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Stability and Persistence of Fish Faunas and Assemblages in Three Midwestern Streams

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Long term stability of summer fish assemblages was examined in three distinct systems: Piney Creek, a medium-sized Ozark upland tributary of the White River, Arkansas; Brier Creek, a small prairie-margin stream, tributary to the Red River, Oklahoma; and the Kiamichi River, a medium-sized river in the Ouachita Uplands draining into the Red River, Oklahoma. Sampling periods and numbers of surveys of the three stream systems were 14 yr and six collections for Piney Creek, 17 yr and five surveys for Brier Creek, and 5 yr and three surveys for the Kiamichi River. The fish faunas of all three streams were persistent (regarding presence-absence of species). In all three streams overall faunal structure was stable, as indicated by similarity indices and by concordance of rank abundance of the common species in each stream across all collection years. The results corroborated a conclusion from earlier work that the total fish fauna is more stable in a more environmentally benign stream (Piney Creek) than in a stream subject to greater environmental extremes (Brier Creek). The fish fauna of the Kiamichi River was also stable across three survey periods with respect to rank order of species abundance. Stability of the fish assemblages at individual locations on all three streams was variable, but four of five locations on Brier Creek, and all five locations on Piney Creek exhibited significant concordance overall in ranks of species abundance. Of 59 possible cases, assemblages at 27 individual locations (=46%) on the three streams showed assemblage stability >0.60 between survey periods. We conclude that at the level of whole-stream faunas, all three of these midwestern streams were stable across the survey years, and that many, but not all, individual locations had relatively stable fish assemblages.

"IN all types of waters, fish populations appear to fluctuate in abundance and in species composition from year to year." (Starrett, 1951).

". . . one can return to a locality at the same time of year and collect essentially the same species . . . in the same relative numbers." (Smith and Powell, 1971).

The debate about stability of stream fish faunas or local assemblages is not new. The perceived stability of stream fish assemblages can relate to the taxa studied, harshness of the environment, magnitudes of disturbances, location within a watershed, or the spatial limits set to a study by the investigator (Harrell, 1978; Grossman et al., 1985; Moyle and Vondracek, 1985; Ross et al., 1985; Matthews, 1986a). Findings about stability or persistence of fishes in stream systems are important. From a practical view, ichthyologists and fisheries managers need to know how much variation (or stability, or persistence) is characteristic of relatively undisturbed faunas if they are to correctly assess faunal changes that indicate environmental alteration. From a theoretical view, if stream fish assemblages are unstable, non-persistent, or regulated mostly by stochastic events, equilibrium-based community theory might not apply to stream fishes (Grossman et al., 1982). Despite the papers cited above, there are relatively few long-term (i.e., several generations of most fish) data sets on fish assemblages at locations on streams in North America. Data from additional streams, or temporal extension of existing data sets are needed if we are to know whether or not individual streams are largely unique with respect to fish stability, and if generalization and prediction are possible.

Ross et al. (1985) evaluated stability and persistence of summer fish assemblages in Brier Creek, Oklahoma, for surveys made in 1969, 1976 and 1981, and in Piney Creek, Arkansas, for surveys in 1972 and 1981. Matthews (1986a) examined fish assemblage stability year-around in Piney Creek for four surveys from 1972–83,

TABLE 1. FISH COLLECTIONS IN PINEY CREEK, BRIER CREEK, AND KIAMICHI RIVER THAT ARE INCLUDED IN THE PRESENT ANALYSES. R = data included in Ross et al. (1985); M = data included in Matthews (1986).

Stream	Date	Collectors	Included in previous reports
Brier Creek	17 June–31 July 1969	Smith and Powell (1971)	R
	28 June 1976	WJM/A.A. Echelle	R
	15 June–20 July 1981	WJM/class	R
	19 June 1985	WJM/FPG/class	
	12 June 1986	RCC/class	
Piney Creek	21–29 July 1972	WJM	M, R
	29 Aug. 1981	WJM	R
	6–7 Aug. 1982	WJM	M
	25–26 Aug. 1983	WJM	M
	5 Aug. 1985	WJM	
	2 Aug. 1986	WJM/FPG	
Kiamichi River	11–12 July 1981	WJM/class	
	29–30 June 1985	WJM/FPG/class	
	13–14 July 1986	RCC/WJM/class	

a period that included an extreme flood. From additional surveys of Brier and Piney creeks in the summers of 1985 and 1986 we now present a more comprehensive, long-term view of stability and persistence of fishes of those streams. These recent data lead us to results that substantiate many of the findings of Ross et al. (1985), but that differ in part from those previous findings. For comparison, we also provide information on stability and persistence of the fishes at locations in the Kiamichi River, Oklahoma, in three surveys from 1981–86.

We follow Connell and Sousa (1983) in regarding stability as a quantitative feature of an animal community, based on abundance data from collections that span at least one complete generation of most species, and persistence as a qualitative feature describing continued presence of species. We treat the fish in a single collection at one station (200–400 m of stream) as an assemblage, and assume that in such stream reaches individual fish have the potential to interact ecologically within relatively short periods of time (Grossman et al., 1982). We also pool data for all collections (5–7 locations) at one time within a stream to provide a view of the fauna of the stream for each survey. Thus, we distinguish between "assemblages," which are local, potentially interacting groups of fishes, and "faunas," which include fish that occur within the watershed as a whole at a given time (but which may not have the opportunity to interact as often as those within local assemblages).

STUDY AREAS AND METHODS

The three streams in this study are: Piney Creek, Izard Co., Arkansas; Brier Creek, Marshall Co., Oklahoma; and Kiamichi River, Pushmataha and LeFlore Counties, Oklahoma. Table 1 summarizes all collections included in the present analysis. Numbered study sites in Piney and Brier creeks correspond to those in Ross et al. (1985) and Matthews (1986a).

Piney Creek is an upland stream of the White River drainage in the southern Ozark Mountains, with permanent base flow due to springs, rubble-gravel-sand substratum, generally clear water, and 50 known fish species (Matthews and Harp, 1974; Matthews, 1986a). In Piney Creek, oxygen and temperature are not limiting to native fishes, even at headwaters stations. Across all seasons of 1 yr, the lowest oxygen concentration found at 12 stations on Piney Creek was 7 ppm, in late summer (Matthews, 1973). Extremes in temperature for all collections on Piney Creek are 6 and 31 C (Matthews, unpubl.). Individual collecting stations on Piney Creek are on the mainstream, ranging in average width from 6–35 m, with maximum pool depths typically 80–150 cm. Most of the area at each station consists of shallow pools <1 m deep, and runs or riffles with water <40 cm deep.

Brier Creek, in southcentral Oklahoma, is a prairie-margin tributary of the Red River (now Lake Texoma), characterized by a lack of permanent flow in the headwaters, sand-gravel-rubble substratum, and a known fauna of 30 fish species. Ross et al. (1985) established that Brier Creek is overall more physically harsh and fluctuating than Piney Creek, and Matthews (1987) documented harsh temperatures and oxygen concentrations in Brier Creek headwaters. Distinct longitudinal variation in physicochemical conditions that exist in Brier Creek can limit fish distribution within the creek (Matthews, 1987). Individual collecting stations on Brier Creek are described in Smith and Powell (1971) and in Ross et al. (1985). Stations on Brier Creek range from two headwater locations (Stations 2 and 3) that are completely dry in summers with low rainfall (Matthews, 1987) to two on the lower mainstream (Stations 5 and 6) that always contain pools of water, even though in extreme drought years surface flow may cease briefly (Matthews et al., 1982). During normal flow, the headwater stations consist of pools 3–5 m wide, connected by narrow riffles often <1 m wide. The downstream pools are typically 8–10 m wide and up to 1 m deep, but none are too deep to sample effectively by seining.

The Kiamichi River, in the Ouachita Mountains of southeastern Oklahoma, is a medium-sized upland stream of the Red River drainage. The Kiamichi River has 98 known fish species (Pigg and Hill, 1974; Echelle and Schnell, 1976), although many are rare. Thus, at any particular location the diversity of fishes or complexity of the assemblages in Kiamichi River is similar to that at Piney Creek localities. The collections in the Kiamichi River, as described in Matthews (1986b), were at mainstream localities spaced from the headwaters near Big Cedar, Oklahoma, to the lower mainstream near Antlers, Oklahoma, and at one locality on a tributary creek. At upstream locations the Kiamichi River is a high-gradient stream with bedrock or boulder-cobble-gravel bottoms, clear water, and distinct riffle-pool zonation with pools 3–8 m wide. Lower mainstream stations have mud-sand-cobble substrate, turbid water, and longer, deeper pools.

Numerous visits to field sites on the Kiamichi River since 1976 (WJM) and United States Geological Survey (USGS, 1981-1985) data show that flow is perennial at most sites, and water quality is high. In 5 yrs of USGS water quality records for our most extreme headwaters station on the Kiamichi River (near Big Cedar), flow was zero on an average of 32 d per year. However, even including all low or no-flow periods, dissolved oxygen <6.4 ppm was not reported, and the highest recorded temperature was 28.5 C (USGS, 1981–1985). These values for temperature and oxygen are well within limits of tolerance even for sensitive native fishes (Matthews, 1987). At this station, forest canopy shades pools and helps keep temperatures low. Farther downstream (at Clayton and Antlers), the flow of the Kiamichi River is continuous in all but the most extreme drought conditions, and water quality values reported at those stations (USGS, 1981–1985) never exceeded acceptable limits for stream fishes. We thus assume that physical conditions for fishes in the Kiamichi River are benign for most native warmwater fish species, and that in this characteristic the Kiamichi River is more like Piney Creek (=benign) than Brier Creek (=harsh).

Sampling.—Collections of fishes in these streams were made in daylight as described in Smith and Powell (1971), Ross et al. (1985) and Matthews (1986a). Small-meshed seines of appropriate lengths for the various localities were used to thoroughly sample all microhabitats in a 200–400 m reach of stream at each location for 1.0–1.5 h. Collections in Brier Creek in 1969 were made by C. L. Smith of the American Museum of Natural History, using seines 4.6 m long (in pools) and 1.2 m long (in riffles) with 0.3 cm mesh. In 1976–85 in Brier Creek we used a combination of mesh sizes from 0.3–0.6 cm, collecting most with seines 4.6 m long × 1.2 m deep with 0.45 cm mesh. In Kiamichi River, all collections have been with 0.6 cm mesh bag seines 7.6 m long and/or 0.5 cm mesh straight seines 4.6 m long, with the larger seines used more at the larger and deeper locations. All collections on Piney Creek have been with a 4.6 m × 1.2 m seine with 0.5 cm mesh. Within each stream the same reaches were sampled in every year that is included in the present paper, except that in 1985 we shifted Brier Creek Station 5 ca 200 m downstream to avoid disturbance of long-term experiments that were in progress by another investigator. All sampling locations included both riffles and pools, with the exception of Kiamichi Station 1, which consisted of one long pool.

Details of our collecting techniques and validity of seine collected fish samples are discussed fully in Matthews (1986a). As indicated in Matthews (1986a), all pools were seined vigorously and repeatedly, with care to work the seine in all potential hiding locations for fishes such as undercut banks, rootwads, etc. In flowing riffles, most collecting was by kick-sets, but the seine was also passed downstream through the riffles to sample free-swimming (i.e., non-benthic) fishes. Matthews (1986a) discussed potential biases and limitations inherent in sampling fishes by seining, but the conclusion of numerous studies (cited therein) is that in many situations seines are reliably used to take quantitative samples of small fishes from a variety of streams. Worst limitations to use of seines are water too deep to sample effectively, and habitats with snags or fixed substrates such as upthrust shale from which benthic fishes cannot be effectively dislodged by kicking. All of our samples were taken at times when we judged that thorough collections were possible, avoiding periods of high water or other phenomena that could have impeded collecting. With the exception of the 1969 collections by Smith and Powell, one or more of the authors participated in all sampling to insure comparability of effort among collections within a given stream.

In Piney Creek, stations had very little structure that would obstruct seining, and only a small percent of any station was in water too deep to seine effectively (Matthews, 1986a). In Brier Creek, all parts of all stations were shallow enough to be seined, and most stations were free of serious obstructions. Brier Creek Station 4 had some rock rubble that complicated collecting, and Station 6 included some snags (dead trees deposited by flood), but at all localities we judge that an acceptable sample was made by seining. Kiamichi River, Station 1 (most downstream), was too deep to be effectively seined at midchannel, but at this site we have consistently collected in a variety of microhabitats near shore. Station 8 in Kiamichi River (the most upstream site) had some large cobble over which seining was difficult, but this site also had narrow riffles in which kick-sets were effective, and pools in which seining was efficient. Kiamichi Station 4 had a channel 1–1.5 m deep, but in which collections could be made relatively well. The other stations on the Kiamichi River were readily seined. A critical point for all streams is that although not all stations were equally easy locations in which to collect fish, all were seined sufficiently well to produce collections that, within a station, could be compared with validity across years. Repeatability of our collections is exemplified by surveys of Brier Creek in June and July 1981: faunal resemblance between those collections was high (Moristia's index = 0.93) (Ross et al., 1985).

Analysis.—Raw data for Brier Creek were adjusted for 1969 and 1981 to catch per a single collection by dividing total catch by number of collections. All other years and streams reflect a single collection per station per summer. Similarity of the fish faunas or assemblages between any 2 yr was estimated by Morisita's (1959) index (I_m), which is independent of sample size or species diversity (Wolda, 1981) and by a percent similarity index (PSI = Renkonens' index; Wolda, 1981). (Note that the PSI gives values identical to Schoener's [1968] index, which was compared to Morisita's index by Linton et al., 1981.) I_m varies from zero (no faunal similarity) to slightly above 1.00 (all elements identical); PSI varies from 0.0–1.00. Ross et al. (1985) excluded from analysis any species in Brier or Piney creeks not comprising at least 1% of the assemblage at at least one location, but in the present similarity analyses all species were included. For each station, Kendall's W with correction for ties (Siegel, 1956) was used to test for significant rank concordance of abundance of the 10 most common species across all surveys. (At three Kiamichi River locations, only 6–9 species were sufficiently abundant to be included in rank order analysis, as we excluded species from this analysis at any locality where <10 individuals were collected.) For whole stream faunas (pooled data), rank concordance analysis was carried out on the 10 species that were most abundant overall in a given stream.

In Piney Creek, Matthews (1986a) found empirically that including 15 instead of 10 species increased the chance that significant concordance of ranks would be found, because the expanded suite of 15 species included taxa that never approached the abundance of the 10 most common species. In each of the three present stream systems, the suite of 10 most common species includes only taxa that are truly common in the watershed, i.e., in none of the streams does the 10 most common suite include any rare species. We also considered including more species in the analysis in one stream than another, e.g., analyzing a standard percentage, say 25% of the total number of species known in each stream. However, although the known fauna (including rare species) is richer for the Kiamichi River than for Piney or Brier creeks (98 vs 50 and 30 known species, respectively), the actual number of species taken in the collections on which this analysis is based is much more even. For the collections on which this analysis is based (i.e., excluding winter collections, collections in small tributaries, etc., that have added to our knowledge of fishes of the systems, but are not included here) there was a total of 49, 40, and 29 species for Kiamichi River, Piney Creek, and Brier Creek, respectively. Thus, the decision to include the most common 10 species in each system is more nearly equitable than might appear based on the total number of species known from each system. Including 10 species for each system also focuses the analysis on taxa that are ecologically important components of the biotic community.

Results

Qualitative persistence of faunas.—Ross et al. (1985) and Matthews (1986a) found (for data through 1981 and 1983, respectively) that the fish faunas of Brier and Piney creeks were persistent overall (presence-absence of species, sensu Connell and Sousa, 1983), with which our results through 1986 agree. Throughout our studies, abundant species have not disappeared from or become rare in any of the streams with two exceptions, and no originally absent or rare species has become abundant.

For 11 of the species present in Brier Creek, no specimens were collected in two or more of the five survey years. Eight of the collections of those species involved a total of only 29 specimens. The low numbers were due to the fact that most of these species were always rare if present and were represented by only 1–12 specimens (most by only 1–4). In two cases, however, there was a marked decline of a dominant or abundant species in Brier Creek. *Pimephales promelas*, the fathead minnow, was fairly common in the 1969 Smith and Powell survey, comprising the seventh most abundant species in their collections. The species was absent from two of the four more recent surveys and was represented by only 11 specimens in the 2 yr it was collected. The spotted bass, *Micropterus punctulatus*, has shown a sharp decline, from 136 specimens taken in 1969 to only one individual in the other four surveys.

In Piney Creek, only nine of 50 known species have been absent from our collections in two or more of the five survey years. Six of these cases involve a total of only seven specimens. The species change involving the most specimens was the golden redhorse, *Moxostoma erythrurum*, which was absent in the first two surveys, but has been well represented in the last three. The golden redhorse is a stream species whose sporadic collection in a given area can be understood in light of its known tendency to make substantial upstream migrations to spawn.

Table 2. Concordance of Ranks (Kendall's W) for the 10 Most Abundant Species in Each Stream, with Data from All Stations Pooled, across All Years for Which Collections are Available (Table 1).

Stream	W	X^2	*P*
Brier Creek (1969–86)	0.56	25.92	<0.01
Piney Creek (1972–86)	0.752	40.58	<0.001
Kiamichi River	0.859	23.19	<0.01

The Kiamichi River exhibited the most changes in presence-absence of species across the survey years. Twenty-four of the species in the Kiamichi River collections were absent in one of the three surveys, and 12 were absent in two of the three surveys. However, in all cases species that were non-persistent were species that were rare when collected (i.e., were never represented by more than a few specimens). Therefore, in each of these streams, the common or abundant species were also persistent, whereas the non-persistent species were usually rare when they were taken. (We recognize that although collecting a specimen is proof of presence of the species, one cannot show unequivocally that a rare species is truly absent from a study area on the basis of any single survey.)

Quantitative stability of the faunas.—In each of the streams the fish fauna (abundance pooled across stations within streams) showed significant concordance of ranks of the common species over all surveys (Table 2). To assess faunal similarity between all possible years within each creek we used both Morisita's Index and the PSI. Linton et al. (1981) compared Morisita's and Schoener's (=PSI) indices, finding that for true similarities below ca 0.75, PSI underestimates and Morisita's index overestimates similarity but with PSI closest to the true value. Above 0.75, PSI increases underestimation until at a true value of about 0.88 or greater, Morisita's index is more accurate. Many of our values lie in the range 0.50–0.99, and Morisita's index and PSI followed the trends predicted by Linton et al. (1981), with PSI estimating a lower value than Morisita's Index in all but two cases on Brier Creek. We present both indices (Table 3) so that readers can make comparisons to ear-

TABLE 3. SIMILARITY OF FISH FAUNAS OF THE STUDY STREAMS BETWEEN ALL POSSIBLE YEARS, WITH DATA POOLED ACROSS STATIONS WITHIN EACH SURVEY OF EACH STREAM. Tabled values = Morisita's index, followed by percent similarity index.

Piney Creek:					
	1972	1981	1982	1983	1985
1981	.72–.60				
1982	.91–.74	.85–.69			
1983	.87–.72	.82–.65	.98–.85		
1985	.90–.71	.82–.63	.98–.84	.99–.86	
1986	.66–.52	.92–.76	.79–.67	.79–.67	.80–.70
Brier Creek:					
	1969	1976	1981	1985	
1976	.74–.55				
1981	.40–.42	.67–.56			
1985	.50–.47	.84–.66	.83–.70		
1986	.97–.77	.77–.57	.42–.52	.57–.51	
Kiamichi River:					
	1981	1985			
1985	.82–.67				
1986	.90–.74	.87–.72			

lier studies using either measure; trends in both indices were highly similar for all three streams.

Morisita's index of similarity between all temporally sequential surveys in Piney Creek (diagonal, Table 3) ranged 0.72–0.99; PSI values for the same comparisons ranged 0.60–0.86. Both rank correlation and indices of similarity for the fauna of Piney Creek 1972–86 support the conclusion of Ross et al. (1985) for 1972–81 that the fish fauna of this upland stream was rather stable overall. Indices are not statistics; they have no significance levels. However, they seem to us highly useful in comparing relative stability of different sites or different streams, and there is precedent for considering some general ranges of values to represent various degrees of stability. For example, Horn (1979) considered PSI values of 64–76% as "high." K. R. Matthews (1985) considered PSI values of 0.71 and 0.74 "relatively high" and judged that the reef fish communities being compared were "fairly similar." Pennington et al. (1983) considered PSI values >0.65 "high." Ross et al. (1985) considered Morisita's index values of 0.40 = "low" and 0.74 = "high." There are no absolute cut-offs, but most authors using similarity indices have judged values greater than about 0.7 as indicating stability in assemblages. To obtain a rough approximation of the relationship between rank correlation and similarity index results for our study, we compared mean PSI for each station versus scores for Kendall's W, by station, across all years. In eight of nine cases in which mean PSI was 0.60 or greater, rank correlation of species abundance was statistically significant ($P < 0.05$) overall.

In Brier Creek, Ross et al. (1985) found low overall faunal similarity ($I_m = 0.40$) in a comparison of surveys in 1969 and 1981, and concluded that the fish fauna of this environmentally harsh stream was less stable than that of Piney Creek. Table 3 suggests that between the particular years of 1969 and 1981 there was unusually low faunal similarity in Brier Creek relative to most other possible pairs of collecting years (but see also 1981 vs 1986). In the four successive intervals (diagonals, Table 3) for which we now have information, the similarity of the Brier Creek fauna ranged from 0.57–0.83 (I_m) or 0.51–0.70 (PSI). However, Brier Creek is probably less faunally stable overall than Piney Creek: 4 of 10 possible comparisons between years in Brier Creek are lower than the lowest similarity ($I_m = 0.66$) found between any years in Piney Creek (Table 3) and there is a similar trend in PSI values. Additionally, analysis of variance comparing all possible pairs of similarity indices for faunas of Piney and Brier Creeks (Table 3) showed significantly higher I_m values ($F = 7.69$; $P < 0.05$) and PSI values ($F = 10.91$; $P < 0.01$) in Piney than in Brier Creek. On the basis of the data set now available, we support the conclusion of Ross that the more environmentally benign stream (Piney Creek) had a more stable fish fauna than did Brier Creek.

In Piney Creek, one species, *Notropis pilsbryi*, was most abundant (or once tied for most abundant) in every survey. Also in Piney Creek, *N. telescopus* was the second most abundant species in three surveys, tied once for most abundant, and was never lower than fourth in abundance. In contrast, none of the fish species in Brier Creek was consistently first or second in abundance. *Notropis boops* was the most abundant species in Brier Creek in three of five surveys, but dropped to fourth in abundance in 1981. No other Brier Creek species approached the stability in relative abundance that was exhibited by at least two of the dominant species in Piney Creek. In the three possible comparisons between years, the fish fauna of the Kiamichi River showed overall similarity comparable to that in Piney Creek (Table 3). For reasons detailed in the description of study sites, we consider the Kiamichi River, like Piney Creek, to lie toward the benign end of a continuum of streams from harsh to benign environmental conditions, further suggesting that benign streams have more stable faunas overall.

Assemblages at individual localities.—In Piney Creek, every station had very significant ($P <$ 0.01–0.001) concordance of rank abundance of the common species (Table 4). This result contrasts with Ross et al. (1985) who reported (on the basis of only two collecting years, 1972 and 1981) significant concordance of species ranks at only two of five Piney Creek stations. In Brier Creek, Ross et al. found concordance significant in rank abundance of species at three of five stations. With the data set now available, four of five Brier Creek stations show significant concordance ($P < 0.05$) in abundance of common species across all years (Table 4). Thus, the new data set with additional years of collections shows more concordance in ranks of species at more individual stations than did the data set available to Ross et al. Overall for Brier and Piney creeks, we now report significant concordance of ranks of fish species at 9 of 10 stations, as compared to 5 of 10 in Ross et al. (1985). We wish to point out, however, that some unknown part of this difference could be due to use of two different statistical tests: a two sample Spearman ranks test in Ross et al. (1985) and a multiple-sample Kendall's W in the new analysis.

In the Kiamichi River, Station 3 was omitted from rank correlation tests of individual stations because the total catch of fishes at that site was too low to permit ranking with confidence. (For example, in 1985 we did not collect more then 15 individuals of any species at Station 3.) Of the remaining six Kiamichi River stations, three show significant ($P < 0.05$) rank correlation of common species (Stations 2, 6, and 7), and three show no significant correlation of species ranks across time (Stations 1, 5, and 8) (Table 4). There was no clear pattern (e.g., longitudinal position, stream size, etc.) with respect to the kinds of stations showing stable or unstable rank order of species in the Kiamichi River. It is tempting to question the data for Station 1 on the basis that it was the most difficult to sample. It was the only station too deep to seine bank-to-bank. However, as at all stations, effort at Station 1 was approximately equal across all

TABLE 4. CONCORDANCE OF RANKS OF THE MOST ABUNDANT SPECIES AT EACH STATION, ACROSS ALL YEARS OF SAMPLING AS DETERMINED BY KENDALL'S W. S = number of species included in analysis for each station, df = degrees of freedom.

Stream and station	S	W	X^2	df	*P*
Piney Creek					
9	10	0.481	25.96	9	<0.01
5	10	0.440	23.79	9	<0.01
4	10	0.494	26.65	9	<0.01
2	10	0.504	27.24	9	<0.01
1	10	0.593	32.02	9	<0.001
Brier Creek					
2	10	0.403	18.13	9	<0.05
3	10	0.308	13.87	9	n.s.
4	10	0.496	22.30	9	<0.01
5	10	0.663	29.85	9	<0.001
6	10	0.427	19.20	9	<0.05
Kiamichi River					
8	6	0.663	9.94	5	n.s.
7	9	0.674	16.18	8	<0.05
6	9	0.821	19.71	8	<0.02
5	10	0.544	14.68	9	n.s.
2	10	0.802	21.66	9	<0.01
1	10	0.413	11.15	9	n.s.

years. It is probably best to tentatively accept that in this river the rank order of some of the common species varies among years within some locations.

Some individual locations on all three streams showed more overall changes in assemblages between collections (Table 5) than did the whole faunas of the streams (Table 3). Several of the stations on all three streams showed low similarity values in at least one interval between collections (Table 5). Mean values of similarity across all time intervals were virtually indistinguishable between Piney Creek and Kiamichi River, with mean $I_m = 0.74$ and 0.78, and PSI = 0.60 and 0.62, (Table 5). The mean similarity values for individual stations on Brier Creek were slightly lower ($I_m = 0.65$; PSI = 0.53), but the differences between Piney Creek and Brier Creek values were not significant (F = 1.55 and F = 1.77 for I_m and PSI, respectively).

DISCUSSION

Ross et al. (1985) compared stability and persistence of fish assemblages for collections made

TABLE 5. MORISITA'S INDEX OF SIMILARITY FOLLOWED BY PERCENT SIMILARITY INDEX FOR FISH ASSEMBLAGES (ALL SPECIES) AT ALL STATIONS ON THE STUDY STREAMS. For each stream, stations are listed from headwaters to lower mainstream; major environmental events are noted.

Stream and station	Morisita's Index—PSI					
Piney Creek	1972–81	1981–82	1982–83 (flood)	1983–85	1985–86	Mean
P-9	.62–.51	.81–.65	.79–.65	.85–.67	.75–.57	.76–.61
P-5	.27–.24	.38–.35	.78–.54	.83–.67	.40–.42	.53–.54
P-4	.36–.27	.59–.49	.92–.73	.76–.59	.63–.60	.65–.54
P-2	.76–.57	.74–.59	.96–.80	.91–.74	.58–.49	.79–.64
P-1	.97–.78	.93–.75	.99–.84	.99–.87	.87–.69	.95–.78
Mean for interval:	.60–.47	.69–.56	.89–.71	.87–.71	.65–.55	Y = 0.74–0.60
Brier Creek	1969–76	1976-81 (drought)	1981–85 (flood)	1985–86		Mean
2	.32–.22	.71–.50	.87–.64	.97–.79		.72–.54
3	.03–.06	.41–.25	.68–.55	.99–.85		.53–.43
4	.79–.61	.78–.55	.95–.77	.80–.61		.83–.63
5	.97–.78	.33–.42	.90–.75	.50–.46		.68–.60
6	.57–.51	.43–.46	.47–.42	.51–.38		.50–.44
Mean for the interval:	.54–.44	.53–.44	.77–.63	.75–.62		Y = 0.65–0.53
Kiamichi River	1981–85	1985–86				Mean
8	.97–.80	.83–.59				.90–.70
7	.86–.68	.85–.65				.86–.67
6	.98–.79	.98–.82				.98–.81
5	.64–.57	.65–.52				.65–.54
3	.73–.49	.75–.53				.74–.51
2	.83–.63	.95–.77				.89–.70
1	.48–.45	.35–.43				.42–.44
Mean for interval:	.78–.63	.77–.62				Y = 0.78–0.62

in Piney Creek in the summers of 1972 and 1981 and in Brier Creek during 1969, 1976, and 1981 (with emphasis on 1969 vs 1981). In the present paper we evaluated stability of fish assemblages of Piney and Brier creeks on the basis of those previous collections and new collections in 1985 and 1986 (and 1982–83 in Piney Creek). Our results show that at the level of whole-stream faunas all three of the streams have been stable throughout the study period. With the temporally expanded data set we found significant rank correlation of abundance of common species in the faunas of all three streams across all times (stations pooled).

We found significant concordance of ranks of common species at 9 of 10 individual stations on Brier and Piney creeks. Ross et al. (1985) found significant concordance of ranks at only two of five Piney Creek stations, and suggested that the lack of concordance at individual stations in Piney Creek might be due to fishes moving readily among locations in an environmentally benign stream. The most parsimonious explanation of differences in the outcome of Ross et al. (1985) and the present study may be that there is indeed long-term stability to the assemblages at most sites on these two creeks, but that the shorter data set failed to provide evidence of this phenomenon. Therefore, although they differ markedly in environmental features and in potential physicochemical stress to native fishes, both of these creeks have fish assemblages that are generally stable or predictable across time at the local level (200–400 m stream reach).

It is clear, however, from Table 5 that some stations at some time intervals, particularly in Brier Creek, had substantial changes in fish assemblages as indicated by low similarity values. Several low-similarity intervals at Brier Creek stations are understandable in light of known conditions during the study years. For example, why does Station 3 (Table 5) in Brier Creek show a very low similarity of assemblage structure from 1969–76, high similarity in 1985–86, and a low mean for similarity values across the entire study (0.53 and 0.43, for Morisita's and PSI, respectively)? Station 3 is probably the least environmentally stable collecting location on Brier Creek. It is an ephemeral tributary, smaller even than Station 2 which is on the Brier Creek mainstream. Station 3 lacks water for long periods of time in most years, and the composition of the fish assemblage at this location in each summer depends almost completely upon dynamics of recolonization of fishes from permanent pools downstream. Thus, in some years an assemblage very similar to that of the previous year may be established, and some years by chance it may not. Station 6 on Brier Creek never showed similarity values as low as extreme values at Station 3, but Station 6 showed no intervals of high similarity (Table 5), and overall this site had lower mean similarity than other Brier Creek stations. Station 6 was probably unstable for two reasons. It is most downstream of our Brier Creek stations, and is subject to some movement of fishes in and out of the collecting reach from the nearby reservoir (Lake Texoma). Additionally, Station 6 was physically altered by a major flood in Oct. 1981, during which a large number of whole trees were deposited in the reach, remaining to the present and forming much different structure for fish habitat than existed before autumn 1981. About some low individual similarity values at stations on Piney or Brier creeks we can only speculate, but in many cases, like the above, known disturbances relate to low similarities of fish assemblages among years. Clearly, future research might focus on specific effects of particular disturbances, habitat alterations, etc., in stream fish communities, and we might also focus profitably upon compensating mechanisms such as migration, altered fecundity, or altered recruitment (as suggested in Matthews, 1986a, and Starrett, 1951) following perturbation.

We regard conclusions from the Kiamichi River data, which includes only three summers of sampling, as yet preliminary, but they provide comparison to the two smaller streams. Our findings on the Kiamichi River contrast in part with those for Piney and Brier creeks, in that only three of six individual stations show concordance of ranks of common species.

TABLE 6. SUMMARY OF SIMILARITY INDEX VALUES, BY RANGES, FOR ALL STATIONS ON THE THREE STREAMS, FROM TABLE 5. The combined index column is derived by applying the rules suggested by Linton et al. (1981) to use Morisita's index if its value equals or is greater than 0.92, and otherwise to use PSI.

Range of similarity index values	Number of stations with the indicated values		
	Morisita's	PSI	"Combined"
0–0.20	1	1	1
0.21–0.40	7	6	6
0.41–0.60	9	25	25
0.61–0.80	17	23	13
0.81–1.00	25	4	14
Total	59	59	59

To provide an overview of stability of fish assemblages at individual locations on these three midwestern streams, we tabulated in Table 6 the distribution of values for Moristia's index, PSI, and a combination of the two indices as explained below, for comparisons between all consecutive surveys for the stations on all three streams. For the PSI, 46% of the possible comparisons show similarity >0.60 between surveys at individual stations (Table 6). Of all calculated values for PSI, 88% are >0.40, and very few show complete or near-complete changes in the assemblages (<0.40). For Morisita's index, 71% of the possible comparisons were >0.80. Linton et al. (1981) showed in a detailed analysis of Morisita's index and PSI (as Schoener's index, with which PSI is identical) that Morisita's index generally overestimated, and PSI underestimated the true similarity value. Linton et al. (1981) showed that for similarity indices calculated from field data, Morisita's index was more near the true value than was PSI whenever Morisita's index = 0.92 or higher. If calculated values for Morisita's index were <0.92, Linton et al. recommended use of PSI. Therefore, in the combined column in Table 6, we summarize the frequency distribution of similarity indices for all comparisons at individuals stations, using Morisita's index values if they were 0.92 or greater, and PSI otherwise. In this combined view of similarities, which we regard as a best approximation to the unknowable true similarity, 46% of the cases have similarity >0.60, 42% of the cases are 0.41–0.60, and only 12% of the cases are 0.40 or lower. On the basis of this summary, we conclude overall that the majority of these, and probably other midwestern stream fish assemblages, have moderate to high stability even at the level of 200–400 m reaches of stream. We suggest that equilibrium-based community models could thus be applied, with caution, to typical fish assemblages of such stream reaches.

Many biologists have suggested that events like flood and drought play major roles in the structure of stream fish assemblages. However, Ross et al. (1985) pointed out that a very severe drought in 1980 had little permanent effect on the fish assemblages in Brier Creek. Matthews (1987) found that the fish assemblages in the headwaters of Brier Creek could be re-established rapidly by colonization when desiccated stream reaches were rewatered, and Ross et al. (1985) previously pointed out that the headwater fish assemblage of Brier Creek was stable, apparently resistent to or resilient following drought. Matthews (1986a) found that recovery of the Piney Creek fish community was rapid following a catastrophic flood in Dec. 1982. During the period included in the present study, both Brier and Piney creeks had very major floods (Power and Stewart, 1987; Matthews, 1986), and Brier Creek had severe droughts (Matthews et al., 1982; Matthews, 1987). Despite these disturbances, the fish faunas have been stable, and the local assemblages at individual locations have in many cases showed little change over time.

Ross et al. (1985), Matthews (1986a) and Ross et al. (1987) argued that stability of fish assemblages needs to be evaluated across more than one locality in any stream. The present results also suggest, for any given site, the desirability of having as many sampling periods as practical across time. Two glimpses in time (e.g., Piney Creek in Ross et al., 1985) may be less likely to detect long-term patterns in communities than are multiple samples. Increasing the number of years of sampling at any single site should give a better estimate of variance in community properties, and decrease the chance that a collection taken in a year with unusual environmental conditions will result in misleading conclusions about stability of an assemblage.

Our conclusions from the three streams are, therefore, that fish faunas in midwestern streams tend to be stable and persistent at the level of entire streams and that assemblages at many individual locations change little with time. Generalizations about North American stream fish assemblages as typically stable or typically unstable may not, however, be warranted (c.f. some Kiamichi River locations). A similar lack of generalization about temporal stability exists in studies of other kinds of fish assemblages. For example, numerous authors have found conflicting results about stability of reef fish assemblages (Sale and Douglas, 1984; Ebling et al., 1980; Ogden and Ebersole, 1981). Evidence based from additional long-term data sets is clearly needed before general conclusions can be made about stability of stream fish assemblages. Future studies should also be planned to address mechanisms in addition to merely documenting observed magnitudes of changes in faunas or assemblages.

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