AN ABSTRACT FOR THE THESIS OF

David P. Gillette for the Master of Science Degree in Biological Sciences

presented on 22 May 2002. Title: Spatio-temporal patterns of fish assemblage structure and habitat use on gravel bars in the Neosho River, Lyon County, KS.

Abstract approved:

I studied spatio-temporal variation in fish assemblages on eight shallow gravel bars along a 34 km stretch of the Neosho River in Lyon County, Kansas, from November 2000 to October 2001. Analysis revealed temporal variation to be greater than spatial variation. Temporal variation was associated with fish life history events such as spawning and recruitment, and with abiotic environmental gradients. Spatial variation was related to the presence of two low-head dams that created contrasting lotic and lentic stream reaches with differing fish assemblages, similar to patterns predicted by the Serial Discontinuity Concept. Benthic and midwater guild fishes responded similarly to environmental gradients at the microhabitat level, although substrate played a slightly stronger role for the benthic fish assemblage. Juvenile members of both guilds generally utilized shallower, slower flowing habitat than adult conspecifics. Larger scale spatio-temporal patterns differed, however; the benthic guild showed significant spatial and temporal variation, whereas the midwater guild displayed neither. My results suggest that distinctions between water column habitat guilds may yield information helpful to understanding the structure and function of stream fish assemblages.

SPATIO-TEMPORAL PATTERNS OF FISH ASSEMBLAGE STRUCTURE AND HABITAT USE ON GRAVEL BARS IN THE NEOSHO RIVER, LYON COUNTY, KS

A Thesis Presented to
The Department of Biological Sciences
EMPORIA STATE UNIVERSITY

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

----

by
David Patrick Gillette
August 2002

David R. Edds

Approved by Major Advisor
(Dr. David Edds)

Approved by Committee Member
(Dr. Dwight Moore)

Mark L. Wildhaber

Approved by Committee Member
(Dr. Mark Wildhaber)

Approved by Committee Member
(Dr. Derek Zelmer)

Approved by Department Chairman
(Dr. Marshall Sundberg)

Approved for the Graduate Council

ACKNOWLEDGMENTS

I thank J. Tiemann for help in sampling, data management, and analysis. I thank B. Chance, J. Dean, L. Freeman, B. Harkins, J. Howard, S. Sherraden, and I. Singh for assistance in the field. I am grateful to Mr. and Mrs. W. Leffler, Mr. and Mrs. P. Matile, Mrs. L. Schlessener, Mr. G. Gulde, Emporia State University, and Girl Scout Council of the Flint Hills, landowners, for providing access to their land for this study. At Emporia State, I thank S. Crupper for providing laboratory supplies, R. Sleezer, L. Sneed, and B. Flock for assistance with ArcView, D. Zelmer, L. Scott, and D. Moore for statistical advice, R. Ferguson, G. Sievert, and G. Head for technical assistance, and J. Bartley and P. Fillmore for fiscal management. I also thank the Department of Biological Sciences at Emporia State University for providing funds for travel and other expenses. I thank my major advisor, D. Edds, for assistance in almost all of the above categories, and for securing landowner permission along with M. Wildhaber. At the Columbia Environmental Research Center, I thank S. Olson, B. Lakish, J. Albers, J. Fairchild, C. Witte, and A. Allert for laboratory assistance, and M. Wildhaber for equipment and statistical advice. At the U. S. Geological Survey office in Lawrence, KS, I thank J. Putnam for assistance in downloading data. I am grateful to S. Gillette for assisting with data entry and checking, and for her patience and understanding throughout this study. Funding for this study was provided by a Faculty Research and Creativity Grant and a Graduate Student Research Grant from Emporia State University, and by the U.S. Geological Survey, Department of the Interior, under USGS Cooperative Agreement No. 00CRAG0025.

PREFACE

My thesis will be submitted for publication to *Copeia*, the journal of the American Society of Ichthyologists and Herpetologists, and is formatted for that journal.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF APPENDICES

INTRODUCTION

Many aquatic ecologists have examined factors controlling the structure of stream fish assemblages. Longitudinal and temporal assemblage patterns have been investigated (Baker and Ross 1981, Gelwick 1990, Taylor et al. 1996), as have environmental gradients affecting such patterns (Matthews 1985, Edds 1993, Maret et al. 1997). Biotic factors have also been studied (Matthews and Hill 1980, Taylor 1996, Grossman et al. 1998), including the manner in which fish species use habitat differently as they pass from juvenile to adult stages (Schlosser 1982, Gelwick 1990, Gido and Propst 1999).

Fish assemblages often exhibit longitudinal zonation in rivers, with different species occurring in different sections along a river's length (Sheldon 1968, Stewart et al. 1992, Edds 1993). This zonation typically results in fish species diversity increasing from stream headwaters to lower stream reaches (Gorman and Karr 1978, Schlosser 1982, Williams et al. 1996). The commonly accepted mechanism to explain this increase is a downstream increase in microhabitat diversity that facilitates increased species diversity, usually by species addition (Gorman and Karr 1978, Schlosser 1982, Edds 1993).

Temporal patterns of fish assemblage structure are less clear. Gelwick (1990) distinguished between pool and riffle habitat while examining longitudinal and temporal fish assemblage variation, with juveniles and adults analyzed as separate taxa. Results showed that although longitudinal zonation explained much of the assemblage variability among pools, temporal variation was a better predictor among riffle areas. Matthews et al. (1994) documented temporal consistency of pool fish assemblage composition, even when their study site was subjected to major flood events. Taylor et al. (1996) found both spatial and temporal differences in fish assemblage structure of the Red River basin of Oklahoma. Stewart et al. (1992) and Williams et al. (1996) combined pool and riffle habitats for analysis, and found no seasonal variation in fish assemblages, describing this condition as one of faunal stability. Gido et al. (1997) found temporal variation greater than spatial variation for some species, while for others the opposite was true. They attributed these patterns to variations in life history traits, as well as to microhabitat variation. Gorman and Karr (1978) found fish communities in natural streams to be more stable (i.e., less temporally variable) than those of streams modified by human activity such as ditching and entrenchment, and attributed this change to destruction of habitat heterogeneity, among other factors.

Both longitudinal and temporal patterns of fish distribution have both been shown to depend on gradients of abiotic environmental factors. These include water temperature (Gelwick 1990, Edds 1993, Waite and Carpenter 2000), water depth (Gorman and Karr 1978, Schlosser 1982, Fuselier and Edds 1996), current velocity (Schlosser 1982, Edds 1993, Taylor et al. 1996), stream width (Williams et al. 1996), stream gradient (Edds 1993, Williams et al. 1996, Waite and Carpenter 2000), riffle/pool differentiation (Gelwick 1990, Fuselier and Edds 1996, Taylor 2000), and substrate composition (Schlosser 1982, Fuselier and Edds 1996, Williams et al. 1996). Species composition is often best explained by a combination of these factors, corresponding to a complexity of habitat (Gorman and Karr 1978, Edds 1993, Matthews 1998).

The role of interspecific interactions, such as competition and predation, in structuring fish assemblages has been the subject of debate, with varying effects seen according to microhabitat characteristics. Heins and Matthews (1987) reviewed the debate, noting that the role of competition likely is complex, especially because many stream fish assemblages, particularly those of shallow riffles, might not be at equilibrium. Gelwick (1990) observed that predation seemed to have a stronger effect on assemblage structure in deep pools than in riffles. Taylor (1996), however, found that biotic interactions between two benthic riffle fishes (*Cottus carolinae* and *Etheostoma spectabile*) influenced localized patterns of their distribution.

The River Continuum Concept (RCC), set forth by Vannote et al. (1980), and further developed by Minshall et al. (1985), sought to unify biotic and abiotic community structure theories by looking at the entire river as a "continuously integrating series of physical gradients and associated biotic adjustments." The RCC stated that stream ecology cannot be looked at in terms of isolated microhabitats, while acknowledging that localized habitat variation might at times override this holistic approach. According to the RCC, biotic density-dependent relationships, such as competition, also are present, and play a role in determining fish assemblage structure.

When a river's longitudinal gradients of these biotic and abiotic processes are interrupted, discontinuous zonation patterns can result (Balon and Stewart 1983). Maret et al. (1997) found distinctly different fish assemblages over a relatively short longitudinal distance, upstream and downstream from a large waterfall. Balon and Stewart (1983) found a simple longitudinal sequence of fish assemblage composition inadequate to explain patterns of fish assemblage structure in the Luongo River in Zaire, due to the presence of waterfalls and rapids, as well as an unusual "reverse flow" hydrological condition in that river system. Longitudinal gradients can also be interrupted by anthropogenic alterations; low-head dams with heights less than 1.5 m were shown by Porto et al. (1999) to significantly alter fish assemblage composition, with a general decline in species richness immediately upstream from such structures.

To explain patterns of faunal distribution in lotic systems with flow patterns altered by damming, Ward and Stanford (1983) developed the Serial Discontinuity Concept (SDC) as an alternative to the RCC. The SDC claims that impoundments can "reset the continuum," such that areas immediately downstream from dams take on characteristics normally associated with river segments of lower order, closer to the headwaters. Although the SDC was formulated with hypolimnial release dams in mind, some of its predictions are applicable to situations of impoundment by different structures. Specifically, increases in substrate diameter and flow velocity downstream from dams should not be restricted to large dams, but should occur wherever flow is slowed behind a structure, then rushes over the structure at high velocity.

In addition to large-scale spatiotemporal patterns of fish assemblage structure, small-scale habitat use patterns also occur. At this microhabitat level, biotic density-dependent relationships can play a strong role in structuring stream fish assemblages (e.g. Taylor 1996). These relationships lead to resource and habitat partitioning (Matthews and Hill 1980, Ross 1986, Grossman et al. 1998), and to the formation of trophic and habitat guilds as different species become specialized for specific environments and life histories (Gorman and Karr 1978, Gorman 1988, Taylor 2000). Reviewing studies of resource partitioning in fishes, Ross (1986) noted that trophic and spatial separation are equally important to freshwater fishes in partitioning resources. Spatially, flow and depth heterogeneity have received considerable study, with riffles and pools being shown to possess distinctive fish faunas (Gelwick 1990, Fuselier and Edds 1996, Taylor 2000).

Analyses of fish assemblages inhabiting riffles and pools have shown patterns of assemblage structure to differ between these two mesohabitats; pool fish assemblages are generally more stable and governed by biotic interactions, while riffle assemblages are generally less stable and structured by abiotic factors (Schlosser 1982, Gelwick 1990).

In addition to a riffle-pool dichotomy in species habitat preference, temperate stream fishes also have been shown to partition habitat by water column position. Grossman et al. (1998), studying a North Carolina creek, found that fish species belonged to one of three microhabitat guilds: benthic, lower water column, and midwater column. Habitat partitioning by water column position is further supported by work done by Baker and Ross (1981), who found water column position and association with aquatic vegetation to be the most important spatial resource gradients in a southeastern United States river system. Gorman (1988) also found that Ozark minnows in a Missouri creek segregated habitat most clearly according to water column position. While the presence of water column habitat guilds has been well documented, no studies have investigated whether or not they react differently to spatial and temporal environmental gradients.

Habitat use in stream fishes also has been shown to differ between juveniles and adults of the same species. Schlosser (1982) found young age groups (Age I-II) of many species primarily in shallow upstream areas and in riffles. Gelwick (1990) also found juveniles more numerous in shallow riffles than pools, whereas the opposite was generally true of adults. From these results, she hypothesized that riffles might function as supplemental juvenile habitat for species found primarily in pools.

Studies of fish assemblage spatial and temporal variability, such as those cited, have varied greatly in length and substrate composition of study reaches. As noted above, substrate composition has been shown by many researchers to exert a strong effect on fish assemblage structure. Most studies in the midwestern United States have examined short river stretches. Gelwick (1990) studied a 6 km section of river, Matthews et al. (1994) covered a 1 km stretch, and Fuselier and Edds (1996) examined a 0.43 km reach of stream. Furthermore, these studies all focused on variation between riffle and pool habitats, and sampling sites covered a wide variety of substrates.

From November 2000 to October 2001, I studied spatio-temporal variation and habitat use of fish assemblages on eight gravel bars along a 34 km stretch of the Neosho River in Lyon County, Kansas. I predicted that spatial variation patterns would resemble predictions of the SDC more than the RCC due to impoundment by lowhead dams, although the length of river studied should show some longitudinal zonation. I also predicted that temporal variation would be high due to shallow site depths. I predicted that habitat use of benthic guild taxa would be determined more strongly by substrate composition, while that of midwater guild taxa would be more dependent on water depth and flow velocity.

Results showed temporal variation to be greater than spatial variation. Temporal variation was primarily seasonal, while spatial variation was related to the presence of two low-head dams along the study reach. Juveniles generally utilized shallower, slower flowing habitat than adult conspecifics. Gradients of flow velocity and water depth were most important in structuring benthic and midwater guild fishes; substrate was a secondary component, and was more important for the benthic guild. These two guilds also exhibited different spatial and temporal abundance patterns. Based upon these results, I conclude that distinctions between water column habitat guilds can yield information helpful to understanding the structure and function of stream fish assemblages.

MATERIALS AND METHODS

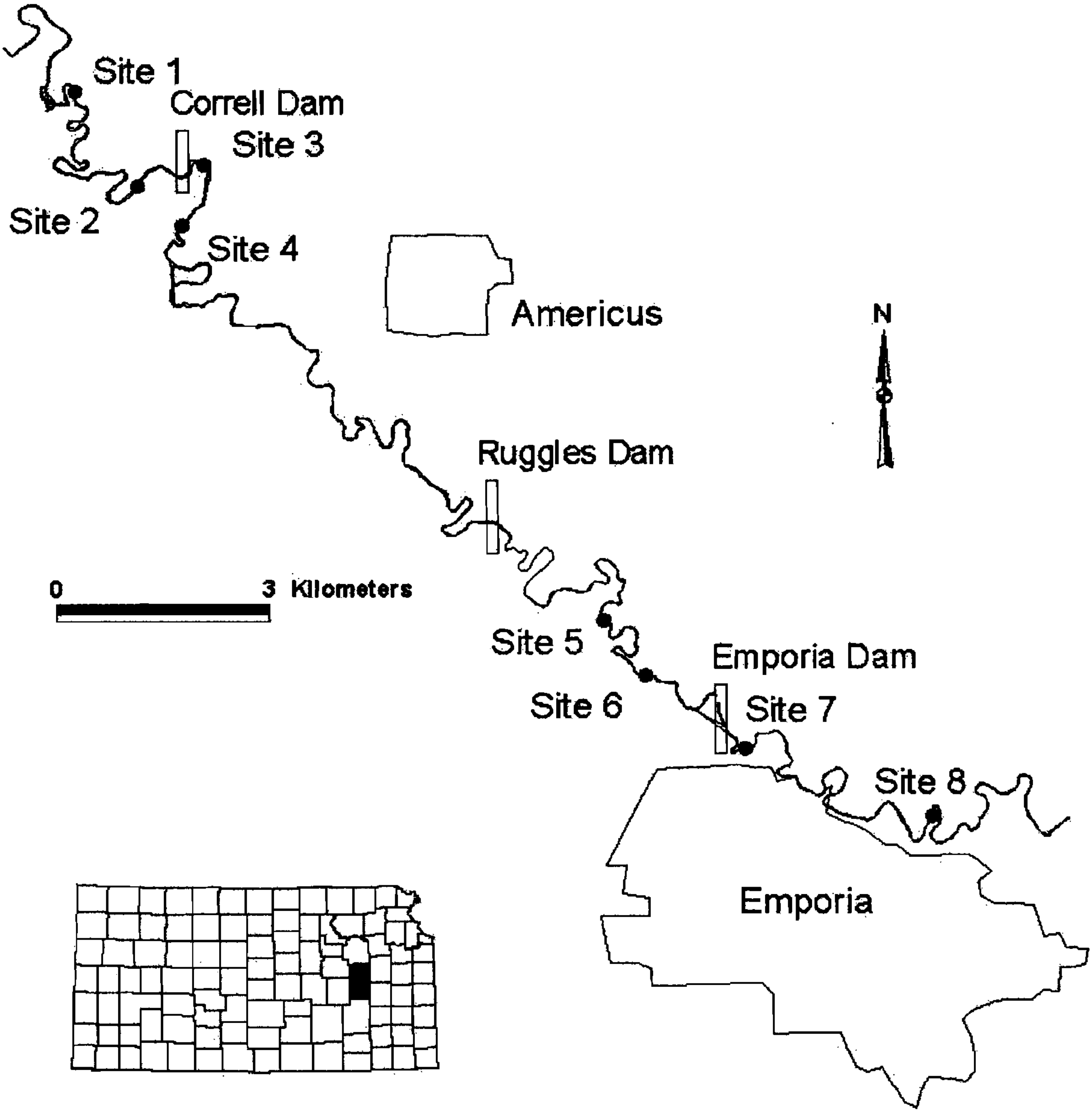
Study Area

The Neosho River lies within the Prairie Parkland Province ecoregion, and is part of the Arkansas River drainage. It is fifth-order in my study reach, draining mostly mixed-grass prairie and cropland, with mature riparian vegetation along some sections. Three low-head dams occur along the reach, with dam heights between 2 and 4 m.

I sampled eight sites along a 34 km stretch of the Neosho River from Americus to Emporia in Lyon County, Kansas (Fig. 1). Sites were selected based on landowner permission and the presence of a gravel bar. At each site, I fixed five cross-river transects perpendicular to shore. Transects were spaced equally every 5 to 10 m, depending on the length of rocky substrate at each site.

After obtaining global positioning coordinates (Appendix A) with a Garmin GPS unit (Garmin International, Romsey, Hampshire, England), I used ArcView computer software (Environmental System Research Institute, Inc., Redlands, CA) to calculate stream gradient over the length of my study area. I calculated distance between sites from digital orthoquads, and elevation from digital elevation models obtained from the United States Geological Survey (USGS) online Data Access and Support Center (http://mapster.kgs.ukans.edu/dasc/catalog). Overall gradient was 0.44 m/km, although variation in gradient between sites was extreme due to low-head dams. Gradient was lowest between sites 5 and 6 (negligible), and highest between sites 6 and 7 (1.31 m/km).

Fig. 1. Map of study area in Lyon County, KS, showing the eight study sites and three low-head dams along the Neosho River from Americus to Emporia.


Site 1
Correll Dam
Site 3
Site 2
Site 4
Americus
N
Ruggles Dam
0
3 Kilometers
Site 5
Emporia Dam
Site 6
Site 7
Site 8
Emporia

Sampling

I sampled each site monthly for one year, from November 2000 to October 2001. All samples were taken between the 9th and 22nd of each month during daylight hours (Appendix B). Sampling order of sites was randomized each month. I was unable to sample Site 2 in January and February and sites 5 and 6 from December through February due to ice cover. Sampling at each site proceeded from downstream to upstream transects, and from near shore to far shore points along each transect. I sampled up to five points along each transect, depending on river width and depth, and landowner permission; all sampling points along each transect were separated by a minimum of 0.5 m to minimize disturbance to adjacent points. Sampling along each transect continued until one of four conditions was met: 1. Five points were sampled, 2. water became too deep to sample effectively (approx. 1.25 m), 3. the mid-river demarcation line of land for which I had permission to sample was reached, or 4. the opposite shore of the river was reached.

At each point along each transect, an assistant and I sampled fishes by kick seining. To facilitate capture of juveniles, I used seines with a mesh diameter of 3 mm. Upon fixing a 1.5 m seine at the sampling point, I disturbed substrate beginning 3 m upstream from the seine. In this manner, fishes within the 4.5 m^2 sampling area were disturbed and carried downstream into the seine. This methodology has been shown to capture both midwater and benthic species (Wildhaber et al. 1999). After the substrate was disturbed, the seine was lifted and carried to shore, where fishes were identified and counted. I identified fishes collected as juvenile or adult, using a 30 mm total length (TL) maximum juvenile length for minnows (*Campostoma, Phenacobius, Pimephales, Cyprinella, Notropis,* and *Lythrurus* spp.) and darters (*Etheostoma* and *Percina* spp.), and a 50 mm TL maximum juvenile length for madtoms (*Noturus* spp.) and sunfishes (*Lepomis* spp.) (Gelwick 1990). Fishes not included in these two categories were measured individually, and classified as juvenile or adult based on previously published accounts. I used a 305 mm cutoff length for channel catfish (*Ictalurus punctatus*), 380 mm cutoff for flathead catfish (*Pylodictis olivaris*), and 280 mm cutoff for redhorse (*Moxostoma* spp.) based on work by Deacon (1961) in the Neosho River, and 220 mm for spotted bass (*Micropterus punctulatus*) and white bass (*Morone chrysops*) (Carlander 1977, 1997). I did not distinguish between juvenile and adult *Gambusia affinis* because of length sexual dimorphism in the species. After these data were recorded, all collected fishes were held in a bucket until sampling of the site was completed, then returned to the river. Redhorse and carpsucker were difficult to identify due to small size and were recorded as *Moxostoma* sp. and *Carpiodes* sp., respectively.

Guild Classification

Poor water clarity made in-stream observation impossible, so I surveyed the secondary literature to classify fishes as members of either a benthic or midwater habitat guild. I used volumes by Robison and Buchanan (1988), Etnier and Starnes (1993), Cross and Collins (1995), and Pflieger (1997) to assign guild classification. In the case of disagreement among references, I consulted the primary literature. My criteria in delineating these guilds was that, while midwater species occasionally might utilize habitat adjacent to the substrate, benthic taxa are those that generally do not utilize the water column, and spend the majority of time in contact with, or immediately above, the substrate.

I assigned 15 species to the benthic habitat guild and 16 species to the midwater habitat guild (Table 1). For almost all species, authors of the secondary literature were in agreement on water column preference. *Pimephales vigilax* was characterized as occupying both the lower water column and the benthic zone in several accounts, so I consulted Parker (1964) for further information. Both in the laboratory and in the field, Parker (1964) observed *P. vigilax* spending most of its time lying on the substrate, often under rocks or other shelter. He characterized the species as a sedentary bottom dweller; based on his account, I classified *P. vigilax* as a benthic guild species.

Microhabitat

At each point on each transect, I dropped a float with a string attached to a weight. After sampling for fish at a site was completed, I returned to each point to measure microhabitat. At each point, an assistant or I measured water depth, flow velocity at 60% depth, substrate composition, and substrate compaction. Water depth was measured with a meter stick, with depth being read at the downstream side. Flow velocity was measured using a Global Flow Probe (Global Water Company, Gold River, CA). I visually estimated substrate at each point as percentage composition of clay/silt, sand, gravel, pebble, cobble, boulder, and bedrock (Mullner et al. 2000). Definition of substrate categories and sampling methodology followed Bain (1999). Compaction is a surrogate measure of the amount of fine sediment surrounding larger substrate types, and was quantified by tactile evaluation; each point was assigned a compaction index value from 1 to 4, with 1 representing loose

Table 1. Species composition of fish benthic and midwater habitat guilds, Neosho River, Lyon Co., KS, November 2000 to October 2001, showing inclusion of adult (A) and juvenile (J) taxa in ordination analyses. Criteria for inclusion was minimum 5% occurrence in the sampling unit being ordinated. (*Juveniles and adults were not distinguished for *G. affinis*, which met criteria for DCA but not CCA ordination.)

Species	% Composition by Guild	Collections DCA	Points CCA
Benthic			
slenderhead darter *(Percina phoxocephala)*	36.91	A, J	A
bullhead minnow *(Pimephales vigilax)*	24.12	A, J	A, J
orangethroat darter *(Etheostoma spectabile)*	14.83	A, J	A
suckermouth minnow *(Phenacobius mirabilis)*	6.30	A	A
central stoneroller *(Campostoma anomalum)*	5.86	A, J	A
channel catfish *(Ictalurus punctatus)*	3.67	J	J
logperch *(Percina caprodes)*	2.73	A, J	A
Neosho madtom *(Noturus placidus)*	2.15	A, J	A, J
channel darter *(Percina copelandi)*	2.03	A	A
stonecat *(Noturus flavus)*	0.79	A, J	
freshwater drum *(Aplodinotus grunniens)*	0.28	J	
redhorse *(Moxostoma* sp.)	0.18	J	
flathead catfish *(Pylodictis olivaris)*	0.11		
fantail darter (*Etheostoma flabellare*)	0.03		
carpsucker *(Carpiodes* sp.*)*	0.02		
Midwater			
red shiner *(Cyprinella lutrensis)*	56.64	A, J	A, J
ghost shiner *(Notropis buchanani)*	14.00	A, J	A
bluntnose minnow *(Pimephales notatus)*	13.68	A, J	A, J
orangespotted sunfish *(Lepomis humilis)*	9.65	A, J	J
slim minnow *(Pimephales tenellus)*	3.50	A, J	A
sand shiner *(Notropis stramineus)*	1.07	A	A
western mosquitofish *(Gambusia affinis)*	0.53	*	
green sunfish *(Lepomis cyanellus)*	0.45	A, J	
bluegill *(Lepomis macrochirus)*	0.28	J	
bluntface shiner *(Cyprinella camura)*	0.08		
longear sunfish *(Lepomis megalotis)*	0.04		
blackstripe topminnow *(Fundulus notatus)*	0.03		
redfin shiner *(Lythrurus umbratilis)*	0.02		
spotted bass *(Micropterus punctulatus)*	0.01		
white bass *(Morone chrysops)*	0.01		
gizzard shad *(Dorosoma cepedianum)*	0.01		

substrate, 2 substrate lightly packed with clay/silt, 3 substrate tightly packed with clay/silt, and 4 bedrock (Fuselier and Edds 1996).

Physicochemistry

After fish sampling and microhabitat analysis of all points on all transects at a site, I moved immediately upstream from the furthest upstream transect to conduct physicochemical analysis. I measured water temperature with a laboratory thermometer, and used a Hach kit model AL-36B to measure dissolved oxygen and pH. I then took a 1-L sample of surface water from this area for further analysis in the laboratory. In the lab, alkalinity and hardness were measured using a Hach kit model AL-36B. Nitrate, ammonia, carbon dioxide, total acidity, and orthophosphate were measured using a Hach Surface Waters kit. Chloride and sulfate were measured using a Hach kit model DREL/1C, and turbidity was measured with a Hach 2100P turbidimeter. All Hach kits were manufactured by the Hach Company, Loveland, CO. Two 100 ml portions of the 1-L sample were vacuum filtered using Pall-Gelman Type A/E round 47 mm glass fiber filters, and the filtrate frozen at −10° C for future determination of chlorophyll *a* and particulate organic carbon (POC). I measured chlorophyll *a* using a Model 10-AU-005 Field Flourometer (Turner Designs, Sunnyvale, CA), and POC using a Coulometrics Carbon Model 5014 Analyzer (UIC, Inc., Joliet, IL).

Data Analysis

Statistical analyses were performed using SAS (SAS Version 8, SAS Institute Inc., Cary, NC) and SPSS (SPSS for Windows, Version 7.5.1, SPSS Inc., Chicago, IL) statistical software. Ordinations were conducted using PC-Ord software (McCune and Mefford 1999). For ordinations, I included only those taxa occurring in $\geq$ 5% of the sampling unit being analyzed (Gauch 1982).

Spatio-temporal Patterns of Fish Assemblage Structure

Collections

To examine spatio-temporal patterns of fish assemblage structure, I first used Detrended Correspondence Analysis (DCA) to ordinate collections made at each site during each month. DCA is a method of indirect gradient analysis; scores along each axis are based solely on the relative abundance of various taxa occurring in each collection (Gauch 1982). Data were relativized so that sums of abundance of all taxa for each collection equalled one, then square root transformed. I chose not to downweight rare taxa, and ran defaults on all DCA options.

To test for spatio-temporal variability along each DCA axis, I performed a two-way analysis of variance (ANOVA) on axis scores of all collections, using month and site as treatments (Zar 1999). Because sample size was equal or nearly so among sites and among months, I assumed that ANOVA was robust and would not be affected by heteroscedasticity (Zar 1999); examination of plots of axis scores suggested no severe deviations from normality. I used a Tukey-Kramer pairwise multiple comparison test to distinguish significantly different subgroups. To examine relationships between environmental gradients and DCA axes, I calculated Pearson's correlation coefficient between axis scores of each collection, and the mean and standard deviation of environmental variables for each collection. I transformed environmental variables when necessary to improve normality based on the Shapiro-Wilk test; all proportional data were arcsine transformed, and mean compaction, flow, water temperature, alkalinity, turbidity, chlorophyll *a*, and standard deviation percent composition sand were $\log_{10}$ transformed. Normality of all other variables was not improved by transformation, so analysis was performed on untransformed values. Inspection of plots of variables included in the correlation matrix revealed no serious deviations from normality. To investigate the possible effects of flow regime on fish assemblage structure, I included in the correlation analysis daily river discharge for the day of each collection, as well as the mean daily discharge for 15 days before each collection; these data were obtained from the U.S.Geological Survey gauging station on the Neosho River at Americus, KS (http://ks.water.usgs.gov/nwis.sw). I used a Bonferroni correction to reduce potential Type I error, dividing $\alpha = 0.05$ by the number of pairwise comparisons in my correlation matrix (70) to produce a critical $\alpha = 0.00071$ required to reject Ho: $\rho = 0$.

Guilds

To examine spatio-temporal patterns by habitat guild, I performed a two-way ANOVA on abundance of midwater and benthic habitat guilds in each collection standardized as the number colllected per square meter of substrate sampled, then used a Tukey-Kramer pairwise multiple comparison test to distinguish significantly different subgroups by month and site sampled. To examine environmental correlates with these patterns, I calculated Pearson's correlation coefficient for standardized abundance of each guild and environmental variables.

Species

To test for patterns of spatio-temporal variability at the species level, I performed a two-way ANOVA on abundance of each fish species occurring in ≥ 5% of collections, standardized as the number collected per square meter of substrate sampled. I used a Tukey-Kramer pairwise multiple comparison test to distinguish significantly different subgroups by month and site.

Environmental Gradients Affecting Benthic and Midwater Guild Taxa

To examine patterns of microhabitat use by different taxa, I used Canonical Correspondence Analysis (CCA) to ordinate taxa in multivariate "points space" based on the sampling points at which each taxon occurred. CCA is a method of direct gradient analysis, where site and species scores along ordination axes are a function of multiple regression of ordination scores with environmental variables (Palmer 1993). Data were relativized so that sums of abundance of all fishes collected at each point equalled one, then arcsine square root transformed. I chose not to downweight rare taxa, and ran defaults on all CCA options.

I conducted two ordinations, one for the eight midwater guild taxa occuring at ≥ 5% of all points where midwater fishes were collected (adult *Notropis stramineus, N. buchanani, Pimephales tenellus, P. notatus*, and *Cyprinella lutrensis*, and juvenile *P. notatus, C. lutrensis,* and *Lepomis humilis*), and the other for the 11 benthic guild taxa occurring at ≥ 5% of all points where benthic fishes were collected (adult *Percina caprodes, P. copelandi, P. phoxocephala, Etheostoma spectabile, Campostoma anomalum, P. vigilax, Phenacobius mirabilis,* and *Noturus placidus*, and juvenile

P. vigilax and *N. placidus*). Ordination of midwater taxa was based on 966 4.5 m^2 points that I kick-seined, and ordination of benthic taxa on 765 points. I included only the 5 microhabitat parameters in the environmental matrix, excluding physicochemical variables because I did not measure physicochemistry separately at each point. To examine the effects of substrate composition on the fish assemblage, I conducted a DCA of all points included in the CCA, based upon substrate composition at each point. I then included axis 1 and 2 scores from this DCA for each point in the environmental matrix, rather than including each substrate category separately for each point. Substrate DCA 1 scores increased as substrate diameter increased from clay/silt to boulder, whereas DCA 2 described a gradient dominated by bedrock high along the axis. I tested significance of the relationship between species and environmental matrices using a Monte Carlo simulation with a random number seed generated based upon time of day and 9,999 permutations to calculate the probability of no relationship between the two matrices.

RESULTS

I collected 15,215 fish of 31 species, accounting for 46 taxa including juveniles and adults (Appendix C). Ten families from five orders were represented (Appendices D, E), with Cyprinidae having the greatest number of species (10), followed by Percidae (5), Centrarchidae (5), and Ictaluridae (4).

Spatio-temporal patterns of fish assemblage structure

Collections

I included 86 collections in the DCA, composed of 16 juvenile and 18 adult taxa (Table 1). I excluded samples taken in December at Site 8 and January at Site 7 because these collections consisted of only one fish, and were identified as outliers by PC-Ord outlier analysis (McCune and Mefford 1999); the presence of outliers has been shown to adversely effect ordination techniques (Gauch 1982). To determine the effects of removing these outliers on the analysis, I conducted a parallel analysis with these collections included; significant results were the same as those obtained after removing outliers.

The first DCA axis (DCA 1) covered a gradient of more than 5.5 standard deviations, had an eigenvalue of 0.400, and indicated a temporal pattern of fish assemblage structure (Fig. 2). DCA 1 was positively correlated with dissolved oxygen, alkalinity, and dissolved carbon dioxide, and negatively correlated with water temperature, turbidity, and mean water depth (Table 2, Appendix F).

ANOVA of DCA 1 collection scores grouped by site, followed by a Tukey-Kramer test, distinguished two non-significant sub-groups, one including all sites except Site 1 and the other including sites 1, 7, and 3 (Fig. 3). Similar analysis of DCA 1 collection scores grouped by month revealed five non-significant subgroups (Fig. 3). A late spring through mid-fall group scored lowest, including April, May, June, July, August, September, and October. A winter group of December, January, and February scored highest along DCA 1. Collections from November and March fell in between

Fig. 2. Temporal DCA scores of 86 collections from the Neosho River, Lyon County, KS, from November 2000 to October 2001. Triangles represent collections from April through October (late spring through mid-fall fish assemblage), diamonds those from March and November (transitional fish assemblage), and asterisks those from December through February (winter fish assemblage).

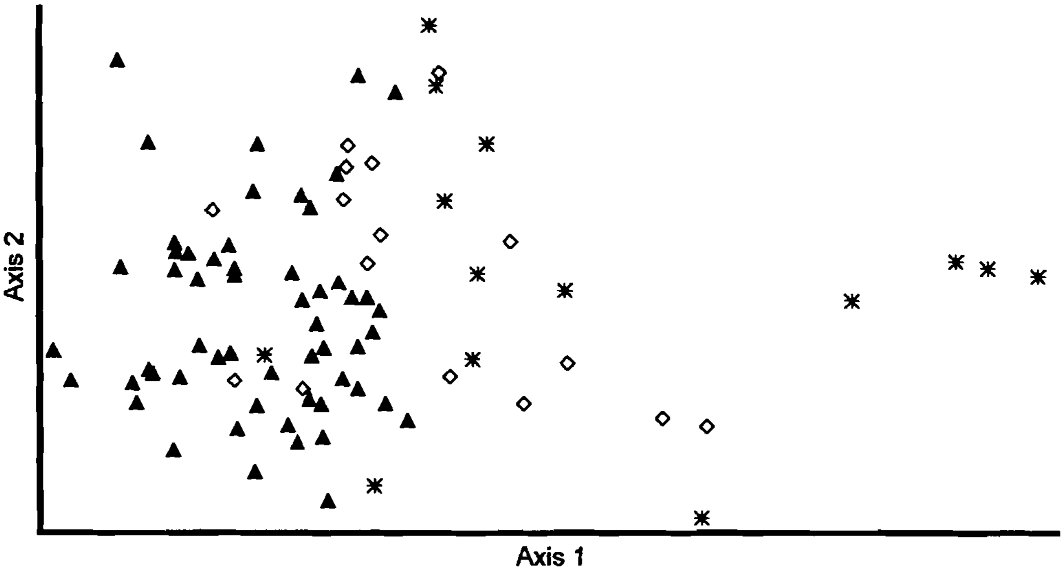

Axis 2
Axis 1

Table 2. Pearson's correlation coefficient of environmental variables with DCA 1 and DCA 2 collection scores. Associated p-values are shown in parentheses; correlations significant at $P < 0.00071$ are denoted by an asterisk.

		DCA 1	DCA 2
Percent substrate composition			
clay/silt	Mean	-0.24950 (0.0205)	0.05500 (0.6150)
	S.D.	-0.24334 (0.0240)	0.03270 (0.7650)
sand	Mean	-0.12816 (0.2396)	-0.15381 (0.1574)
	S.D.	-0.16567 (0.1274)	-0.17961 (0.098)
gravel	Mean	-0.11940 (0.2735)	0.05675 (0.6038)
	S.D.	-0.25485 (0.0179)	0.01949 (0.8586)
pebble	Mean	0.04996 (0.6478)	0.14025 (0.1978)
	S.D.	-0.12586 (0.2482)	0.05683 (0.6032)
cobble	Mean	0.02292 (0.8341)	-0.10238 (0.3482)
	S.D.	0.07741 (0.4787)	-0.08135 (0.4565)
boulder	Mean	-0.01312 (0.9046)	0.01908 (0.8616)
	S.D.	0.00042 (0.9969)	0.03928 (0.7195)
bedrock	Mean	0.15662 (0.1498)	-0.06952 (0.5248)
	S.D.	0.15234 (0.1614)	-0.10472 (0.3373)
Other microhabitat variables			
substrate compaction	Mean	0.08347 (0.4448)	0.09096 (0.4049)
	S.D.	-0.08161 (0.4551)	-0.03154 (0.7731)
water depth	Mean	-0.38601 (0.0002)*	0.11643 (0.2857)
	S.D.	-0.34383 (0.0012)	0.10722 (0.3258)
water flow velocity	Mean	0.17800 (0.1011)	-0.54726 (<0.0001)*
	S.D.	0.10124 (0.3537)	-0.46349 (<0.0001)*
Physicochemical variables			
dissolved oxygen		0.56260 (<0.0001)*	0.08284 (0.4483)
pH		0.06019 (0.5820)	0.00982 (0.9285)
alkalinity		0.39001 (0.0002)*	0.19919 (0.0660)
hardness		0.16086 (0.1390)	0.15757 (0.1474)
turbidity		-0.51327 (<0.0001)*	-0.40235 (0.0001)*
dissolved carbon dioxide		0.39009 (0.0002)*	0.21290 (0.0491)
ammonia		-0.05867 (0.5916)	-0.10309 (0.3449)
nitrate		-0.11143 (0.3071)	-0.23685 (0.0281)
chloride		0.06418 (0.5571)	0.13760 (0.2064)
sulfate		0.33894 (0.0014)	0.09642 (0.3772)
particulate organic carbon		-0.25555 (0.0176)	-0.21892 (0.0429)
chlorophyll *a*		-0.29954 (0.0051)	0.05811 (0.5951)
water temperature		-0.74881 (<0.0001)	-0.16001 (0.1411)

Fig. 3. Results of two-way ANOVA on DCA 1 and DCA 2 collection scores pooled by month and site. Non-significant subgroups determined by Tukey-Kramer pairwise multiple comparison test underlined.

DCA 1

Sites ($F_{7,67}$=4.99, P = 0.0001)

5 6 2 4 8 3 7 1

Months ($F_{11,67}$=10.34, P < 0.0001)

Jun May Jul Apr Oct Sep Aug Nov Mar Feb Dec Jan

DCA 2

Sites ($F_{7,67}$=11.72, P < 0.0001)

7 3 1 4 8 6 5 2

Months ($F_{11,67}$=8.56, P < 0.0001)

Jul Jun Feb Mar May Oct Apr Sep Nov Jan Aug Dec these two groups; these two transitional months scored significantly higher than May and June, but lower than January.

Benthic guild species scored highest along DCA 1, dominating fish assemblages in winter (Fig. 4). With the exception of *G. affinis*, which only occurred in November and December, the seven highest scoring taxa along DCA 1 were members of the benthic guild. Taxa characteristic of summer collections scored lowest along DCA 1. Two juvenile darters, *P. caprodes* and *P. phoxocephala,* scored lowest of all; these young-of-the-year fishes were first captured in June. *Percina caprodes* juveniles had reached the 30 cm adult cutoff by August, whereas *P. phoxocephala* juveniles persisted until October. Species scoring lowest as adults included *P. copelandi, N. buchanani*, and *L. humilis.*

DCA 2 was primarily a spatial pattern axis (Fig. 5), with a slight temporal component. It covered a gradient of 2.1 standard deviations and had an eigenvalue of 0.180. None of the environmental variables I measured were positively correlated with DCA 2; negative correlates included mean turbidity and mean and standard deviation of flow velocity (Table 2). ANOVA of DCA 2 scores followed by a Tukey-Kramer test revealed four overlapping non-significant spatial subgroups (Fig. 3). Scoring lowest on DCA 2 were sites 7 and 3, both of which were directly downstream from low-head dams, with high mean and standard deviation of flow velocity, and high mean turbidity; substrate at Site 3 was primarily bedrock (Appendix H). Sites 6, 5, and 2 scored highest along DCA 2, and formed a non-significant subgroup. Sites 6 and 2 were immediately upstream from low-head dams, and had low flow velocity and turbidity (Appendix H). Site 5 also was a deeper site, with a mean flow velocity equal to that of Site 6 (Appendix H). Temporally on DCA 2, four non-significant subgroups were distinuished by the

Fig. 4. DCA scores for 34 taxa from 21 species collected from the Neosho River, Lyon County, KS, from November 2000 through October 2001; location for each taxon in ordination denoted by “+”. (See Appendix F for species abbreviations; A=adults and J=juveniles.)

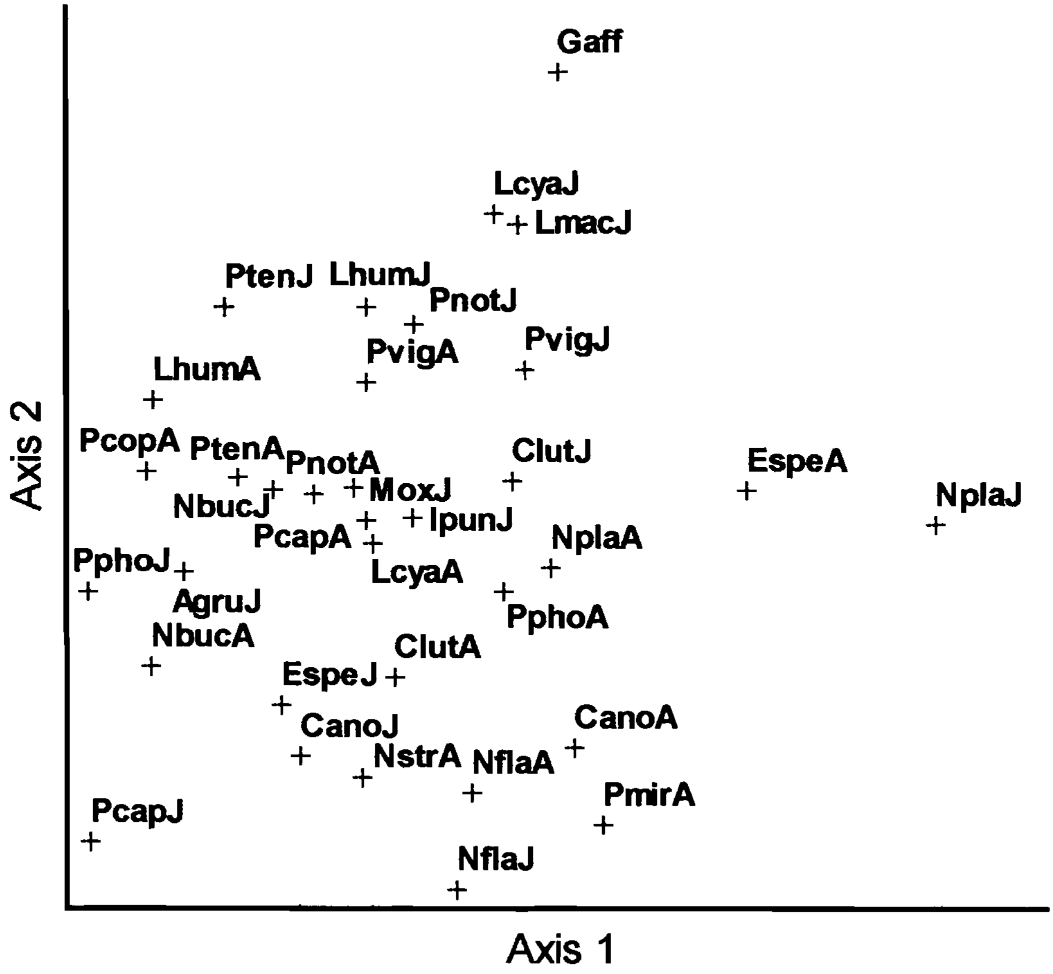
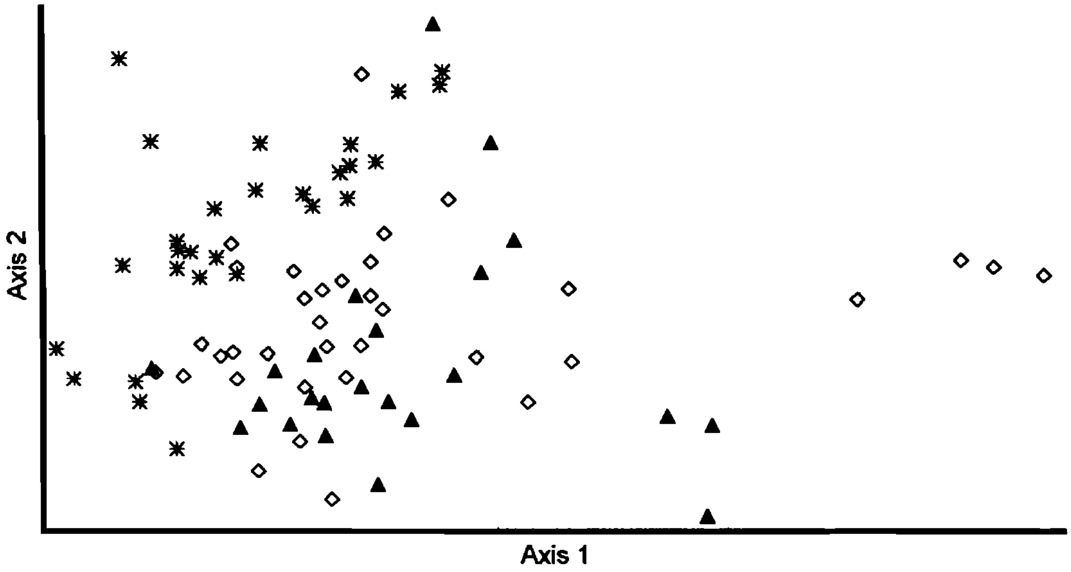

Gaff
LcyaJ
LmacJ
PtenJ
LhumJ
PnotJ
PvigA
PvigJ
LhumA
PcopA
PtenA
PnotA
ClutJ
EspeA
NplaJ
NbucJ
MoxJ
IpunJ
PcapA
NplaA
PphoJ
LcyaA
AgruJ
PphoA
NbucA
ClutA
EspeJ
CanoJ
CanoA
NstrA
NflaA
PmirA
PcapJ
NflaJ
Axis 2
Axis 1

Fig. 5. Spatial DCA scores of 86 collections from the Neosho River, Lyon County, KS, from November 2000 to October 2001. Triangles represent collections from sites 3 and 7 (immediately downstream from low-head dams), asterisks those from sites 2, 5, and 6 (immediately upstream from low-head dams), and diamonds those from sites 1, 4, and 8 (neither immediately downstream or immediately upstream from low-head dams).


Axis 2
Axis 1

ANOVA and Tukey- Kramer test (Fig. 3).

Scores of fish taxa on DCA 2 showed a progression from higher-velocity lotic habitat species to species normally inhabiting pool environments (Fig. 4). Scoring lowest were benthic riffle fishes, including juvenile and adult *N. flavus*, juvenile *P. caprodes*, adult *P. mirabilis*, adult *N. stramineus*, and juvenile and adult *C. anomalum*. Midwater species typically found in slower waters scored high on DCA 2; *G. affinis* scored highest, followed by *Lepomis* sunfishes and minnows of the genus *Pimephales*.

Six of the eight collections scoring highest on DCA 2 were taken from Site 2, immediately upstream from the Correll Dam. However, the collection that scored highest overall was taken in December at Site 7, just downstream from the Emporia Dam. This site had a high mean and standard deviation of flow velocity (Appendix H), but there was no water flowing over the dam in December 2000, changing it to a lentic environment limited to the scour pool just below the dam, with a corresponding shift in fish species. The next highest scoring collection from this site occurred in August, and ranked 54th out of 86. Site 3 also scored high on DCA 2 in December, when *G. affinis* was collected near shore; *L. humilis*, *L. cyanellus*, and *P. vigilax* also occurred in greater numbers than usual. Site 8 scored high during low flow conditions in August, when there was barely enough water to cover a riffle at the site, and all adjacent habitat had little flow. Surprisingly, *C. lutrensis* and *N. buchanani* were absent from this sample, as were benthic fishes, and the collection was dominated by *L. humilis*, *L. cyanellus*, and *P. notatus*.

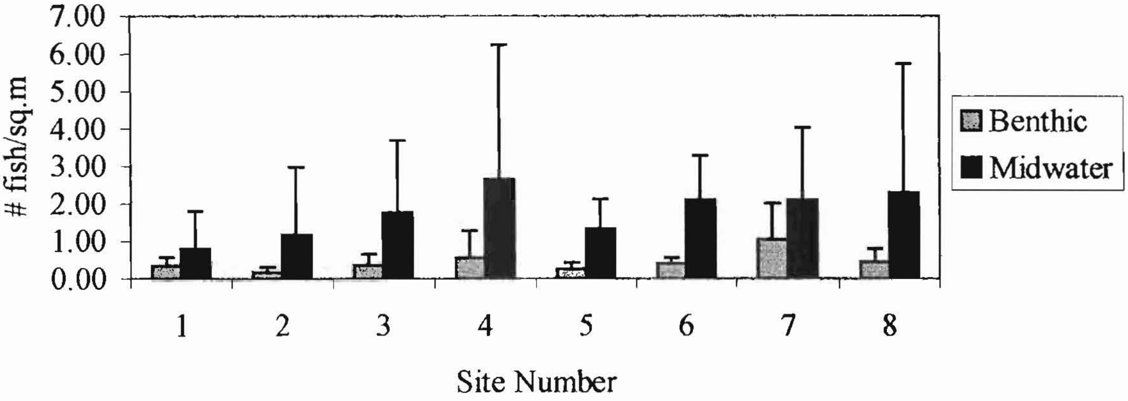
Collections scoring low on DCA 2 were characterized by riffle species and associated with high flow velocities. Eleven of the 15 lowest scoring collections were from sites 3 and 7, immediately downstream from low-head dams with high mean and standard deviation flow velocities (Appendix H). The other four low-scoring collections were taken from sites 1, 4, 6, and 8 during July. July collections were atypical for these sites, generally due to increased relative abundance of low-scoring benthic fishes. At Site 1 for example, occurrence of *C. anomalum* juveniles plus large numbers of adult *P. mirabilis*, *N. buchanani*, *C. lutrensis*, and *P. phoxocephala* resulted in a much lower axis score than for other months. Juvenile *C. anomalum* generally remained less than the adult cutoff length for only one or two months, and so did not typically affect DCA scores for any other month.

Guilds

Benthic guild taxa abundance varied significantly by site ($F_{7,69}$=4.22, P=0.0006) and month ($F_{11,69}$=2.81, P=0.0044). Spatially, benthic taxa abundance was high at high flow-velocity sites 7 and 4, and low at sites 2 and 5 (Fig. 6), both low flow-velocity sites upstream from dams. The Tukey-Kramer test distinguished two non-significant subgroups, one including sites 7 and 4, and the other all except Site 7 (Fig. 7). Temporally, abundance of benthic taxa was high during November and April, and low during January, February, and March (Fig. 6). A Tukey-Kramer test revealed two broad non-significant subgroups (Fig. 7). Benthic guild abundance was not significantly correlated with any of the 38 environmental variable at the Bonferroni-corrected $\alpha = 0.0013$. At $\alpha = 0.05$, benthic guild abundance was significantly correlated with four microhabitat variables and two physicochemical variables: substrate composed of cobble (r=0.225) and clay/silt (r=-0.227), compaction (r=-0.240), flow velocity (r=0.238), chloride (r=-0.273) and sulfate (r=-0.315). Midwater guild taxa abundance did not vary

Fig. 6. Mean and standard deviation abundance of benthic and midwater guild fishes by site (A) and month (B), standardized as number of fishes collected per m^2.

A.


7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
fish/sq.m
1
2
3
4
5
6
7
8
Site Number
Benthic
Midwater

B.

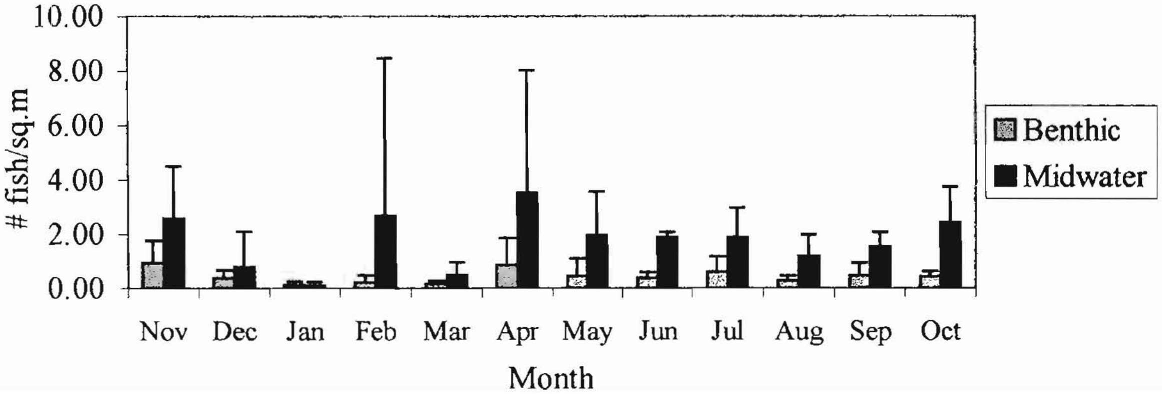

10.00
8.00
6.00
4.00
2.00
0.00
fish/sq.m
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Month
Benthic
Midwater

Fig. 7. Results of two-way ANOVA on standardized abundance of benthic guild taxa by month and site. Non-significant subgroups determined by Tukey-Kramer pairwise multiple comparison test underlined.

Benthic Guild Abundance

Sites ($F_{7,69}$=4.22, P=0.0006)

2 5 6 1 3 8 4 7

Months ($F_{11,69}$=2.81, P=0.0044)

Jan Feb Mar Aug Dec Jun Oct May Sep Jul Apr Nov significantly by site ($F_{7,69}$=0.96, P=0.469) or month ($F_{11,69}$=1.40, P=0.192), and was not significantly correlated with any environmental variables at the Bonferroni adjusted alpha level. At $\alpha = 0.05$, midwater guild taxa abundance was correlated with water hardness (r=-0.244), turbidity (r=0.327), and chloride (r=-0.221). Species spatio-temporal abundace patterns varied with habitat guild. Four of the six species varying spatially were from the benthic guild, whereas both species varying temporally were from the midwater guild (Table 3).

Species

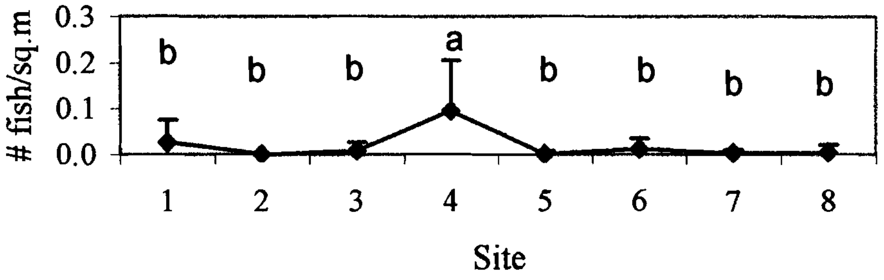
Six species showed significant spatial abundance patterns, including one benthic *(P. mirabilis)* and two midwater (*N. stramineus* and *P. tenellus)* minnows, one madtom catfish *(N. placidus),* and two darters (*P. copelandi* and *P. phoxocephala*) (Table 3). Two midwater minnows, *N. buchanani* and *P. notatus*, showed significant temporal distribution patterns (Table 3). Most species did not exhibit significant differences in spatial or temporal abundance (Table 3).

Several patterns were evident among species varying in abundance spatially (Fig. 8). *Notropis stramineus* was most abundant at Site 4. *Phenacobius mirabilis* abundance was low directly upstream (sites 2 and 6), and high directly downstream (sites 3 and 7), from low-head dams. *Pimephales tenellus* and *Percina copelandi* abundance was low immediately downstream from low-head dams and at upstream sites, and high at the constantly flowing sites 4, 5, 6, and 8. *Noturus placidus* abundance was low immediately upstream (sites 2 and 6) and downstream (sites 3 and 7) from low-head dams, and relatively high at sites farthest from those structures (sites 1, 4, 5, and 8). *Percina*

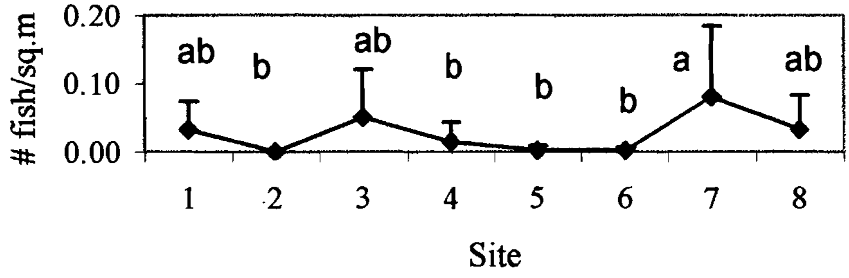
Table 3. Results of two-way Analysis ANOVA on standardized abundance of fish species per collections by site and month. Results significant at Bonferroni corrected $\alpha = 0.0012$ denoted by asterisk.

Species	Site		Month	
	$F_{7,69}$	P	$F_{11,69}$	P
Campostoma anomalum	1.74	0.114	2.44	0.012
Cyprinella lutrensis	1.36	0.237	1.40	0.194
Notropis buchanani	1.09	0.377	4.59	<0.0001*
N. stramineus	5.81	<0.0001*	1.09	0.379
Phenacobius mirabilis	4.29	0.001*	2.26	0.020
Pimephales notatus	2.98	0.009	3.48	0.001*
P. tenellus	10.07	<0.0001*	2.99	0.003
P. vigilax	2.26	0.039	2.12	0.030
Moxostoma sp.	0.88	0.530	1.00	0.458
Ictalurus punctatus	0.77	0.613	2.22	0.023
Noturus flavus	2.45	0.026	1.67	0.099
N. placidus	5.68	<0.0001*	1.25	0.273
Gambusia affinis	0.91	0.506	1.48	0.160
Lepomis cyanellus	0.74	0.642	1.66	0.102
L. humilis	1.40	0.218	1.17	0.326
L. macrochirus	0.55	0.793	1.37	0.206
Aplodinotus grunniens	0.82	0.570	1.34	0.224
Etheostoma spectabile	2.90	0.010	3.16	0.002
Percina caprodes	2.58	0.020	1.68	0.098
P. copelandi	3.86	0.001*	1.27	0.260
P. phoxocephala	5.89	<0.0001*	1.60	0.117

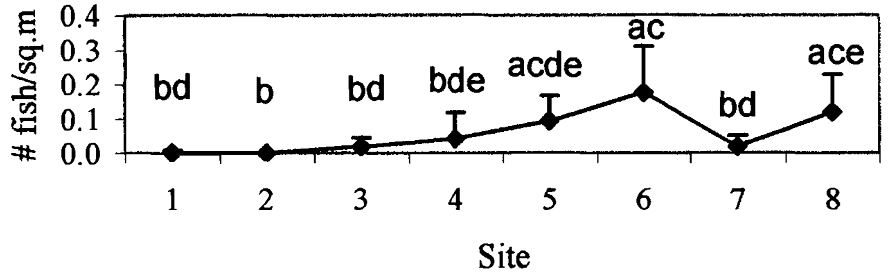
Fig. 8. Mean and standard deviation abundance of species with significant spatial abundance patterns. Non-significant subgroups determined by Tukey-Kramer test for each species denoted by same lowercase letters.



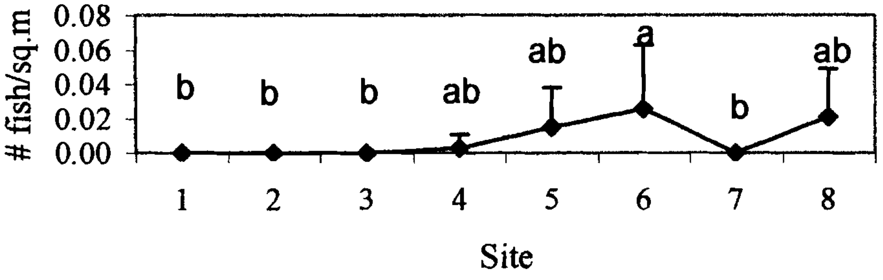
Notropis stramineus

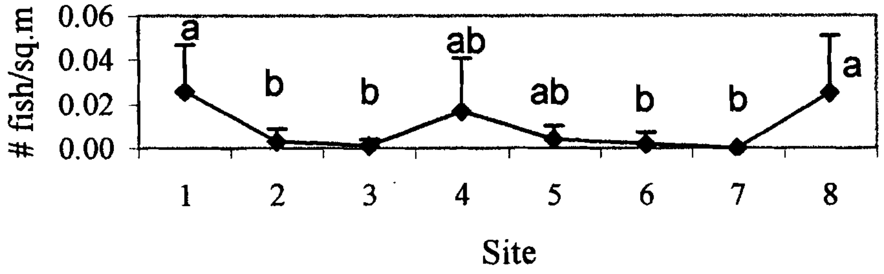


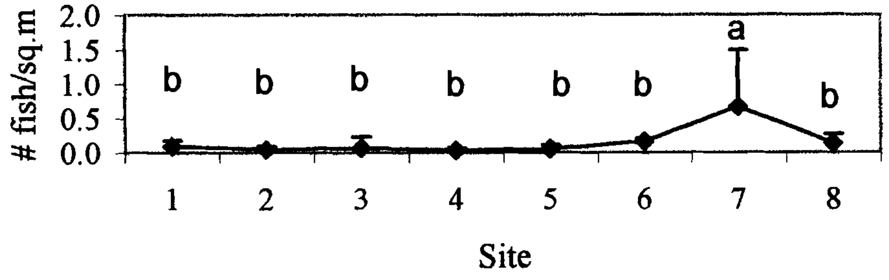
Phenacobius mirabilis



Pimephales tenellus


Percina copelandi


Noturus placidus


Percina phoxocephala

phoxocephala abundance was highest immediately downstream from the Emporia Dam (Site 7).

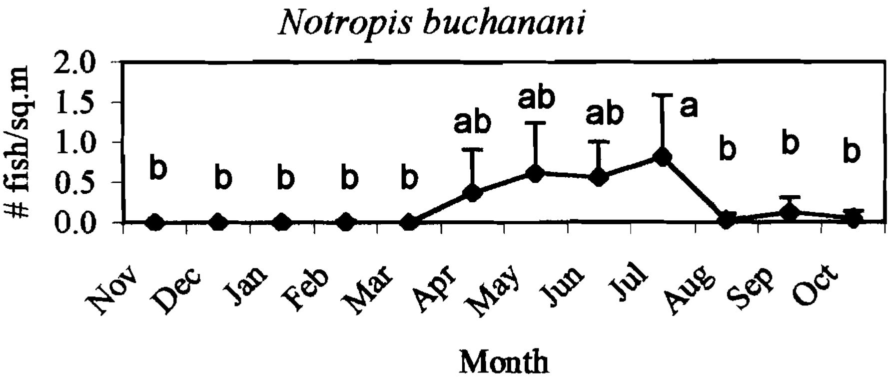
Abundance of both species varying temporally was low in winter (Fig. 9). *Notropis buchanani* was virtually absent from November through March (even more so than other midwater species), but increased greatly from April through July, with adults replacing *C. lutrensis* as the most abundant midwater taxon in July. In August, *N. buchanani* abundance was less than 10% of what it had been in July, and numbers remained low through October, while *P. notatus* was generally high in abundance from April through October.

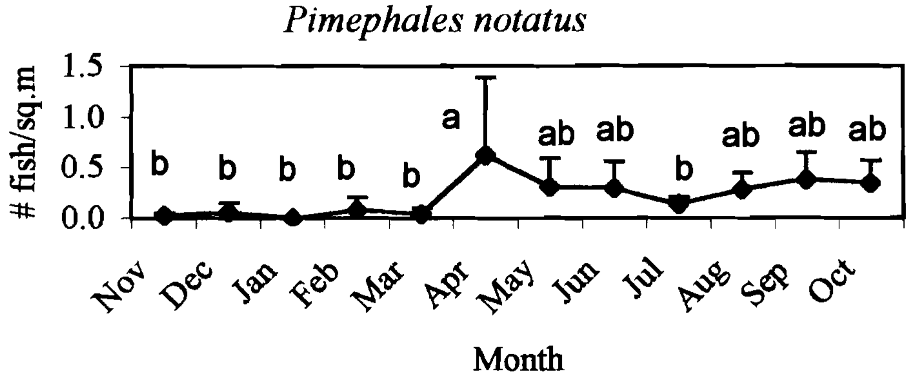
Environmental Gradients Affecting Benthic and Midwater Guild Taxa

I collected 15 species and 23 taxa of benthic guild fishes, and 16 species and 23 taxa of midwater guild fishes. At all sites and during all months except January, abundance of midwater guild species tended to be greater than that of benthic guild species (Fig. 6). Overall, the number of midwater guild individuals collected (12,100) was almost four times that of benthic guild individuals (3,115). There was a significant relationship between species and microhabitat matrices for both benthic and midwater guilds (CCA Monte Carlo P = 0.0001). *Percina phoxocephala*, *P. vigilax*, and *E. spectabile* were the most common members of the benthic guild, while *C. lutrensis*, *N. buchanani, and P. notatus* were most abundant among midwater species (Table 1).

The first axis (CCA 1) explained 2.7% of the variance in benthic species data, with a species-microhabitat correlation of 0.490. CCA 1 was significantly correlated with substrate DCA 2, as well as substrate compaction, and flow velocity.

Fig. 9. Mean and standard deviation abundance of species showing significant temporal differences in abundance. Non-significant subgroups determined by Tukey-Kramer test for each species denoted by same lowercase letters.


Notropis buchanani
fish/sq.m
2.0
1.5
1.0
0.5
0.0
b
b
b
b
b
ab
ab
ab
a
b
b
b
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Month


Pimephales notatus
fish/sq.m
1.5
1.0
0.5
0.0
b
b
b
b
b
a
ab
ab
b
ab
ab
ab
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Month

well as with water depth and flow velocity (Table 4). CCA 2 explained 2.2% of the variance in the species data, with a species-microhabitat correlation of 0.452. CCA 2 was significantly correlated with substrate DCA 1, as well as with water depth, and substrate compaction (Table 4). Benthic taxa were arranged in three broad groups along CCA 1 and CCA 2 (Fig. 10); juvenile *P. vigilax* and *N. placidus* occupied relatively shallower water than conspecific adults, with similar flow velocities.

For midwater taxa, CCA 1 explained 3.8% of the variance in the species data, and had a species-microhabitat correlation of 0.477. CCA 1 was significantly correlated with substrate DCA 1 and 2, as well as with water depth, compaction, and flow velocity (Table 5). CCA 2 explained 3.3% of the variance in the species data, and had a species-environment correlation of 0.430. CCA 2 was significantly correlated with substrate DCA 2, as well as with water depth, compaction, and flow velocity (Table 5). Midwater taxa clustered into three groups (Fig. 11), and juvenile *P. notatus* and *C. lutrensis* both generally utilized slower flowing, shallower habitat than adult conspecifics.

DISCUSSION

The 31 fish species I collected were more than the 26 encountered by Deacon (1961) upstream in the Neosho River, but less than the 46 documented by Cross (1967) to occur in the Neosho River in Lyon County. I captured fewer catostomids, centrarchids, and ictalurids, but more percids and cyprinids than did Deacon. These discrepancies are likely due to differences in design between the two studies rather than to changes in the Neosho River fish fauna. I sampled a much longer stretch of river, 34 km, compared to 1.6 km for Deacon's study, which also followed a severe drought. My study was

Table 4. Correlations between CCA 1 and CCA 2 and microhabitat variables at all points where benthic taxa were collected. Correlations significant at α=0.0025 (Bonferroni corrected alpha) denoted by a single asterisk, those significant at α=0.001 by two asterisks.

Variable	CCA 1	CCA 2
Substrate DCA 1	-0.033	-0.621**
Substrate DCA 2	0.591**	-0.124*
Water depth	-0.118*	0.891**
Compaction	-0.161**	-0.475**
Flow velocity	0.860**	0.082

Fig. 10. CCA biplot of 11 benthic guild taxa and associated microhabitat variables. Only environmental variables with biplot scores greater than 0.20 are shown. (See Appendix G for species abbreviations; "A" denotes adult taxa, "J" juvenile taxa).

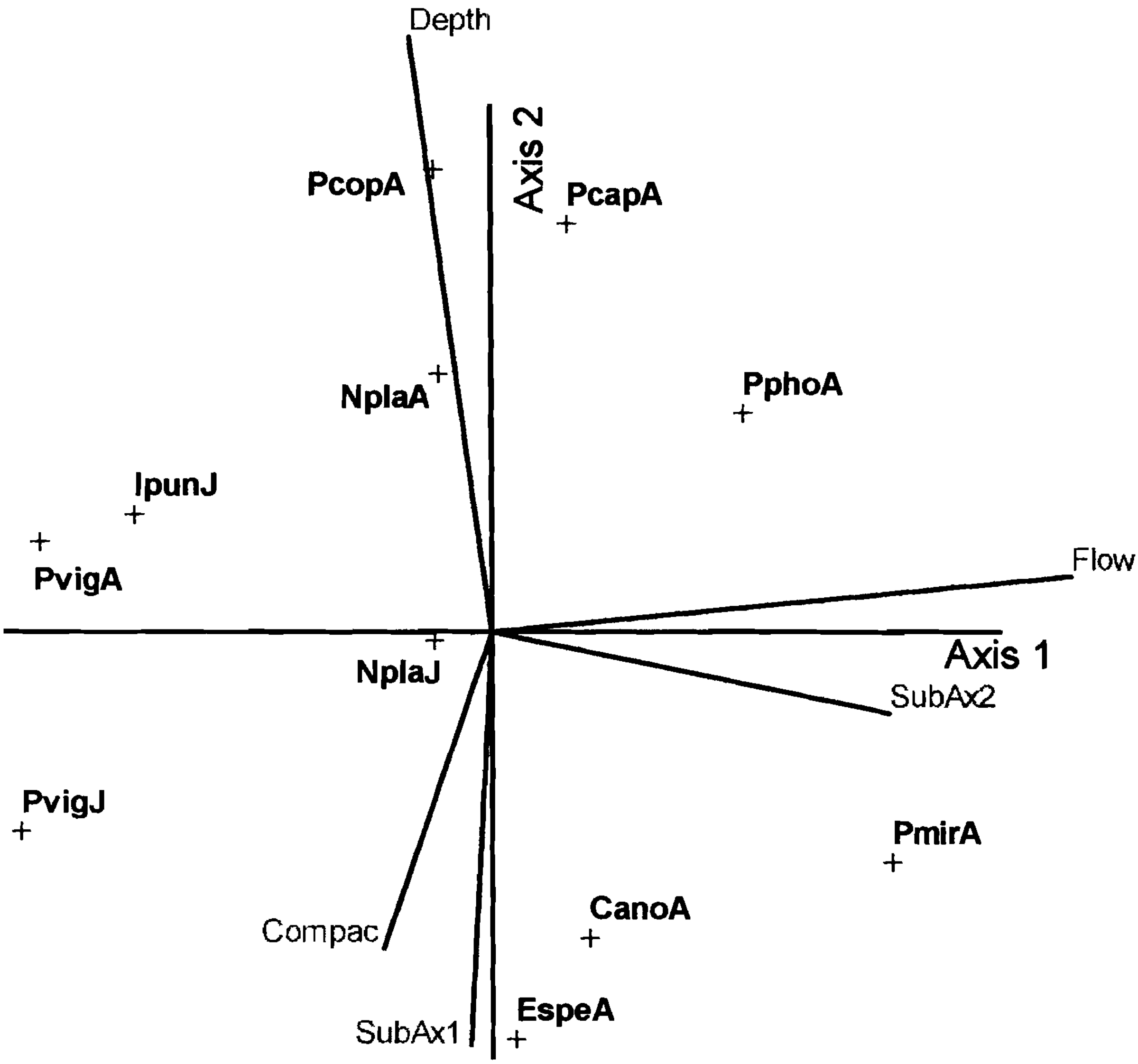
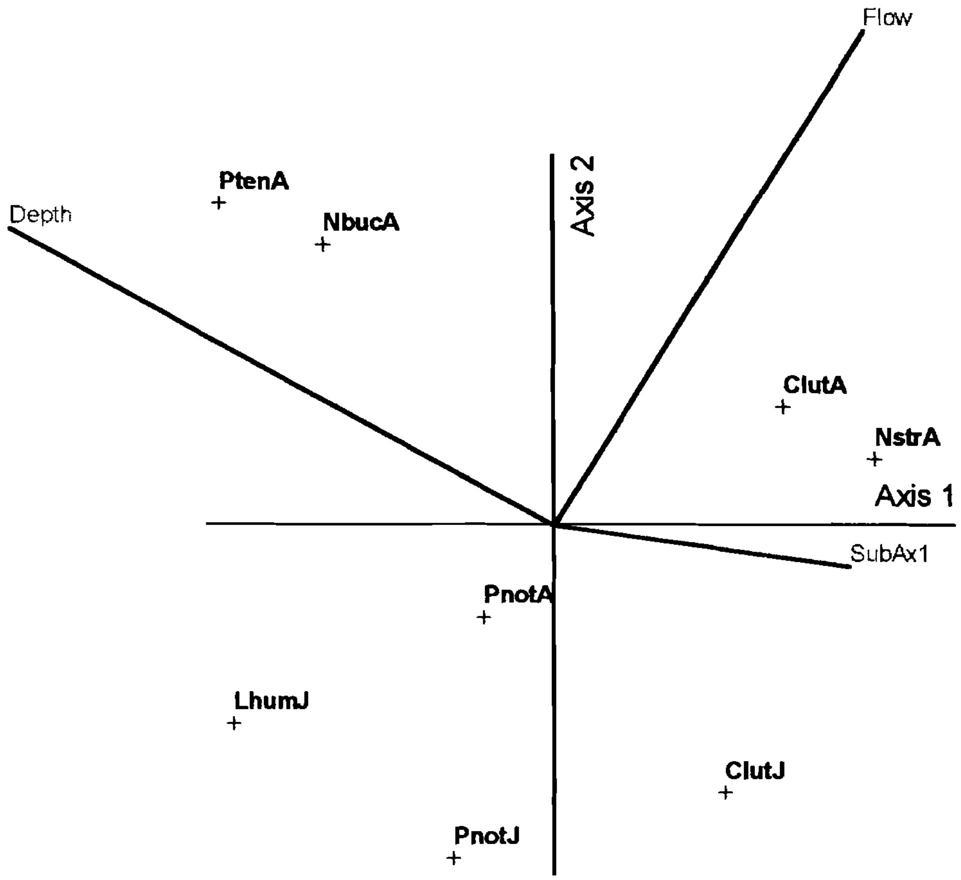

Depth
Axis 2
PcopA
PcapA
NplaA
PphoA
IpunJ
PvigA
Flow
Axis 1
NplaJ
SubAx2
PvigJ
PmirA
CanoA
Compac
EspeA
SubAx1

Table 5. Correlations between CCA 1 and CCA 2 and microhabitat variables at all points where midwater taxa were collected. Correlations significant at $\alpha=0.0025$ (Bonferroni corrected alpha) denoted by a single asterisk, those significant at $\alpha=0.001$ by two asterisks.

Variable	CCA 1	CCA 2
Substrate DCA 1	0.469**	-0.066
Substrate DCA 2	0.306**	0.230**
Water depth	-0.863**	0.478**
Compaction	0.174**	-0.328**
Flow velocity	0.493**	0.792**

Fig. 11. CCA biplot of eight midwater guild taxa and associated microhabitat variables. Only microhabitat variables with biplot scores greater than 0.20 are shown. (See Appendix G for species abbreviations; "A" denotes adult taxa, "J" juvenile taxa).


Flow
Axis 2
PtenA
Depth
NbucA
ClutA
NstrA
Axis 1
SubAx1
PnotA
LhumJ
ClutJ
PnotJ

restricted to shallow gravel bars, whereas Deacon sampled many types of mesohabitat, including pools and backwaters. In shallow habitat, centrarchids, catostomids (e.g. *Ictiobus* and *Carpiodes* spp.), and some species of ictalurids (e.g. *Ameiurus* spp.) are less likely to occur, but various species of darters are found. Many species listed by Cross (1967) that I did not collect were also pool species, including *Lepisosteus, Pomoxis, Ictiobus, Moxostoma,* and *Ameiurus* spp.

Spatio-temporal Patterns of Fish Assemblage Structure

The fish assemblage on gravel bars along this stretch of the Neosho River exhibited more temporal than spatial variation in structure, as shown by ANOVA of DCA 1 scores. Because DCA calculates axes of decreasing ecological significance (Gauch 1982), it may be inferred that patterns associated with DCA 1 play a stronger role in structuring the fish assemblage than those associated with DCA 2. The temporal nature of DCA 1 is confirmed by correlations of axis scores with environmental variables that vary seasonally (Table 2); the strongest correlation with DCA 1 was a negative relationship with water temperature. DCA 1 represented a gradient of 5.5 standard deviations; a complete faunal change typically occurs across 4 standard deviations (Gauch 1982), so seasonal variation in the fish assemblage was strong. This variation came from two sources: fish life history traits and assemblage responses to changing abiotic factors. *Notropis buchanani* was absent from study sites until early summer, when individuals arrived in great numbers. This likely illustrates a spawning migration from nearby pools; Pflieger (1997) stated that this pool species spawns over riffles from late April through August, dates corroborated in Kansas by Cross and Collins (1995). Likewise, reproduction of *E. spectabile*, *P. phoxocephala*, *P. caprodes*, *P. mirabilis*, and *C. anomalum* led to an influx of juveniles of these species from June through September (Appendix D). Many species declined greatly in abundance or were absent during winter months. Benthic fishes in this category included *I. punctatus*, *N. flavus*, and *P. copelandi*; midwater fishes included *C. lutrensis*, *P. notatus*, and *N. stramineus*. This pattern seems unrelated to life history stages, because all of these species spawn from late spring through summer in Kansas (Cross and Collins 1995) and were present during both early spring and fall (Appendices D, E). Rather, this pattern is likely related to a sharp drop in water temperature from November to December, which, coupled with shallower water in winter, likely caused these species to vacate sampling sites and retreat to pools. With the exception of *N. flavus*, all of these species have been shown to inhabit pools at various times; *N. flavus* occasionally spawns in pools with moderate current in Kansas (Cross and Collins 1995), so it may also be able to utilize this habitat. A sharp rise in water temperature from March to April corresponded to increased abundance in April for most of these species. It could be argued that separation of each species into juvenile and adult taxa inherently biases my study towards temporal variation because of natural processes such as recruitment. However, I conducted a parallel analysis on species only (as most previous studies have done) that also showed assemblage variation to be greater temporally than spatially (Gillette unpubl. data).

Multiple comparison of collection DCA scores showed five overlapping, non-significant subgroups by month (Fig. 3). The lowest scoring group along DCA 1 included the five spring-summer months of April through August, while the highest scoring group consisted of the winter months of December, January, and February. November and March fell between these two groups, and could be said to represent "transitional" fish assemblages; only two of the spring-summer months (May and June) and one of the winter months (January) were significantly different from these months. Additional non-significant subgroups indicated that these three groups were not mutually exclusive, but rather were components of a gradual faunal shift over the study year. Analysis of variance and multiple comparison of collections grouped by site along DCA 1 also revealed a significant difference, although this may have been an artifact of the temporal pattern strongly correlated with water temperature. Sites 2, 5, and 6 scored lowest along this axis; all three sites were not sampled in winter, resulting in a higher mean annual water temperature for these sites (Appendix H).

A spatial pattern of fish assemblage structure related to the presence of low-head dams was evident along DCA 2, with temporal effects playing a small role. Mean flow velocity, standard deviation of flow velocity, and water turbidity were all significantly correlated with DCA 2, suggesting a gradient from lotic collections with turbid waters, to lentic, less turbid collections. DCA 2 covered a gradient of 2.1 standard deviations, a much shorter gradient than that associated with DCA 1.

Collections dominated by pool species scored highest along DCA 2, whereas those with lotic species scored lowest. Most high-scoring collections occurred at the slow flowing and relatively deep sites 2, 5, and 6, immediately upstream from low-head dams. Exceptions to this pattern occurred at Site 7 in August and December, when low river discharge changed lotic habitat into pool habitat, with a corresponding change in fish assemblage composition. Low scoring collections on DCA 2 were characterized by *G. affinis*, *Lepomis* spp., and *Pimephales* spp., species that favor habitat with low flow velocities (Cross and Collins 1995, Pflieger 1997).

Most collections scoring low along DCA 2 occurred at sites 3 and 7, both shallow sites with relatively high flow velocities (Appendix H) situated immediately downstream from low-head dams. These collections were dominated by riffle species, including *N. flavus*, *P. caprodes*, *P. mirabilis*, *N. stramineus*, and *C. anomalum*. Low-scoring collections were also partly determined by temporal factors, however. This seasonal component of DCA 2 is likely a function of summer life-history events. Besides an influx of low-scoring juvenile *C. anomalum*, abundance of adult *P. mirabilis* also increased, likely due to spawning movements. This species spawns from April to August in Kansas (Cross and Collins 1995), usually over rocky riffles, although little is known of its spawning behavior (Pflieger 1997). The question remains, however, why this species was so much more abundant in July than during other months at some sites, since it is considered a shallow water riffle fish year-round, not only during its spawning season (Pflieger 1997).

Multiple comparison of DCA 2 scores grouped by site distinguished four non-significant subgroups based on location relative to low-head dams (Fig. 3). Sites 7 and 3 grouped together, and were statistically different from sites 6, 5, and 2. Sites 1, 4, and 8 were intermediate between these two groups. Sites 7 and 3 were shallow, high flow velocity sites just downstream from the two dams, whereas sites 2 and 6 were the closest sites upstream from the dams, with deeper water and slower flow velocities (Appendix F). Site 5 was only a short distance upstream from Site 6; also, there was very low stream gradient between these two sites, resulting in similar habitat. Sites 1, 4, and 8 were neither immediately downstream nor immediately upstream from dams.

Abundance of benthic guild species varied both spatially and temporally, but midwater guild species abundance did not show significant spatial or temporal patterns. Spatially, abundance of benthic taxa was low at slow flowing, deep sites upstream from low-head dams, and high at swiftly-flowing sites with high gravel composition substrate. Benthic guild abundance was high in November (Fig. 6), due primarily to large numbers of *P. vigilax* collected during that month. Abundance of *E. spectabile* was high as well during this month, especially at sites 3 and 7 (Appendix D). Benthic guild abundance was also high in April (Fig. 6), due to large numbers of *P. phoxocephala*; these were likely breeding congregations of this species, which spawns from March to May in Kansas (Cross and Collins 1995). Benthic guild abundance was lowest from January through March, increasing sharply as water temperatures warmed in April.

Abundance of neither guild was strongly correlated with measured environmental variables. Among highest correlations, substrate variables were correlated with benthic, but not midwater, abundance. Percent substrate composition of clay/silt and substrate compaction were negative correlates, and percent substrate composition of cobble was positively correlated. This suggests that substrate might play a stronger role in determining spatial abundance of benthic fishes than of midwater fishes, and that benthic fishes might be more abundant at sites with rockier habitat and less siltation.

At the species level, spatio-temporal abundance patterns also differed slightly by guild (Figs. 8, 9). Two species from each guild varied in abundance spatially; *N. placidus* exhibited a spatial pattern associated with both low-head dams, while *P. phoxocephala* was most abundant at Site 7, immediately downstream from the Emporia Dam. *Notropis stramineus* and *P. tenellus* showed spatial abundance patterns not associated with dams. These results are consistent with those obtained via DCA ordination of collections, suggesting that impoundment by low-head dams creates a spatial gradient along this stretch of river that affects some species. Both species that varied in abundance temporally were from the midwater guild (Fig. 9), and reached low abundance during winter. *Notropis buchanani* abundance increased in late spring and remained high all summer, while that of *P. notatus* was greatest in spring. This pattern of low winter and high spring-summer abundance was a major component of the strong temporal variation in this assemblage evident on DCA 1.

Environmental Gradients Affecting Benthic and Midwater Guild Taxa

I collected nearly equal numbers of benthic and midwater guild species (Table 1), although abundance of midwater species was almost four times that of benthic species. Grossman et al. (1998) collected seven benthic and six midwater species in a relatively undisturbed fourth-order stream in North Carolina's Appalachian Mountains; abundance of midwater taxa was 1.5 times that of benthic taxa, according to their visual abundance assessment (Grossman and Freeman 1987). Although they did not collect data during winter, they observed little temporal variation in either guild, seasonally or yearly; in their multi-year study, assemblage structure was affected most strongly by hydrological period (e.g. pre-drought, drought, post-drought) (Grossman et al. 1998).

I observed a sharp decrease in abundance of species from both guilds during winter, though this pattern was more pronounced among midwater fishes (Fig. 6). Grossman et al. (1998) found that abundance of midwater species was more affected by abiotic change than that of benthic species; this phenomenon might also explain the greater seasonal fluctuation I observed in midwater fish abundance. In Grossman et al.'s case, the abiotic change was caused by a drought, while in my study it was primarily due to seasonal fluctuation in water temperature. Alternatively, it is also possible that shallower mean water depth of sites studied during winter resulted in less available water column habitat, forcing midwater species to retreat to deeper pools to find suitable habitat. Low mean flow velocities occurred during winter, despite the exclusion of deeper, slower flowing sites (2, 5, and 6), which could not be sampled in winter due to ice cover. However, even sites that I was able to sample year-round experienced a sharp drop in midwater species abundance during winter months (Appendix C). At Site 1, for example, no midwater taxa were collected from December through February – the only taxa occurring were adult *E. spectabile* and *P. phoxocephala* and juvenile *N. placidus*. Sites 3, 4, and 7 also showed patterns of decreased midwater taxa abundance during winter, relative to benthic guild fishes. Site 8 had no midwater taxa collected in December and January, but 913 midwater fishes were captured in February, including 662 *C. lutrensis* at one sampling point.

Flow velocity and water depth were the most important habitat gradients structuring both benthic and midwater habitat guild composition at the microhabitat (4.5

m^2) level, according to results of CCA ordination. Flow velocity and depth both were strongly correlated with either the first or second CCA axis for both guilds (Tables 4, 5). Based on CCA axis loadings, flow was a stronger gradient than depth for benthic fishes, while the oppositie was true for midwater fishes, as axis 1 represents the strongest pattern of assemblage structure, and axis 2 the next strongest. Substrate was a secondary component and was more important for benthic guild species, particularly substrate DCA 2, representing a gradient from small to large substrate sizes. The importance of water flow and depth in structuring stream fish communities has been well documented. Moyle and Baltz (1985) found flow more important than any other measured variable, including water depth and substrate composition, in niche determination for eight species of native California stream fishes. Flow velocity and depth were shown by Gorman and Karr (1978) to have a stronger relation to fish species diversity than other variables such as substrate. Fuselier and Edds (1996) found most of the variation in riffle and pool fish assemblages of the Cottonwood River, KS, explained by a combination of current speed, water depth, substrate, and total alkalinity.

For both benthic and midwater guild species, juveniles generally occupied shallower, slower-flowing habitat than adult conspecifics, with the exception of *N. placidus* in regard to flow velocity (Figs. 10, 11). These results are similar to those of Gelwick (1990), Schlosser (1982), and Gido and Propst (1999), who found older age classes occurring in deeper habitats with higher flow velocities than those occupied by juveniles. Gelwick (1990) hypothesized that shallow waters (in her case riffles) serve as refugia, sheltering small fishes from larger piscivores, while deeper water protects larger fishes from avian and mammalian predators. Whether lower flow velocities are also actively selected by juveniles, or are simply associated with shallow habitats, remains to be determined. Adults might frequent higher flow velocity areas than juveniles to facilitate feeding on drift and benthic insects; it is also possible that juveniles seek out slower flow velocities for bioenergetic purposes, as has been shown for some salmonids (Nislow et al. 2000). Whatever the mechanism, this phenomenon in fishes lends credence to Polis' (1984) hypothesis of an "age structure component" which causes realized niche width to change as an organism passes through various life stages. This can lead to intraspecific resource partitioning, and force ecologists to make a choice: either characterize adults and juveniles, or even separate year classes of a single species, as separate "ecological taxa," or deal with taxa whose realized niche changes throughout life (Polis 1984).

Conclusions

The relative importance of longitudinal and temporal patterns in stream fish assemblage structure often depends on the scale of the investigation. As predicted by the River Continuum Concept (Vannote et al. 1980), studies encompassing multiple stream orders often uncover strong patterns of longitudinal faunal zonation associated with changes in stream order (Matthews 1990, Tripe and Guy 1999), mainstem – tributary (Taylor et al. 1996, Wilkinson and Edds 2001) or mainstem – headwater (Matthews 1990, Edds 1993) transitions. On a smaller spatial scale, variation between riffle and pool fish assemblages has also been demonstrated (e.g. Gelwick 1990, Fuselier and Edds 1996). The occurrence of intra-order "faunal breaks" (Matthews 1986), or variation in stream fish assemblages greater than or equal to that between stream orders, has also been documented (Matthews 1986, Stewart et al. 1992, Edds 1993). Temporal patterns typically depend more on overall habitat stability (Gido et al. 1997), hydrologic regimes (Taylor et al. 1996, Gido et al. 1997), and species life history events such as recruitment (Gelwick 1990, Taylor et al. 1996). In unstable environments such as riffles, temporal variation in fish assemblages often is greater than spatial variation, especially over short stream reaches (Gelwick 1990, Fuselier and Edds 1996). For any type of habitat-dictated spatial or temporal assemblage patterns to occur, however, a gradient of abiotic factors must be present; when no such gradient is present, there is no environmental force to order the fish assemblage.

Data from this study do not reveal longitudinal zonation of fish assemblages in this stretch of the Neosho River, despite the fact that the stretch of river I studied was longer than those studied by many investigators finding evidence for zonation (e.g. Sheldon 1968, Gelwick 1990, Stewart et al. 1992). The only spatial pattern present was associated with site location relative to low-head dams. Thus, for this 34 km stretch of river, the effects of low-head dams on the fish assemblage override any longitudinal patterns. Instead, habitat and fish taxa characteristic of stream headwater regions occurred directly downstream from these dams, while those typically found associated with pool habitat of downstream reaches were prevalent immediately upstream from these structures. This "resetting" of the continuum follows the predictions of Ward and Stanford (1983) in their model of regulated systems, the Serial Discontinuity Concept.

Although the SDC was formulated with deep-release storage reservoirs in mind, several of its tenets are also applicable to patterns of fish assemblage structure in the Neosho River in the presence of low-head dams. For example, fine substrates typical of higher order streams may give way to a substrate composed of larger particles such as cobble immediately downstream from dams; such large substrata are typically associated with the upper reaches of rivers. Water depth is another example; water immediately downstream from dams is typically shallow (with the frequent exception of a deep "plunge pool" adjacent to the dam), similar to upper reaches, in contrast to deeper water behind the dam, typical of lower reaches. Both of these patterns were evident to some extent in my study. Sites 3 and 7, immediately downstream from the low-head dams, were the two shallowest sites, while sites 2 and 6 immediately upstream from the dams, were two of the three deepest. With regard to substrate, Site 3 was the only site composed primarily of bedrock substrate, while Site 7 had the second highest amount of cobble and boulder. Sites 2 and 6, however, did not have the characteristic finer substrate. Thus, in this case, flow seems to have been affected more than substrate composition by low-head dam impoundment.

Given the tendency for different fish faunas to inhabit different environments, the high degree of habitat alteration caused by dams would be expected to create a corresponding difference in the fish assemblage, and this was observed in my study. Sites upstream from low-head dams had considerably more low flow velocity pool species (e.g. *L. humilis*) and fewer high velocity riffle species (e.g. *P. mirabilis*, *E. spectabile*, *P. phoxocephala*) than sites downstream from dams. This difference was evident in the ordination of collections along DCA 2, where sites 3 and 7 scored lowest, and sites 6 and 2 scored highest. The fact that Site 5 scored approximately the same as Site 6 on this axis emphasizes the importance of flow and stream gradient in structuring fish assemblages. Although Site 6 was closer (upstream) to the dam than Site 5, mean flow velocity at each site was equal and there was almost no gradient between these two sites, resulting in similar fish assemblages. With few free-flowing streams of the type upon which the RCC was formulated left in the United States, it is possible that the SDC and its tenets are applicable to many other rivers besides the Neosho.

As apparent as the effect of low-head dams on this stretch of the Neosho River was, temporal patterns of fish assemblage structure were stronger than spatial patterns. Temporal patterns were associated with DCA 1, the axis that explains the largest amount of assemblage structure, and were influenced primarily by fish life history events and environmental change, particularly water temperature. Thus, for my study reach, these two factors exerted an even stronger influence over fish assemblage structure than impoundment.

Results of my study also suggest that spatio-temporal pattens may depend on the relative abundance of benthic and midwater fishes in the fish assemblage. Classification of fishes by water column habitat guild may provide insight into the function of riverine fish assemblages, as benthic and midwater fishes responded differently to spatio-temporal environmental gradients, both on small and large scales. To some extent, this variation was not only guild-specific, but also species-specific. The lack of significant temporal and spatial abundance patterns in the midwater guild observed in this study was partly due to the fact that the most common member of this guild, *C. lutrensis*, did not vary in abundance spatially or temporally. If other midwater species whose abundance did vary significantly, such as *N. buchanani*, *P. notatus*, *P. tenellus*, or *N. stramineus*, dominated the assemblage, overall results could have been different. In general, however, fewer midwater species showed significant spatial or temporal abundance distribution patterns than did benthic species.

This information on the species-specific function of microhabitat guilds over space and time is also valuable in predicting the effects of change to spatio-temporal environmental gradients on fish assemblages. Regulated rivers are ideal systems to study biotic responses to changing environmental gradients, because each impoundment represents an "experimental unit" with extreme change in environmental gradients over short distances (Ward and Stanford 1983). Such study is particularly important now, when many river systems in the United States have had their flow regimes altered in one way or another, resulting in changing patterns of environmental variation (Poff et al. 1997). Effective conservation of these river systems requires knowledge of spatio-temporal variation of fish assemblages in relation to these habitat alterations.

LITERATURE CITED

Bain, M.B. 1999. Substrate. Pages 95-100 *in* M.B. Bain and N.J. Stevenson, editors. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, MD.

Baker, J.A. and S.T. Ross. 1981. Spatial and temporal resource utilization in southeastern cyprinids. Copeia 1981: 178-189.

Balon, E.K. and D.J. Stewart. 1983. Fish assemblages in a river with unusual gradient (Luongo, Africa – Zaire system), reflections on river zonation, and description of another new species. Environmental Biology of Fishes 9: 225-252.

Braaten, P.J. and C.R. Berry, Jr. 1997. Fish associations with four habitat types in a South Dakota prairie stream. Journal of Freshwater Ecology 12: 477-489.

Carlander, K.D. 1977. Handbook of freshwater fishery biology. Volume 2. 1st edition. Iowa State University Press. Ames, IA.

Carlander, K.D. 1997. Handbook of freshwater fishery biology. Volume 3. 1st edition. Iowa State University Press. Ames, IA.

Cross, F.B. 1967. Handbook of fishes of Kansas. University of Kansas Museum of Natural History Miscellaneous Publication 45:1-357.

Cross, F.B. and J.T. Collins. 1995. Fishes in Kansas. 2nd edition, revised. University Press of Kansas. Lawrence, KS.

Deacon, J.E. 1961. Fish populations, following a drought, in the Neosho and Marais de Cygnes rivers of Kansas. University of Kansas Publications, Museum of Natural History 13: 359-427.

Edds, D.R. 1993. Fish assemblage structure and environmental correlates in Nepal's Gandaki River. Copeia 1993: 48-60.

Etnier, D.A. and W.C. Starnes. 1993. The fishes of Tennessee. The University of Tennessee Press. Knoxville, TN.

Fuselier, L. and D. Edds. 1996. Seasonal variation of riffle and pool fish assemblages in a short mitigated stream reach. The Southwestern Naturalist 41: 299-306.

Gauch, H.G., Jr. 1982. Multivariate analysis in community ecology. Cambridge University Press, Cambridge, England.

Gelwick, F.P. 1990. Longitudinal and temporal comparison of riffle and pool fish assemblages in a northeastern Oklahoma Ozark stream. Copeia 1990: 1072-1082.

Gido, K.B. and D.L. Propst. 1999. Habitat use and association of native and nonnative fishes in the San Juan River, New Mexico and Utah. Copeia 1999: 321-332.

Gido, K.B., D.L. Probst and M.C. Molles, Jr. 1997. Spatial and temporal variation of fish communities in secondary channels of the San Juan River, New Mexico and Utah. Environmental Biology of Fishes 49: 417-434.

Gorman, O.T. 1988. The dynamics of habitat use in a guild of Ozark minnows. Ecological Monographs 58: 1-18.

Gorman. O.T. and J.R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59: 501-515.

Grossman, G.D. and M.C. Freeman. 1987. Microhabitat use in a stream fish assemblage. Journal of Zoology, London 212: 151-176.

Grossman, G.D., R.A. Ratajcak, Jr., M. Crawford and M.C. Freeman. 1998. Assemblage organization in stream fishes: effects of environmental variation and interspecific interactions. Ecological Monographs 68: 395-420.

Heins, D.C. and W.J. Matthews. 1987. Historical perspectives on the study of community and evolutionary ecology of North American stream fishes. Pages 3-7 *in* W.J. Matthews and D.C. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman, OK.

Maret, T.R., C.T. Robinson and G.W. Minshall. 1997. Fish assemblages and environmental correlates in least-disturbed streams of the upper Snake River basin. Transactions of the American Fisheries Society 126: 200-216.

Matthews, W.J. 1985. Distribution of midwestern fishes on multivariate environmental gradients, with emphasis on *Notropis lutrensis*. American Midland Naturalist 113: 225-237.

Matthews, W.J. 1986. Fish faunal “breaks” and stream order in the eastern and central United States. Environmental Biology of Fishes 17: 81-92.

Matthews, W.J. 1990. Spatial and temporal variation in fishes of riffle habitats: a comparison of analytical approaches for the Roanoke River. American Midland Naturalist 124: 31-45.

Matthews, W.J. and L. G. Hill. 1980. Habitat partitioning in the fish community of a southwestern river. The Southwestern Naturalist 25: 51-66.

Matthews, W.J., B.C. Harvey and M.E. Power. 1994. Spatial and temporal patterns in the fish assemblage patterns of individual pools in a midwestern stream. Environmental Biology of Fishes 39: 381-397.

Matthews, W.J. 1998. Patterns in freshwater fish ecology. Chapman and Hall, New York.

McCune, B., and M.J. Mefford. 1999. PC-Ord. Multivariate Analysis of Ecological Data, Version 4. MjM Software Design, Glenedon Beach, OR.

Minshall, W.G., K.W. Cummins, R.C. Peterson, C.E. Cushing, D.A. Bruns, J.R. Sedell and R.L. Vannote. 1985. Developments in stream ecosystem theory. Canadian Journal of Fisheries and Aquatic Sciences 42: 1045-1055.

Moyle, P.B. and D.M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: developing criteria for instream flow determination. Transactions of the American Fisheries Society 114: 695-704.

Mullner, S.A., W.A. Hubert and T.A. Wesche. 2000. Visually estimating substrate composition at potential spawning sites for trout in mountain streams. Journal of Freshwater Ecology 15: 199-207.

Nislow, K.H., C.L. Folt and D.L. Parrish. 2000. Spatially explicit bioenergetics analysis of habitat quality for age-0 Atlantic salmon. Transactions of the American Fisheries Society 129: 1067-1081.

Palmer, M.W. 1993. Putting things in even better order: the advantages of canonical correspondence analysis. Ecology 74:2215-2230.

Parker, H.L. 1964. Natural history of *Pimephales vigilax* (Cyprinidae). The Southwestern Naturalist 8: 228-235.

Pflieger, W.L. 1997. The fishes of Missouri. Revised edition. Missouri Department of Conservation. Jefferson City, MO.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. Bioscience 47: 769-784.

Polis, G. A. 1984. Age structure component of niche width and intraspecific resource partitioning: can age groups function as ecological species? The American Naturalist 123: 541-564.

Porto, L.M., R.L. McLaughlin and D.L.G. Noakes. 1999. Low-head barrier dams restrict the movements of fishes in two Lake Ontario streams. North American Journal of Fisheries Management 19: 1028-1036.

Robison, H.W. and T.M. Buchanan. 1988. The fishes of Arkansas. The University of Arkansas Press. Fayetteville, AR.

Ross, S.T. 1986. Resource partitioning in fish assemblages: a review of field studies. Copeia 1986: 352-388.

Schlosser, I.J. 1982. Fish community structure and function along two habitat gradients in a headwater stream. Ecological Monographs 52: 395-414.

Sheldon, A.L. 1968. Species diversity and longitudinal succession in stream fishes. Ecology 49:193-198.

Stewart, B.G., J. G. Knight and R.C. Cashner. 1992. Longitudinal distribution and assemblages of fishes of Byrd's Mill Creek, a southern Oklahoma Arbuckle Mountain stream. The Southwestern Naturalist 37: 138-147.

Taylor, C.M. 1996. Abundance and distribution within a guild of benthic stream fishes: local processes and regional patterns. Freshwater Biology 36: 385-396.
pools: effects of pool volume and spatial position. Oecologia 110: 560-566.

Taylor, C.M. 2000. A large-scale comparative analysis of riffle and pool fish communities in an upland stream system. Environmental Biology of Fishes 58: 89-95.

Taylor, C.M., M.R. Winston and W.J. Matthews. 1996. Temporal variation in tributary and mainstem fish assemblages in a Great Plains stream system. Copeia 1996: 280-289.

Tripe, J.A. and C.S. Guy. 1999. Spatial and temporal variation in habitat and fish community characteristics in a Kansas Flint Hills stream. Ecology of Freshwater Fishes 1999: 216-226.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130-137.

Waite, I.R. and K.D. Carpenter. 2000. Associations among fish assemblage structure and environmental variables in Wilamette basin streams, Oregon. Transactions of the American Fisheries Society 129: 754-770.

Ward, J.V. and J.A. Stanford. 1983. The serial discontinuity concept of lotic ecosystems. Pages 29- 42 *in* T.D. Fontaine III and S.M. Bartell, editors. Dynamics of lotic ecosystems. Ann Arbor Science, Ann Arbor, MI.

Wildhaber, M.L., A.L. Allert and C.J. Schmitt. 1999. Potential effects of interspecific competition on Neosho madtom (*Noturus placidus*) populations. Journal of Freshwater Ecology 14: 19-30.

Wilkinson, C. D. and D. R. Edds. 2001. Spatial pattern and environmental correlates of a midwestern stream fish community: including spatial autocorrelation as a factor in community analyses. The American Midland Naturalist 146: 271-289.

Williams, L.R., C.S. Toepfer and A.D. Martinez. 1996. The relationship between fish assemblages and environmental gradients in an Oklahoma prairie stream. Journal of Freshwater Ecology 11: 459-467.

Zar, J.H. 1999. Biostatistical analysis. 4th edition. Prentice Hall, Inc. Upper Saddle River, NJ. 663 pp. + appendices.

APPENDICES

Appendix B. Dates and number of points sampled for monthly collections from 2000 to 2001. (Note: Sites 5 and 6 were frozen and not sampled from December through February; Site 2 was frozen and not sampled in January and February.)

Site	Date	# Points Sampled
1	Nov 10th	16
1	Dec 17th	11
1	Jan 13th	12
1	Feb 10th	14
1	Mar 11th	24
1	Apr 14th	24
1	May 15th	21
1	Jun 18th	20
1	Jul 10th	20
1	Aug 13th	21
1	Sep 13th	19
1	Oct 12th	19
2	Nov 10th	10
2	Dec 10th	13
2	Mar 10th	14
2	Apr 22nd	13
2	May 15th	14
2	Jun 19th	9
2	Jul 12th	15
2	Aug 14th	14
2	Sep 10th	14
2	Oct 12th	14
3	Nov 11th	25
3	Dec 9th	25
3	Jan 14th	25
3	Feb 18th	25
3	Mar 11th	25
3	Apr 14th	25
3	May 13th	25
3	Jun 18th	25
3	Jul 10th	25
3	Aug 14th	25
3	Sep 11th	25
3	Oct 10th	25
4	Nov 13th	12
4	Dec 9th	15
4	Jan 13th	17
4	Feb 19th	16
4	Mar 12th	20
4	Apr 14th	17
4	May 12th	19
4	Jun 19th	12
4	Jul 9th	16
4	Aug 13th	17
4	Sep 10th	17
4	Oct 11th	17

Site	Month	# Points Sampled
5	Nov 15th	14
5	Mar 14th	19
5	Apr 22nd	20
5	May 15th	20
5	Jun 19th	11
5	Jul 10th	20
5	Aug 13th	20
5	Sep 12th	20
5	Oct 12th	17
6	Nov 17th	11
6	Mar 10th	16
6	Apr 22nd	15
6	May 15th	15
6	Jun 19th	15
6	Jul 9th	15
6	Aug 14th	14
6	Sep 12th	16
6	Oct 10th	15
7	Nov 11th	13
7	Dec 10th	12
7	Jan 14th	14
7	Feb 10th	25
7	Mar 11th	23
7	Apr 14th	18
7	May 12th	21
7	Jun 20th	14
7	Jul 11th	19
7	Aug 13th	22
7	Sep 10th	19
7	Oct 10th	18
8	Nov 12th	11
8	Dec 17th	6
8	Jan 13th	6
8	Feb 18th	15
8	Mar 11th	17
8	Apr 21st	20
8	May 11th	20
8	Jun 19th	13
8	Jul 10th	16
8	Aug 14th	9
8	Sep 12th	10
8	Oct 12th	12

Appendix C. Number and taxa of fishes collected by site per month from the Neosho River in Lyon Co., KS, from 2000 to 2001.

SITE: 1

	Month					
Taxa	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
Dorosoma cepedianum-A	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0
Campostoma anomalum-A	0	0	0	0	1	0
C. anomalum-J	0	0	0	0	0	0
Cyprinella camura-A	0	0	0	0	0	0
Cyprinella lutrensis-A	13	0	0	0	4	18
C. lutrensis-J	10	0	0	0	4	0
Notropis buchanani-A	0	0	0	0	0	4
N. buchanani-J	0	0	0	0	0	1
Notropis stramineus-A	0	0	0	0	2	0
N. stramineus-J	0	0	0	0	0	0
Phenacobius mirabilis-A	4	0	0	0	0	1
P. mirabilis-J	0	0	0	0	0	0
Pimephales notatus-A	0	0	0	0	0	2
P. notatus-J	0	0	0	0	0	1
Pimephales tenellus-A	0	0	0	0	0	3
P. tenellus-J	0	0	0	0	0	0
Pimephales vigilax-A	0	0	0	0	0	0
P. vigilax-J	0	0	0	0	0	0
Carpiodes sp.	0	0	0	0	0	0
Moxostoma sp.	0	0	0	0	0	0
Ictalurus punctatus-J	1	0	0	0	0	0
Pylodictis olivaris-J	0	0	0	0	0	0
Noturus flavus-A	0	0	0	0	0	0
N. flavus-J	0	0	0	0	0	0
Noturus placidus-A	0	0	0	0	0	2
N. placidus-J	3	3	2	2	0	0
Fundulus notatus-A	0	0	0	0	0	0
Gambusia affinis	0	0	0	0	0	0
Lepomis cyanellus-A	0	0	0	0	0	0
L. cyanellus-J	0	0	0	0	0	0
Lepomis humilis-A	0	0	0	0	0	0
L. humilis-J	1	0	0	0	0	8
Lepomis megalotis-A	0	0	0	0	0	1
Lepomis macrochirus-J	0	0	0	0	0	0
Micropterus punctulatus-J	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0
Aplodinotus grunniens-J	0	0	0	0	0	0
Etheostoma flabellare-A	0	0	0	0	0	0
Etheostoma spectabile-A	19	1	2	2	11	7
E. spectabile-J	0	0	0	0	0	0
Percina caprodes-A	0	0	0	0	0	2
P. caprodes-J	0	0	0	0	0	0
Percina copelandi-A	0	0	0	0	0	0
Percina phoxocephala-A	9	0	0	1	4	7
P. phoxocephala-J	0	0	0	0	0	0
Total	60	4	4	5	26	57

(Appendix C. cont.)

SITE: 1				*Month*			
Taxa	**May**	**June**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**
Dorosoma cepedianum-A	0	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0	0
Campostoma anomalum-A	0	0	2	9	3	4	19
C. anomalum-J	0	0	6	0	0	0	6
Cyprinella camura-A	0	0	0	0	0	0	0
Cyprinella lutrensis-A	9	28	42	27	14	31	186
C. lutrensis-J	1	1	5	9	22	153	205
Notropis buchanani-A	24	17	188	20	0	6	259
N. buchanani-J	0	1	1	2	0	0	5
Notropis stramineus-A	0	0	4	2	15	4	27
N. stramineus-J	0	0	0	0	0	1	1
Phenacobius mirabilis-A	1	0	10	10	3	6	35
P. mirabilis-J	0	0	0	0	0	0	0
Pimephales notatus-A	4	6	4	6	44	20	86
P. notatus-J	1	0	3	8	12	11	36
Pimephales tenellus-A	0	0	0	0	0	0	3
P. tenellus-J	0	0	0	0	0	0	0
Pimephales vigilax-A	2	9	0	1	10	15	37
P. vigilax-J	0	1	0	1	3	1	6
Carpiodes sp.	0	0	0	0	0	0	0
Moxostoma sp.	0	0	0	0	1	0	1
Ictalurus punctatus-J	0	0	0	12	8	6	27
Pylodictis olivaris-J	0	0	0	0	0	0	0
Noturus flavus-A	0	0	0	1	0	0	1
N. flavus-J	0	1	1	0	0	2	4
Noturus placidus-A	1	0	0	0	0	0	3
N. placidus-J	2	0	5	2	0	1	20
Fundulus notatus-A	0	0	0	0	0	0	0
Gambusia affinis	0	0	0	0	0	0	0
Lepomis cyanellus-A	0	0	0	0	0	0	0
L. cyanellus-J	0	0	0	0	0	0	0
Lepomis humilis-A	0	2	0	2	1	0	5
L. humilis-J	0	1	2	6	7	4	29
Lepomis megalotis-A	0	0	0	0	0	0	1
Lepomis macrochirus-J	0	0	0	2	2	3	7
Micropterus punctulatus-J	0	0	0	0	0	0	0
Morone chrysops-A	0	0	0	1	0	0	1
Aplodinotus grunniens-J	0	0	0	0	0	0	0
Etheostoma flabellare-A	0	0	0	0	0	0	0
Etheostoma spectabile-A	5	1	8	11	6	6	79
E. spectabile-J	0	1	1	0	0	0	2
Percina caprodes-A	0	1	0	2	2	2	9
P. caprodes-J	0	2	1	0	0	0	3
Percina copelandi-A	0	0	0	0	0	0	0
Percina phoxocephala-A	8	8	25	14	9	13	98
P. phoxocephala-J	0	3	0	0	0	0	3
Total	58	83	308	148	162	289	1204

(Appendix C. cont.)

SITE: 2

			Month			
Taxa	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
Dorosoma cepedianum-A	0	0	N/A	N/A	0	0
Lythrurus umbratilis-A	0	0	N/A	N/A	0	0
Campostoma anomalum-A	0	0	N/A	N/A	0	0
C. anomalum-J	0	0	N/A	N/A	0	0
Cyprinella camura-A	0	0	N/A	N/A	0	0
Cyprinella lutrensis-A	40	2	N/A	N/A	0	0
C. lutrensis-J	119	4	N/A	N/A	19	0
Notropis buchanani-A	0	0	N/A	N/A	0	2
N. buchanani-J	0	0	N/A	N/A	0	0
Notropis stramineus-A	0	0	N/A	N/A	0	0
N. stramineus-J	0	0	N/A	N/A	0	0
Phenacobius mirabilis-A	0	0	N/A	N/A	0	0
P. mirabilis-J	0	0	N/A	N/A	0	0
Pimephales notatus-A	0	1	N/A	N/A	0	2
P. notatus-J	2	0	N/A	N/A	0	0
Pimephales tenellus-A	0	0	N/A	N/A	0	0
P. tenellus-J	0	0	N/A	N/A	0	0
Pimephales vigilax-A	0	3	N/A	N/A	1	1
P. vigilax-J	0	3	N/A	N/A	0	0
Carpiodes sp.	0	0	N/A	N/A	0	0
Moxostoma sp.	0	0	N/A	N/A	0	0
Ictalurus punctatus-J	0	0	N/A	N/A	0	0
Pylodictis olivaris-J	0	0	N/A	N/A	0	0
Noturus flavus-A	0	0	N/A	N/A	0	0
N. flavus-J	0	0	N/A	N/A	0	0
Noturus placidus-A	0	0	N/A	N/A	0	0
N. placidus-J	0	0	N/A	N/A	0	0
Fundulus notatus-A	0	1	N/A	N/A	0	0
Gambusia affinis	0	3	N/A	N/A	0	0
Lepomis cyanellus-A	0	0	N/A	N/A	0	0
L. cyanellus-J	1	3	N/A	N/A	1	0
Lepomis humilis-A	0	0	N/A	N/A	0	0
L. humilis-J	108	34	N/A	N/A	25	8
Lepomis megalotis-A	0	0	N/A	N/A	0	0
Lepomis macrochirus-J	1	1	N/A	N/A	1	0
Micropterus punctulatus-J	0	0	N/A	N/A	0	0
Morone chrysops-A	0	0	N/A	N/A	0	0
Aplodinotus grunniens-J	0	0	N/A	N/A	0	0
Etheostoma flabellare-A	0	0	N/A	N/A	0	0
Etheostoma spectabile-A	4	17	N/A	N/A	8	0
E. spectabile-J	0	0	N/A	N/A	0	0
Percina caprodes-A	0	0	N/A	N/A	0	0
P. caprodes-J	0	0	N/A	N/A	0	0
Percina copelandi-A	0	0	N/A	N/A	0	0
Percina phoxocephala-A	0	7	N/A	N/A	0	0
P. phoxocephala-J	0	0	N/A	N/A	0	0
Total	275	79	N/A	N/A	55	13

(Appendix C. cont.)

SITE: 2			*Month*				
Taxa	**May**	**June**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**
Dorosoma cepedianum-A	0	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	2	0	0	2
Campostoma anomalum-A	0	1	0	0	0	0	1
C. anomalum-J	0	1	1	0	0	0	2
Cyprinella camura-A	0	0	0	0	0	0	0
Cyprinella lutrensis-A	0	11	3	0	1	4	61
C. lutrensis-J	0	0	0	3	1	3	149
Notropis buchanani-A	0	53	0	0	0	0	55
N. buchanani-J	0	0	2	0	0	0	2
Notropis stramineus-A	0	0	0	0	0	0	0
N. stramineus-J	0	0	0	0	0	0	0
Phenacobius mirabilis-A	0	0	0	0	0	0	0
P. mirabilis-J	0	0	0	0	0	0	0
Pimephales notatus-A	0	9	6	3	3	2	26
P. notatus-J	1	5	4	9	25	2	48
Pimephales tenellus-A	0	0	0	0	0	0	0
P. tenellus-J	0	0	0	0	0	0	0
Pimephales vigilax-A	3	2	1	0	0	3	14
P. vigilax-J	0	0	1	0	0	0	4
Carpiodes sp.	0	0	0	0	0	0	0
Moxostoma sp.	0	0	1	0	0	0	1
Ictalurus punctatus-J	0	0	1	0	0	0	1
Pylodictis olivaris-J	0	0	0	0	0	0	0
Noturus flavus-A	0	0	0	0	0	0	0
N. flavus-J	0	0	0	0	0	0	0
Noturus placidus-A	0	0	0	0	0	0	0
N. placidus-J	0	0	1	0	1	0	2
Fundulus notatus-A	0	0	0	0	0	0	1
Gambusia affinis	0	0	0	0	0	0	3
Lepomis cyanellus-A	0	0	0	0	0	0	0
L. cyanellus-J	0	0	0	0	0	0	5
Lepomis humilis-A	3	0	3	1	0	0	7
L. humilis-J	0	6	5	11	13	12	222
Lepomis megalotis-A	0	0	0	0	0	0	0
Lepomis macrochirus-J	0	0	0	0	2	0	5
Micropterus punctulatus-J	0	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0	0
Aplodinotus grunniens-J	0	0	1	0	0	0	1
Etheostoma flabellare-A	0	0	0	0	0	0	0
Etheostoma spectabile-A	0	1	1	0	2	0	33
E. spectabile-J	0	1	4	1	0	0	6
Percina caprodes-A	0	1	2	1	0	1	5
P. caprodes-J	0	2	0	0	0	0	2
Percina copelandi-A	0	0	0	0	0	0	0
Percina phoxocephala-A	0	2	0	2	1	6	18
P. phoxocephala-J	0	3	4	0	0	0	7
Total	7	98	41	33	49	33	683

(Appendix C. cont.)

SITE: 3			*Month*			
Taxa	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
Dorosoma cepedianum-A	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0
Campostoma anomalum-A	0	1	0	1	2	4
C. anomalum-J	0	0	0	0	0	0
Cyprinella camura-A	0	0	0	0	0	9
Cyprinella lutrensis-A	21	2	2	0	0	662
C. lutrensis-J	138	7	13	0	1	6
Notropis buchanani-A	0	0	0	0	0	10
N. buchanani-J	0	0	0	0	0	1
Notropis stramineus-A	0	0	0	0	0	0
N. stramineus-J	0	0	0	0	0	0
Phenacobius mirabilis-A	0	0	1	3	5	28
P. mirabilis-J	0	0	0	0	0	0
Pimephales notatus-A	1	2	1	0	0	7
P. notatus-J	4	2	0	0	0	0
Pimephales tenellus-A	0	0	0	0	0	9
P. tenellus-J	0	0	0	0	0	0
Pimephales vigilax-A	0	1	1	0	0	13
P. vigilax-J	0	2	3	0	0	0
Carpiodes sp.	0	0	0	0	0	0
Moxostoma sp.	0	0	0	0	0	0
Ictalurus punctatus-J	1	0	0	0	0	0
Pylodictis olivaris-J	0	0	0	0	0	0
Noturus flavus-A	0	0	0	0	0	1
N. flavus-J	0	0	0	0	0	0
Noturus placidus-A	0	0	0	0	0	0
N. placidus-J	0	0	0	0	0	0
Fundulus notatus-A	0	1	0	0	0	0
Gambusia affinis	0	2	0	0	0	0
Lepomis cyanellus-A	0	0	0	0	0	0
L. cyanellus-J	0	1	0	0	0	0
Lepomis humilis-A	0	0	0	0	0	3
L. humilis-J	1	2	0	0	0	3
Lepomis megalotis-A	0	0	0	0	0	0
Lepomis macrochirus-J	1	0	0	0	0	0
Micropterus punctulatus-J	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0
Aplodinotus grunniens-J	0	0	0	0	0	0
Etheostoma flabellare-A	0	0	0	0	0	0
Etheostoma spectabile-A	70	17	4	4	18	18
E. spectabile-J	0	0	0	0	0	0
Percina caprodes-A	0	0	0	0	0	3
P. caprodes-J	0	0	0	0	0	0
Percina copelandi-A	0	0	0	0	0	0
Percina phoxocephala-A	0	0	0	0	0	63
P. phoxocephala-J	0	0	0	0	0	0
Total	237	40	25	8	26	840

(Appendix C. cont.)

SITE: 3				*Month*			
Taxa	**May**	**June**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**
Dorosoma cepedianum-A	0	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0	0
Campostoma anomalum-A	0	1	0	0	1	0	10
C. anomalum-J	0	3	3	0	0	0	6
Cyprinella camura-A	0	0	0	0	0	0	9
Cyprinella lutrensis-A	104	55	71	63	62	328	1370
C. lutrensis-J	1	5	2	201	100	17	491
Notropis buchanani-A	218	15	3	0	0	3	249
N. buchanani-J	0	1	0	0	1	0	3
Notropis stramineus-A	4	0	2	6	0	0	12
N. stramineus-J	0	0	0	0	0	0	0
Phenacobius mirabilis-A	0	6	9	12	3	1	68
P. mirabilis-J	0	1	0	0	0	0	1
Pimephales notatus-A	38	3	13	27	35	26	153
P. notatus-J	0	0	0	18	2	0	26
Pimephales tenellus-A	5	4	4	1	0	1	24
P. tenellus-J	0	0	0	0	0	0	0
Pimephales vigilax-A	20	4	1	10	3	3	56
P. vigilax-J	0	0	0	3	2	0	10
Carpiodes sp.	1	0	0	0	0	0	1
Moxostoma sp.	0	0	0	0	0	0	0
Ictalurus punctatus-J	0	1	1	16	0	0	19
Pylodictis olivaris-J	0	0	0	1	0	0	1
Noturus flavus-A	0	0	0	4	1	0	6
N. flavus-J	0	0	2	1	2	0	5
Noturus placidus-A	0	1	0	0	0	0	1
N. placidus-J	0	0	1	0	0	0	1
Fundulus notatus-A	0	0	0	0	0	0	1
Gambusia affinis	0	0	0	0	0	0	2
Lepomis cyanellus-A	1	0	2	0	0	0	3
L. cyanellus-J	0	0	1	4	0	0	6
Lepomis humilis-A	1	0	1	5	0	1	11
L. humilis-J	22	6	8	4	3	2	51
Lepomis megalotis-A	0	0	0	0	0	0	0
Lepomis macrochirus-J	0	0	0	0	0	0	1
Micropterus punctulatus-J	0	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0	0
Aplodinotus grunniens-J	0	0	0	0	0	0	0
Etheostoma flabellare-A	0	0	0	0	0	0	0
Etheostoma spectabile-A	2	2	15	3	6	14	173
E. spectabile-J	0	15	12	0	0	0	27
Percina caprodes-A	0	0	0	0	0	0	3
P. caprodes-J	0	2	0	0	0	0	2
Percina copelandi-A	0	0	0	0	0	0	0
Percina phoxocephala-A	10	11	6	2	0	1	93
P. phoxocephala-J	0	2	0	0	0	0	2
Total	427	138	157	381	221	397	2897

(Appendix C. cont.)

SITE: 4			*Month*			
Taxa	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
Dorosoma cepedianum-A	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0
Campostoma anomalum-A	0	1	1	1	0	0
C. anomalum-J	0	0	0	0	0	0
Cyprinella camura-A	0	0	0	0	0	0
Cyprinella lutrensis-A	42	2	9	6	25	454
C. lutrensis-J	69	1	15	3	3	167
Notropis buchanani-A	0	0	0	0	0	55
N. buchanani-J	0	0	0	0	0	30
Notropis stramineus-A	11	0	0	0	26	1
N. stramineus-J	1	0	0	0	1	0
Phenacobius mirabilis-A	0	0	0	3	0	1
P. mirabilis-J	0	0	0	0	0	0
Pimephales notatus-A	2	11	0	4	9	150
P. notatus-J	2	6	0	3	0	14
Pimephales tenellus-A	0	2	0	0	3	19
P. tenellus-J	0	0	0	0	0	0
Pimephales vigilax-A	60	16	2	0	6	87
P. vigilax-J	72	4	3	0	0	2
Carpiodes sp.	0	0	0	0	0	0
Moxostoma sp.	0	0	0	0	0	0
Ictalurus punctatus-J	0	0	0	0	0	0
Pylodictis olivaris-J	0	0	0	0	0	0
Noturus flavus-A	0	0	0	0	0	0
N. flavus-J	0	0	0	0	0	0
Noturus placidus-A	0	3	1	0	0	0
N. placidus-J	0	2	1	0	0	0
Fundulus notatus-A	0	0	0	0	1	0
Gambusia affinis	0	0	0	0	0	0
Lepomis cyanellus-A	0	0	0	0	0	0
L. cyanellus-J	0	0	0	0	0	3
Lepomis humilis-A	0	0	0	0	0	3
L. humilis-J	2	2	0	0	4	132
Lepomis megalotis-A	0	0	0	0	0	1
Lepomis macrochirus-J	0	0	0	0	0	0
Micropterus punctulatus-J	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0
Aplodinotus grunniens-J	0	0	0	0	0	0
Etheostoma flabellare-A	1	0	0	0	0	0
Etheostoma spectabile-A	7	22	20	8	0	0
E. spectabile-J	0	0	0	0	0	0
Percina caprodes-A	0	0	0	0	0	0
P. caprodes-J	0	0	0	0	0	0
Percina copelandi-A	0	0	0	0	0	0
Percina phoxocephala-A	1	0	0	0	0	3
P. phoxocephala-J	0	0	0	0	0	0
Total	270	72	52	28	78	1122

(Appendix C. cont.)

SITE: 4	*Month*						
Taxa	**May**	**June**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**
Dorosoma cepedianum-A	0	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0	0
Campostoma anomalum-A	0	0	11	1	0	3	18
C. anomalum-J	0	0	0	4	0	0	4
Cyprinella camura-A	0	0	0	0	0	0	0
Cyprinella lutrensis-A	65	87	75	49	76	77	967
C. lutrensis-J	6	3	7	10	28	159	471
Notropis buchanani-A	44	38	0	3	4	0	144
N. buchanani-J	3	0	0	0	2	0	35
Notropis stramineus-A	13	14	8	2	2	2	79
N. stramineus-J	0	0	0	0	0	0	2
Phenacobius mirabilis-A	1	0	7	1	1	0	14
P. mirabilis-J	0	0	0	0	0	0	0
Pimephales notatus-A	34	31	3	12	9	26	291
P. notatus-J	0	0	0	35	5	0	65
Pimephales tenellus-A	4	7	0	0	2	0	37
P. tenellus-J	0	0	0	0	0	0	0
Pimephales vigilax-A	2	11	0	2	4	14	204
P. vigilax-J	0	0	0	1	2	1	85
Carpiodes sp.	0	0	0	0	0	0	0
Moxostoma sp.	0	0	0	0	0	0	0
Ictalurus punctatus-J	0	0	0	0	0	0	0
Pylodictis olivaris-J	0	0	0	0	0	0	0
Noturus flavus-A	0	0	0	0	0	0	0
N. flavus-J	0	0	0	0	0	0	0
Noturus placidus-A	0	0	0	0	0	0	4
N. placidus-J	0	0	0	3	2	3	11
Fundulus notatus-A	0	0	0	0	0	0	1
Gambusia affinis	0	0	0	0	0	0	0
Lepomis cyanellus-A	2	0	0	0	0	0	2
L. cyanellus-J	5	0	0	3	0	0	11
Lepomis humilis-A	0	1	1	0	2	4	11
L. humilis-J	18	16	0	7	7	6	194
Lepomis megalotis-A	0	0	0	0	0	0	1
Lepomis macrochirus-J	0	0	0	0	1	0	1
Micropterus punctulatus-J	0	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0	0
Aplodinotus grunniens-J	0	3	0	0	0	0	3
Etheostoma flabellare-A	0	0	0	0	0	0	1
Etheostoma spectabile-A	0	0	0	0	0	1	58
E. spectabile-J	0	0	1	0	0	0	1
Percina caprodes-A	0	1	0	0	0	0	1
P. caprodes-J	0	2	0	0	0	0	2
Percina copelandi-A	0	0	1	2	0	0	3
Percina phoxocephala-A	1	1	5	8	4	6	29
P. phoxocephala-J	0	0	0	0	0	0	0
Total	198	215	120	147	154	302	2758

(Appendix C. cont.)

SITE: 5

			Month			
Taxa	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
Dorosoma cepedianum-A	0	N/A	N/A	N/A	0	0
Lythrurus umbratilis-A	0	N/A	N/A	N/A	0	0
Campostoma anomalum-A	0	N/A	N/A	N/A	0	0
C. anomalum-J	0	N/A	N/A	N/A	0	0
Cyprinella camura-A	0	N/A	N/A	N/A	0	0
Cyprinella lutrensis-A	38	N/A	N/A	N/A	15	12
C. lutrensis-J	94	N/A	N/A	N/A	1	5
Notropis buchanani-A	0	N/A	N/A	N/A	0	29
N. buchanani-J	0	N/A	N/A	N/A	0	0
Notropis stramineus-A	0	N/A	N/A	N/A	0	0
N. stramineus-J	0	N/A	N/A	N/A	0	0
Phenacobius mirabilis-A	0	N/A	N/A	N/A	0	0
P. mirabilis-J	0	N/A	N/A	N/A	0	0
Pimephales notatus-A	0	N/A	N/A	N/A	10	77
P. notatus-J	0	N/A	N/A	N/A	2	13
Pimephales tenellus-A	2	N/A	N/A	N/A	16	16
P. tenellus-J	3	N/A	N/A	N/A	2	0
Pimephales vigilax-A	14	N/A	N/A	N/A	0	11
P. vigilax-J	19	N/A	N/A	N/A	0	0
Carpiodes sp.	0	N/A	N/A	N/A	0	0
Moxostoma sp.	0	N/A	N/A	N/A	0	0
Ictalurus punctatus-J	0	N/A	N/A	N/A	0	1
Pylodictis olivaris-J	0	N/A	N/A	N/A	0	0
Noturus flavus-A	0	N/A	N/A	N/A	0	0
N. flavus-J	0	N/A	N/A	N/A	0	0
Noturus placidus-A	0	N/A	N/A	N/A	0	0
N. placidus-J	0	N/A	N/A	N/A	0	1
Fundulus notatus-A	0	N/A	N/A	N/A	0	0
Gambusia affinis	9	N/A	N/A	N/A	0	0
Lepomis cyanellus-A	0	N/A	N/A	N/A	0	0
L. cyanellus-J	0	N/A	N/A	N/A	0	0
Lepomis humilis-A	0	N/A	N/A	N/A	0	0
L. humilis-J	43	N/A	N/A	N/A	19	9
Lepomis megalotis-A	0	N/A	N/A	N/A	0	0
Lepomis macrochirus-J	0	N/A	N/A	N/A	0	0
Micropterus punctulatus-J	0	N/A	N/A	N/A	0	0
Morone chrysops-A	0	N/A	N/A	N/A	0	0
Aplodinotus grunniens-J	0	N/A	N/A	N/A	0	0
Etheostoma flabellare-A	0	N/A	N/A	N/A	0	0
Etheostoma spectabile-A	0	N/A	N/A	N/A	0	0
E. spectabile-J	0	N/A	N/A	N/A	0	0
Percina caprodes-A	0	N/A	N/A	N/A	0	0
P. caprodes-J	0	N/A	N/A	N/A	0	0
Percina copelandi-A	0	N/A	N/A	N/A	0	6
Percina phoxocephala-A	6	N/A	N/A	N/A	4	5
P. phoxocephala-J	0	N/A	N/A	N/A	0	0
Total	228	N/A	N/A	N/A	69	185

(Appendix C. cont.)

SITE: 5

	Month						
Taxa	**May**	**June**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**
Dorosoma cepedianum-A	0	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0	0
Campostoma anomalum-A	0	0	0	0	0	0	0
C. anomalum-J	0	0	0	1	0	0	1
Cyprinella camura-A	0	0	0	0	0	0	0
Cyprinella lutrensis-A	3	14	24	10	34	7	157
C. lutrensis-J	0	0	0	8	9	3	120
Notropis buchanani-A	59	37	116	1	11	0	253
N. buchanani-J	1	0	0	0	0	5	6
Notropis stramineus-A	0	0	2	0	0	0	2
N. stramineus-J	0	0	0	0	0	0	0
Phenacobius mirabilis-A	0	0	0	0	0	0	0
P. mirabilis-J	0	0	2	0	0	0	2
Pimephales notatus-A	31	5	7	1	9	20	160
P. notatus-J	5	0	2	17	1	1	41
Pimephales tenellus-A	7	5	0	1	4	11	62
P. tenellus-J	0	0	0	0	0	1	6
Pimephales vigilax-A	17	2	2	6	6	19	77
P. vigilax-J	0	0	0	4	2	0	25
Carpiodes sp.	0	0	0	0	0	0	0
Moxostoma sp.	0	0	0	0	0	0	0
Ictalurus punctatus-J	4	0	0	6	2	0	13
Pylodictis olivaris-J	0	0	0	0	0	0	0
Noturus flavus-A	0	0	0	0	0	0	0
N. flavus-J	0	0	0	0	0	0	0
Noturus placidus-A	1	0	0	0	0	0	1
N. placidus-J	0	0	0	0	0	1	2
Fundulus notatus-A	0	0	0	0	0	0	0
Gambusia affinis	0	0	0	0	0	0	9
Lepomis cyanellus-A	0	0	0	0	0	0	0
L. cyanellus-J	0	0	0	0	0	0	0
Lepomis humilis-A	1	1	1	0	2	1	6
L. humilis-J	7	4	6	1	8	13	110
Lepomis megalotis-A	0	0	0	0	0	0	0
Lepomis macrochirus-J	0	0	0	1	0	1	2
Micropterus punctulatus-J	0	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0	0
Aplodinotus grunniens-J	0	0	0	0	0	0	0
Etheostoma flabellare-A	0	0	0	0	0	0	0
Etheostoma spectabile-A	0	0	0	1	0	0	1
E. spectabile-J	0	0	0	0	0	0	0
Percina caprodes-A	0	0	2	2	0	0	4
P. caprodes-J	0	0	0	0	0	0	0
Percina copelandi-A	3	0	2	0	1	0	12
Percina phoxocephala-A	1	0	0	0	3	14	33
P. phoxocephala-J	0	3	0	0	1	0	4
Total	140	71	166	60	93	97	1109

(Appendix C. cont.)

SITE: 6

			Month			
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
Dorosoma cepedianum-A	0	N/A	N/A	N/A	0	0
Lythrurus umbratilis-A	0	N/A	N/A	N/A	0	0
Campostoma anomalum-A	0	N/A	N/A	N/A	0	0
C. anomalum-J	0	N/A	N/A	N/A	0	0
Cyprinella camura-A	0	N/A	N/A	N/A	0	0
Cyprinella lutrensis-A	7	N/A	N/A	N/A	1	33
C. lutrensis-J	23	N/A	N/A	N/A	5	5
Notropis buchanani-A	0	N/A	N/A	N/A	0	90
N. buchanani-J	0	N/A	N/A	N/A	0	0
Notropis stramineus-A	0	N/A	N/A	N/A	0	0
N. stramineus-J	0	N/A	N/A	N/A	0	0
Phenacobius mirabilis-A	0	N/A	N/A	N/A	0	0
P. mirabilis-J	0	N/A	N/A	N/A	0	0
Pimephales notatus-A	0	N/A	N/A	N/A	0	75
P. notatus-J	0	N/A	N/A	N/A	3	2
Pimephales tenellus-A	0	N/A	N/A	N/A	7	14
P. tenellus-J	0	N/A	N/A	N/A	1	5
Pimephales vigilax-A	6	N/A	N/A	N/A	4	13
P. vigilax-J	1	N/A	N/A	N/A	2	5
Carpiodes sp.	0	N/A	N/A	N/A	0	0
Moxostoma sp.	0	N/A	N/A	N/A	0	0
Ictalurus punctatus-J	3	N/A	N/A	N/A	0	3
Pylodictis olivaris-J	0	N/A	N/A	N/A	0	0
Noturus flavus-A	0	N/A	N/A	N/A	0	0
N. flavus-J	0	N/A	N/A	N/A	0	0
Noturus placidus-A	0	N/A	N/A	N/A	0	0
N. placidus-J	0	N/A	N/A	N/A	0	0
Fundulus notatus-A	0	N/A	N/A	N/A	0	0
Gambusia affinis	2	N/A	N/A	N/A	0	0
Lepomis cyanellus-A	0	N/A	N/A	N/A	0	0
L. cyanellus-J	1	N/A	N/A	N/A	0	1
Lepomis humilis-A	0	N/A	N/A	N/A	0	0
L. humilis-J	21	N/A	N/A	N/A	2	45
Lepomis megalotis-A	0	N/A	N/A	N/A	0	0
Lepomis macrochirus-J	1	N/A	N/A	N/A	0	0
Micropterus punctulatus-J	0	N/A	N/A	N/A	0	0
Morone chrysops-A	0	N/A	N/A	N/A	0	0
Aplodinotus grunniens-J	0	N/A	N/A	N/A	0	0
Etheostoma flabellare-A	0	N/A	N/A	N/A	0	0
Etheostoma spectabile-A	1	N/A	N/A	N/A	7	0
E. spectabile-J	0	N/A	N/A	N/A	0	0
Percina caprodes-A	1	N/A	N/A	N/A	1	3
P. caprodes-J	0	N/A	N/A	N/A	0	0
Percina copelandi-A	2	N/A	N/A	N/A	1	1
Percina phoxocephala-A	8	N/A	N/A	N/A	14	11
P. phoxocephala-J	0	N/A	N/A	N/A	0	0
Total	77	N/A	N/A	N/A	48	306

(Appendix C. cont.)

SITE: 6			*Month*				
Taxa	**May**	**June**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**
Dorosoma cepedianum-A	0	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0	0
Campostoma anomalum-A	0	12	11	0	2	0	25
C. anomalum-J	0	7	9	0	0	0	16
Cyprinella camura-A	0	0	0	0	0	0	0
Cyprinella lutrensis-A	5	103	37	9	20	39	254
C. lutrensis-J	0	0	0	18	21	2	74
Notropis buchanani-A	35	61	94	0	27	17	324
N. buchanani-J	1	1	0	0	11	0	13
Notropis stramineus-A	0	3	4	0	0	0	7
N. stramineus-J	0	0	0	0	0	0	0
Phenacobius mirabilis-A	0	0	1	0	0	0	1
P. mirabilis-J	0	0	0	0	0	0	0
Pimephales notatus-A	28	49	13	5	19	48	237
P. notatus-J	32	3	0	16	12	2	70
Pimephales tenellus-A	17	11	4	4	15	29	101
P. tenellus-J	0	0	0	0	1	0	7
Pimephales vigilax-A	6	6	1	3	0	3	42
P. vigilax-J	0	0	0	0	0	0	8
Carpiodes sp.	0	0	0	0	0	0	0
Moxostoma sp.	0	0	0	0	0	0	0
Ictalurus punctatus-J	1	0	0	0	2	0	9
Pylodictis olivaris-J	0	0	0	0	0	0	0
Noturus flavus-A	0	0	0	0	0	0	0
N. flavus-J	0	0	0	0	0	0	0
Noturus placidus-A	0	0	0	0	0	0	0
N. placidus-J	0	0	0	1	0	0	1
Fundulus notatus-A	0	0	0	0	0	0	0
Gambusia affinis	0	0	0	0	0	0	2
Lepomis cyanellus-A	0	1	0	2	0	0	3
L. cyanellus-J	0	0	0	1	0	0	3
Lepomis humilis-A	2	3	3	0	0	1	9
L. humilis-J	4	0	5	17	17	37	148
Lepomis megalotis-A	0	0	0	0	0	0	0
Lepomis macrochirus-J	0	0	0	3	0	0	4
Micropterus punctulatus-J	0	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0	0
Aplodinotus grunniens-J	0	0	0	0	0	1	1
Etheostoma flabellare-A	0	0	0	0	0	0	0
Etheostoma spectabile-A	2	0	1	2	2	0	15
E. spectabile-J	0	1	2	0	0	0	3
Percina caprodes-A	0	1	0	1	1	1	9
P. caprodes-J	0	0	0	0	0	0	0
Percina copelandi-A	1	8	0	0	0	2	15
Percina phoxocephala-A	9	3	6	6	10	19	86
P. phoxocephala-J	0	9	0	1	0	0	10
Total	143	282	191	89	160	201	1497

(Appendix C. cont.)

SITE: 7			*Month*			
Taxa	**Nov**	**Dec****	**Jan**	**Feb**	**Mar**	**Apr**
Dorosoma cepedianum-A	1	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0
Campostoma anomalum-A	17	0	0	0	0	1
C. anomalum-J	0	0	0	0	0	0
Cyprinella camura-A	0	0	0	0	0	0
Cyprinella lutrensis-A	122	11	0	14	0	31
C. lutrensis-J	151	19	0	4	0	3
Notropis buchanani-A	0	0	0	0	0	0
N. buchanani-J	0	0	0	0	0	0
Notropis stramineus-A	1	0	0	0	0	0
N. stramineus-J	0	0	0	0	0	0
Phenacobius mirabilis-A	11	0	0	1	3	24
P. mirabilis-J	0	0	0	0	0	0
Pimephales notatus-A	1	1	0	0	0	1
P. notatus-J	0	1	0	0	0	0
Pimephales tenellus-A	1	0	0	0	0	1
P. tenellus-J	0	0	0	0	0	0
Pimephales vigilax-A	11	2	0	0	0	1
P. vigilax-J	2	0	0	0	0	0
Carpiodes sp.	0	0	0	0	0	0
Moxostoma sp.	0	0	0	0	0	1
Ictalurus punctatus-J	0	0	0	0	0	0
Pylodictis olivaris-J	0	0	0	0	0	0
Noturus flavus-A	0	0	0	0	0	0
N. flavus-J	0	0	0	0	0	0
Noturus placidus-A	0	0	0	0	0	0
N. placidus-J	0	0	0	0	0	0
Fundulus notatus-A	0	0	0	0	0	0
Gambusia affinis	0	53	0	0	0	0
Lepomis cyanellus-A	0	0	0	0	0	0
L. cyanellus-J	0	8	0	0	0	0
Lepomis humilis-A	0	0	0	0	0	2
L. humilis-J	0	80	0	0	0	2
Lepomis megalotis-A	0	0	0	0	0	0
Lepomis macrochirus-J	0	9	0	0	0	0
Micropterus punctulatus-J	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0
Aplodinotus grunniens-J	0	0	0	0	0	0
Etheostoma flabellare-A	0	0	0	0	0	0
Etheostoma spectabile-A	46	23	1	0	9	1
E. spectabile-J	0	0	0	0	0	0
Percina caprodes-A	2	1	0	0	0	15
P. caprodes-J	0	0	0	0	0	0
Percina copelandi-A	0	0	0	0	0	0
Percina phoxocephala-A	7	10	0	0	5	207
P. phoxocephala-J	0	0	0	0	0	0
Total	373	218	1	19	17	290

** During December and August, there was no water covering transects at Site 7, so I sampled in the pool area just upstream, below the Emporia Dam.

(Appendix C. cont.)

SITE: 7

	Month						
Taxa	**May**	**June**	**Jul**	**Aug****	**Sep**	**Oct**	**Total**
Dorosoma cepedianum-A	0	0	0	0	0	0	1
Lythrurus umbratilis-A	0	0	0	0	0	0	0
Campostoma anomalum-A	7	0	8	0	4	4	41
C. anomalum-J	0	1	1	0	0	0	2
Cyprinella camura-A	2	0	0	0	1	0	3
Cyprinella lutrensis-A	330	14	195	93	100	218	1128
C. lutrensis-J	4	5	4	8	23	88	309
Notropis buchanani-A	90	25	85	0	0	2	202
N. buchanani-J	0	0	0	0	0	0	0
Notropis stramineus-A	2	0	0	0	0	0	3
N. stramineus-J	0	0	0	0	0	0	0
Phenacobius mirabilis-A	2	3	7	0	21	3	75
P. mirabilis-J	0	1	0	0	0	0	1
Pimephales notatus-A	29	6	24	1	2	12	77
P. notatus-J	0	0	0	6	5	0	12
Pimephales tenellus-A	4	7	1	1	0	3	18
P. tenellus-J	0	0	0	0	0	0	0
Pimephales vigilax-A	5	0	7	0	0	1	27
P. vigilax-J	0	0	0	0	0	0	2
Carpiodes sp.	0	0	0	0	0	0	0
Moxostoma sp.	1	0	0	0	0	0	2
Ictalurus punctatus-J	0	0	3	4	2	4	13
Pylodictis olivaris-J	0	0	0	0	3	0	3
Noturus flavus-A	1	0	1	0	1	0	3
N. flavus-J	0	0	0	0	1	0	1
Noturus placidus-A	0	0	0	0	0	0	0
N. placidus-J	0	0	0	0	0	0	0
Fundulus notatus-A	0	0	0	0	0	0	0
Gambusia affinis	0	0	0	0	0	0	53
Lepomis cyanellus-A	0	0	2	0	3	0	5
L. cyanellus-J	0	0	0	0	1	0	9
Lepomis humilis-A	0	0	3	0	0	0	5
L. humilis-J	5	6	17	2	0	2	114
Lepomis megalotis-A	2	0	0	0	0	0	2
Lepomis macrochirus-J	0	0	0	0	0	0	9
Micropterus punctulatus-J	1	0	0	0	0	0	1
Morone chrysops-A	0	0	0	0	0	0	0
Aplodinotus grunniens-J	0	1	2	0	0	0	3
Etheostoma flabellare-A	0	0	0	0	0	0	0
Etheostoma spectabile-A	12	7	4	0	5	6	114
E. spectabile-J	0	0	2	0	0	0	2
Percina caprodes-A	4	2	2	0	8	1	35
P. caprodes-J	0	0	0	0	0	0	0
Percina copelandi-A	0	0	0	0	0	0	0
Percina phoxocephala-A	164	25	119	12	74	46	669
P. phoxocephala-J	0	0	1	0	0	0	1
Total	665	103	488	127	254	390	2945

** During December and August, there was no water covering transects at Site 7, so I sampled in the pool area just upstream, below the Emporia Dam.

(Appendix C. cont.)

SITE: 8

Taxa	*Month* **Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
Dorosoma cepedianum-A	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0
Campostoma anomalum-A	1	0	0	0	0	0
C. anomalum-J	0	0	0	0	0	0
Cyprinella camura-A	0	0	0	0	0	0
Cyprinella lutrensis-A	28	0	0	778	75	26
C. lutrensis-J	24	0	0	42	12	10
Notropis buchanani-A	0	0	0	1	0	5
N. buchanani-J	0	0	0	2	1	0
Notropis stramineus-A	0	0	0	0	0	0
N. stramineus-J	0	0	0	0	0	0
Phenacobius mirabilis-A	5	0	0	2	4	1
P. mirabilis-J	0	0	0	0	0	0
Pimephales notatus-A	0	0	0	19	2	45
P. notatus-J	0	0	0	1	0	8
Pimephales tenellus-A	11	0	0	10	5	31
P. tenellus-J	0	0	0	2	1	1
Pimephales vigilax-A	35	0	0	26	0	12
P. vigilax-J	5	0	0	1	0	0
Carpiodes sp.	0	0	0	0	0	0
Moxostoma sp.	0	0	0	0	0	1
Ictalurus punctatus-J	0	0	0	0	0	0
Pylodictis olivaris-J	0	0	0	0	0	0
Noturus flavus-A	1	0	0	0	0	0
N. flavus-J	0	0	0	0	0	0
Noturus placidus-A	0	0	0	1	0	3
N. placidus-J	2	0	1	0	0	0
Fundulus notatus-A	0	0	0	0	0	0
Gambusia affinis	0	0	0	0	0	0
Lepomis cyanellus-A	0	0	0	0	0	0
L. cyanellus-J	0	0	0	0	0	1
Lepomis humilis-A	0	0	0	5	0	0
L. humilis-J	11	0	0	19	2	16
Lepomis megalotis-A	0	0	0	0	1	0
Lepomis macrochirus-J	2	0	0	0	0	0
Micropterus punctulatus-J	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0
Aplodinotus grunniens-J	0	0	0	0	0	0
Etheostoma flabellare-A	0	0	0	0	0	0
Etheostoma spectabile-A	0	0	2	1	0	0
E. spectabile-J	0	0	0	0	0	0
Percina caprodes-A	0	0	0	1	0	0
P. caprodes-J	0	0	0	0	0	0
Percina copelandi-A	0	0	0	4	0	5
Percina phoxocephala-A	1	1	0	13	9	21
P. phoxocephala-J	0	0	0	0	0	0
Total	126	1	3	928	112	186

(Appendix C. cont.)

SITE: 8			*Month*				
Taxa	**May**	**June**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**
Dorosoma cepedianum-A	0	0	0	0	0	0	0
Lythrurus umbratilis-A	0	0	0	0	0	0	0
Campostoma anomalum-A	0	0	11	2	1	1	16
C. anomalum-J	0	0	1	0	0	0	1
Cyprinella camura-A	1	0	0	0	0	0	1
Cyprinella lutrensis-A	97	86	45	1	23	29	1188
C. lutrensis-J	3	2	2	0	16	31	142
Notropis buchanani-A	4	4	50	0	7	0	71
N. buchanani-J	0	0	0	0	2	0	5
Notropis stramineus-A	0	0	4	0	0	0	4
N. stramineus-J	0	0	0	0	0	0	0
Phenacobius mirabilis-A	1	0	12	0	0	1	26
P. mirabilis-J	0	0	0	0	0	0	0
Pimephales notatus-A	7	21	9	2	16	31	152
P. notatus-J	0	0	1	9	21	0	40
Pimephales tenellus-A	9	8	4	0	9	7	94
P. tenellus-J	0	0	0	0	0	0	4
Pimephales vigilax-A	6	1	3	1	4	2	90
P. vigilax-J	0	0	0	0	0	0	6
Carpiodes sp.	0	0	0	0	0	0	0
Moxostoma sp.	0	0	0	0	0	0	1
Ictalurus punctatus-J	1	0	1	0	17	2	21
Pylodictis olivaris-J	0	0	0	0	0	0	0
Noturus flavus-A	0	0	0	0	0	0	1
N. flavus-J	0	0	4	0	0	2	6
Noturus placidus-A	0	0	0	0	0	0	4
N. placidus-J	0	0	4	0	3	3	13
Fundulus notatus-A	0	0	0	0	0	0	0
Gambusia affinis	0	0	0	0	0	0	0
Lepomis cyanellus-A	0	0	0	0	0	0	0
L. cyanellus-J	0	0	0	6	0	0	7
Lepomis humilis-A	0	0	0	0	1	2	8
L. humilis-J	7	2	7	11	3	0	78
Lepomis megalotis-A	0	0	0	0	0	0	1
Lepomis macrochirus-J	0	0	0	1	0	0	3
Micropterus punctulatus-J	0	0	0	0	0	0	0
Morone chrysops-A	0	0	0	0	0	0	0
Aplodinotus grunniens-J	0	0	0	0	0	0	0
Etheostoma flabellare-A	0	0	0	0	0	0	0
Etheostoma spectabile-A	0	1	0	1	0	0	5
E. spectabile-J	0	0	0	0	0	0	0
Percina caprodes-A	0	0	5	0	0	0	6
P. caprodes-J	0	0	0	0	0	0	0
Percina copelandi-A	4	4	0	0	0	1	18
Percina phoxocephala-A	11	4	21	0	20	9	110
P. phoxocephala-J	0	0	0	0	0	0	0
Total	151	133	184	34	143	121	2122

Appendix D. Abundance of benthic guild taxa collected from the Neosho River from Americus to Emporia in Lyon CO., KS, from November 2000 to October 2001 by site and month. Abundance is standardized as number of individuals collected per 10 m^2. (Note: "-A" denotes adult taxa, and "-J" denotes juvenile taxa. Juveniles and adults were not distinguished for *Gambusia affinis.*)

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Order Cypriniformes								
Family Cyprinidae								
Campostoma anomalum-A	0.19	0.02	0.07	0.20	0.00	0.42	0.41	0.23
C. anomalum-J	0.06	0.03	0.04	0.05	0.01	0.27	0.02	0.01
Phenacobius mirabilis-A	0.35	0.00	0.50	0.16	0.00	0.02	0.75	0.37
P. mirabilis-J	0.00	0.00	0.01	0.00	0.03	0.00	0.01	0.00
Pimephales vigilax-A	0.37	0.24	0.42	2.32	1.06	0.71	0.27	1.29
P. vigilax-J	0.06	0.07	0.07	0.97	0.34	0.14	0.02	0.09
Family Catostomidae								
Carpiodes sp.	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Moxostoma sp.	0.01	0.02	0.00	0.00	0.00	0.00	0.02	0.01
Order Siluriformes								
Family Ictaluridae								
Ictalurus punctatus-J	0.27	0.02	0.14	0.09	0.18	0.15	0.13	0.3.0
Pylodictis olivaris-J	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.00
Noturus flavus-A	0.01	0.00	0.04	0.00	0.00	0.00	0.03	0.01
N. flavus-J	0.04	0.00	0.04	0.00	0.00	0.00	0.01	0.09
Noturus placidus-A	0.03	0.00	0.01	0.05	0.01	0.00	0.00	0.06
N. placidus-J	0.20	0.03	0.01	0.12	0.03	0.02	0.00	0.19
Order Perciformes								
Family Percidae								
Etheostoma flabellare-A	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Ethestoma spectabile-A	0.79	0.56	1.28	0.66	0.01	0.25	1.15	0.07
E. spectabile-J	0.02	0.10	0.20	0.01	0.00	0.05	0.02	0.00
Percina caprodes-A	0.09	0.08	0.02	0.01	0.06	0.15	0.35	0.09
P. caprodes-J	0.03	0.03	0.02	0.02	0.00	0.00	0.00	0.00
Percina copelandi-A	0.00	0.00	0.00	0.03	0.17	0.25	0.00	0.26
Percina phoxocephala-A	0.98	0.31	0.69	0.33	0.46	1.45	6.73	1.58
P. phoxocephala-J	0.03	0.12	0.02	0.00	0.06	0.17	0.01	0.00
Family Sciaenidae								
Aplodinotus grunniens-J	0.00	0.02	0.00	0.03	0.00	0.02	0.03	0.00
Total:	3.55	1.66	3.59	5.08	2.41	4.06	10.00	4.64

(Appendix D. cont.)

	Nov	Dec	Jan	Feb	Mar	Apr
Order Cypriniformes						
Family Cyprinidae						
Campostoma anomalum-A	0.36	0.05	0.03	0.05	0.04	0.07
C. anomalum-J	0.00	0.00	0.00	0.00	0.00	0.00
Phenacobius mirabilis-A	0.40	0.00	0.03	0.21	0.17	0.80
P. mirabilis-J	0.00	0.00	0.00	0.00	0.00	0.00
Pimephales vigilax-A	2.52	0.60	0.09	0.61	0.16	2.02
P. vigilax-J	2.04	0.24	0.18	0.02	0.03	0.10
Family Catostomidae						
Carpiodes sp.	0.00	0.00	0.00	0.00	0.00	0.00
Moxostoma sp.	0.00	0.00	0.00	0.00	0.00	0.03
Order Siluriformes						
Family Ictaluridae						
Ictalurus punctatus-J	0.10	0.00	0.00	0.00	0.00	0.06
Pylodictis olivaris-J	0.00	0.00	0.00	0.00	0.00	0.00
Noturus flavus-A	0.02	0.00	0.00	0.00	0.00	0.02
N. flavus-J	0.00	0.00	0.00	0.00	0.00	0.00
Noturus placidus-A	0.00	0.08	0.03	0.02	0.00	0.07
N. placidus-J	0.10	0.14	0.12	0.05	0.00	0.02
Order Perciformes						
Family Percidae						
Etheostoma flabellare-A	0.02	0.00	0.00	0.00	0.00	0.00
Etheostoma spectabile-A	2.92	2.17	0.87	0.35	0.74	0.38
E. spectabile-J	0.00	0.00	0.00	0.00	0.00	0.00
Percina caprodes-A	0.06	0.03	0.00	0.02	0.01	0.34
P. caprodes-J	0.00	0.00	0.00	0.00	0.00	0.00
Percina copelandi-A	0.04	0.00	0.00	0.09	0.01	0.18
Percina phoxocephala-A	0.64	0.49	0.00	0.33	0.51	4.64
P. phoxocephala-J	0.00	0.00	0.00	0.00	0.00	0.00
Family Sciaenidae						
Aplodinotus grunniens-J	0.00	0.00	0.00	0.00	0.00	0.00
Total:	9.21	3.80	1.36	1.76	1.67	8.72

(Appendix D. cont.)

	May	Jun	Jul	Aug	Sep	Oct
Order Cypriniformes						
Family Cyprinidae						
Campostoma anomalum-A	0.10	0.26	0.61	0.05	0.13	0.20
C. anomalum-J	0.00	0.22	0.24	0.08	0.00	0.00
Phenacobius mirabilis-A	0.07	0.17	0.70	0.36	0.44	0.18
P. mirabilis-J	0.00	0.04	0.03	0.00	0.00	0.00
Pimephales vigilax-A	0.88	0.65	0.23	0.36	0.43	0.97
P. vigilax-J	0.00	0.02	0.02	0.14	0.14	0.03
Family Catostomidae						
Carpiodes sp.	0.01	0.00	0.00	0.00	0.00	0.00
Moxostoma sp.	0.01	0.00	0.02	0.00	0.02	0.00
Order Siluriformes						
Family Ictaluridae						
Ictalurus punctatus-J	0.09	0.02	0.11	0.66	0.54	0.20
Pylodictis olivaris-J	0.00	0.00	0.00	0.02	0.05	0.00
Noturus flavus-A	0.01	0.00	0.02	0.08	0.03	0.00
N. flavus-J	0.00	0.02	0.11	0.02	0.05	0.06
Noturus placidus-A	0.03	0.02	0.00	0.00	0.00	0.00
N. placidus-J	0.03	0.00	0.17	0.09	0.10	0.13
Order Perciformes						
Family Percidae						
Etheostoma flabellare-A	0.00	0.00	0.00	0.00	0.00	0.00
Etheostoma spectabile-A	0.30	0.22	0.44	0.28	0.33	0.44
E. spectabile-J	0.00	0.34	0.34	0.02	0.00	0.00
Percina caprodes-A	0.06	0.11	0.17	0.09	0.18	0.08
P. caprodes-J	0.00	0.15	0.02	0.00	0.00	0.00
Percina copelandi-A	0.12	0.22	0.05	0.03	0.02	0.05
Percina phoxocephala-A	2.92	1.01	2.77	0.69	1.92	1.85
P. phoxocephala-J	0.00	0.37	0.08	0.02	0.02	0.00
Family Sciaenidae						
Aplodinotus grunniens-J	0.00	0.08	0.05	0.00	0.00	0.02
Total:	4.63	3.92	6.14	2.97	4.38	4.20

Appendix E. Abundance of midwater guild taxa collected from the Neosho River from Americus to Emporia in Lyon CO., KS from November 2000 to October 2001 by site and month. Abundance is standardized as number of individuals collected per 10 m^2.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Order Clupeiformes								
Family Clupeidae								
Dorosoma cepedianum-A	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Order Cypriniformes								
Family Cyprinidae								
Lythrurus umbratilis-A	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinella camura-A	0.00	0.00	0.07	0.00	0.00	0.00	0.03	0.01
Cyprinella lutrensis-A	1.87	1.04	10.15	11.02	2.17	4.28	11.34	17.03
C. lutrensis-J	2.06	2.55	3.64	5.37	1.66	1.25	3.11	2.04
Notropis buchanani-A	2.60	0.94	1.84	1.64	3.49	5.46	2.03	1.02
N. buchanani-J	0.05	0.03	0.02	0.40	0.08	0.22	0.00	0.07
Notropis stramineus-A	0.27	0.00	0.09	0.90	0.03	0.12	0.03	0.06
N. stramineus-J	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Pimephales notatus-A	0.86	0.44	1.13	3.32	2.21	3.99	0.77	2.18
P. notatus-J	0.36	0.82	0.19	0.74	0.57	1.18	0.12	0.57
Pimephales tenellus-A	0.03	0.00	0.18	0.42	0.86	1.70	0.18	1.35
P. tenellus-J	0.00	0.00	0.00	0.00	0.08	0.12	0.00	0.06
Order Cyprinodontiformes								
Family Fundulidae								
Fundulus notatus-A	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.00
Family Poeciliidae								
Gambusia affinis	0.00	0.05	0.02	0.00	0.12	0.03	0.53	0.00
Order Perciformes								
Family Centrarchidae								
Lepomis cyanellus-A	0.00	0.00	0.02	0.02	0.00	0.05	0.05	0.00
L. cyanellus-J	0.00	0.08	0.04	0.12	0.00	0.05	0.09	0.10
Lepomis humilis-A	0.05	0.12	0.08	0.12	0.08	0.15	0.05	0.12
L. humilis-J	0.29	3.80	0.38	2.21	1.52	2.49	1.15	1.12
Lepomis megalotis-A	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01
L. macrochirus-J	0.07	0.08	0.01	0.01	0.03	0.07	0.09	0.04
Micropterus punctulatus-J	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Family Moronidae								
Morone chrysops-A	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	8.56	10.01	17.87	26.34	12.89	21.14	19.61	25.78

(Appendix E. cont.)

	Nov	Dec	Jan	Feb	Mar	Apr
Order Clupeiformes						
Family Clupeidae						
Dorosoma cepedianum-A	0.02	0.00	0.00	0.00	0.00	0.00
Order Cypriniformes						
Family Cyprinidae						
Lythrurus umbratilis-A	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinella camura-A	0.00	0.00	0.00	0.00	0.00	0.13
Cyprinella lutrensis-A	6.17	0.46	0.33	18.67	1.69	18.07
C. lutrensis-J	12.46	0.84	0.84	1.15	0.63	2.86
Notropis buchanani-A	0.00	0.00	0.00	0.02	0.00	2.85
N. buchanani-J	0.00	0.00	0.00	0.05	0.01	0.47
Notropis stramineus-A	0.24	0.00	0.00	0.00	0.39	0.02
N. stramineus-J	0.02	0.00	0.00	0.00	0.01	0.00
Pimephales notatus-A	0.06	0.41	0.03	0.54	0.30	5.25
P. notatus-J	0.08	0.24	0.00	0.09	0.07	0.56
Pimephales tenellus-A	0.28	0.05	0.00	0.23	0.44	1.36
P. tenellus-J	0.06	0.00	0.00	0.05	0.06	0.09
Order Cyprinodontiformes						
Family Fundulidae						
Fundulus notatus-A	0.00	0.05	0.00	0.00	0.01	0.00
Family Poeciliidae						
Gambusia affinis	0.22	1.57	0.00	0.00	0.00	0.00
Order Perciformes						
Family Centrarchidae						
Lepomis cyanellus-A	0.00	0.00	0.00	0.00	0.00	0.00
L. cyanellus-J	0.04	0.32	0.00	0.00	0.01	0.07
Lepomis humilis-A	0.00	0.00	0.00	0.12	0.00	0.12
L. humilis-J	3.71	3.20	0.00	0.44	0.73	3.26
Lepomis megalotis-A	0.00	0.00	0.00	0.00	0.01	0.03
Lepomis macrochirus-J	0.10	0.27	0.00	0.00	0.01	0.00
Micropterus punctulatus-J	0.00	0.00	0.00	0.00	0.00	0.00
Family Moronidae						
Morone chrysops-A	0.00	0.00	0.00	0.00	0.00	0.00
Total:	23.44	7.42	1.20	21.36	4.38	35.13

(Appendix E. cont.)

	May	Jun	Jul	Aug	Sep	Oct
Order Clupeiformes						
Family Clupeidae						
Dorosoma cepedianum-A	0.00	0.00	0.00	0.00	0.00	0.00
Order Cypriniformes						
Family Cyprinidae						
Lythrurus umbratilis-A	0.00	0.00	0.00	0.03	0.00	0.00
Cyprinella camura-A	0.04	0.00	0.00	0.00	0.02	0.00
Cyprinella lutrensis-A	8.79	7.43	6.85	3.52	5.02	11.89
C. lutrensis-J	0.22	0.30	0.30	4.02	3.49	7.40
Notropis buchanani-A	6.80	4.67	8.16	0.38	0.78	0.45
N. buchanani-J	0.07	0.06	0.05	0.03	0.25	0.08
Notropis stramineus-A	0.27	0.32	0.36	0.16	0.27	0.10
N. stramineus-J	0.00	0.00	0.00	0.00	0.00	0.02
Pimephales notatus-A	2.45	2.43	1.20	0.89	2.18	3.00
P. notatus-J	0.56	0.15	0.15	1.85	1.32	0.26
Pimephales tenellus-A	0.66	0.78	0.20	0.11	0.48	0.83
P. tenellus-J	0.00	0.00	0.00	0.00	0.02	0.02
Order Cyprinodontiformes						
Family Fundulidae						
Fundulus notatus-A	0.00	0.00	0.00	0.00	0.00	0.00
Family Poeciliidae						
Gambusia affinis	0.00	0.00	0.00	0.00	0.00	0.00
Order Perciformes						
Family Centrarchidae						
Lepomis cyanellus-A	0.07	0.00	0.02	0.22	0.02	0.00
L. cyanellus-J	0.10	0.13	0.18	0.12	0.10	0.15
Lepomis humilis-A	0.90	0.77	0.76	0.92	0.92	1.23
L. humilis-J	0.03	0.00	0.00	0.00	0.00	0.00
L. megalotis-A	0.00	0.00	0.00	0.11	0.08	0.06
L. macrochirus-J	0.01	0.00	0.00	0.00	0.00	0.00
Micropterus punctulatus-J	0.00	0.00	0.00	0.00	0.00	0.00
Family Moronidae						
Morone chrysops-A	0.00	0.00	0.00	0.00	0.00	0.00
Total:	20.97	17.03	18.23	12.36	14.92	25.48

Appendix F. Correlations between DCA 1, DCA 2 and environmental variables for each collection. Pearson's correlation coefficient shown on the top line, and associated p-value in parentheses on bottom line for each correlation. Variable abbreviations are given at end of appendix.

	DCA1	DCA2	MBed	SDBed	MBou	SDBou	MCob
DCA1	1.0000	0.2015	0.1566	0.1523	-0.0131	0.0004	0.0229
		(0.063)	(0.150)	(0.161)	(0.905)	(0.997)	(0.834)
DCA2	0.2015	1.0000	-0.0695	-0.1047	0.0191	0.0393	-0.1024
	(0.063)		(0.525)	(0.337)	(0.862)	(0.720)	(0.348)
MBed	0.1566	-0.0695	1.0000	0.8474	-0.0443	-0.0659	0.1010
	(0.150)	(0.525)	(0.150)	(<0.001)	(0.686)	(0.547)	(0.355)
SDBed	0.1523	-0.1047	0.8474	1.0000	-0.0023	-0.0309	0.1462
	(0.161)	(0.337)	(<0.001)		(0.983)	(0.778)	(0.179)
MBou	-0.0131	0.0191	-0.0524	-0.0443	1.0000	0.9639	0.7370
	(0.905)	(0.862)	(0.686)	(0.983)		(<0.001)	(<0.001)
SDBou	0.0004	0.0393	-0.0659	-0.0309	0.9639	1.0000	0.6444
	(0.997)	(0.720)	(0.547)	(0.778)	(<0.001)		(<0.001)
MCob	0.0229	-0.1024	0.1010	0.1461	0.7370	0.6444	1.0000
	(0.834)	(0.348)	(0.355)	(0.179)	(<0.001)	(<0.001)	
SDCob	0.0774	-0.0814	0.1847	0.2729	0.6604	0.5986	0.9280
	(0.479)	(0.457)	(0.089)	(0.011)	(<0.001)	(<0.001)	(<0.001)
MC/S	-0.2495	0.0550	-0.4761	-0.3994	-0.3413	-0.2801	-0.5391
	(0.021)	(0.615)	(<0.001)	(<0.001)	(0.001)	(0.009)	(<0.001)
SDC/S	-0.2433	0.0327	-0.3416	-0.2905	-0.4114	-0.3500	-0.5972
	(0.024)	(0.765)	(0.001)	(0.007)	(<0.001)	(0.001)	(<0.001)
MDep	-0.3860	0.1164	-0.5031	-0.4034	0.0999	0.1222	-0.0977
	(<0.001)	(0.286)	(<0.001)	(<0.001)	(0.365)	(0.262)	(0.371)
SDDep	-0.3438	0.1072	-0.6089	-0.5205	0.2466	0.2284	0.0641
	(0.001)	(0.326)	(<0.001)	(<0.001)	(0.022)	(0.034)	(0.558)
MCom	0.0835	0.0910	0.8177	0.6887	0.0798	0.0690	0.1512
	(0.445)	(0.405)	(<0.001)	(<0.001)	(0.465)	(0.528)	(0.163)
SDCom	-0.0816	-0.0315	0.0274	0.2923	-0.3683	-0.3321	-0.4142
	(0.455)	(0.773)	(0.802)	(0.006)	(0.001)	(0.002)	(<0.001)
MFlo	0.1780	-0.5473	0.1122	0.1610	-0.2700	-0.2711	-0.1623
	(0.101)	(<0.001)	(0.304)	(0.139)	(0.012)	(0.012)	(0.136)
SDFlo	0.1012	-0.4635	0.0198	0.1244	-0.2657	-0.2538	-0.2199
	(0.354)	(<0.001)	(0.857)	(0.254)	(0.013)	(0.018)	(0.042)
MGra	-0.1184	0.0568	-0.9118	-0.7338	-0.0546	-0.0356	-0.1624
	(0.274)	(0.604)	(<0.001)	(<0.001)	(0.618)	(0.745)	(0.135)
SDGra	-0.2549	0.0195	-0.3468	-0.1404	-0.1407	-0.0844	-0.3442
	(0.018)	(0.859)	(0.001)	(0.197)	(0.196)	(0.440)	(0.001)
MPeb	0.0500	0.1403	-0.7766	-0.6201	0.0916	0.0842	0.0450
	(0.658)	(0.198)	(<0.001)	(<0.001)	(0.402)	(0.441)	(0.681)
SDPeb	-0.1259	0.0568	-0.1642	0.0745	-0.0643	-0.0422	-0.2297
	(0.248)	(0.603)	(0.131)	(0.495)	(0.556)	(0.700)	(0.033)

(Appendix F. cont.)

	SDCob	MC/S	SDC/S	MDep	SDDep	MCom	SDCom
DCA1	0.0774	-0.2495	-0.2433	-0.3860	-0.3438	0.0835	-0.0816
	(0.479)	(0.021)	(0.024)	(<0.001)	(0.001)	(0.445)	(0.455)
DCA2	-0.0814	0.0050	0.0327	0.1164	0.1072	0.0910	-0.0315
	(0.457)	(0.615)	(0.765)	(0.286)	(0.326)	(0.405)	(0.773)
MBed	0.1848	-0.4761	-0.3416	-0.5031	-0.6089	0.8177	0.0274
	(0.089)	(<0.001)	(0.001)	(<0.001)	(<0.001)	(<0.001)	(0.802)
SDBed	0.2729	-0.3994	-0.2905	-0.4034	-0.5205	0.6887	0.2923
	(0.011)	(<0.001)	(0.007)	(<0.001)	(<0.001)	(<0.001)	(0.006)
MBou	0.6604	-0.3413	-0.4114	0.0990	0.2466	0.0798	-0.3683
	(<0.001)	(0.001)	(<0.001)	(0.365)	(0.022)	(0.465)	(<0.001)
SDBou	0.5986	-0.2801	-0.3501	0.1222	0.2284	0.0689	-0.3321
	(<0.001)	(0.009)	(0.001)	(0.262)	(0.034)	(0.528)	(0.002)
MCob	0.9280	-0.5391	-0.5972	-0.0977	0.0641	0.1516	-0.4142
	(<0.001)	(<0.001)	(<0.001)	(0.371)	(0.558)	(0.163)	(<0.001)
SDCob	1.0000	-0.5093	-0.5560	-0.0852	0.0229	0.2183	-0.2607
		(<0.001)	(<0.001)	(0.435)	(0.835)	(0.044)	(0.015)
MC/S	-0.5093	1.0000	0.8881	0.5715	0.4320	-0.2893	0.3801
	(<0.001)		(<0.001)	(<0.001)	(<0.001)	(0.007)	(<0.001)
SDC/S	-0.5560	0.8881	1.0000	0.4016	0.2856	-0.2779	0.4976
	(<0.001)	(<0.001)		(<0.001)	(0.008)	(<0.001)	(0.832)
MDep	-0.0852	0.5715	0.4016	1.0000	0.8325	-0.1718	-0.2935
	(0.435)	(<0.001)	(<0.001)		(<0.001)	(0.114)	(0.376)
SDDep	0.0229	0.4320	0.2856	0.8325	1.0000	-0.3112	-0.3015
	(0.835)	(<0.001)	(0.008)	(<0.001)		(0.004)	(0.697)
MCom	0.2183	-0.2893	-0.2779	-0.1718	-0.3112	1.0000	-0.0805
	(0.044)	(0.007)	(0.010)	(0.114)	(0.004)		(0.461)
SDCom	-0.2607	0.3801	0.4976	0.0966	-0.0425	-0.0805	1.0000
	(0.015)	(<0.001)	(<0.001)	(0.376)	(0.697)	(0.461)	
MFlo	-0.1120	-0.0787	0.0232	-0.2935	-0.3015	-0.1487	0.1725
	(0.304)	(0.471)	(0.832)	(0.006)	(0.005)	(0.172)	(0.112)
SDFlo	-0.1789	-0.0065	0.1416	-0.3072	-0.2288	-0.2372	0.2980
	(0.099)	(0.953)	(0.194)	(0.004)	(0.034)	(0.028)	(0.005)
MGra	-0.2219	0.2754	0.2310	0.3419	0.4579	-0.8572	0.0226
	(0.040)	(0.010)	(0.032)	(0.001)	(<0.001)	(<0.001)	(0.837)
SDGra	-0.2599	0.7414	0.8225	0.4527	0.3316	-0.2848	0.5571
	(0.016)	(<0.001)	(<0.001)	(<0.001)	(0.002)	(0.008)	(<0.001)
MPeb	-0.0328	0.0147	-0.0698	0.1760	0.3169	-0.6456	-0.1371
	(0.765)	(0.893)	(0.523)	(0.105)	(0.003)	(<0.001)	(0.208)
SDPeb	-0.1424	0.4479	0.5855	0.2668	0.1778	-0.1226	0.4566
	(0.191)	(<0.001)	(<0.001)	(0.013)	(0.101)	(0.261)	(<0.001)

Appendix G. Abbreviations for species used in figures 4, 10, and 11.

Scientific Name	Common Name	Abbreviation
Campostoma anomalum	central stroneroller	Cano
Cyprinella lutrensis	red shiner	Clut
Notropis buchanani	ghost shiner	Nbuc
N. stramineus	sand shiner	Nstr
Phenacobius mirabilis	suckermouth minnow	Pmir
Pimephales notatus	bluntnose minnow	Pnot
Pimephales vigilax	bullhead minnow	Pvig
Pimephales tenellus	slim minnow	Pten
Moxostoma sp.	redhorse species	Mox
Ictalurus punctatus	channel catfish	Ipun
Noturus flavus	stonecat	Nfla
Noturus placidus	Neosho madtom	Npla
Gambusia affinis	western mosquitofish	Gaff
Lepomis cyanellus	green sunfish	Lcya
Lepomis humilis	orangespotted sunfish	Lhum
Lepomis megalotis	longear sunfish	Lmeg
Aplodinotus grunniens	freshwater drum	Agru
Etheostoma spectabile	orangethroat darter	Espe
Percina caprodes	logperch	Pcap
Percina copelandi	channel darter	Pcop
Percina phoxocephala	slenderhead darter	Ppho

Appendix H. Mean and standard deviation of all environmental variables measured from November 2000 through October 2001 at eight sites on the Neosho River from Americus to Emporia, Lyon Co., KS. Free acidity was not detected at any site. (Note: Site 2 was not sampled in January or February, and sites 5 and 6 were not sampled in December, January, or February).

		Depth	Flow	Emb.	% Substrate Composition						
Site		(cm)	(m/s)		Clay/silt	Sand	Gravel	Pebb.	Cobb.	Bould.	Bdrck.
1	Mean	37.40	0.40	1.76	18.28	6.73	41.88	32.90	0.32	0.00	0.00
	S.D.	22.37	0.38	0.73	30.58	7.12	19.25	16.81	3.46	0.00	0.00
2	Mean	61.89	0.01	2.44	17.41	3.48	42.23	36.45	0.27	0.00	0.00
	S.D.	22.99	0.04	0.51	22.34	2.96	16.71	13.28	2.00	0.00	0.00
3	Mean	17.73	0.37	3.69	2.15	0.69	6.21	6.81	2.44	0.22	80.83
	S.D.	9.16	0.33	0.82	5.69	2.16	12.19	13.27	7.44	1.70	30.19
4	Mean	35.08	0.36	1.67	17.01	5.88	43.57	33.50	0.08	0.00	0.00
	S.D.	18.31	0.38	0.67	27.60	6.79	18.14	15.90	0.62	0.00	0.00
5	Mean	58.98	0.08	1.99	32.35	3.59	37.94	26.03	0.06	0.00	0.00
	S.D.	22.38	0.12	0.75	39.35	3.23	24.31	17.76	0.56	0.00	0.00
6	Mean	52.97	0.08	2.05	4.50	3.02	35.93	37.68	14.27	4.50	0.00
	S.D.	24.86	0.15	0.50	3.87	1.63	12.92	13.40	13.35	11.35	0.00
7	Mean	30.08	0.51	1.96	5.39	4.74	43.31	38.80	5.53	1.51	0.00
	S.D.	22.35	0.44	0.55	12.74	5.85	12.94	13.77	7.90	6.74	0.00
8	Mean	40.86	0.30	1.77	14.50	5.33	39.92	40.28	0.03	0.00	0.00
	S.D.	25.43	0.22	0.64	21.75	5.00	14.72	14.27	0.40	0.00	0.00

(Appendix H. cont.)

Site		Ammonia (mg/L)	Nitrate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Orthophosphate (mg/L)	POC (ug/L)	Chl *a* (ug/L)
1	Mean	0.00	0.00	8.50	30.25	0.06	1594.69	603.69
	S.D.	0.01	0.01	3.92	6.21	0.05	1081.24	609.80
2	Mean	0.02	0.00	9.90	32.20	0.05	1388.15	692.50
	S.D.	0.03	0.00	5.55	11.75	0.03	810.44	515.93
3	Mean	0.02	0.00	10.08	28.75	0.05	1453.58	716.96
	S.D.	0.04	0.00	6.11	6.28	0.06	893.28	865.69
4	Mean	0.02	0.00	9.92	27.92	0.06	1089.20	489.12
	S.D.	0.06	0.01	4.54	7.61	0.06	692.83	524.07
5	Mean	0.01	0.00	9.33	25.89	0.05	1685.43	753.14
	S.D.	0.03	0.00	4.53	8.48	0.06	957.99	807.80
6	Mean	0.02	0.00	8.11	25.67	0.06	1612.30	667.50
	S.D.	0.04	0.00	3.95	7.73	0.03	1102.38	527.19
7	Mean	0.01	0.00	7.45	24.27	0.03	1906.19	368.93
	S.D.	0.03	0.00	3.75	7.42	0.03	1170.44	291.26
8	Mean	0.01	0.00	8.18	26.18	0.04	1875.43	357.89
	S.D.	0.03	0.02	3.97	9.43	0.04	1050.11	274.75

(Appendix H. cont.)

Site		Water Temp (°C)	DO_2 (mg/L)	pH	Alkalinity (mg/L)	Hardness (mg/L)	Turbidity (NTU)	DCO_2 (mg/L)
1	Mean	15.08	9.33	8.04	185.19	255.13	32.88	15.00
	S.D.	11.42	2.31	0.14	47.20	45.14	33.21	11.68
2	Mean	18.30	7.90	8.00	182.97	241.11	26.63	10.50
	S.D.	9.51	2.47	0.00	59.34	35.57	19.47	3.69
3	Mean	15.58	10.25	7.96	176.64	247.95	33.09	9.92
	S.D.	10.69	2.99	0.26	53.69	44.63	34.18	4.06
4	Mean	15.83	9.75	8.00	185.19	232.22	33.31	9.58
	S.D.	11.13	2.14	0.21	66.35	52.84	35.17	3.34
5	Mean	19.67	8.44	8.00	157.66	224.18	38.83	8.89
	S.D.	8.35	2.24	0.00	51.13	47.88	38.27	2.20
6	Mean	19.67	8.67	7.94	169.12	231.88	35.48	11.11
	S.D.	9.46	2.06	0.17	58.31	49.93	24.11	4.17
7	Mean	16.73	9.55	7.95	169.46	220.76	52.34	10.45
	S.D.	10.63	1.75	0.15	53.69	56.43	62.08	4.16
8	Mean	15.91	8.00	7.91	166.38	222.30	51.46	10.91
	S.D.	10.13	3.46	0.20	61.73	47.20	47.01	4.91

Permission to Copy Statement

I, David Patrick Gillette, hereby submit this thesis to Emporia State University as partial fulfillment of the requirements for an advanced degree. I agree that the Library of the University may make it available to use in accordance with its regulations governing materials of this type. I further agree that quoting, photocopying, or other reproduction of this document is allowed for private study, scholarship (including teaching) and research purposes of a nonprofit nature. No copying which involves potential financial gain will be allowed without written permission of the author.

Signature of Author

7 August 2002
Date

Spatio-temporal patterns of fish assemblage structure and habitat use on gravel bars in the Neosho River, Lyon County, KS.
Title of Thesis

Signature of Graduate Office Staff

8-7-02
Date Received