# FISH ASSEMBLAGE STRUCTURE FROM 20 YEARS OF COLLECTIONS IN THE KIAMICHI RIVER, OKLAHOMA

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ABSTRACT—We tested for long-term changes in fish assemblages using collections made from 1972 to 1992 in the Kiamichi River, Oklahoma. Reservoirs were constructed in the Kiamichi River basin in 1974 (mainstem) and 1983 (tributary). A significant difference was found for local species richness but not Shannon-Wiener diversity nor evenness in comparisons from before and after reservoir construction. There was an effect of collection date on the relationship between species richness and upstream distance from the mainstem reservoir; species richness was highest prior to reservoir construction. Sites further from the tributary reservoir outflow were more similar in species composition over time than sites closer to the outflow. Comparisons of site scores for principal components revealed that *Fundulus olivaceus, Notropis atherinoides,* and *Labidesthes sicculus* decreased in abundance following reservoir construction. Although the Kiamichi River retains its overall species richness, our results indicate that reservoir construction has influenced fish assemblage structure.

RESUMEN—Experimentamos cambios a largo plazo en bancos de peces usando colecciones hechas entre 1972 a 1992 en el río Kiamichi, Oklahoma. Se construyeron embalses en la cuenca del río Kiamichi en 1974 (río principal) y en 1983 (en un afluente). Se encontró una diferencia significativa en la riqueza local de especies pero no en la diversidad Shannon-Wiener, ni en la igualdad de proporciones de especies en pruebas provenientas de la época antes y después de la construcción de los embalses. Hubo un efecto de la fecha de colección en la relación entre la riqueza de especies y la distancia río arriba del embalse principal; la riqueza de especies fue más alta antes de la construcción de embalse. La composición de especies en sitios lejos de la boca de embalse del afluente fue más estable a través del tiempo que en aquellos sitios cerca de la boca. Comparaciones entre indices por sitio de los componentes principales mostraron que *Fundulus olivaceus, Notropis antherinoides,* y *Labidesthes sicculus* fueron menos abundantes después de la construcción de los embalses. Aunque el río Kiamichi mantiene su riqueza de especies, nuestros resultados indican que la construcción de los embalses ha in fluido la estructura poblacional de los peces.

Fish assemblages often show negative effects in response to major environmental perturbations, including reservoir construction (Neves and Angermeier, 1990; Edwards and Contreras-Balderas, 1991; Warren and Burr, 1994). These effects may include changes in species composition upstream and downstream of reservoirs (Smith, 1971; Richards, 1976; Hansen and Ramm, 1994). Downstream fish communities appear to be most severely affected by modifications in natural flow regimes that occur below reservoirs (Bain et al., 1988; Travnichek et al., 1995), although dams also prevent dispersal of migrating fishes. Our objective was to compare fish assemblages in the Kiamichi River to test the hypothesis that changes occurred after impoundment.

The Kiamichi River is a medium-sized river (180 km length, drainage area of 4,800 km$^2$) in southeastern Oklahoma with moderate gradient (0.47 m/km). Ninety-nine fish species have been collected in the Kiamichi River (Pigg and Hill, 1974; Taylor et al., 1993). Two reservoirs influence the river. Hugo Reservoir, constructed in 1974 impounds the mainstem of the river (Fig. 1). Sardis Reservoir, con-

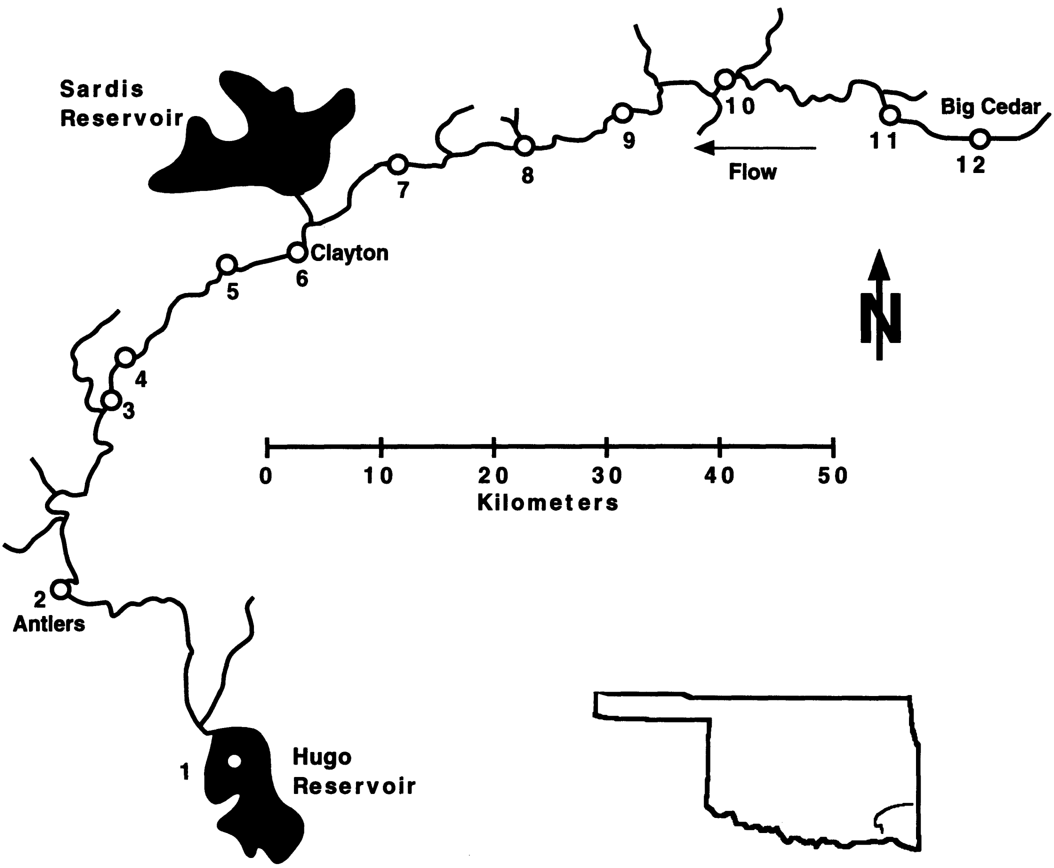


FIG. 1—Collection sites on the Kiamichi River, Oklahoma, numbered from downstream to upstream. Hugo and Sardis are reservoirs.

structed in 1983, impounds a major tributary of the river (Fig. 1). Other anthropogenic effects on river biota derive from agricultural and forest harvesting activities, although these effects appear minimal, perhaps due to the narrow river basin (5–20 km in width) (Vaughn and Pyron, 1995).

METHODS—Analyses were based on 185 fish collections from the Kiamichi River from 1972 to 1992 (these data have been archived at the Oklahoma Biological Survey). Collections were made by ourselves, Matthews (1986), and R. Cashner (pers. comm.). All of these surveys were conducted in summer or fall with the exception of five winter and nine spring collections. Collections were made by seining at least a 100-m river reach at each site to sample every available habitat, with gill-netting at some sites, following best professional judgment. Earlier surveys in the Kiamichi River reported only presence/absence of species (Meek, 1895; Ortenburger and Hubbs, 1927; Pigg and Hill, 1974).

All of the fish collections discussed in this paper were made upstream of the mainstem reservoir (Hugo). We were interested in two types of reservoir influences on fish assemblages; those from the tributary reservoir and those from the mainstem reservoir (Hugo). Sites 7–12 were upstream of the tributary reservoir (Fig. 1). Prior to reservoir construction 32 collections were made at these sites; 50 collections were made following construction. Sites 1–6 were downstream of the tributary reservoir but upstream of the mainstem reservoir (Fig. 1); 35 collections were made at these sites prior to reservoir construction and 68 collections following reservoir construction. Although more collections were made after reservoir construction, collections represented equitable sampling for our comparisons.

To determine the influence of the downstream mainstem reservoir on fish assemblages we examined the relationship between species richness, Shannon-Wiener diversity, evenness (modified Hill's ratio, Ludwig and Reynolds, 1988), and the upstream distance of sites (from the mainstem reservoir) for an effect of time (before and after Sardis Reservoir construction) with ANCOVA. A positive relationship between species richness and stream size (or stream distance) is common (Angermeier and Schlosser, 1989; Watters, 1992).

To examine influences of the tributary reservoir on fish assemblages we conducted the following analyses. We compared Jaccard's index of similarity before and after reservoir construction (Ludwig and Reynolds, 1988) from sites below the Sardis Reservoir inflow (Fig. 1) to sites above the Sardis inflow with an independent $t$-test, to test for temporal changes in species composition. Jaccard's index was calculated from presence/absence data for summed collections prior to 1984 and after 1984 by site (for 11 sites with collections made during both time periods), for collections made during summer and fall months. We chose to make comparisons with a presence/absence index (Jaccard's) as a more conservative approach than using an index based on abundances, because sites were not equally sampled. We used a regression approach to test for a relationship between the distance (upstream or downstream) from Sardis Reservoir outflow for each site and Jaccard's similarity values at sites. Finally, for three sites sampled regularly during the study period, we tested if the slopes of regressions of species richness and $H'$ against collection date were different from zero, which may indicate negative effects of reservoirs or time.

In our multivariate approach, collections were separated into before and after construction of Sardis Reservoir (before and after 1984) and combined by site. This analysis tested for changes in the ordination position of sites from before and after reservoir construction. Rare species were not used in principal components analysis; species were eliminated if they did not represent more than one percent of the total number of fishes collected, or if they did not occur at more than two sites. Transformed ($\log_{10}+1$) species abundances were subjected to principal components (PC) analysis, and the subsequent site factor scores compared by time of collection (before and after 1984) with paired $t$-tests for the PC axes that explain greater than 10% of total variance. All statistical analyses were done with SYSTAT (1992).

RESULTS—A total of 101 fish species was taken in 185 collections at 12 sites (localities are listed in Appendix 1). Several rare species (occurred in only one or two collections) are at the edge of their geographic ranges (Lee et al., 1980): *Lepomis marginatus, Etheostoma vivax, Etheostoma chlorosomum,* and *E. proeliare. Morone chrysops* probably was rare in collections because it is not commonly captured by seine. *Crystallaria asprella* was a new occurrence for the Kiamichi River (Taylor et al., 1993) and *Notropis suttkusi* (formerly *N. rubellus*) recently was described by Humphries and Cashner (1994).

No interactions existed between collection date (before or after Sardis Reservoir) and upstream distance in an ANCOVA with species richness as the dependent variable ($F_{2,179}$ = 0.003, $P > 0.997$). There was a significant effect of collection date on the relationship between upstream distance and richness ($F_{2,181}$ = 33.5, $P < 0.04$, Fig. 2). Fisher's LSD multiple comparisons resulted in significance for comparisons between collections in the earliest time period and collections made in the second time period ($P < 0.02$), and in comparisons between the most recent and second time period ($P < 0.05$). No significant interaction occurred between the date of collection and river distance in a test with Shannon-Wiener diversity as the dependent variable (ANCOVA; $F_{2,179} = 1.1$, $P < 0.336$) and no significant difference was found for date of collection ($F_{2,181}$ = 1.4, $P < 0.24$). No significant interaction occurred between the date of collection and river distance in a test with evenness as the dependent variable (ANCOVA; $F_{2,179}$ = 0.28, $P <$ 0.75) and no significant difference was found for date of collection ($F_{2,181}$ = 0.03, $P < 0.97$; Fig. 2).

There was no significant difference in Jaccard's similarity index for collections from downstream of the Sardis input ($\bar{X}$ = 0.38, $SD$ = 0.15) compared to collections upstream of the input ($\bar{X}$ = 0.47, $SD$ = 0.14; ind. $t_9 = -1.1$, $P < 0.30$; Fig. 3). A significant positive relationship was found between stream distance from the Sardis Reservoir outflow and Jaccard's similarity index ($R^2 = 0.724$; $P < 0.012$; Fig. 3). Comparisons of species richness and diversity at the three regularly sampled sites resulted in regression slopes not significantly different than zero for collections at Antlers and Clayton. Species richness and diversity increased with collection date for Big Cedar collections.

There was a significant difference in site scores for the third PC axis from before and after construction of Sardis Reservoir (Table 1). Scores on this axis primarily reflect numbers of *Fundulus olivaceus, Notropis atherinoides,* and *Labidesthes sicculus,* with lower numbers in

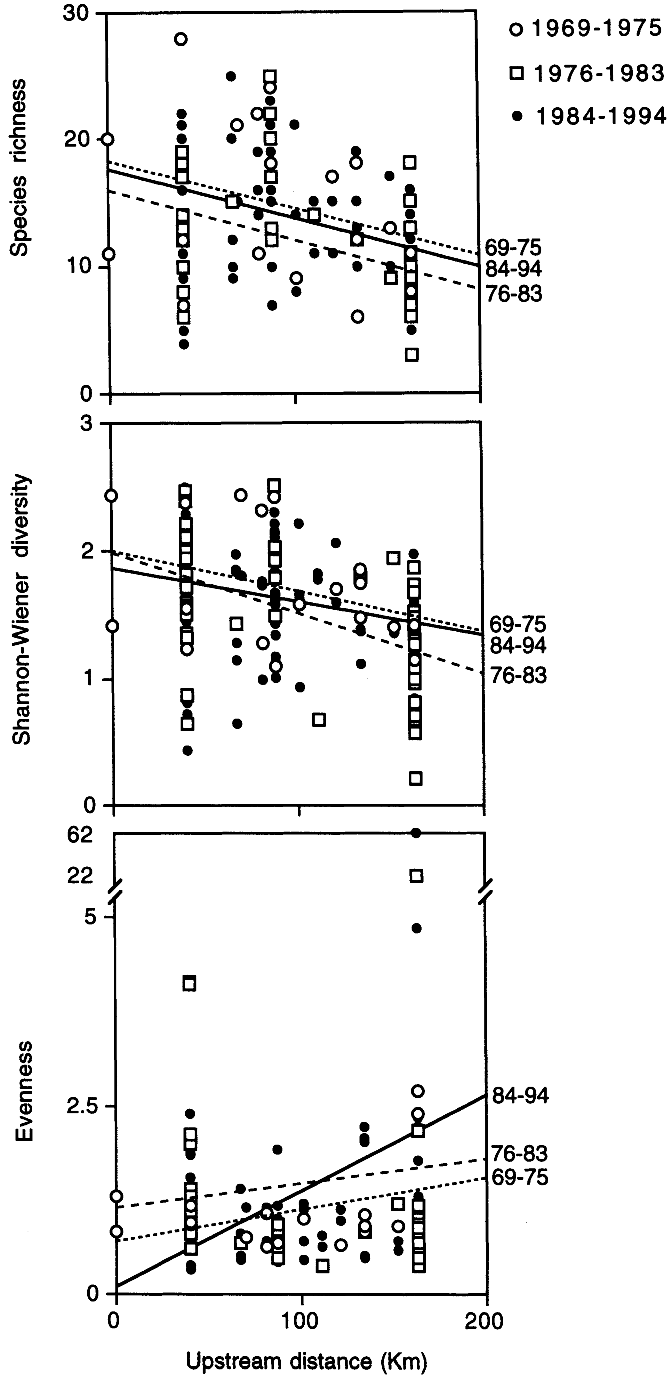


FIG. 2—Species richness (upper plot), Shannon-Wiener diversity (middle plot), and evenness (lower plot) versus upstream distance of sites for collections made during three time periods.

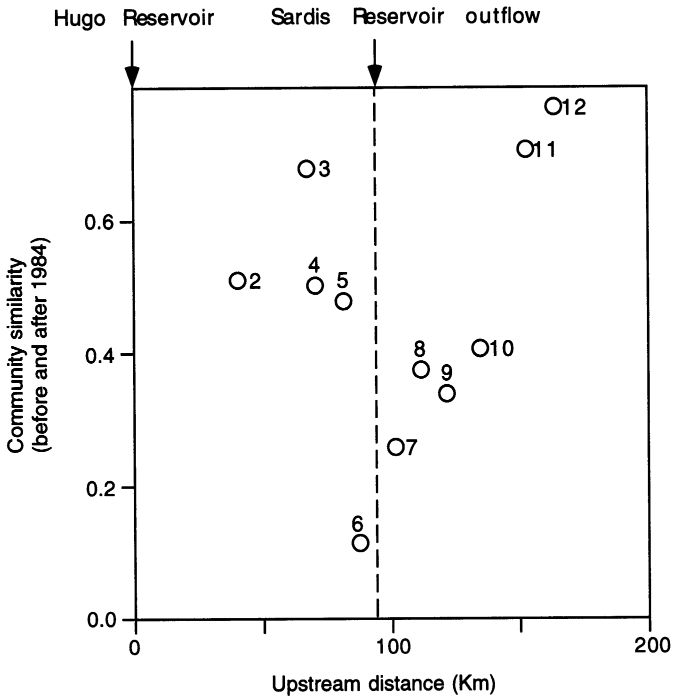


FIG. 3—Community similarity (Jaccard's index) for collections prior to 1984 and after 1984 and upstream distance for 11 sites. Site numbers are from Fig. 1.

TABLE 1—Principal component loadings greater than 0.500, $t$-values (T) and associated probabilities ($P$) from paired $t$-tests ($df = 10$) comparing principal component scores for collections before and after construction of Sardis Reservoir (before and after 1984).

| Species | PC1 | PC2 | PC3 | PC4 |
|---|---|---|---|---|
| *Campostoma anomalum* | 0.774 | 0.501 | | |
| *Lepomis megalotis* | 0.772 | | | |
| *Gambusia affinis* | 0.740 | | | |
| *Lythrurus umbratilis* | −0.728 | | | |
| *Notropis boops* | −0.543 | | | |
| *Cyprinella whipplei* | | −0.756 | | |
| *Notropis suttkusi* | | −0.678 | | |
| *Notropis ortenburgeri* | | 0.549 | | |
| *Fundulus olivaceus* | | | −0.807 | |
| *Notropis atherinoides* | | | −0.673 | |
| *Labidesthes sicculus* | | | −0.532 | |
| *Etheostoma radiosum* | | | | −0.737 |
| *Lepomis macrochirus* | | | | |
| *Notropis volucellus* | | | | |
| Percent of total variance | 22.6 | 18.1 | 12.8 | 10.5 |
| T | −0.685 | 1.32 | 2.76 | 0.415 |
| ($P$) | (0.509) | (0.215) | (0.020) | (0.687) |

collections after 1984. No differences between collection periods were found for the other PC axes (Table 1).

DISCUSSION—We found significant changes in local fish assemblages in the Kiamichi River in comparisons of collections made before and after construction of the tributary reservoir. Basin-wide species richness of fishes did not decrease. Species richness decreased at local sites in comparisons between the earliest and second collection time period, and increased after the second collection time period. The increase in local species richness in the third time period may be due to more sampling during this period. Fish community similarity, in comparisons of local sites from before and after reservoirs, was a function of distance from the tributary reservoir. Sites adjacent to the reservoir outflow were less similar over time than sites that were farther from the outflow (Fig. 3), suggesting a negative effect of the reservoir.

We did not find decreases in species richness and diversity over time at three regularly sampled sites. Species richness and diversity increased over time at the regularly sampled upstream site. Only one PC axis was related to time of reservoir construction: three species of fishes decreased in abundance after construction of the tributary reservoir. This PC axis accounted for only 13% of total variation.

Eley et al. (1981), working in a nearby river, the Mountain Fork, found changes in species composition and decreases in diversity of fish assemblages from construction of a mainstem reservoir. One of the major effects of reservoirs on fish communities is from disruptions of natural flow regimes (Travnichek et al., 1995). Severe alterations in both discharge volume and seasonality have been observed in the Kiamichi River below the tributary outflow (Vaughn, pers. obs.); but without a suitable control river for comparison we have only identified correlative evidence. However, an effect of reservoirs in the Kiamichi River basin was also found for the endangered mussel, *Arkansia wheeleri*. The mussel is extirpated in reaches of the Kiamichi River below Hugo Reservoir and reduced in abundance below inflow from Sardis Reservoir (Vaughn and Pyron, 1995). Mussels appear to be more sensitive than fishes to reservoir-caused environmental changes (Bogan, 1993).

Echelle and Schnell (1976) predicted that construction of reservoirs on the Kiamichi River would result in increases in lacustrine species and decreases in riverine species. This is not what we observed in our comparisons of local collections upstream from the mainstem impoundment. However, such changes would most likely occur in reaches with lacustrine habitats (within and downstream of Hugo Reservoir, where we did not collect). Winston et al. (1991) linked the extirpation of four minnow species in tributaries of the Red River, Oklahoma to reservoir construction. Migratory fish species are predicted to be extirpated by mainstem reservoirs. Known migratory species in the Kiamichi River include *Anguilla rostrata* and *Hybognathus nuchalis*; *H. placitus* was collected at a site downstream from ours (Pigg and Hill, 1974). We do not know if other fish species we captured are migratory or if reservoirs are affecting fish movements.

Our results also likely reflect natural fluctuations in local fish assemblages. Temporal changes are expected in stream fish assemblages from natural disturbances, largely determined by geographic location and stream order (Detenbeck et al., 1992). Matthews et al. (1988) used similarity indices and concordance of rank abundance of common fishes to examine stability and persistence of the Kimichi River fish fauna between 1981 and 1986. They concluded that rank order of common species varied among years and locations in the Kiamichi River over a shorter time period when reservoirs were already in place.

Many river ecosystems are being lost at an alarming rate (Dynesius and Nilsson, 1994). The Kiamichi River retains most of it's species of fishes and mussels, and the insect fauna is only beginning to be described. This rich system should be protected from further human alterations of the watershed (reservoirs, increased agriculture, and poor forestry practices).

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Appendix 1.—Descriptions of collection sites on the Kiamichi River.

Site 1. Lake Hugo. Pushmataha County, T5S, R18E
Site 2. Antlers Bridge. Pushmataha County, T3S, R16E
Site 3. Payne's Bridge. Pushmataha County, T1S, R16E
Site 4. Dunbar. Pushmataha County, T1S, R17E
Site 5. Stanley. Pushmataha County, T1N, R17E
Site 6. Clayton City Park. Pushmataha County, T1N, R19E
Site 7. Tuskahoma Bridge. Pushmataha County, T2N, R19E
Site 8. Walnut Creek. Pushmataha County, T2N, R21E
Site 9. Albion. Pushmataha County, T2N, R20E
Site 10. Whitesboro. Leflore County, T3N, R22E
Site 11. Muse. Leflore County, T2N, R24E
Site 12. Big Cedar. Leflore County, T2N, R25E