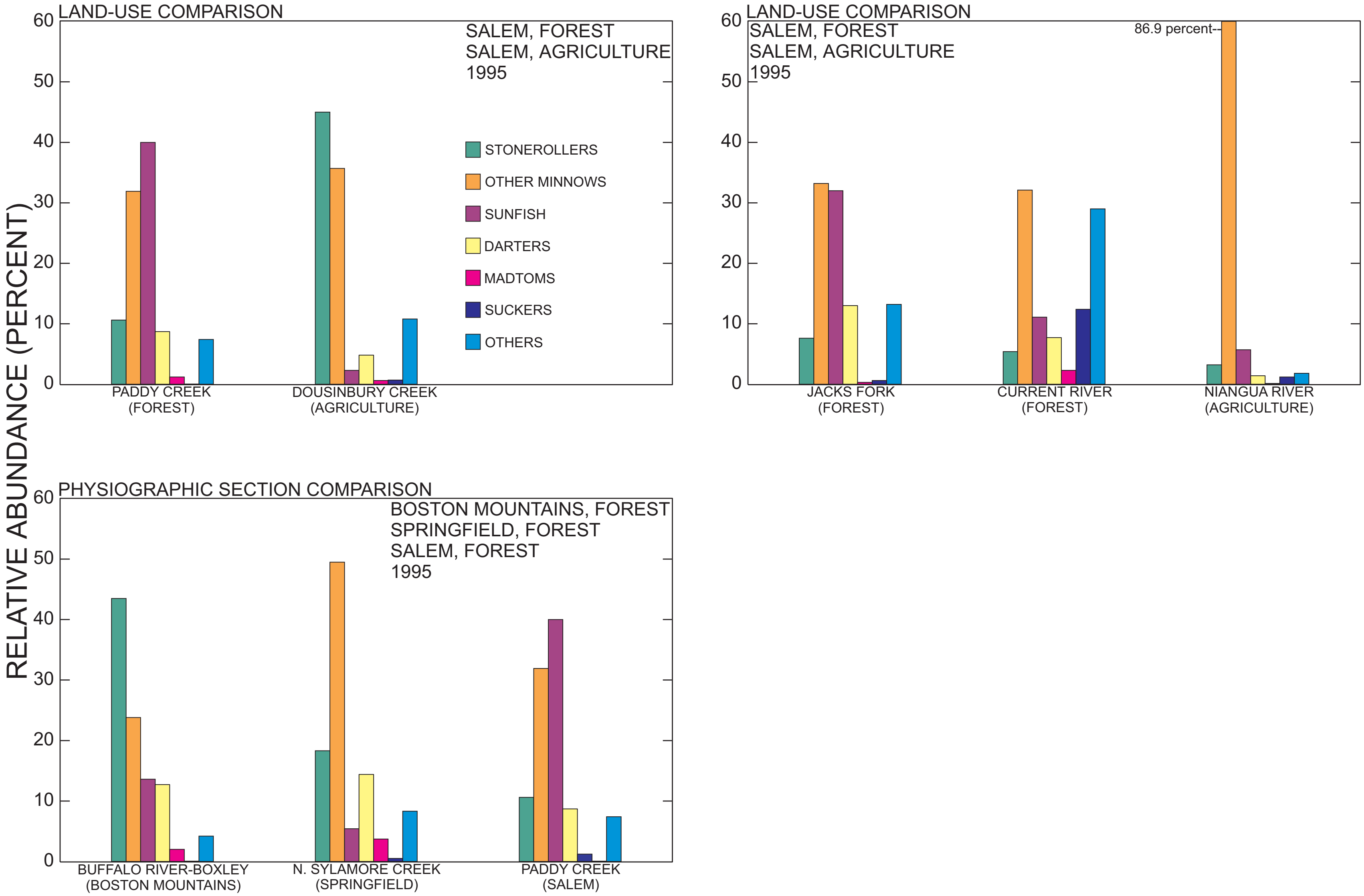

Figure 3. Relative abundance of selected taxa at individual reaches (page 3 of 3).

compared temporally. Samples collected in 1963 or the mid-1980's were compared with samples collected in 1993 or 1994 from the same sites or from sites very close to the original site. Most sites had more pasture and animal production in their basins in the mid-1990's than 10 to 30 years previous. The relative abundance of stonerollers consistently increased, while the relative abundance of darters decreased at most sites.

Agricultural reaches do not always have higher relative abundances of stonerollers than the forest reaches. For example, at Yocum Creek (an agriculture reach) in 1995 stonerollers had a relative abundance of about 20 percent, while Big Creek and Buffalo River near Boxley (both forest reaches) had stonerollers with relative abundances of about 35 to 45 percent. This indicates that the higher nutrient concentrations and more open canopy associated with agriculture reaches are not the only factors that determine stoneroller relative abundance. Gorman (1987) reported that adult and young-of-the- year stonerollers have habitat preferences related to depth, velocity, and substrate size. The limited amount of water-quality data for Big Creek suggests that nutrient concentrations may be higher at Big Creek than at most of the other forest reaches. Stream morphology (greater width, depth, and width-to-depth ratio, and gradient), lower alkalinity, and location in the Boston Mountains (rather than the Springfield-Salem Plateaus) are noticeable differences between the Buffalo River near Boxley and other small, forest reaches. Relative abundance of stonerollers at the Niangua River (an agriculture reach) was about 3 percent. However, at Niangua River only total phosphorus concentrations are greater than at forest reaches; nitrate concentrations and canopy angles are similar to those at forest reaches.

Perturbations resulting from activities other than agriculture activities have been shown to result in increased relative abundance of stonerollers. Ebert and Filipek (1988) reported that central stonerollers were more abundant in reaches of a third order Boston Mountains stream altered by channelization than in natural reaches. These channelized reaches were shallower and canopy closure was lacking. Brown and Lyttle (1992) reported substantial increases in the density of central stonerollers in riffles at and downstream of a gravel mining area on the Kings River, although similar increases were not found at similar locations on Crooked Creek and the Illinois River. Also, stonerollers typically are more abundant downstream from wastewater-treatment plants.

Relative abundance of stonerollers at the two reaches closest to wastewater-treatment plants (Center Creek and Kings River) ranged from 2 to 17 percent at Center Creek to 46 percent at Kings River (fig. 3). The relative abundances for Center Creek are low for a reach with elevated nutrient concentrations and an open canopy (table 2). Center Creek has elevated lead concentrations in bed sediment and elevated zinc concentrations in water and bed sediment (table 4). The elevated trace element concentrations and elevated semivolatile organic compound concentrations in bed sediment may be major factors in the low relative abundance of stonerollers and also a high relative abundance of fish tolerant of degraded water chemistry or habitat (Petersen and others, 1998). The higher relative abundance of stonerollers at the Kings River reach are more typical of reaches downstream from wastewater-treatment plants with elevated nutrient concentrations.

Relative abundance of stonerollers, other minnows, darters, and sunfish at the Black River reach (fig. 3) are typical of reaches in forested basins; the fish community does not appear affected by the lead-zinc mining upstream. Although lead and zinc concentrations in bed sediment are somewhat higher than concentrations at a nearby station they are substantially lower than concentrations at Center Creek (table 4).

Stoneroller Abundance and Community Functions

Greater relative abundance of stonerollers at agriculture reaches (and downstream from wastewater-treatment plants) likely is related to the food preference of stonerollers. Stonerollers graze upon periphyton and, in most habitats in Ozark streams, are the most abundant herbivores. The increased nutrient concentrations and less shaded conditions at agriculture reaches probably result in increased periphyton production, and, therefore, a more abundant food source for stonerollers. Smart and others (1985) reported greater chlorophyll *a* values associated with benthic algae (periphyton) from streams draining agricultural basins in the Missouri Ozarks.

Stonerollers have been shown to regulate algal community composition and distribution (Power and others, 1985; Power and others, 1988; Matthews and others, 1987), and primary production (Stewart, 1987). In a manipulative field experiment, Gelwick and Matthews (1992) found that several structural and functional characteristics of a south-central Oklahoma stream were affected by stonerollers. Grazing by stonerollers decreased net primary productivity per unit area, decreased algal height, decreased areal percentage of *Spirogyra*, and increased the percentage of diatoms and blue-green algae. In pools grazed by stonerollers invertebrate densities were higher than in pools not grazed by stonerollers, and the invertebrates were primarily collector-gatherers. Benthic particulate organic matter also was finer in these pools, suggesting that food of the appropriate size for these invertebrates was more available. This may have been the result of reduction of algal matter to smaller sizes (by feces production or mechanical fragmentation) by stonerollers.

Temporal and Spatial Variability

Temporal and spatial variability of fish communities were evaluated by comparing relative abundance values for 1993 and 1995 samples at individual reaches and for the samples at the three reaches at the multiple-reach stations. The percentage similarity index (PSC) was used.

Similarity of the 1993 and 1995 fish community samples at a reach varied considerably; PSC values ranged from 44 to 85 percent (table 9). The median PSC was 67 percent. The percentage similarity does not appear to be affected by land use or stream size, except that the two lead-zinc mining reaches (Black River and Center Creek) both have low similarity. Part of the low similarity of the Center Creek samples may be because of higher stream-stage conditions during the 1993 sampling, resulting in less efficient sampling.

Table 9. Similarity of fish communities in 1993 and 1995

[PSC is the percentage similarity index. Values are calculated from relative abundance data]

Reach	PSC	Reach	PSC
Dousinbury Creek	66	Buffalo Rive-Boxley	76
Niangua Creek	71	Buffalo River-St. Joe	67
Paddy Creek	53	North Sylamore Creek	85
Yocum Creek	66	Black River	44
Center Creek	55	Elk River	81
Illinois River	81		

Three adjacent reaches were sampled on North Sylamore Creek and Yocum Creek (multiple-reach stations) in 1993. Percentage similarity between the three reaches ranged from 71 to 82 percent at North Sylamore Creek and from 84 to 86 percent at Yocum Creek (table 10).

These few comparisons may indicate that samples (and presumably communities) collected at adjacent reaches during a single year, generally are more similar to each other than are samples collected at the same location, but in different years. However, for the two reaches where direct comparisons can be made (North Sylamore and Yocum Creeks), one had very similar PSC values for the temporal and spatial comparisons and one had substantially higher PSC values for the spatial comparison.

RESULTS OF ORDINATION ANALYSES

Two types of ordination analysis (detrended correspondence analysis and canonical correspondence analysis) were used to examine the relative abundance data. In general, the results of the two analyses and the associated examination of related environmental factors were similar.

Detrended Correspondence Analysis

Detrended correspondence analysis (DCA) was used to compare the community structure in 1993 and 1995 at 22 reaches. The results of this single DCA ordination are discussed below.

In a preliminary ordination of the 1993 and 1995 data, the ordination scores for the reach on Center Creek (a reach downstream from lead-zinc mining areas) were distinctly separate from the scores for all other reaches. Much of this separation is probably because of the abundance of bluntface shiner (*Cyprinella camura*) and western mosquitofish (*Gambusia affinis*), two species not widely distributed in the Ozarks (Pflieger, 1997) and not collected at other reaches. Sampling difficulties in 1993 related to seining difficulties associated with elevated flows during the sampling period probably also were factors. Because of the wide separation of this reach from the other reaches in the preliminary ordination, the two Center Creek samples were only included as passive samples (i.e., they were added to the ordination after the ordination axes had been extracted) in the final ordination. The ordination scores for the Black River reach (the other reach downstream from lead-zinc mining) were not distinctly separate from scores of other reaches.

Table 10. Similarity of fish communities of Yocum and North Sylamore Creeks in 1993

[Values are percentage similarity index (PSC), calculated from relative abundance data]

Reach	Reach					
	Yocum Creek (upper)	Yocum Creek (middle)	Yocum Creek (lower)	North Sylamore Creek (upper)	North Sylamore Creek (middle)	North Sylamore Creek (lower)
Yocum Creek (upper)	100					
Yocum Creek (middle)	86	100				
Yocum Creek (lower)	86	84	100			
North Sylamore Creek (upper)	52	48	53	100		
North Sylamore Creek (middle)	54	49	49	71	100	
North Sylamore Creek (lower)	61	57	58	82	82	100

The ordination of the 1993 and 1995 data set slightly separates most of the agriculture reaches from other reaches (fig. 4). DCA axis 1 and axis 2 accounted for only about 30 percent of the variance in the species data. The DCA axis 1 and 2 scores are plotted in figure 4. Agriculture reaches generally had lower scores than other reaches on DCA axis 1. However, considerable overlap of DCA axis 1 scores of agriculture and forest reaches occurred. Along DCA axis 2 reaches were not separated by land use. Large-basin reaches generally have higher DCA axis 2 scores, although considerable overlap of axis 2 scores of large-basin and small-basin reaches occurred. Reaches that have some of their drainage areas within the Boston Mountains physiographic section (Kings River, Illinois River, and Buffalo River) also tend to have higher DCA axis 2 scores than other reaches.

Several environmental factors correlated strongly (Spearman's rho greater than or equal to 0.35) with axis 1 and axis 2 scores (table 11). Correlations between ordination axes and environmental factors show that substrate embeddedness and size, nutrient concentrations, alkalinity, percent agriculture in basin, and canopy angle are strongly correlated with axis 1. Relative to reaches with large DCA axis 1 scores (often those categorized as forest reaches), reaches with small DCA axis 1 scores (often those categorized as agriculture reaches) tend to be typified by greater substrate embeddedness; higher concentrations of nitrate and phosphorus; greater (more open) canopy angles; higher percent agricultural land use in the basin; lower alkalinity, sinuosity, and discharge coefficient of variation; and smaller substrate size. Width, depth, width-to-depth ratio, dissolved oxygen concentrations (5th percentile), suspended sediment concentration, alkalinity, and embeddedness are strongly correlated with DCA axis 2. Relative to reaches with large DCA axis 2 scores (often those with larger basins), reaches with small DCA axis 2 scores (often those with smaller basins) tend to be typified by greater dissolved oxygen (5th percentile), nitrate, and alkalinity concentrations; greater specific conductance; lower suspended sediment concentrations; narrower width; shallower depth; smaller width-to-depth ratios; less embedded substrate; and smaller drainage areas. The strong correlations indicate that water quality, substrate, stream morphology, and canopy angle are important determinants of these fish communities.

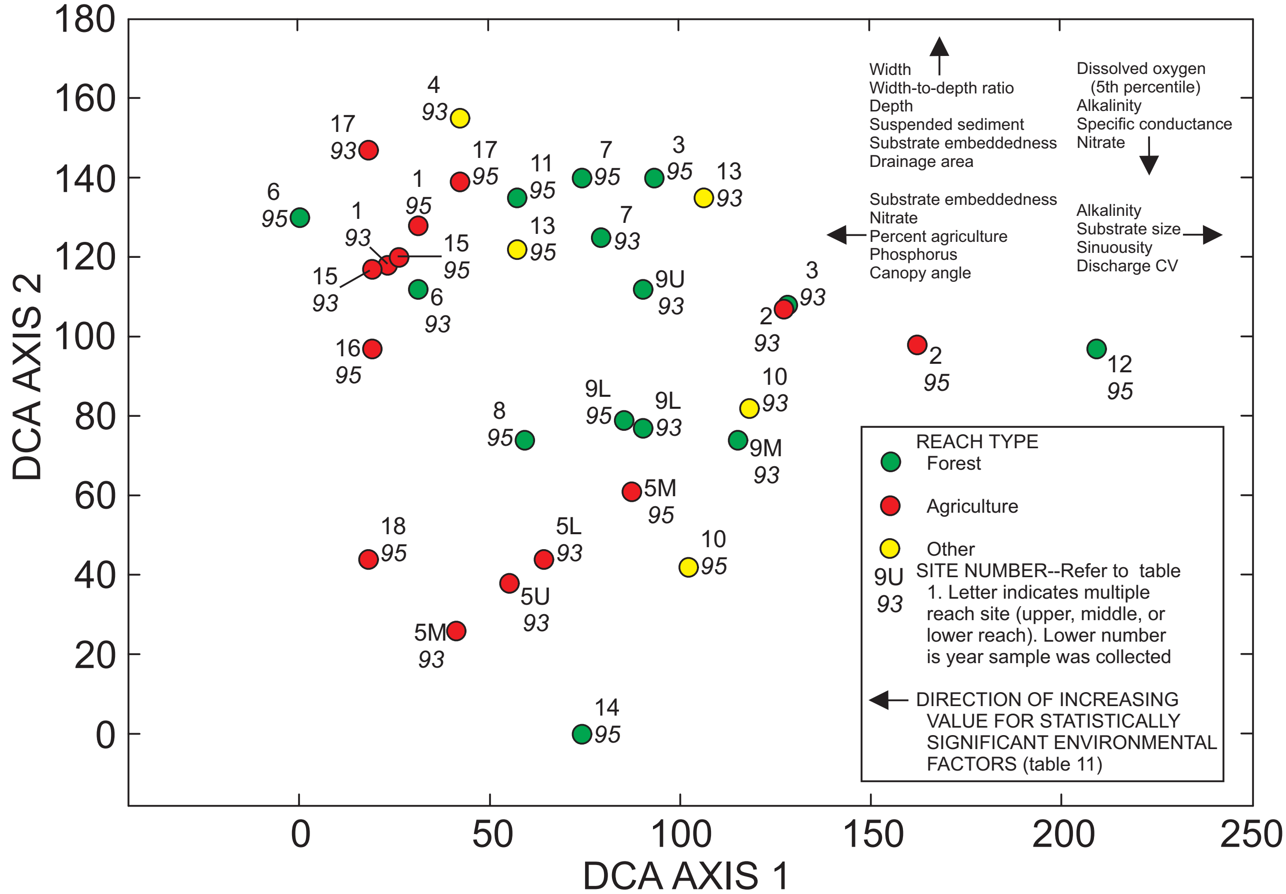

Figure 4. Detrended correspondence analysis (DCA) ordination plot of reach scores showing generalized correlation with environmental factors.

Table 11. Correlation between detrended correspondence analysis axis values and selected chemical, physical, and biological factors

[Spearman's rho correlation values can range from 0 to 1 or 0 to -1. Negative values indicate an inverse relation. A value of 0 would indicate no correlation between the ranks of the axis score and the habitat factor, whereas a value of 1 or -1 would indicate perfect correlation between the axis score and the factor. p-values are two-sided probability values from a t-test]

Environmental factor	Axis 1 score		Axis 2 score	
	Spearman's rho	p-value	Spearman's rho	p-value
Alkalinity	0.40	0.03	-0.37	0.04
Specific conductance	.18	.32	-.33	.07
pH	.18	.34	.02	.91
Dissolved oxygen (5th percentile)	.25	.21	-.40	.04
Dissolved nitrite plus nitrate	-.44	.01	-.31	.09
Total phosphorus	-.41	.02	.04	.82
Dissolved organic carbon	.28	.13	.28	.12
Suspended sediment	-.04	.85	.36	.04
Percent agricultural land use	-.42	.02	-.12	.52
Drainage area	.13	.48	.32	.08
Stream order	.06	.77	.26	.16
Width	-.20	.28	.45	.01
Depth	-.09	.62	.41	.02
Width-to-depth ratio	-.21	.25	.43	.02
Streambed gradient	-.05	.80	.23	.21
Segment sinuosity	.34	.06	.15	.43
Velocity	.23	.22	-.09	.62
Discharge	-.20	.31	.28	.15
Coefficient of variation of discharge	.33	.09	.15	.45
Embeddedness	-.45	.01	.36	.05
Dominant substrate	.36	.04	-.15	.44
Phi	-.07	.74	.07	.72
Canopy angle	-.38	.03	.24	.19
Woody vegetation density	.25	.18	.04	.84

Canonical Correspondence Analysis

Canonical correspondence analysis (CCA) was used to compare community structure at the 22 reaches sampled in 1993 and 1995. As in the DCA, the Center Creek samples were included as passive samples. Results were similar to the results of the DCA and Spearman correlation analysis. Approximately 23 percent of the variance in the species data and 50 percent of the variance in the species-environment relation was explained by the first two axes.

The CCA ordination included 9 environmental factors that were selected from 20 factors, primarily using principal components analysis (PCA). The reduced list of factors satisfied a requirement of CCA that the number of environmental factors be less than the number of samples, and also simplified the analysis and interpretations based on redundant environmental data.

PCA of the 20 environmental factors identified six principal components with eigenvalues greater than 1. Loadings with an absolute value greater than 0.70 (table 12, values in bold) indicated groups of closely associated factors. These included factors related to stream size, ionic strength (such as alkalinity and specific conductance), nutrient concentrations, riparian vegetation, substrate size, and organic carbon concentration on principal components 1, 2, 3, 4, 5, and 6, respectively. Six factors representing the six groups of closely associated factors plus three other factors (table 12, factors in bold) were selected for use in the CCA.

The ordination of all reaches sampled in 1993 and 1995 shows a general separation of reaches by land use and basin size category (fig. 5). Reaches with forest land use generally have lower scores on CCA axis 1 than agriculture reaches. Reaches with large basins generally have higher scores on CCA axis 2 than reaches with small basins. However, as in the DCA results, a considerable amount of overlap occurs in reaches with small and large basins and also in reaches with forest and agriculture basins.

Table 12. Principal components analysis of environmental factors on the first six principal components

[Groups of closely associated factors with absolute values of varimax-rotated loadings greater than 0.70 shown in bold. Factors selected for canonical correspondence analysis shown in bold]

Environmental factor	Loading for indicated principal component					
	1	2	3	4	5	6
Width	**0.942**	-0.047	0.063	-0.154	-0.106	-0.092
Drainage area	**.939**	.023	-.017	.004	.194	.012
Width-to-depth ratio	**.833**	.163	.040	-.221	-.173	-.209
Depth	**.816**	-.266	.036	-.047	.037	.076
Stream order	**.796**	-.020	.057	.438	.304	.050
Alkalinity	-.075	**.903**	.169	-.050	.115	.100
pH	.126	**.892**	-.013	-.012	-.094	.106
Specific conductance	-.031	**.840**	.454	.086	.114	.055
Percent agriculture	.039	.165	**.941**	.105	-.139	-.014
Dissolved nitrite plus nitrate	.142	.148	**.912**	.175	.019	-.200
Total phosphorus	.015	.098	**.875**	-.079	-.019	.310
Woody vegetation density	.004	.195	-.269	**-.842**	.184	.132
Dominant substrate	.002	.009	-.118	-.013	**.882**	-.155
Dissolved organic carbon	-.105	.428	.045	-.064	-.229	**.768**
Suspended sediment	.542	-.077	.364	-.136	.284	.398
Canopy angle	.607	.201	.427	.067	-.429	-.189
Velocity	.597	.307	.222	.409	.196	-.023
Embeddedness	-.205	.393	-.173	.644	.420	.123
Streambed gradient	-.537	-.145	-.091	-.063	-.682	-.042
Segment sinuosity	.613	.037	-.087	.360	.062	.383

The environmental-gradient arrows indicate the relation of environmental factors to the CCA axes. The arrow points in the direction of maximum change in values of the associated factor, and the arrow length is proportional to the maximum rate of change (Ter Braak and Verdonschot, 1995). Greater absolute values of canonical coefficients (table 13) indicate stronger correlation between a factor and a CCA axis. Therefore, locations of reaches along axis 1 are most influenced by alkalinity, nitrate, and organic carbon concentrations. Locations of reaches along axis 2 are most influenced by drainage area.

Table 13. Canonical coefficients for environmental factors

Environmental factor	Canonical coefficient	
	Axis 1	Axis 2
Drainage area	4	83
Alkalinity	-88	37
Dissolved nitrite plus nitrate	59	-17
Woody vegetation density	27	-12
Dominant substrate	-41	9
Dissolved organic carbon	59	15
Suspended sediment	36	19
Canopy angle	30	-30
Embeddedness	27	-46

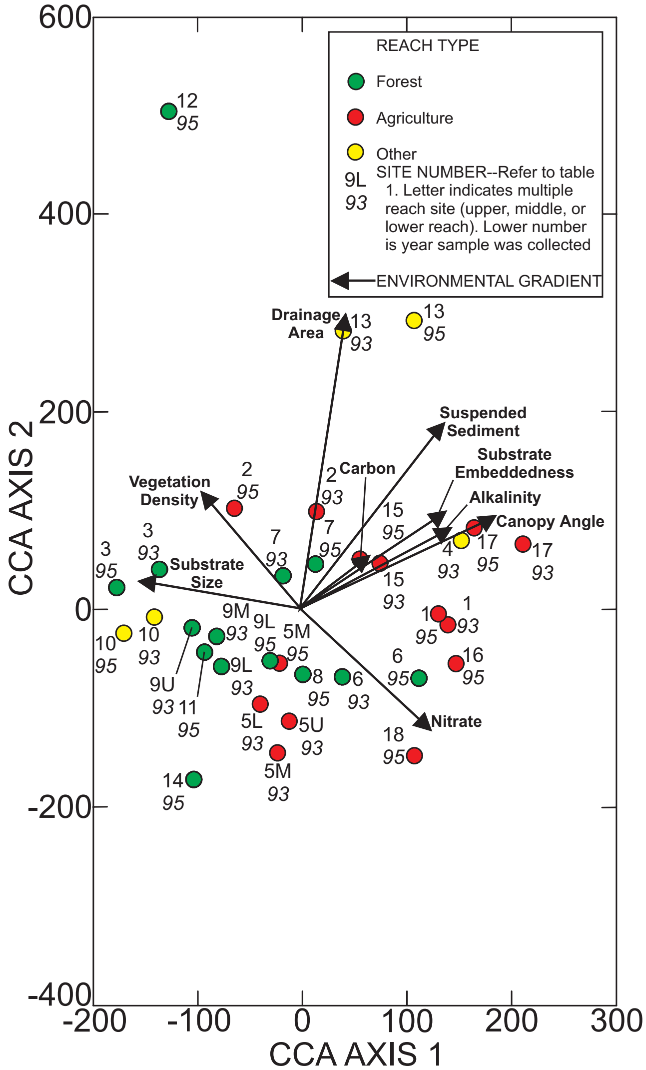

Figure 5. Canonical correspondence analysis (CCA) ordination plot of reach scores with selected environmental factors.

Relative to reaches with small CCA axis 2 scores (generally those with small basins), reaches with large axis 2 scores (generally those with large basins) tend to be typified by greater drainage area (and associated factors, table 12; many of the other factors listed below also represent associated factors); higher concentrations of alkalinity, suspended sediment, and dissolved organic carbon; lower nitrate concentrations; coarser and more embedded substrates; greater canopy angles; and greater density of woody vegetation. Relative to reaches with small axis 1 scores (generally, forest reaches), reaches with large axis 1 scores (generally, agriculture reaches) tend to be typified by higher concentrations of suspended sediment, dissolved organic carbon, nitrate, and alkalinity; smaller and more embedded substrates; greater canopy angles; and less dense woody vegetation.

The three reaches not categorized as forest or agriculture reaches plotted in three separate areas of the ordination plot. The Black River, with its slightly elevated lead and zinc concentrations and low nutrient concentrations, plotted with the majority of the forest reaches. The Kings River with its elevated nutrient concentrations (downstream from a wastewater-treatment plant) plotted nearer the agriculture reaches. Center Creek with its substantially elevated lead and zinc concentrations and elevated nutrient concentrations (downstream from municipal and industrial wastewater) plotted separate from all other reaches.

RESULTS OF CLASSIFICATION ANALYSIS

Two-way indicator species analysis (TWINSPAN), a classification technique, was used to classify reaches using community data collected in 1993 and 1995. The resulting hierarchies of reaches are shown in a dendrogram for 1993 and 1995 (fig. 6). Similar reaches are joined at a low level in the dendrogram, while more dissimilar reaches are not joined until a higher level (Gauch, 1982).

The classification based on the combined 1993 and 1995 data yielded relatively consistent separation of reaches by basin-size and land-use categories (fig. 6). The first TWINSPAN classification step separated most of the reaches in smaller basins (reaches 1-22 in fig. 6) from most of the reaches in larger basins (reaches 23-33 in fig. 6). Several measures that commonly relate to stream size (drainage area, stream order, mean width, mean depth, width-to-depth ratio, gradient, sinuosity, velocity, and discharge), dissolved organic carbon concentration, suspended-sediment concentration, and canopy angle were statistically different ($p<0.10$) between these two groups of reaches (table 14). Most of the reaches with small, forested basins (reaches 4-14 in fig. 6) were separated from the small, agriculture basin reaches (reaches 15-22 in fig. 6). Values of nitrate concentration, total phosphorus concentration, specific conductance, dissolved oxygen concentration, percent agricultural land use, canopy angle, woody vegetation density, phi (a measure of substrate size), sinuosity, coefficient of variation of discharge, and drainage area were statistically different ($p<0.10$) between these two groups containing mostly small agriculture or small forest reaches (table 14).

Preferential species (actually pseudospecies) of the group containing most of the small-basin reaches (reaches 1-22 of fig. 6) include pseudospecies representing greater relative abundances of banded sculpin and of hornyhead or redspot chubs. Species most characteristic of the group containing most of the large-basin reaches (reaches 23-33 of fig. 6) included bluntnose minnow and black redhorse.

Preferential species (again, actually pseudospecies) of the group containing most of the small, forest-basin reaches (reaches 4-14 of fig. 6) include the telescope shiner (this is mostly due to natural distributions) and the pseudospecies representing greater relative abundance of smallmouth bass, longear sunfish, and rock bass/shadow bass/Ozark bass. Preferential species of the group containing most of the small, agriculture basin reaches (reaches 15-22 of fig. 6) include largemouth bass.

IMPLICATIONS FOR WATER-QUALITY ASSESSMENT

The relations between land use, stream size, and fish communities described in this report have implications for water-quality assessments of Ozark streams. Compared to other parts of the United States, many fish species live in the Ozarks. Approximately 175 species (including introduced species) are present in the Ozark Plateaus province part of the Ozark Plateaus NAWQA study unit; at least 19 of these species are endemic to the Ozarks area. Consequently, widespread and extreme degradation of water quality (chemical or aquatic habitat factors) could affect several species found nowhere else in the world. Many of these 175 species are intolerant of habitat or water-chemistry

Table 14. Probabilities that selected environmental factors do not differ between TWINSPAN groups

[p-values are two-sided values from Wilcoxon rank sum test. Reach numbers are from figure 6]

Environmental factor	p-value	
	Difference between reaches 1-22 (primarily small basins) and reaches 23-33 (primarily large basins)	**Differences between reaches 4-14 (primarily small forested basins) and 15-22 (primarily small agricultural basins)**
Drainage area	0.002	0.05
Stream order	<.001	.85
Percent agricultural land use	.12	<.001
Alkalinity	.85	.21
Specific conductance	.54	.07
pH	.78	.39
Dissolved oxygen (5th percentile)	.86	.05
Dissolved nitrite plus nitrate	.37	<.001
Total phosphorus	.16	.001
Dissolved organic carbon	.05	.10
Suspended sediment	<.001	.93
Width	.02	.90
Depth	.002	.23
Width-to-depth ratio	.08	.34
Streambed gradient	.02	.38
Segment sinuosity	.009	.03
Velocity	.007	.54
Discharge	.008	.57
Coefficient of variance of discharge	.50	.04
Embeddedness	.95	.81
Dominant substrate	.56	.15
Phi	.51	.02
Canopy angle	.09	.03
Woody vegetation density	.18	.02

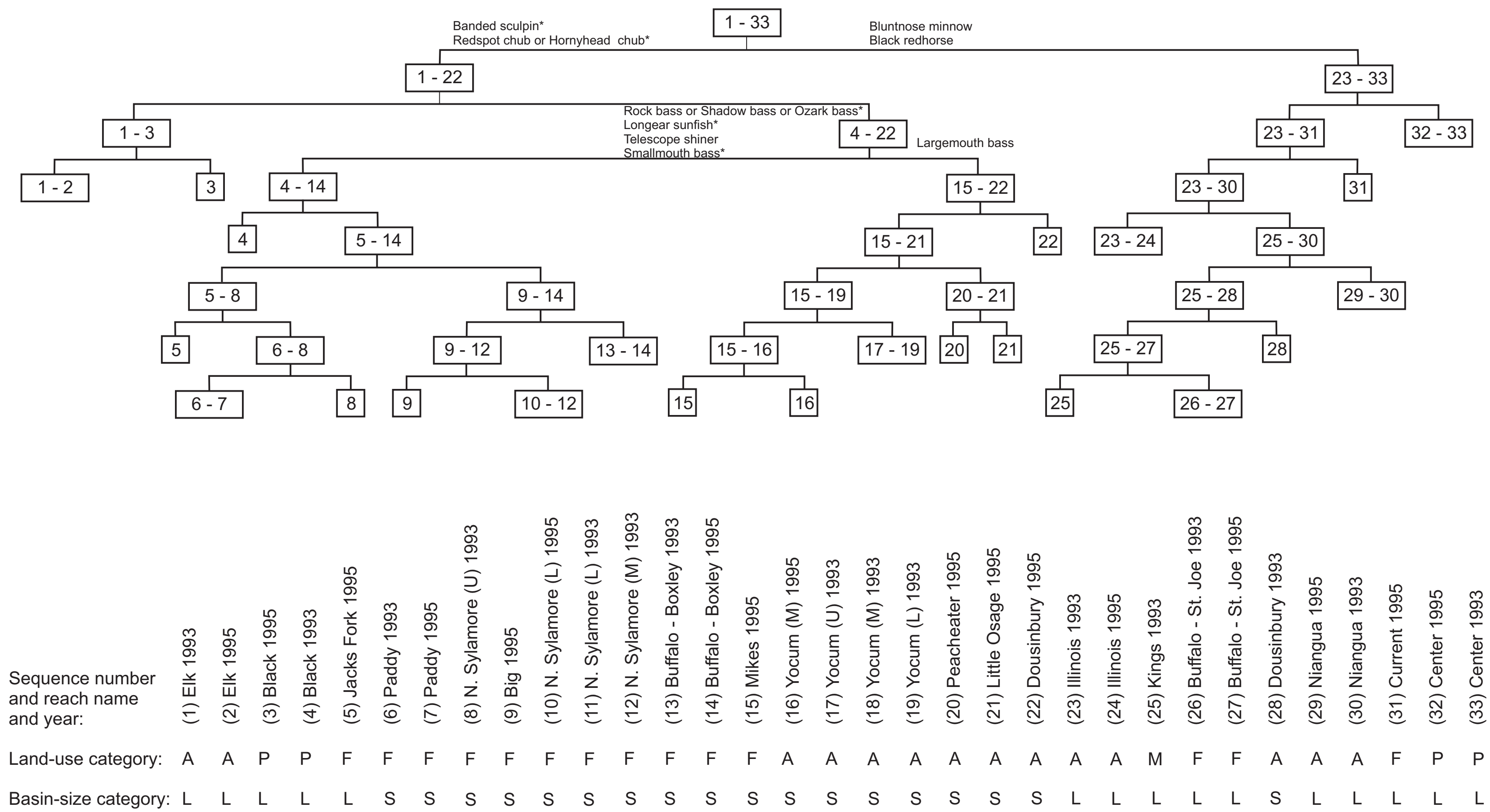

Figure 6. Classification of fish communities by two-way indicator species analysis. The most preferential species are shown are selected divisions (occurrence and relative abundance are considered in determination of preferential species; x indicates greater relative abundance). Reach: L is lower, M is middle, U is upper. Land Use: A is agriculture, P is lead-zinc mining, F is forest, M is mixed. Size: L is large, S is small.

degradation (Jester and others, 1992; W.E. Keith, Arkansas Department of Pollution Control and Ecology, written commun., 1997). This characteristic makes fish a useful tool for assessing water-chemistry and other habitat conditions of Ozark streams.

Several differences in water chemistry and other environmental factors were found at stations representative of different combinations of drainage-basin size and land use (table 3). Stations representative of basins with greater agricultural land use generally had higher nutrient concentrations and greater canopy angles (meaning that these streams were less shaded), relative to stations representative of more forested basins. These two factors would be expected to cause more growth of periphyton in streams in agricultural basins. Such growth has been reported in streams in the Missouri Ozarks (Smart and others, 1985). Streams representative of larger basins had higher concentrations of suspended sediment, greater canopy angles, greater water velocities, and were wider, deeper, steeper, and more sinuous than streams representative of smaller basins. These factors and others interact to determine the fish communities of Ozark streams.

A common trait of fish communities of Ozark streams in agricultural basins or downstream of wastewater treatment plants is increased relative abundance of stonerollers. Generally, 10 to 20 percent of the individuals at reaches sampled in forest basins were stonerollers. At reaches in agriculture basins, generally 20 to 50 percent of the individuals were stonerollers. Increased periphyton production resulting from more nutrients and sunlight provides a more abundant food source for stonerollers.

Often, darters and sunfish compose a smaller percentage of the fish communities of Ozark streams in agricultural basins than in forested basins. Part of this difference results from the elevated relative abundance of stonerollers in agriculture reaches. However, even when stoneroller abundance is not included in calculations, data suggest (but differences are not statistically significant) that relative abundance values of darters and sunfish are lower in agricultural basins (median relative abundance of darters 8 percent, median relative abundance of sunfish 6 percent) than in forested basins (median relative abundance of darters 18 percent, median relative abundance of sunfish 26 percent). Most species of darters are intolerant of degraded water chemistry and habitat. In a study of water quality and fish communities in the White River Basin, the Arkansas Department of Pollution Control and Ecology (1995) reported decreases in relative abundance of darters between the 1960-1980's and the 1990's in areas where agricultural land use or road construction has increased.

Three types of multivariate analyses (DCA, CCA, and TWINSPAN) yielded similar insights into the community structure of the sampled reaches; the most general of these is that fish communities of Ozark streams are influenced by stream size and other factors that can be related to basin size, by water chemistry and other factors that can be related to land use, and by other factors. The multivariate analyses did not completely segregate reaches by basin size or land use, although there were general trends in the results that could be explained by these two major factors. For example, in both the DCA and CCA results the majority of the agriculture reaches were separated from the majority of the forest reaches. However, even if only the most similar agriculture-reach and the most similar forest-reach communities are considered, the separation between these two groups was small relative to the amount of separation of reaches within groups. This result indicates that, although the communities associated with the two land uses tend to be different, some differences are not related to land use. Water-chemistry (for example, nutrients and suspended sediment) and other factors (for example, canopy angle and substrate characteristics) that may be affected by land use appear to be related to the fish community differences detected by the multivariate analyses. Elevated nutrient concentrations and greater canopy angles can increase periphyton production. Greater canopy angles can raise water temperatures and, if they reflect the presence of less woody vegetation along the banks of streams, can be associated with greater streambank erosion. Elevated suspended sediment concentrations and finer and more embedded substrates can reduce benthic macroinvertebrate populations, decrease spawning success of many fish species, and decrease protection of benthic fish from water velocities and predators. TWINSPAN results suggest that some intolerant species of fish (smallmouth bass and rock bass, shadow bass, or Ozark bass) are more common (relative to other species) in small, forest streams than in small, agriculture streams.

Differences between fish communities at two stations downstream from lead-zinc mining areas suggest that lead and zinc concentrations can be high enough to cause some changes in fish communities, but that at lower concentrations fish communities may not be substantially affected. Elevated concentrations of semivolatile organic compounds at the station with the higher lead and zinc concentrations (Center Creek) could also have been a factor affecting the fish community.

The fish community of the Center Creek reach illustrates that Ozark fish communities are the result of zoogeographical factors (factors related to geographical distribution of animals), non-toxic water-quality factors (such as nutrient enrichment from urban and agricultural sources), potentially toxic water-quality factors (such as trace elements and organic compounds from mining and urban sources), and several other habitat factors. Biological interactions are also important.

SUMMARY

Fish communities from 22 reaches at 18 stream stations in the Ozark Plateaus were sampled in 1993, 1994, and 1995. The 18 stations were chosen to represent selected combinations of major environmental factors (geology/physiographic area, land use, and basin size). Additional physical, chemical, and biological factors also were measured for each of the 22 reaches and the influence of these factors upon the fish communities was investigated.

Results suggest that Ozark fish communities are the result of zoogeographical factors, toxic and non-toxic water-quality factors, and several other factors. These other factors include stream size, substrate characteristics, and riparian characteristics. Biological interactions are also important.

Fish community samples collected at the 22 reaches identified differences in these communities that can be attributed to differences in land use and related water-quality and habitat characteristics. These differences were determined using a variety of methods—species counts, calculation of relative abundance of selected taxa, two ordination techniques, and a classification technique. Communities from agriculture reaches tended to have more species, increased relative abundance of stonerollers and members of the sucker family, and decreased relative abundance of members of the sunfish and darter families. The ordination and classification techniques generally grouped most agriculture reaches slightly separate from forest reaches. Several groups of environmental factors (concentrations of nutrients, organic carbon, suspended sediment, and dissolved oxygen; measures related to ionic strength; measures related to riparian vegetation; measures related to substrate; and measures related to stream size) appear to be related to land-use differences and fish community differences.

In general, communities from reaches with larger drainage areas were composed of a greater number of species than were communities from reaches with smaller drainage areas. Also, a greater number of species usually occurred at reaches with a greater percentage of agricultural land in the drainage basin. The greater number of species at the reaches with larger drainage areas is commonly reported. Some additional species at some reaches with larger and with more agricultural basins may be coming from nearby farm ponds and reservoirs.

At most reaches, most individuals were members of the minnow family. Stonerollers, duskystripe shiners, bleeding shiners, or cardinal shiners generally were more abundant than any other species. Sunfish, darters, and sculpins also were abundant.

Land-use differences appear to have affected the relative abundance of stonerollers, sunfish, darters, and suckers. Stonerollers and suckers generally were more abundant at agriculture reaches than at forest reaches. Sunfish and darters generally were more abundant at forest reaches than at agriculture reaches.

Similarity of fish community samples collected in 1993 and 1995 at the same reach varied considerably, ranging from 44 to 85 percent. Similarity of three adjacent reaches at each of the two multiple-reach stations ranged from 71 to 86 percent. This range in similarities between years indicates that because of the natural temporal variability of fish communities, sampling errors, or both, there is some additional uncertainty involved when a reach is sampled only once.

Three multivariate analysis techniques (two ordination techniques and a classification technique) yielded similar results when applied to the fish community data. Fish communities generally were grouped so that fish communities from reaches with more similar land use in their basins and with similar drainage areas generally were grouped closer together in the analysis.

Detrended correspondence analysis (DCA, an ordination technique) slightly separated reaches into a group of forest reaches and a group of agriculture reaches. DCA axis scores correlated strongly (Spearman's rho greater than 0.35) with water quality, substrate, and stream morphology measures.

Canonical correspondence analysis (CCA, an ordination technique) of all reaches sampled in 1993 and 1995 shows a general separation of reaches by land use and basin size category. However, as with the DCA results, a considerable amount of overlap occurs in reaches with small and large basins and also in reaches with forest and agriculture basins. Relative to reaches in small basins, reaches in larger basins tend to be characterized by higher concentrations of alkalinity, suspended sediment, and dissolved organic carbon; lower nitrate concentrations; larger and more embedded substrates, greater canopy angles; and greater density of woody vegetation.

Two-way indicator species analysis (TWINSPAN, a classification technique) of the combined 1993 and 1995 data also generally grouped reaches by basin size and by land use. The first TWINSPAN classification step separated most of the reaches in smaller basins from most of the reaches in larger basins. Dissolved organic carbon concentration, suspended sediment concentration, and several measures that commonly relate to stream size were statistically different between the two groups of reaches. Most of the reaches with small, forested basins were separated from the small, agricultural basin reaches. Factors including nutrient, alkalinity, and dissolved oxygen concentrations; riparian vegetation measures; and substrate size were statistically different between these two groups of reaches.

TWINSPAN also identified species (or pseudospecies) which preferred reaches representing the TWINSPAN land-use and basin-size categories. Small-basin reaches tended to have more (greater relative abundance) banded sculpins and hornyhead chubs or redspot chubs than reaches in large basins. Reaches with large basins tended to be more preferred than reaches with small basins by bluntnose minnows and black redhorse. Preferential species or pseudospecies at reaches with small, forest basins include telescope shiners and the pseudospecies representing greater relative abundances of smallmouth bass and longear sunfish. Largemouth bass was a preferential species at reaches in small, agriculture basins.

The relations between land use, stream size, and fish communities described in this report have implications for water-quality assessments of Ozark streams. Compared to other parts of the United States, many fish species live in the Ozark Plateaus. Approximately 175 species (including introduced species) are present in the Ozark Plateaus province part of the Ozark Plateaus NAWQA study unit; at least 19 of these species are endemic to the Ozarks area. Consequently, widespread and extreme degradation of water quality (chemical or aquatic habitat factors) could affect several species found nowhere else in the world. Many of these 175 species are intolerant of habitat or water-chemistry degradation. This characteristic makes fish a useful tool for assessing water-chemistry and other habitat conditions of Ozark streams.

Several environmental factors can contribute to differences in fish communities. Reaches representative of basins with greater agricultural land use generally had higher nutrient concentrations and greater canopy angles (meaning that these streams were less shaded), relative to reaches representative of more forested basins. Elevated nutrient concentrations and greater canopy angles can increase periphyton production. Greater canopy angles can raise water temperatures and, if they reflect less woody vegetation along the banks of streams, can be associated with greater streambank erosion. Elevated suspended sediment concentrations and finer and more embedded substrates can reduce benthic macroinvertebrate populations, decrease spawning success of many fish species, and decrease protection of benthic fish from water velocities and predators. A common trait of fish communities of Ozark streams in agricultural basins or downstream from wastewater-treatment plants is increased relative abundance of stonerollers. Increased periphyton production resulting from more nutrients and sunlight provides a more abundant food source for stonerollers. Often, darters and sunfish compose a smaller percentage of the fish communities of Ozark streams in agricultural basins than in forested basins. Most species of darters and some species of sunfish are intolerant of degraded water chemistry and habitat.

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APPENDIX

Appendix 1. List of scientific and common names of collected fish

PETROMYZONTIDAE *Lampreys*

Ichthyomyzon castaneus	Chestnut lamprey

LEPISOSTEIDAE Gars

Lepisosteus osseus	Longnose gar

CLUPEIDAE Herrings

Dorosoma cepedianum	Gizzard shad

ESOCIDAE *Pikes*

Esox niger Lesueur	Chain pickerel

CYPRINIDAE Minnows and Carps

Campostoma anomalum	Central stoneroller
Campostoma oligolepis	Largescale stoneroller
Cyprinella camura	Bluntface shiner
Cyprinella galactura	Whitetail shiner
Cyprinella lutrensis	Red shiner
Cyprinella whipplei	Steelcolor shiner
Cyprinus carpio	Common carp
Erimystax harryi	Ozark chub
Erimystax x-punctata	Gravel chub
Luxilus cardinalis	Cardinal shiner
Luxilus chrysocephalus	Striped shiner
Luxilus pilsbryi	Duskystripe shiner
Luxilus zonatus	Bleeding shiner
Lythurus umbratilis	Redfin shiner
Nocomis asper	Redspot chub
Nocomis biguttatus	Hornyhead chub
Notropis amblops	Bigeye chub
Notropis boops	Bigeye shiner
Notropis greenei	Wedgespot shiner
Notropis nubilus	Ozark minnow
Notropis ozarcanus	Ozark shiner
Notropis rubellus	Rosyface shiner
Notropis telescopus	Telescope shiner
Notropis volucellus	Mimic shiner
Phoxinus erythrogaster	Southern redbelly dace
Pimephales notatus	Bluntnose minnow
Pimephales promelas	Fathead minnow
Pimephales tenellus	Slim minnow
Semotilus atromaculatus	Creek chub

CATOSTOMIDAE Suckers

Carpiodes velifer	Highfin carpsucker
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hog sucker
Ictiobus bubalus	Smallmouth buffalo
Ictiobus niger	Black buffalo
Moxostoma carinatum	River redhorse
Moxostoma duquesnei	Black redhorse
Moxostoma erythrurum	Golden redhorse
Moxostoma macrolepidotum	Shorthead redhorse

ICTALURIDAE *Bullhead catfishes*

Ameiurus melas	Black bullhead
Ameiurus natalis	Yellow bullhead
Ictalurus punctatus	Channel catfish
Noturus albater	Ozark madtom
Noturus exilis	Slender madtom
Noturus flavater	Checkered madtom
Noturus miurus	Brindled madtom
Pylodictis olivaris	Flathead catfish

FUNDULIDAE *Killifishes*

Fundulus catenatus	Northern studfish
Fundulus notatus	Blackstripe topminnow
Fundulus olivaceus	Blackspotted topminnow

POECILIIDAE *Livebearers*

Gambusia affinis	Western mosquitofish

ATHERINIDAE Silversides

Labidesthes sicculus	Brook silverside

MORONIDAE *Temperate basses*

Appendix 1. List of scientific and common names of collected fish--Continued

CENTRARCHIDAE *Sunfishes*	
Ambloplites ariommus	Shadow bass
Ambloplites constellatus	Ozark bass
Ambloplites rupestris	Rock bass
Lepomis cyanellus	Green sunfish
Lepomis gulosus	Warmouth
Lepomis humilis	Orangespotted sunfish
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Lepomis microlophus	Redear sunfish
Micropterus dolomieu	Smallmouth bass
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Pomoxis nigromaculatus	Black crappie
PERCIDAE *Perches*	
Etheostoma blennioides	Greenside darter
Etheostoma caeruleum	Rainbow darter
Etheostoma euzonum	Arkansas saddled darter
Etheostoma flabellare	Fantail darter
Etheostoma juliae	Yoke darter
Etheostoma punctulatum	Stippled darter
Etheostoma spectabile[1]	Orangethroat darter
Etheostoma stigmaeum	Speckled darter
Etheostoma tetrazonum	Missouri saddled darter
Etheostoma zonale	Banded darter
Percina caprodes	Logperch
Percina evides	Gilt darter
Percina maculata	Blackside darter
Percina phoxocephala	Slenderhead darter
SCIAENIDAE *Drums*	
COTTIDAE *Sculpins*	
Cottus bairdi	Mottled sculpin
Cottus carolinae	Banded sculpin
Cottus hypselurus	Ozark sculpin

[1]Individuals identified as *E. spectabile* in the sample from the Black River presumably were *E. burri* (brook darter), a species recently described by Ceas and Page (1997).