Fishes of First-Order Streams in North-Central Mississippi

Peter C. Smiley, Jr.[1,2,*], Eric D. Dibble[1], and Stephen H. Schoenholtz[1,3]

Abstract - We sampled fishes and measured physical habitat in 14 first-order streams in north-central Mississippi to document fish community characteristics and examine the relationships between the fish communities and physical habitat characteristics. We documented 36 species and 11 families from 6943 captures. The five most abundant species were creek chub (*Semotilus atromaculatus* Mitchell), least brook lamprey (*Lampetra aepyptera* Abbot), blackspotted topminnow (*Fundulus olivaceus* Storer), creek chubsucker (*Erimyzon oblongus* Mitchell), and green sunfish (*Lepomis cyanellus* Rafinesque). We also observed that most streams (> 50%) were numerically dominated by: 1) Cyprinidae, 2) fishes having a maximum body size between 300–399 mm TL, 3) insectivores, and 4) guarder-nest spawners. Fish species composition of our study streams was similar to the species composition documented in other medium- and low-gradient headwater streams in the Gulf Coastal Plain. Additionally, fish community structure in first-order streams was significantly correlated with channel cross-section area, woody debris, canopy cover, water depth, velocity, wet width, and substrate types. The observed relationships between fish communities and physical habitat characteristics in first-order stream were similar to fish-habitat relationships observed by previous investigators working in northern Mississippi streams ranging in size from first to fifth-order.

Introduction

Past research conducted in the midwestern United States has characterized headwater streams as small, hydrologically variable streams exhibiting reduced fish species richness and abundance compared to larger streams with less hydrological variability (Horwitz 1978, Schlosser 1987). Additionally, variation in species composition among streams is expected to be greater in small headwater streams than larger order streams (Matthews 1998). Zoogeographic changes in fish community characteristics occurs among different types of headwater streams in the southeastern United States. Fish communities in high-gradient streams in the Appalachian region are typically dominated by brook trout (*Salvalinus fontinalis* Mitchell), mottled sculpin (*Cottus bairdi* Girard), and blacknose dace (*Rhinichthys atralutus* Hermann) (Wallace et al. 1992). Conversely, fish species composition in medium- and low-gradient headwater streams in the Gulf Coastal Plains consists mostly of sunfishes (Centrarchidae), minnows (Cyprinidae), and darters (Percidae) (Felley 1992). Additionally, medium- and low-gradient streams exhibit higher species diversity than high-gradient streams in the southeastern United States (Felley 1992).

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[1]Forest and Wildlife Research Center, Mississippi State University, PO Box 9690, Mississippi State, MS 39762. [2]Current address - USDA-ARS, Soil Drainage Research Unit, 590 Woody Hayes Drive, Columbus, OH 43210. [3]Current address - Department of Forest Engineering, Oregon State University, 267 Peavy Hall, Corvallis, OR 97331. [*]Corresponding author - smiley.50@osu.edu.

Mississippi contains 204 native species of freshwater fishes and ranks fifth among states in species richness of native fishes (Ross 2002). Total species richness of native freshwater fishes among the ten major river drainages in Mississippi ranges from 68 to 125 (Ross 2002). Additionally, species composition within streams throughout the state and within north-central Mississippi consists mostly of Centrarchidae, Cyprinidae, and Percidae (Ross 2002, Warren et al. 2002). Previous work conducted in Mississippi summarizes the results of fish sampling from stream sizes ranging from small first-order streams to major river drainages (Ross 2002, Warren et al. 2002). However, despite this body of available information, a synthesis of the characteristics of the fish communities from first-order streams of Mississippi is not available. Our objectives are to summarize the results of four years of fish sampling in first-order streams of north-central Mississippi and to describe the relationships between fish communities and physical habitat characteristics within these small streams.

Study Area

Soil types in north-central Mississippi consist of highly erodible sand and clay soils (Lohonefener and Altig 1983, Warren et al. 2002). Topography consists of irregular hills with elevations between 100 and 200 m above sea level (Lohonefener and Altig 1983, Warren et al. 2002). Average annual precipitation ranges from 102 to 152 cm per year (Bailey 1980), and precipitation is the greatest during the winter and spring (Felley 1992). The majority of the land use in the region is either oak-hickory or pine (*Pinus* spp.) forest land (Hartsell and London 1995). All study streams were located in managed pine forests. Typical forestry management in this region involves: 1) clearcut harvest of forests at 30 years of age, 2) streamside management zones, and 3) site preparation and replanting (Miller 2003). Our study streams were first-order streams (Strahler 1957) of the Big Black, Pearl, Tombigbee, and Yazoo River drainages (Fig. 1). Substrate types within the streams were predominately sand or sand-clay substrates (Dibble et al. 2004). Instream habitat consists of shallow water depths (< 0.25 m), slow velocities (< 0.10 m/sec), and narrow wet widths (< 2.5 m) (Dibble et al. 2004).

Methods

We collected fishes from eight streams (B2, B3, T1, Y2, Y4, Y5, Y6, Y7) from September 1999 until November 2002, while six streams were sampled (B1, B4, P1, P2, Y1, Y3) from March 2001 until November 2002. Each stream was sampled at least three times a year. We established two sampling sites in each stream (total 28 sampling sites), and the distance between sites within a stream was at least 100 m. Sites were delineated to ensure all representative habitat units (e.g., pools, riffles, runs) were present, and as a result some variation in site length (19 to 50 m) occurred. However, the individual site lengths were constant overtime. The total length sampled in each stream ranged from 57 to 84 m, which is the equivalent of 26 to 135 stream widths (mean = 58 stream widths) calculated using the mean stream width of each stream over the entire study period. Angermeier and Smogor (1995) recommended sampling > 10 stream widths, and observed that a minimum of 22 stream widths was necessary to document 90% of the fish species within a reach.

We collected fishes from each site using a backpack electroshocker (250 to 300 volts, DC current). Electrofishing began at the downstream end of a site and proceeded upstream. One person carried and operated the electroshocker, while a second person dipnetted stunned fish. We took care to ensure that all habitat units within each site were sampled thoroughly. Total electrofishing time among streams ranged from 43 to 296 minutes. All fishes that could be identified in the field were identified, enumerated, and

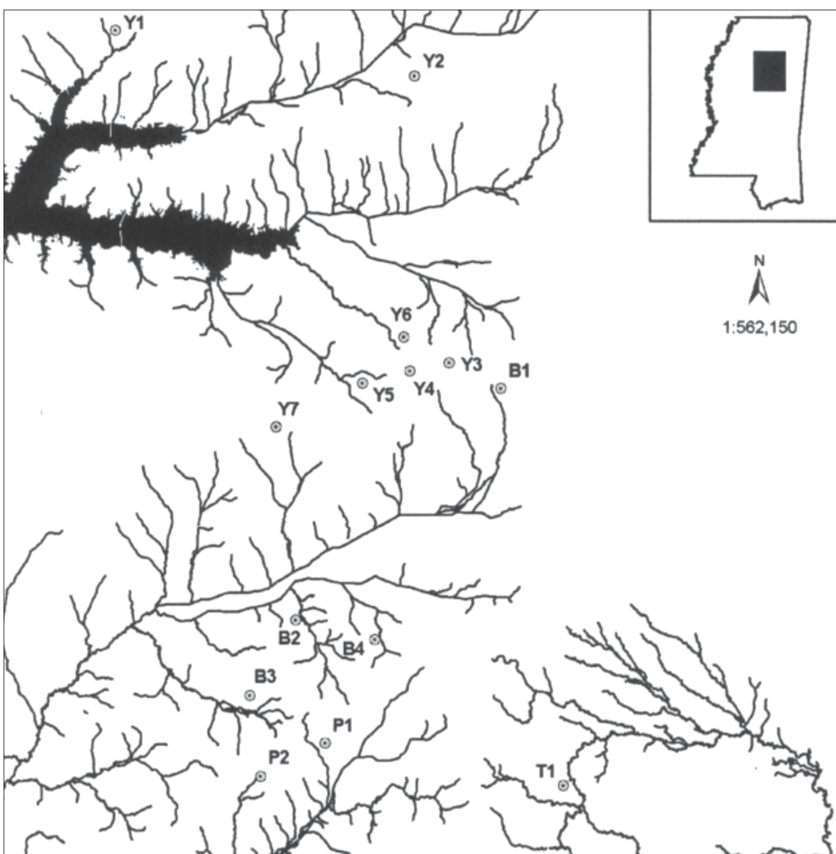

Figure 1. Map showing location of 14 study streams in north-central Mississippi. The first letter of each stream number represents the river drainage and abbreviations are: B = Big Black, P = Pearl, T = Tombigbee, and Y = Yazoo. Mississippi Automated Resource Information System (MARIS) classified all study streams as intermittent streams and for clarity only perennial streams are depicted.

released. Those fishes not identified in the field were euthanized with MS-222 (tricaine methanesulfonate), fixed with a 10% Formalin solution, and subsequently identified in the laboratory. Voucher specimens have been deposited in the Mississippi Natural Science Museum.

We summarized the results of all fish sampling within our study streams by determining the total species richness and number of captures in each stream. We also calculated the overall relative abundances (%) of species, families, trophic guilds, maximum body size categories, and reproductive guilds in each stream.

We adopted an approach similar to Taylor and Warren (2001), and assigned each fish species to a maximum body size category based on its maximum reported total length (Etnier and Starnes 1993, Mettee et al. 1996, Ross 2002). We designated six maximum body size categories: 1) 0–99 mm total length (TL); 2) 100–199 mm TL; 3) 200–299 mm TL; 4) 300–399 mm TL; 5) 400–499 mm TL; and 6) 500–620 mm TL.

Each fish species was assigned to a trophic guild based on information from published literature sources (Etnier and Starnes 1993, Mettee et al. 1996, Ross 2002). Fish were classified as: 1) omnivores—fish species that eat both plants and animals; 2) insectivores—fish species that eat insects or other invertebrates; 3) insectivore-piscivore—fish species that consume fish and invertebrates as adults and those species that feed primarily on invertebrates as juveniles and consume mostly fish as adults; and 4) planktivores—fish species that feed on microscopic plant and animals in the water column.

Each fish species was assigned to a reproductive guild based on its spawning behavior and degree of parental care exhibited (Etnier and Starnes 1993, Fontenot and Rutherford 1999, Johnston 1994, Johnston and Page 1992, Katula 1991, Mettee et al. 1996, Page 1985, and Ross 2002). We chose Balon's reproductive guilds (Balon 1975, Simon 1999) because it provides a classification system for all taxonomic groups. Additionally, its hierarchical structure was advantageous because it enabled us to modify it according to the available information on reproductive behavior. Specifically, our version of Balon's reproductive guilds does not incorporate substrate preferences because this information is not available for many fishes. We recognized five reproductive guilds: 1) internal bearer—fishes that hold fertilized eggs within the body; 2) guarder-nest spawner—fishes that construct a nest for the eggs and then guard the nest and deposited eggs; 3) guarder-substrate chooser—fishes that select substrates or cover types for egg deposition and then guard the deposited eggs; 4) nonguarder-brood hider—fishes that bury eggs in the substrate or place eggs within crevices or nests; and 5) nonguarder-open substrate spawners—fishes that deposit eggs on selected substrate types or in open water.

We conducted an indirect gradient analysis to examine the relationships between selected fish community characteristics and physical habitat characteristics. Specifically, the analysis includes fish and physical habitat data collected from each stream during four sampling trips conducted between March 2001 and April 2002. We were not able to include data from the entire study period in this analysis because: 1) only nine streams were sampled between September 1999 until February 2001, and 2) we are lacking data for some habitat variables for the last seven months of the study period.

We collected physical habitat data concurrently with fish sampling and used a modified version of the habitat sampling protocol used by Gorman and Karr (1978). Permanent transects were established at the upstream, middle, and downstream boundary of each location. The dimensions of the bankfull channel were assessed by obtaining six measurements of channel depth and one measurement of channel width along each transect. Instream habitat was characterized by obtaining one measurement of wet width and three measurements of water depth, water velocity, and substrate types along each transect. Percentage canopy cover was estimated from the middle of each transect. Water quality characteristics of pH, turbidity, water temperature, dissolved oxygen, and conductivity were measured once within each site.

We developed a matrix using the means of 20 habitat variables from each stream: channel width, channel depth, channel cross-section area, water depth, water velocity, wet width, percentage sand, percentage silt, percentage detritus, percentage gravel, percentage clay, percentage cobble, percentage bedrock, number of woody debris, percentage canopy cover, pH, turbidity, water temperature, dissolved oxygen, and conductivity. We also constructed five matrices using the relative abundances of fish species, families, maximum body size categories, trophic guilds, and reproductive guilds. Rare species or ecological groups (i.e., species or groups having < 10% frequency of occurrence) were eliminated from the fish community matrices prior to ordination.

We used ordination to reduce complexity of six matrices into linear axes that described similarity of sites in terms of habitat or community data (Gauch 1982). Specifically, we conducted a principal components analysis (PCA) on the physical habitat matrix, and a detrended correspondence analysis (DCA) on the fish community matrices. Site scores from the PCA of the physical habitat variables are indices of the overall habitat characteristics of the streams, while the DCA site scores are indices that describe the relative abundance patterns of fish species, families, maximum body size categories, trophic guilds, and reproductive guilds among streams.

We used the Pearson correlation test to assess the relationship between the site scores of the first three PCA axes and the site scores of the first two DCA axes of fish species, families, trophic guilds, maximum body size categories, and reproductive guilds. We conducted 30 Pearson correlation tests and the significance level for all tests was $P < 0.05$. PCA and DCA were conducted using PC-ORD for Windows (McCune and Mefford 1999), while Pearson correlation tests were conducted with Statistix (Analytical Software 1996).

Results

We captured 6943 fishes belonging to 36 species and 11 families (Tables 1 and 2). Species richness among streams ranged from 2 to 26 species (mean = 12), while the total number of captures ranged from 5 to 1193 (mean = 496)

Table 1. Common name, scientific name, family, maximum body size category (mm TL), trophic guild, and reproductive guild of fishes documented from 14 first-order streams in north-central Mississippi, 1999-2002. Taxonomic nomenclature follows Ross (2002). Abbreviations for reproductive guilds are: I-BE = internal bearer, G-NS = guarder-nest spawner, G-SC = guarder-substrate chooser, N-BH = nonguarder-brood hider, N-OS = nonguarder-open substrate spawner.

Common name	Scientific name	Family	Body size	Trophic	Reproductive
Banded pygmy sunfish	*Elassoma zonatum* Jordan	Elasomatidae	0–99	Insectivore	G-SC
Black bullhead	*Ameiurus melas*	Ictaluridae	500–620	Insectivore	G-NS
Blackside darter	*Percina maculata* Girard	Percidae	100–199	Insectivore	N-BH
Blackspotted topminnow	*Fundulus olivaceus*	Fundulidae	0–99	Insectivore	N-OS
Bluegill	*Lepomis macrochirus* Rafinesque	Centrarchidae	200–299	Insectivore	G-NS
Bluehead chub	*Nocomis leptocephalus* Girard	Cyprinidae	200–299	Omnivore	N-BH
Bluntnose darter	*Etheostoma chlorosoma*	Percidae	0–99	Insectivore	N-OS
Bluntnose minnow	*Pimephales notatus*	Cyprinidae	100–199	Omnivore	G-NS
Brown madtom	*Noturus phaeus*	Ictaluridae	100–199	Insectivore	G-NS
Cherryfin shiner	*Lythrurus roseipinnis*	Cyprinidae	0–99	Insectivore	N-OS
Creek chub	*Semotilus atromaculatus*	Cyprinidae	300–399	Insectivore	G-NS
Creek chubsucker	*Erimyzon oblongus*	Catostomidae	400–499	Omnivore	N-BH
Cypress darter	*Etheostoma proeliare*	Percidae	0–99	Insectivore	N-OS
Dusky darter	*Percina sciera* Swain	Percidae	100–199	Insectivore	N-BH
Flier	*Centrarchus macropterus* Lacepède	Centrarchidae	200–299	Insectivore	G-NS
Golden shiner	*Notemigonus crysoleucas* Mitchell	Cyprinidae	300–399	Omnivore	N-OS
Goldstripe darter	*Etheostoma parvipinne*	Percidae	0–99	Insectivore	N-OS
Grass pickerel	*Esox americanus*	Esocidae	300–399	Insectivore-piscivore	N-OS
Green sunfish	*Lepomis cyanellus*	Centrarchidae	300–399	Insectivore-piscivore	G-NS
Gulf darter	*Etheostoma swaini* Jordan	Percidae	0–99	Insectivore	N-BH
Least brook lamprey	*Lampetra aepyptera*	Petromyzontidae	100–199	Planktivore	N-BH

Table 1, continued.

Common name	Scientific name	Family	Body size	Trophic	Reproductive
Longear sunfish	*Lepomis megalotis*	Centrarchidae	200–299	Insectivore	G-NS
Pirate perch	*Aphredoderus sayanus*	Aphredoderidae	100–199	Insectivore	N-OS
Pretty shiner	*Lythrurus bellus* Hay	Cyprinidae	0–99	Insectivore	N-OS
Redear sunfish	*Lepomis microlophus* Günther	Centrarchidae	300–399	Insectivore	G-NS
Redfin darter	*Etheostoma whipplei* Girard	Percidae	0–99	Insectivore	N-BH
Redfin shiner	*Lythrurus umbratilis* Girard	Cyprinidae	0–99	Omnivore	N-BH
Redspotted sunfish	*Lepomis miniatus* Jordan	Centrarchidae	100–199	Insectivore	G-NS
Ribbon shiner	*Lythrurus fumeus* Evermann	Cyprinidae	0–99	Insectivore	N-OS
Slough darter	*Etheostoma gracile* Girard	Percidae	0–99	Insectivore	N-OS
Spotted bass	*Micropterus punctulatus* Rafinesque	Centrarchidae	500–620	Insectivore-piscivore	G-NS
Striped shiner	*Luxilus chrysocephalus*	Cyprinidae	200–299	Omnivore	N-BH
Warmouth	*Lepomis gulosus* Cuvier	Centrarchidae	200–299	Insectivore-piscivore	G-NS
Weed shiner	*Notropis texanus* Girard	Cyprinidae	0–99	Omnivore	N-OS
Western mosquitofish	*Gambusia affinis* Baird and Girard	Poecilidae	0–99	Insectivore	I-BE
Yellow bullhead	*Ameiurus natalis*	Ictaluridae	400–499	Insectivore	G-NS

Table 2. Relative abundance (%) of fishes, total number captured, and sampling effort from 14 first-order streams in north-central Mississippi, 1999–2002.

Species	B1	B2	B3	B4	P1	P2	T1	Y1	Y2	Y3	Y4	Y5	Y6	Y7
Ameiurus melas	6.60	0.28			0.16	3.70								
Ameiurus natalis	1.52	0.37												
Aphredoderus sayanus	26.40	3.79	1.65		0.47	3.70							0.16	
Centrarchus macropterus		0.28												
Elassoma zonatum		1.94	1.03		4.58	4.63								
Erimyzon oblongus	19.80	5.26	4.12	2.11	12.01	8.33			15.91		8.22	1.59	2.44	14.82
Esox americanus	0.51	1.11			0.32	6.48								
Etheostoma chlorosoma			1.24		0.32				0.15		0.12	0.25		0.15
Etheostoma gracile	1.02		0.82			0.93								
Etheostoma parvipinne	4.57	0.46	13.81	27.37	7.74	2.78	18.40	60.00	7.58	40.00	1.62		5.20	2.69
Etheostoma proeliare	3.05	8.22	3.51	2.11	1.11				0.45		0.25	0.50	1.30	0.90
Etheostoma swaini		0.28			2.21				0.45		0.12		0.16	
Etheostoma whipplei									0.15					
Fundulus olivaceus	5.08	16.62	5.15		2.37	26.85			10.76			11.32	9.92	1.20
Gambusia affinis		0.28			0.16	7.41								
Lampetra aepyptera		1.11	1.65				53.13		4.24			29.51	50.57	5.24
Lepomis cyanellus	12.18	21.61	2.47	4.21	0.95	12.04			15.76		4.86	0.17		0.30
Lepomis gulosus		0.09	0.62	1.05		2.78					0.12			
Lepomis macrochirus	1.52								0.30					
Lepomis megalotis	6.09	8.03		4.21	0.16	5.56			1.21		0.25			
Lepomis microlophus			0.21											
Lepomis miniatus		0.09												
Luxilus chrysocephalus		3.32		6.32	5.85		0.35		2.27		4.61	3.02	4.72	9.43

Table 2, continued. Relative abundance (%) of fishes, total number captured, and sampling effort from 14 first-order streams in north-central Mississippi, 1999–2002.

Species	B1	B2	B3	B4	P1	P2	T1	Y1	Y2	Y3	Y4	Y5	Y6	Y7
Lythrurus bellus							0.35							
Lythrurus fumeus		0.46												
Lythrurus roseipinnis		13.11			4.58				1.52					
Lythrurus umbratilis		0.92	0.21						1.21				0.65	
Micropterus punctulatus	1.52	0.09												
Nocomis leptocephalus													1.95	
Notemigonus crysoleucas	4.57	4.25				14.81								
Notropis texanus		10.00							0.15					
Noturus phaeus		5.26	4.54	4.21	5.85		7.29		0.61		1.37	2.93	9.43	4.49
Percina maculata	1.52													
Percina sciera							0.69							
Pimephales notatus		0.18	0.82		1.11						12.20	4.86		
Semotilus atromaculatus	4.06	2.59	58.14	48.42	50.08		19.79	40.00	36.82	60.00	66.25	45.85	13.50	60.78
Total captures	197	1083	485	95	633	108	288	110	660	5	803	1193	615	668
Number of samples	12	24	27	12	12	12	24	12	26	12	26	28	26	26
Length sampled (m)	73	81	62	57	76	62	59	84	57	78	66	69	67	64
Sampling effort (min)	138	296	223	72	124	99	252	61	273	43	212	264	266	236

(Table 2). The five most abundant species were creek chub (*Semotilus atromaculatus* Mitchell), least brook lamprey (*Lampetra aepyptera* Abbot), blackspotted topminnow (*Fundulus olivaceus* Storer), creek chubsucker (*Erimyzon oblongus* Mitchell), and green sunfish (*Lepomis cyanellus* Rafinesque). These five species accounted for 72% of all fishes captured. *Semotilus atromaculatus* was the most abundant species in eight streams, while the remaining streams were numerically dominated by either pirate perch (*Aphredoderus sayanus* Gilliams) (B1), *L. cyanellus* (B2), *F. olivaceus* (P2), *L. aepyptera* (T1, Y6), or goldstripe darter (*Etheostoma parvipinne* Gilbert and Swain) (Y1) (Table 2). Six species were present in ten or more streams. *Semotilus atromaculatus* and *E. parvipinne* were the most widespread species occurring in 13 streams (Table 2). *Erimyzon oblongus* occurred in 11 streams, while the brown madtom (*Noturus phaeus* Taylor), cypress darter (*Etheostoma proeliare* Hay), and *L. cyanellus* were found in 10 streams (Table 2).

Most streams (57%) were numerically dominated by Cyprinidae, and the remaining streams were numerically dominated by Aphredoderidae (B1), Centrarchidae (B2), Fundulidae (B3), Petromyzontidae (T1, Y6), and Percidae (Y1) (Table 3). Small bodied fishes (399 mm maximum TL or less) constituted at least 70% of all captures in all streams, and the 300–399 mm TL maximum body size category was most abundant in the majority of streams (57%) (Table 3). Only four streams contained individuals categorized as having a maximum body size between 500 and 620 mm TL (Table 3). Insectivores were the most abundant trophic group in 12 streams, while planktivores were the most abundant trophic group in two streams (Table 3). Most streams (57%) were numerically dominated by guarder-nest spawners, while the remaining streams were numerically dominated by either nonguarder-brood hiders or non-guarder open substrate spawners (Table 3).

The first three PCA axes explained 53% of the variance in the dataset (Table 4), and these axes were retained for inclusion into the correlation analysis based on the results of the broken stick eigenvalues (Jackson 1993). The first PCA axis was correlated positively with the number of woody debris and percentage detritus and correlated negatively with channel cross-section area (Table 4). The second PCA axis was correlated positively with water depth and wet width, and correlated negatively with percentage canopy cover (Table 4). The third PCA axis was correlated positively with percentage clay, and correlated negatively with percentage sand and water velocity (Table 4).

The DCA analyses resulted in 10 axes that summarized the relative abundance patterns of species and ecological groups, and subsequent interpretation of these axes was based on the DCA species scores (Tables 5 and 6). DCA site scores and the species scores are related because the site scores are weighted averages of the species scores (McCune and Mefford 1999). Therefore, those species or ecological groups with the greatest and the least DCA species scores are indicative of the relative abundance patterns associated with the site scores for a particular axis. For example, *A. sayanus* and

Table 3. Relative abundance (%) of families, maximum body size categories, trophic guilds, and reproductive guilds in 14 first-order streams in north-central Mississippi, 1999-2002. Abbreviations for reproductive guilds are: I-BE = internal bearer, G-NS = guarder-nest spawner, G-SC = guarder-substrate chooser, N-BH = nonguarder-brood hider, N-OS = nonguarder-open substrate spawner.

	B1	B2	B3	B4	P1	P2	T1	Y1	Y2	Y3	Y4	Y5	Y6	Y7
Family														
Aphredoderidae	26.40	3.79	1.65		0.47	3.70							0.16	
Catostomidae	19.80	5.26	4.12	2.11	12.01	8.33			15.91		8.22	1.59	2.44	14.82
Centrarchidae	21.32	30.19	3.30	9.47	1.11	20.37			17.73		5.23	0.17		0.30
Cyprinidae	8.63	24.84	59.18	54.74	61.61	14.81	20.49	40.00	41.97	60.00	83.06	53.73	20.81	70.21
Elasomatidae		1.94	1.03		4.58	4.63								
Esocidae	0.51	1.11			0.32	6.48								
Fundulidae	5.08	16.62	5.15		2.37	26.85			0.76			11.32	9.92	1.20
Ictaluridae	8.12	5.91	4.54	4.21	6.00	3.70	7.29		0.61		1.37	2.93	9.43	4.49
Percidae	10.15	8.96	19.38	29.47	11.37	3.70	19.10	60.00	8.79	40.00	2.12	0.75	6.67	3.74
Petromyzontidae		1.11	1.65				53.13		4.24			29.51	50.57	5.24
Poecilidae		0.28			0.16	7.41								
Body size														
0–99 mm TL	13.71	42.29	25.77	29.47	23.06	42.59	18.75	60.00	22.42	40.00	2.12	12.07	17.24	4.94
100–199 mm TL	27.92	10.43	8.66	4.21	7.42	3.70	61.11		5.30		13.57	37.30	60.16	9.73
200–299 mm TL	7.61	11.73	0.62	11.58	6.00	8.33	0.35		3.79		4.98	3.02	06.67	9.43
300–399 mm TL	21.32	29.55	60.82	52.63	51.34	33.33	19.79	40.00	52.58	60.00	71.11	46.02	13.50	61.08
400–499 mm TL	21.32	5.63	4.12	2.11	12.01	8.33			15.91		8.22	1.59	2.44	14.82
500–620 mm TL	8.12	0.37			0.16	3.70								
Trophic														
Insectivore	61.42	62.05	90.10	86.32	79.78	55.56	46.53	100.00	60.45	100.00	69.99	60.85	39.67	70.21
Insectivore-piscivore	14.21	22.90	3.09	5.26	1.26	21.30			15.76		04.98	0.17		0.30
Omnivore	24.37	13.94	5.15	8.42	18.96	23.15	0.35		19.55		25.03	9.47	9.76	24.25
Planktivore		1.11	1.65				53.13		4.24			29.51	50.57	5.24
Reproductive														
I-BE		0.28			0.16	7.41								
G-NS	33.50	38.87	66.80	62.11	58.29	24.07	27.08	40.00	55.15	60.00	85.06	53.81	22.93	65.57
G-SC		1.94	1.03		4.58	4.63								
N-BH	21.32	10.90	5.98	8.42	20.06	8.33	54.17		24.24		12.95	34.12	60.49	29.49
N-OS	45.18	48.01	26.19	29.47	16.90	55.56	18.75	60.00	20.61	40.00	1.99	12.07	16.59	4.94

longear sunfish (*Lepomis megalotis* Rafinesque) had the greatest species scores for the first DCA axis of the relative abundance of fish species (Table 5), which indicates that those streams with the greatest site scores from the first DCA axis are associated with increasing relative abundance of

Table 4. Loadings from principal components analysis (PCA) of physical habitat variables of 14 first-order streams within pine plantations in north-central Mississippi, March 2001 to April 2002. Loadings within the columns that are bolded signify the strongest loadings for each axis and form the basis of the interpretation for each axis.

Response variable	PCA axis 1	PCA axis 2	PCA axis 3
pH	-0.102	-0.038	-0.119
Turbidity	0.121	0.103	0.032
Water temperature	0.046	-0.288	0.185
Dissolved oxygen	-0.094	0.232	-0.327
Conductivity	-0.315	-0.162	0.224
Wet width	-0.186	**0.420**	0.131
Water velocity	-0.088	0.115	**-0.448**
Water depth	0.080	**0.493**	0.202
Percentage silt	0.049	0.298	0.164
Percentage sand	0.087	-0.097	-**0.480**
Percentage gravel	-0.319	-0.081	0.226
Percentage cobble	-0.163	0.051	-0.007
Percentage detritus	**0.244**	-0.089	0.137
Percentage clay	0.074	0.314	**0.322**
Percentage bedrock	-0.285	-0.053	0.142
Number of woody debris	**0.264**	-0.119	0.031
Channel depth	-0.376	-0.080	0.059
Channel width	-0.366	0.011	-0.138
Channel cross-section area	-**0.412**	-0.074	-0.010
Percentage canopy cover	0.127	**-0.387**	0.245
Percent variance explained by axis	26.5	13.3	12.8

Table 5. Species scores from the detrended correspondence analysis (DCA) of the relative abundance of fish species of 14 first-order streams within pine plantations in north-central Mississippi, March 2001 to April 2002. Scores within the columns that are bolded signify the scores that form the basis of the interpretation for each axis.

Species	DCA axis 1	DCA axis 2
Aphredoderus sayanus	**494**	139
Elassoma zonatum	295	72
Erimyzon oblongus	303	**321**
Esox americanus	386	107
Etheostoma chlorosoma	149	**341**
Etheostoma parvipinne	**0**	171
Etheostoma proeliare	290	28
Fundulus olivaceus	301	37
Lampetra aepyptera	104	**-13**
Lepomis cyanellus	317	26
Lepomis megalotis	**427**	95
Luxilus chrysocephalus	169	119
Lythrurus roseipinnis	306	34
Notemigonus crysoleucas	404	178
Noturus phaeus	213	62
Semotilus atromaculatus	174	195

A. sayanus and *L. megalotis*. Additionally, *E. parvipinne* had the least species scores for the first DCA axis (Table 5), which indicates that those streams with the least site scores from this axis are associated with increasing abundance of *E. parvipinne* (Table 5).

The relative abundance of reproductive guilds (DCA axis 2) was significantly correlated ($P < 0.05$) with the site scores of the first PCA axis (Table 7). This positive correlation indicated that increasing relative abundance of guarder-substrate choosers occurred with increasing amounts of woody debris and percentage detritus. Conversely, increasing relative abundance of guarder-nest spawners occurred with increasing channel cross-section area.

The relative abundance of species (DCA axis 1), families (DCA axes 1 and 2), maximum body size categories (DCA axis 2), and trophic guilds (DCA axes 1 and 2) were significantly correlated ($P < 0.05$) with the site scores from the second PCA axis (Table 7). The positive correlations (Table 7) indicated that increasing relative abundance of *A. sayanus*, *L. megalotis*, Aphredoderidae, fishes with maximum body size between 400 and 499 mm

Table 6. Species scores from detrended correspondence analysis (DCA) of the relative abundance of families, maximum body size categories, trophic guilds, and reproductive guilds of 14 first-order streams within pine plantations in north-central Mississippi, March 2001 to April 2002. Scores within the columns that are bolded signify the scores that form the basis of the interpretation for each axis.

	DCA axis 1	DCA axis 2
Family		
Aphredoderidae	**389**	261
Catostomidae	280	**0**
Centrarchidae	306	258
Cyprinidae	147	166
Fundulidae	236	161
Ictaluridae	155	151
Percidae	79	**330**
Petromyzontidae	**-16**	62
Body size		
0–99 mm TL	**0**	81
100–199 mm TL	**261**	-5
200–299 mm TL	157	**-72**
300–399 mm TL	133	120
400–499 mm TL	181	**265**
Trophic		
Insectivore	93	31
Insectivore-piscivore	**-96**	**-59**
Omnivore	17	**192**
Planktivore	**239**	85
Reproductive		
Guarder-nest spawner	104	**-11**
Guarder-substrate chooser	136	**227**
Nonguarder-brood hider	**0**	161
Nonguarder-open substrate spawner	**231**	126

TL, and omnivores occurred with increasing water depth and wet widths. Additionally, increasing relative abundance of *E. parvipinne*, Petromyzontidae, fishes with maximum body size between 200 and 299 mm TL, and insectivore-piscivores occurred with increasing percentage canopy cover. The negative correlations (Table 7) indicated that increasing water depths and wet widths were associated with increasing relative abundance of Catostomidae and insectivore-piscivores. The negative correlations also indicated that increasing percentage canopy cover was associated with increasing relative abundance of Percidae and omnivores.

The relative abundance of species (DCA axis 1), families (DCA axis 1), and trophic guilds (DCA axis 1) were also significantly correlated ($P < 0.05$) with the site scores from the third PCA axis (Table 7). Positive correlations between these axes (Table 7) indicated that increasing relative abundance of bluntnose darter (*Etheostoma chlorosoma* Hay), *E. oblongus*, Aphredoderidae, and fishes with maximum body size between 400 and 499 mm TL occurred with increasing percentage clay. Additionally, the positive correlations indicated that increasing relative abundance of *E. parvipinne*, Petromyzontidae, and fishes with a maximum body size between 200 and 299 mm TL occurred with increasing percentage sand and water velocity. The negative correlations (Table 7) indicated that decreasing relative abundance of insectivore-piscivores occurred with increasing percentage clay and increasing relative abundance of planktivores was associated with increasing percentage sand and water velocities.

Table 7. Pearson correlation coefficients (*r*) from the correlations tests between the detrended correspondence analysis (DCA) site scores of fish species, families, maximum body size categories, trophic guilds, reproductive guilds with the principal components analysis (PCA) site scores of physical habitat variables of 14 first-order streams within pine plantations in north-central Mississippi, March 2001 to April 2002. Correlation coefficients with P values < 0.05 are bolded within the table.

	Physical habitat		
	PCA axis 1	PCA axis 2	PCA axis 3
Species			
DCA axis 1	-0.099	**0.582**	**0.324**
DCA axis 2	-0.243	0.081	0.258
Family			
DCA axis 1	-0.113	**0.558**	**0.404**
DCA axis 2	0.131	**-0.330**	0.129
Body size			
DCA axis 1	-0.136	0.087	-0.138
DCA axis 2	-0.112	**0.389**	**0.284**
Trophic			
DCA axis 1	0.103	**-0.512**	**-0.402**
DCA axis 2	-0.174	**0.283**	-0.074
Reproductive			
DCA axis 1	0.148	-0.150	0.230
DCA axis 2	**0.304**	0.053	-0.101

Discussion

Our results suggest that first-order streams in north-central Mississippi are typically numerically dominated by fishes that belong to the family Cyprinidae, have a maximum TL between 300 and 399 mm, consume aquatic invertebrates, and exhibit parental care by building and guarding nests. Our overall results are in agreement with Schlosser's (1987) model, which predicts that fish communities in headwater streams should be composed mostly of Cyprinidae, insectivores, and small bodied fishes. However, it should be noted that variability in the composition of species, families, and trophic guilds does occur among our study streams and suggests that Schlosser's model can predict community composition of some first-order streams in the southeastern United States, but not all streams.

The species composition of our study streams was similar to that documented in other medium- and low-gradient headwater streams in the Gulf Coastal Plains of the southeastern United States (Felley 1992). All fish species documented in our study streams were native fishes of Mississippi having widespread distributions in the state. Felley (1992) also noted that many freshwater fish species found in medium- and low-gradient headwater streams of Gulf Coastal Plain were widely distributed and not limited to headwater streams (Felley 1992). Additionally, we captured eight species (black bullhead [*Ameiurus melas* Rafinesque], bluntnose minnow [*Pimephales notatus* Rafinesque], *S. atromaculatus*, *E. oblongus*, *E. parvipinne*, *L. cyanellus*, striped shiner [*Luxilus chrysocephalus* Rafinesque], and yellow bullhead [*Ameiurus natalis* Lesueur]) that commonly occur in streams throughout Mississippi (Ross 2002), but were not included in Felley's (1992) summary of the fish fauna of medium- and low-gradient headwater streams.

We also observed relationships between fish communities with channel cross-section area, water depths, velocity, wet widths, woody debris, substrate types, and canopy cover within first-order streams of north-central Mississippi. These fish-habitat relationships are similar to those relationships observed by others working in low-gradient streams in north Mississippi (Shields et al. 1995, Warren et al. 2002). Shields et al. (1995) observed correlations between selected index of biotic integrity (IBI) metrics with channel size, substrate types, canopy cover, streambank vegetative composition, habitat diversity, wet width, and availability of pool habitat in incised streams (orders 1 to 4) within northwestern Mississippi. Warren et al. (2002) observed correlations of fish communities with watershed area, channel depth, water velocity, water depths, and amount of woody debris in streams (orders 1 to 5) of north-central Mississippi. The correspondence of our results with those of Shields et al. (1995) and Warren et al. (2002) suggest that habitat characteristics describing channel size, hydrological conditions, instream cover types, and characteristics of the adjacent streambanks are important determinants of fish community structure among first-order streams and among first to fifth-order streams in northern Mississippi.

The small size of headwater streams makes them easily amendable to anthropogenic alterations. Headwater streams are also more likely to experience anthropogenic alterations because small streams outnumber larger streams. Karr et al. (1985) observed that headwater streams in Illinois and Ohio contain the greatest percentage of species experiencing population declines compared to larger order streams. We observed that all fish species captured in our study streams have stable populations in Mississippi (Ross 2002), but three species collected from our study streams (*Lythrurus roseipinnis* Hay, *E. parvipinne*, *Esox americanus* Gmelin) are predicted to experience population decreases if subjected to increased sedimentation loads or reduced woody debris as a result of riparian or upland land use-modifications (Ross 2002). Continued monitoring of fishes in headwater streams in north-central Mississippi is advised to ensure that fishes within these small streams do not experience the population declines exhibited by fishes within headwater streams in the midwestern United States.

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Literature Cited

Analytical Software. 1996. Statistix for Windows version 1.0, Tallahassee, FL.

Angermeier, P.L., and R.A. Smogor. 1995. Estimating number of species and relative abundances in stream-fish communities: Effects of sampling effort and discontinuous spatial distributions. Canadian Journal of Fisheries and Aquatic Sciences 52:936–949.

Bailey, R.G. 1980. Descriptions of ecoregions of the United States. Miscellaneous Publication No. 1391, US Department of Agriculture, Washington, DC. 77 pp.

Balon, E.K. 1975. Reproductive guilds of fishes: A proposal and definition. Journal of the Fisheries Research Board of Canada 32:821–864.

Dibble, E.D., S.H. Schoenholtz, and P.C. Smiley Jr. 2004. Effectiveness of silvicultural best management practices in protecting aquatic habitat in timber management areas. Final report to Environmental Protection Agency, Region IV, EPA Grant number: X974062-00, Forest and Wildlife Research Center, Mississippi State, MS.

Etnier, D.A., and W.C. Starnes. 1993. The Fishes of Tennessee. University of Tennessee, Knoxville, TN. 681 pp.

Felley, J.D. 1992. Medium-low-gradient streams of the Gulf Coastal Plain. Pp. 233–269, *In* C.T. Hackney, S.M. Adams, and W.H. Martin (Eds.). Biodiversity of the Southeastern United States: Aquatic Communities. John Wiley and Sons, New York, NY. 779 pp.

Fontenot, Q.C., and D.A. Rutherford. 1999. Observations on the reproductive ecology of pirate perch *Aphredoderus sayanus*. Journal of Freshwater Ecology 14:545–549.

Gauch, Jr., H.G. 1982. Multivariate Analysis in Community Ecology. Cambridge University Press, New York, NY. 314 pp.

Gorman, O.T., and J.R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59:507–515.

Hartsell, A.J., and J.D. London. 1995. Forest statistics for Mississippi counties: 1994. Resource Bulletin SO-190, US Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, LA. 89 pp.

Horwitz, R.J. 1978. Temporal variability patterns and the distributional patterns of stream fishes. Ecological Monographs 48:307–321.

Jackson, D.A. 1993. Stopping rules in principal components analysis: A comparison of heuristical and statistical approaches. Ecology 74:2204–2214.

Johnston, C.E. 1994. Spawning behavior of the goldstripe darter (*Etheostoma parvipinne* Gilbert and Swain) (Percidae). Copeia 1994:823–825.

Johnston, C.E., and L.M. Page. 1992. The evolution of complex reproductive strategies in North American minnows (Cyprinidae). Pp. 600–621, *In* R.L. Mayden (Ed.). Systematics, Historical Ecology, and North American Freshwater Fishes. Stanford University Press, Stanford, CA. 969 pp.

Karr, J.R., L.A. Toth, and D.R. Dudley. 1985. Fish communities of midwestern rivers: A history of degradation. BioScience 35:90–95.

Katula, R. 1991. Spawning the pirate perch, one more time. American Currents Spring:24–26.

Lohonefener, R., and R. Altig. 1983. Mississippi Herpetology. MSU Research Center Bulletin 1. National Space Technology Laboratories, Mississippi State, MS. 66 pp.

Matthews, W.J. 1998. Patterns in Freshwater Fish Ecology. Chapman and Hall, New York, NY. 756 pp.

McCune, B., and M.J. Mefford. 1999. Multivariate Analysis of Ecological Data version 4.01. MjM software, Gleneden Beach, OR.

Mettee, M.F., P.E. O'Neil, and J.M. Pierson. 1996. Fishes of Alabama and the Mobile Basin. Oxmoor House, Birmingham, AL. 820 pp.

Miller, D.M. 2003. Species diversity, reproduction, and sex ratios of bats in managed pine forest landscapes of Mississippi. Southeastern Naturalist 2:59–72.

Page, L.M. 1985. Evolution of reproductive behaviors in Percid fishes. Illinois Natural History Survey Bulletin 33:275–295.

Ross, S.T. 2002. The Inland Fishes of Mississippi. University Press of Mississippi, Jackson, MS. 624 pp.

Schlosser, I.J. 1987. A conceptual framework for fish communities in small warmwater streams. Pp. 17–24, *In* W.J. Matthews and D.C. Heins (Eds.). Community and Evolutionary Ecology of North American Stream Fishes. University of Oklahoma Press, Norman, OK. 310 pp.

Shields, Jr., F.D., S.S. Knight, and C.M. Cooper. 1995. Use of the index of biotic integrity to assess physical habitat degradation in warmwater streams. Hydrobiologia 312:191–208.

Simon, T.P. 1999. Assessment of Balon's reproductive guilds with application to midwestern North American freshwater fishes. Pp. 97–121, *In* T.P. Simon (Ed.). Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton, FL. 671 pp.

Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38:913–920.

Taylor, C.M., and M.L. Warren, Jr. 2001. Dynamics in species composition of stream fish assemblages: Environmental variability and nested subsets. Ecology 82:2320–2330.

Wallace, J.B., J.R. Webster, and R.L. Lowe. 1992. High-gradient streams of the Appalachians. Pp. 133–191, *In* C.T. Hackney, S.M. Adams, and W.H. Martin (Eds.). Biodiversity of the Southeastern United States: Aquatic Communities. John Wiley and Sons, New York, NY. 779 pp.

Warren, Jr., M.L., W.R. Haag, and S.B. Adams. 2002. Forest linkages to diversity and abundance in lowland stream fish communities. Pp. 168–182, *In* M.M. Holland, M.L. Warren, Jr., and J.A. Stanturf (Eds.). Proceedings of a Conference on Sustainability of Wetlands and Water Resources: How Well Can Riverine Wetlands Continue to Support Society into the 21st Century? General Technical Report SRS-50, US Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC. 191 pp.