Fish and Habitat Heterogeneity in Four Streams in the Central Oklahoma/Texas Plains Ecoregion

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We examined fish assemblages and habitat characteristics in four streams within the Oklahoma portion of the Central Oklahoma/Texas Plains Ecoregion. Our objective was to evaluate the heterogeneity of habitat and fish assemblages within a single ecoregion. We were also interested in whether observed patterns in habitat and fish assemblages were related. We measured habitat characteristics and sampled fish at four sites within each of the four streams. MANOVA showed significant differences in habitat among streams, and a UPGMA cluster analysis of Morisita's similarity index values showed that fish assemblages also differed among streams. A relationship between habitat and fish assemblages was found with CCA, demonstrating that sampling locations with similar habitat contained similar fish assemblages. In addition, tributary streams of the Arkansas River were more similar to each other, in both fish and habitat characteristics, than to tributaries of the Red River.

INTRODUCTION

Interest in studying fish assemblages at broad spatial scales has increased as many natural resource agencies move toward ecosystem management (*1*). Typically, studies of fishes have focused on stream reaches, a single watershed, or comparisons of two streams. A few studies, however, have compared fish assemblages from several streams and examined factors such as stability (*2-4*), stream order (*5,6*), and environmental variables (*7-9*). Management agencies, concerned with assessing the biological integrity of many streams over a wide geographic area, need an effective tool for choosing which streams to sample and for extrapolating sampling results to unsampled streams. Underlying the use of representative streams is the need for a spatial reference system; one that has been used increasingly is Omernik's ecoregions (*10,11*).

Although ecoregions were defined to have less variation than larger regions, there still may be considerable within-region heterogeneity that influences their applicability as a scale of reference for fish assemblages. An example of a potentially heterogeneous ecoregion is the Central Oklahoma/Texas Plains Ecoregion which extends from northcentral Oklahoma to central Texas. This ecoregion crosses two major subdrainages (Arkansas and Red Rivers) of the Mississippi River as well as three direct drainages (Trinity, Brazos, and Colorado Rivers) to the Gulf Coast. Plains are the typical landform throughout, although portions of the ecoregion, for example the Sandstone Hills and Arbuckle Upland, have more variable relief . Most of the ecoregion is within the Cross Timbers, a vegetational type grading from oak forest to bluestem prairie and containing species from both.

Our primary objective was to evaluate the heterogeneity of the Oklahoma portion of the Central Oklahoma/Texas Plains Ecoregion us-

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ing stream habitat and fish assemblages. We were also interested in determining whether observed patterns in habitat and fish assemblages were related.

METHODS

Field Sampling: We chose four streams aligned longitudinally in the Oklahoma portion of the ecoregion (Fig. 1). The streams were two tributaries of the Arkansas River system, Turkey Creek of the North Canadian River and Lagoon Creek of the Cimarron River, in northcentral Oklahoma and two tributaries of the Red River system, Rock Creek of the Washita River and Sandy Creek of the Clear Boggy River, in southcentral Oklahoma. Fish assemblages and habitat were sampled at four sites on each of the four streams during a two-week period in March 1995. The sites were roughly equidistant from the headwaters to the tailwaters, and each site was 90-150 m long. The longest sites were those with the greatest habitat complexity. We seined vigorously for 1.0-1.5 h with a 3.7×1.2-m seine with 3.2-mm mesh, sampling all available microhabitats at a site . Kicksets were used to sample in riffles and around boulders, rootwads, or other obstructions. Fishes were preserved in 10% formalin and returned to the laboratory where they were identified to species and enumerated.

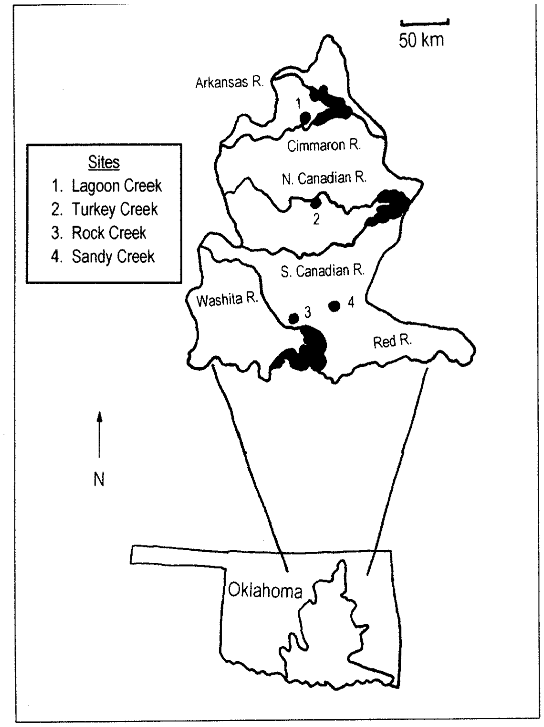

Figure 1. The Oklahoma portion of the Central Oklahoma/Texas Plains Ecoregion.

Habitat structure was determined by measuring variables at four, equally-spaced points along each of several transects. The transects were placed every 3 mean stream widths (MSWs) apart if the MSW was <5 m and 2 MSWs apart if the MSW was >5 m (*12*). Mean stream width was estimated from three to five initial, arbitrarily placed transects. The variables we measured at each point along the transects were water depth (cm) and current velocity (cm/s) at 0.6 of stream depth. Substrate composition, instream cover, and canopy cover were determined for an area covering 1 MSW centered on each transect point. Substrate was visually estimated as percent cover by silt, sand, small gravel, large gravel, cobble, boulder, and bedrock, and both instream and canopy cover were measured as percentages. Maximum values for depth, current velocity, and stream width were recorded for each site. Conductivity and turbidity were measured in water samples collected at each site prior to fish and habitat sampling.

Statistical Analyses: Mean values for width, depth, velocity, instream cover, canopy cover, and percent coverage by each substrate type was determined for each site. Normality of the continuous variables, width, depth, velocity, and the maximums for these three variables, was improved by a log (x+1) transformation. The variables measured as percentages, instream cover, canopy cover, substrate categories, were arcsine transformed.

We used principal components analysis (*13*) to reduce the dimensionality of the habitat data and to examine initially the influence of habitat characteristics. We retained components with an eigenvalue greater than 1. Habitat variables with their highest loadings in the first three of five components were retained for later analyses. Mean width was deleted when preliminary analyses showed a high degree of collinearity with maximum width. Because the substrate variables were a linear combination that summed to 100%, bedrock was arbitrarily deleted to reduce interdependence. A multivariate analysis of variance (MANOVA) of ranked data (*13*) was performed on the reduced habitat data set to test whether streams differed in habitat characteristics. With 32 fish species, including a group of *Lepomis* hybrids, and 16 samples, there were too few degrees of freedom for a MANOVA test of differences in fish assemblages. Therefore, we calculated Morisita's Index (*14*) between all pairs of sampling locations. We used the Morisita's Index matrix in an unweighted pair-groups method using arithmetic averages (UPGMA; 13, 15) to determine clusters of sampling locations with similar fish assemblages.

We used canonical correspondence analysis (CCA) calculated with CANOCO (*16*) to examine the association between patterns of habitat and fish assemblages. Fish abundances were square-root transformed to damp the effect of dominant species. Habitat variables were transformed as in the MANOVA. In a CCA, the total amount of variation in species and sampling locations that can be explained by the environmental variables is calculated by dividing the sum of canonical eigenvalues by the sum of all unconstrained eigenvalues (*17*). The calculation approximates R^2 since CCA is a special type of multiple regression. The R^2 value for CCA is inferred, however, so no associated *p*-value for the relationship can be generated.

RESULTS

We collected a total of 31 fish species and *Lepomis* hybrids from the four streams. Several fishes, including *Gambusia affinis, Lepomis megalotis,* and *Lepomis macrochirus,* were collected from all four streams and nearly all of the sampling locations. Other species, such as *Etheostoma spectabile* and *Labidesthes sicculus* were collected from only one of the four streams. Although some of these species were locally abundant, their frequency of occurrence within the ecoregion was low (Table 1).

Principal components analysis was used primarily for data reduction. Percent boulder, instream cover, canopy cover, and turbidity were deleted from further analyses because their highest loadings were in the last two of five components. The first principal component of habitat variables, accounting for 28% of the variance, included half of the 12 variables and was mostly associated with size-related variables, such as depth and maximum width. Two substrate categories, silt and large gravel, were associated with the second component, which accounted for an additional 16% of the variation. The final retained component, accounting for an additional 13% of the variance, included maximum velocity, percent small gravel, and percent cobble (Table 2). The MANOVA on the reduced set of habitat variables indicated a significant difference in habitat structure among streams ($F = 8.55$, $p < 0.05$).

The UPGMA of Morisita's Index values for fish assemblages indicated two main clusters corresponding to Lagoon/Turkey creeks and Rock/Sandy creeks, although one site in Sandy Creek was grouped with the Lagoon/Turkey cluster. The two downstream sites in Lagoon Creek were more similar to all Turkey Creek sites than they were to the two upstream sites in Lagoon Creek. In the Rock/Sandy cluster, the sites within each stream were more similar to each other than to those in the other stream (Fig. 2).

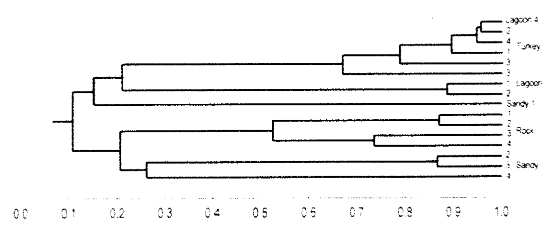

Figure 2. UPGMA clusters of fish assemblages in four sites within each of the four study streams.

CCA indicated a relationship between fish species, sampling locations, and individual environmental variables. The first two axes accounted for 49% of the variation in species abundances and associated habitat variables. The total amount of variation that was explained by the environmental variables, indicated by the approximation of R^2, was 85%. Each arrow in the CCA triplot represents the correlation of an environmental variable with plotted CCA axes. The position of a species

TABLE 1. Species collected from four streams within the Central Oklahoma/Texas Plains Ecoregion.

Species	Abbrev.	Indiv.[a]	Sites[b]	R.A.[c]
Campostoma anomalum	Caan	23	4	0.008
Cyprinella lutrensis	Cylu	796	7	0.224
Cyprinella venusta	Cyve	135	4	0.039
Lythrurus umbratilis	Lyum	105	6	0.039
Notemigonus crysoleucas	Nocr	22	6	0.007
Notropis atherinoides	Noat	6	1	0.002
Notropis boops	Nobo	599	5	0.170
Notropis stramineus	Nost	276	7	0.076
Phenacobius mirabilis	Phmi	12	4	0.003
Pimephales notatus	Pino	190	4	0.066
Pimephales vigilax	Pivi	72	7	0.020
Ameiurus melas	Amme	4	3	0.001
Ameiurus natalis	Amna	1	1	0.000
Noturus gyrinus	Nogy	1	1	0.000
Fundulus notatus	Funo	42	6	0.013
Gambusia affinis	Gaaf	188	12	0.052
Labidesthes sicculus	Lasi	74	3	0.024
Lepomis cyanellus	Lecy	22	12	0.007
Lepomis humilis	Lehu	4	2	0.001
Lepomis macrochirus	Lema	102	13	0.034
Lepomis megalotis	Leme	108	14	0.034
Lepomis microlophus	Lemi	5	3	0.002
Lepomis hybrids	Lehy	25	3	0.007
Pomoxis annularis	Poan	2	2	0.001
Micropterus punctulatus	Mipu	3	2	0.001
Micropterus salmoides	Misa	5	4	0.002
Etheostoma gracile	Etgr	5	1	0.002
Etheostoma radiosum	Etra	129	4	0.042
Etheostoma spectabile	Etsp	396	4	0.106
Percina caprodes	Peca	16	3	0.005
Percina phoxocephala	Peph	1	1	0.000
Percina sciera	Pesc	10	2	0.003

[a] Number of individuals collected.
[b] Number of sites where present.
[c] Relative Abundance.

or site relative to an arrow indicates how strongly that species or site was associated with the environmental variable represented by that arrow. The distribution of sampling sites on the right side of the CCA triplot indicated that the two streams in the Red River system, Sandy and Rock Creeks, were similar and tended to have higher gradients, more small gravel, and greater width and depth than the other two streams. Lagoon and Turkey creeks separated on the left side of the triplot. Lagoon Creek was most strongly associated with large gravel and cobble, while Turkey Creek was strongly associated with higher conductivity, higher current velocities, and more silt (Fig. 3).

The CCA triplot also indicated the relationship of fish species to the environmental

TABLE 2. Principal components loadings for environmental variables.

Environmental Variable	Factors[b] 1	2	3	4	5
Gradient[a]	0.618	-0.190	-0.571	0.177	-0.157
Depth[a]	0.653	-0.431	0.031	-0.013	0.487
Velocity[a]	-0.712	0.627	0.064	0.210	0.067
Maximum Depth[a]	0.612	-0.476	0.341	0.120	0.305
Maximum Width[a]	0.763	0.511	-0.104	-0.132	0.109
Conductivity[a]	-0.569	-0.127	0.565	-0.026	-0.062
Percent Sand[a]	-0.678	-0.012	-0.403	0.050	0.347
Percent Silt[a]	-0.260	-0.619	0.325	-0.288	0.365
Percent Large Gravel[a]	0.207	0.544	0.417	-0.460	-0.039
Maximum Velocity[a]	-0.230	0.454	0.510	0.492	0.162
Percent Small Gravel[a]	-0.036	0.295	-0.775	0.154	0.041
Percent Cobble[a]	0.395	0.202	0.449	0.331	-0.284
Percent Boulder	0.565	-0.172	-0.039	0.597	0.012
Turbidity	-0.440	-0.289	-0.134	0.750	-0.070
Percent Instream Cover	0.421	-0.298	0.324	0.111	-0.632
Percent Canopy Cover	-0.340	-0.393	-0.337	-0.442	-0.460

[a] Variables retained for later multivariate analyses.
[b] Boxing indicates the highest loading for each variable.

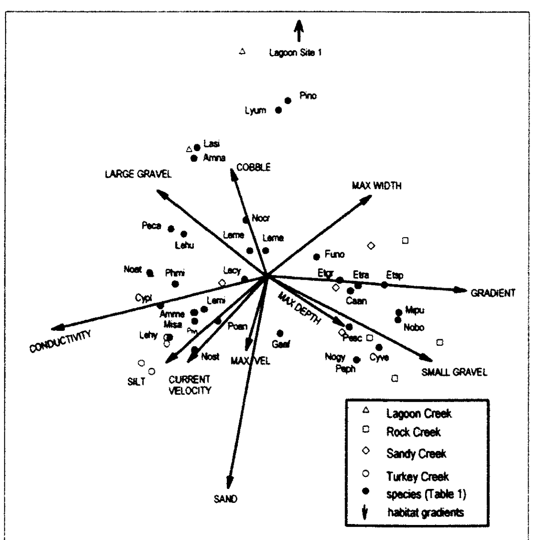

Figure 3. Plot depicting the first two axes of the Canonical Correspondence Analysis.

variables. The species near the center of the triplot, mostly *Lepomis* spp., were found in a wide range of conditions and were collected in similar abundances in all four streams. Other species were strongly associated with certain environmental variables and were most abundant in the streams that also were associated with the same variables. For example, the complex of species on the right side of the triplot, such as *Etheostoma* spp., *Notropis boops*, and *Micropterus punculatus*, were most abundant or were found only in Sandy or Rock Creek. *Lythrurus umbratilis* and *Labidesthes sicculus* were found only in Lagoon Creek, and the greatest abundances of *Percina caprodes* and *Pimephales notatus* were in Lagoon Creek. All four species were located in the same region of the triplot as the Lagoon Creek sites (Fig. 3). *Lepomis* hybrids were strongly associated with high conductivity and were most abundant in Turkey Creek.

DISCUSSION

Ecoregions are defined to have less variation than larger regions, but the distinction of an ecoregion does not guarantee that systems included within it are similar (*11*). In particular, aquatic systems, although influenced by many terrestrial features that are used to define ecoregions, may show distinct differences in both habitat and biotic communities. For example, streams within a single ecoregion may have historical, natural, and anthropogenic differences that influence fish assembleges and habitat characteristics. Our results indicated that habitat differed among four streams of similar size within the Central Oklahoma/Texas Plains Ecoregion, although Rock Creek and Sandy Creek appeared to have some overlap in habitat conditions (Fig. 3). Fish assemblages also differed among the four streams (Figs. 2, 3).

In these four streams, there was a relationship between habitat and fish assemblages. Many species were strongly associated with specific habitat gradients, indicating that presence/absence and abundance of these species was influenced by stream conditions. The species near the edges of the triplot were those whose presence/absence in a stream was highly related to one or a few habitat gradients. Thus, even slight differences in habitat among the four streams were accompanied by differences in community composition. Other species such as *Lepomis* spp., *Gambusia affinis,* and *Pomoxis annularis lo*cated near the center of the CCA triplot were either habitat generalists (*9*) or were specialists within habitats that occurred in all four streams. It should be noted, however, that the distribution and abundance of species that were not strongly associated with individual habitat gradients may be influenced by variables that were not measured in this study.

Fish communities and habitat were clearly related in the four streams, but river system differences can influence community compositions (*18*). Turkey Creek and Lagoon Creek are tributaries of the Arkansas River, whereas Sandy Creek and Rock Creek are tributaries of the Red River. In the UPGMA and CCA, sites from the Red River clustered close to each other. Likewise, sites from the Arkansas River also clustered closely together, indicating differences between the major river systems. An exception to these patterns was the upstream-most site in Sandy Creek, which was clustered with Lagoon and Turkey Creeks in the UPGMA (Fig. 2) and was also associated with those two streams in the CCA triplot (Fig. 3). We believe the upstream-most site in Sandy Creek was impacted by an impoundment on a tributary immediately downstream from the site. The sampling location was dominated by large centrarchids and lacked minnows and darters common to the other three locations in Sandy Creek. In addition, some species, such as white crappie and bluegill, may have escaped from the adjacent impoundment.

Among all four streams, Lagoon Creek showed the greatest amount of variation in fish assemblages (Fig. 2) and habitat (Fig. 3). It is located along an ecotone between upland and prairie stream conditions. A previous study of this stream (*19*) examined 10 sampling sites and found distinct faunal and habitat breaks along the stream's course. For example, upstream sites in Lagoon Creek typically contained upland species such as *Pimephales notatus* and *Lythrurus umbratilis,* and habitat was dominated by cobble/gravel substrate, higher gradients, and increased canopy cover (*19*). Downstream sites were more typical of prairie streams, with species such as *Cyprinella lutrensis* and *Lepomis* spp. Habitat in downstream sites was dominated by smaller substrata, lower gradients, and greater depth and width than in upstream sites (*19*). Although some of these patterns were not as evident when considering relationships among four streams, Lagoon Creek showed more variation than other streams.

Ecoregions have increasingly been used as a spatial reference for regional fish sampling (*10*). When sampling several streams within a potentially heterogeneous ecoregion, however, several additional factors should be considered. Both stream-level and within-stream factors can influence fish assemblage composition and lead to considerable variation among fish assemblages within an ecoregion (*10*). For some studies an ecoregion may be an appropriate reference scale (*10*), but other studies may find the factors we discovered to be more influential.

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