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Distribution of Fish Within Headwater Riffles of the Illinois River System, Washington County, Arkansas

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DISTRIBUTION OF FISH WITHIN HEADWATER RIFFLES OF THE ILLINOIS RIVER SYSTEM, WASHINGTON COUNTY, ARKANSAS

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ABSTRACT

Quantitative sampling of fish was performed in five headwater riffles of the Illinois River System, Washington County, Arkansas during low flow conditions. This study revealed differing fish species composition, biomass and feeding guild segregation between head and tail riffle reaches in 1st through 3rd order. Thirty species representing 10 families were identified. Of this number, darters (Percidae), sculpins (Cottidae), madtoms (Ictaluridae), and central stonerollers *(Campostoma anomalum)* (Cyprinidae) comprised 67 to 98 percent of riffle head populations. Fish biomass was greater for riffle head areas (0.58-6.6/0.28-2.0 g/m²) with insectivores and herbivores dominating. Total fish numbers decreased from riffle heads to tails, while number of species increased. Dominant fish groups in tail areas were minnows (Cyprinidae), darters (Percidae), and sunfishes (Centrarchidae). Feeding guild fish groups in tail areas were predominately insectivore and insectivore-piscivore. Stomach analysis of *Cottus carolinae,* the dominant headwater riffle predator, indicated selective feeding of macrobenthic invertebrates and fish based on size class. Abundance of herbivore and insectivore fishes in riffles, particularly head reaches, suggests a correlation with positive rheotaxic behavior, microhabitat preference or abundance of macrobenthic invertebrate populations.

INTRODUCTION

Stream fish distribution, species number, and diversity have been found to increase with longitudinal distance from headwaters. Increase in species has been found by numerous investigators to be addition of species rather than replacement (Evans and Noble, 1979). Increase in diversity downstream has been steepest for those rivers with the steepest decrease in physical variability, and number of species in downstream sections was greater in rivers with more constant habitat conditions (Horwitz, 1978). Sheldon (1968) cited stream depth rather than longitudinal position in explaining observed changes. In biologically diverse streams distribution of fish species has been found to be constrained by environmental tolerances, competition, and predator-prey interactions (Smith and Powell, 1971). Distribution has also been correlated with habitat preference. Matthews and Hill (1979a; 1979b) and Matthews and Maness (1979) noted that seasonal changes and varying tolerances and preferences of cyprinids might result in differing patterns of distribution and movement.

Investigations into species preferences have suggested positive trends in specific habitat partitioning in a southern Mississippi river (Baker and Ross, 1981) and less structured overlap and transitory associations in a southwestern Oklahoma river (Matthews and Hill, 1980). Multivariate analysis has been used to delineate species preferences for habitat and distribution within stream reaches (Felley and Hill, 1983).

Community structure of fish populations has been shown to change with habitat type and season. Orth and Maughn (1984) working in a southeast Oklahoma stream stated that standing fish stocks were higher in pools than riffles. They also noted a difference in feeding structure between habitat type, with seasonal cycles dictating dominance of feeding guilds in riffles and pools. Matthews (1982) investigated six watersheds in the White River drainage of northwest Arkansas and southeast Missouri and found that the mutual abundance of thirteen species of fish was no more structured than could be explained by random occurrence.

Dewey (1981) reported that seasonal fluctuations in fish abundance occurred throughout the year in Mud Creek, a tributary of Clear Creek, in the Illinois River system, north-central Washington County, Arkansas. Five species of fish, *Notropis boops, Pimephales notatus, Fundulus olivaceus, Labidesthes sicculus,* and *Etheostoma spectabile* populations were estimated by the mark-recapture method twice monthly for one year. Dewey (1981) found *E. spectabile* and *Campostoma anomalum* to be stable, dominant species in his riffle substation. He also noted that riffle substation fish populations remained relatively stable throughout the year while pool populations fluctuated. Gerking (1959), Reed (1968), and Winn (1958) reported that *E. spectabile* was restricted in its movement, seldom moving from one riffle to another.

Position of fish species in riffles may be dependent on food availability or prey selectivity. Lotrich (1973) and Todd and Stewart (1985) have commented on the insectivorous feeding of darters and sculpins. In both studies habitat partitioning and prey selection were important factors in feeding of darters and sculpins.

Brown and Brown (1984) have documented a strong upstream-biased distribution of lotic insects within riffles of the Brazos River, Palo Pinto County, Texas, with greater abundance of insects toward the heads of riffles. Hoover (1985) noted that five species of fish inhabiting riffles of the Illinois River in Oklahoma fed on a diverse assemblage of invertebrates, primarily mayflies and chironomids. Todd and Stewart (1985) working in Flint Creek, Delaware County, Oklahoma found mayflies, chironomids, amphipods and crustacenas to be important dietary items of *E. spectabile, E. punctulatum* and *C. carolinae.* These

investigations suggest that if invertebrates are distributed in riffles with an upstream bias, fish feeding on invertebrates might show a similar bias.

This investigation tested the hypothesis that stream fishes inhabiting headwater riffles in the Illinois River System, Arkansas are partitioned in their distribution based on food and/or microhabitat preference during low flow conditions. And that fish biomass will change from head to tail within riffle reaches.

STUDY AREA

The Illinois River System lies in the extreme northeastern portion of Arkansas draining an area of approximately 1,200 km². The river is located in the Ozark Plateau, flows out of the Boston Mountains Plateau, across the predominantly limestone Springfield Plateau for 64 km attaining fifth order before being impounded at Lake Francis on the Arkansas-Oklahoma border (Limbeck, 1986). The majority of the drainage basin is karst-chert substratum covered by oak-hickory forest and pasture. Continuous flow in the headwater stream reaches is dependent on extended rainfall. Intermittent flow occurs in late summer and early fall (Borengasser, 1968).

Stream channels in the Illinois River System are fluvially-formed alluvial, riffle-pool structure from headwaters to at least fifth order. Long, deep, slow flowing pools alternate with short, shallow riffles. Gravel is concentrated in riffle areas and slopes of pools, while pool bottoms are predominantly bedrock (Brussock, 1986).

MATERIALS AND METHODS

Quantitative fish samples were collected in headwaters through third order reaches of the Illinois River system, Washington County, Arkansas (Fig. 1). Each riffle was visually inspected, measured, then partitioned into two areas, (head-tail) based on depth, flow, and substrate. Small mesh block nets were placed at the ends of each area to prevent fish movement in and out of the study area. Fishes were captured by electroshocking with a generator coupled to a variable voltage pulsator (Coffelt VVP-2C) and hand held electrodes. Specimens were preserved in 10% formalin in the field. Upon return to the laboratory, fish were identified to species (Buchanan, 1973), weighed, measured, preserved in 50% isopropanol and catalogued.

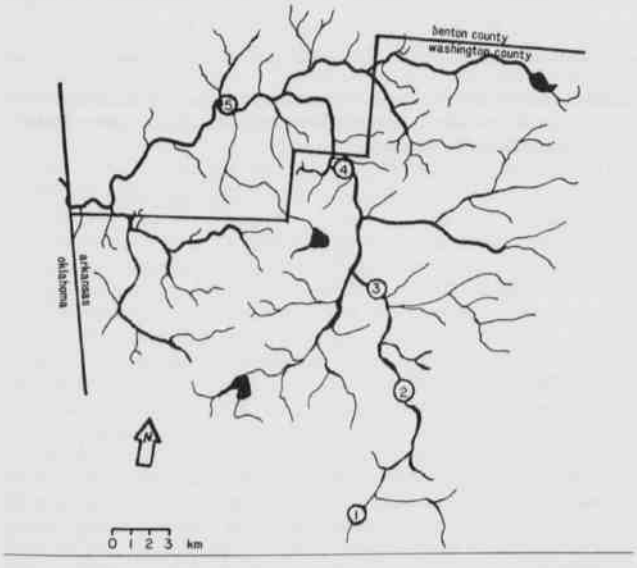

Figure 1. Map of Illinois River System, northwestern Arkansas from Brussock (1986). Stream orders in circles.

Population size for each species was estimated. Areas within sites were compared for fish community distribution and partitioning. Food preference was estimated for selected species. All species were grouped by feeding guilds based on general descriptions of food habits (Pflieger, 1975).

Food habits were determined for *C. carolinae*. After collection specimens were placed on ice. Upon return to the laboratory individual fish were weighed (gm), measured (mm), and 10% formalin was injected into abdominal cavities to preserve stomach contents. Individuals were segregated according to riffle head or tail and size class. Ten representatives were randomly selected from each size class, stomach contents analyzed (Hyslop, 1980), and identified to order. Surber samples were collected in head and tail riffle areas at two sites. Samples were preserved in 10% formalin in the field, upon return to the laboratory samples were washed in tap water, benthic organisms separated, enumerated and identified to order (Merritt and Cummins, 1984; Usinger, 1956).

Structure of the fish community at each site and habitat type was summarized using percentage composition of biomass by species and by feeding guild. Flow, dissolved oxygen, temperature and substrate particle size were determined in each study area following Platts *et al.* (1983).

RESULTS

A total of 1,720 individuals comprising ten families and thirty species were represented in electrofishing samples (Table 1). Although headwater riffle areas had fewer species (6-12/6-15) biomass was consistently higher than tail areas (0.58-6.6/0.28-2.0 g/m²). Fish biomass did not show an increase with stream order, but numbers and total weight of fish samples increased with stream order (Table 2). Mean length and weight per individual also increased with stream order. Darters (Percidae), sculpins (Cottidae), stonerollers (Cyprinidae), and madtom catfish (Ictaluridae) dominated riffle head samples (67-98%) and comprised a substantial percentage of tail area populations (35-77%).

Table 1. Species list for selected riffles, 1st through 3rd order reaches of the Illinois River System, Washington County, Arkansas (1 = herbivore-detritivore; 2 = omnivore; 3 = insectivore; 4 = insectivore-piscivore).

Clupeidae	Poeciliidae
Dorosoma cepedianum (2)	Gambusia affinis (3)
Cyprinidae	Atherinidae
Campostoma anomalum (1)	Labidesthes sicculus (3)
Hybopsis x-punctata (3)	
Nocomis asper (3)	Centrarchidae
Notropis boops (3)	
Notropis chrysocephalus (3)	Ambloplites ariommus (4)
Notropis nubilus (3)	Lepomis cyanellus (4)
Notropis spp. (3)	Lepomis macrochirus (3)
Notropis rubellus (3)	Lepomis megalotis (3)
Notropis telescopus (3)	Micropterus dolomieui (4)
Pimephales notatus (2)	Micropterus salmoides (4)
Catostomidae	Percidae
Hypentelium nigricans (3)	Etheostoma blennioides (3)
Moxostoma spp. juvenile (3)	Etheostoma flabellare (3)
	Etheostoma punctulatum (3)
Ictaluridae	Etheostoma spectabile (3)
	Etheostoma zonale (3)
Noturus exilis (3)	Percina caprodes (3)
Cyprinodontidae	Cottidae
Fundulus olivaceus (3)	Cottus carolinae (4)

Distribution of Fish Within Headwater Riffles of the Illinois River System, Washington County, Arkansas

Sunfishes (Centrarchidae) and minnows (Cyprinidae) were abundant in tail areas (23-61%) (Table 3).

Dominant feeding guilds in riffle head areas were herbivores and insectivores, while riffle tails were dominated by insectivores-piscivores, and omnivores (Table 1). *C. anomalum,* a herbivore, was the most numerous specimen collected at all sites, and was primarily concentrated in head areas of riffles. Large-size *C. carolinae,* insectivore-piscivore, *E. flabellare, E. spectabile* and *Noturus exilis,* insectivores, were also abundant in riffle heads. Smaller sizes of *C. carolinae* were consistently collected in riffle tails. *Lepomis cyanellus, L. megalotis, Micropterus dolomieui,* and *M. salmoides,* insectivores-piscivores; *N. boops, N. spp., N. telescopes,* insectivores; and *P. notatus,* an omnivore; dominated riffle tail areas.

A total of seventy-two *C. carolinae* (49 riffle heads; 23 riffle tails) were colllected. Large-size *C. carolinae* (75-112 mm) were more abundant than small-size sculpins in riffle head areas. Dominant food items for this group consisted of Isopoda (17.4%), Decopoda (26.1%), and fish (43.5%), while Diptera (61.8%) and Ephemeroptera (18.1%) were major food items for small-size sculpins (37-59 mm) (Table 4). In forty percent of large *C. carolinae,* fish and *Orconectes* (Decopoda) were the only food items in stomachs. Surber samples at two sites showed a high abundance of Diptera (Chironomids) and Ephemeroptera in both riffle heads and tails (Table 5).

Study areas differed greatly in channel and water width, depth, substrate particle size, and length (Table 6). Riffle heads were smaller in area (m^2), shallower, swifter and had a more heterogenous substrate than riffle tails. Channel water width was wider in head areas, but length

Table 2. Fish biomass, numbers, and area for head/tail riffle areas of selected reaches (1st - 3rd order) of the Illinois River System, Washington County, Arkansas.

3rd order ---------->	Hwy 31		Savoy Road		Harmon Road		Great House		Small Trib.	
	H	T	H	T	H	T	H	T	H	T
Length (m)	29	43	12	21	60	60	8	30	7	30
Width (m)	17.6	14.3	22.3	7.4	32.0	32.0	17.5	7.3	4.2	6.3
Area (m^2)	510.4	614.9	276.6	255.4	1920	1920	140	219	29.2	189
Number Fish	305	123	706	167	114	72	94	34	47	58
Weight Total	528	568	1384	315	1113	538	262	122	192	153
Biomass (g/m^2)	1.03	0.92	5.00	2.03	0.58	0.28	1.87	0.56	6.60	0.81
Species Number	7	15	12	15	11	11	8	6	7	6

Table 3. Percent composition by number of fish group in head and tail riffle areas (1st - 3rd order), Illinois River System, Washington County, Arkansas.

3rd order ---------->	Hwy 31		Savoy Road		Harmon Road		Great House		Small Trib.	
	H	T	H	T	H	T	H	T	H	T
Darters % Total	0.05	0.06	0.05	0.19	0.06	0.11	0.64	0.21	0.57	0.02
Sculpins % Total	0.02	0.07	0.03	0.03	0.07	0.16	0.10	0.32	0.28	0.03
Stonerollers %Total	0.91	0.36	0.84	0.53	0.34	0.14	0	0.09	0.06	0.30
Madtoms % Total	0	0	0.03	0.02	0.02	0.03	0.13	0.08	0	0
Total (x100)	98	49	95	77	49	44	87	70	94	35
Sunfish % Total	0.02	0.08	0.02	0.01	0.06	0.16	0.07	0	0.06	0.01
Minnows % Total	0	0.25	0.03	0.22	0.42	0.39	0.04	0.26	0	0.60
Total (x100)	2	33	5	23	48	55	11	26	6	61

Table 4. Percentage of food items by number for two size classes of Cottus *Cottus carolinae,* Illinois River System, Washington County, Arkansas.

Food Item	Size Class (37 - 59 mm)	(75 - 112 mm)
Diptera (Chironomids)	61.8	0
Ephemeroptera	18.1	8.7
Plecoptera	1.8	4.3
Tricoptera	7.3	0
Amphipoda	9.1	0
Isopoda	1.8	17.4
Decopoda (Orconectes)	0	26.1
Fish	0	43.5

Table 5. Percentages of benthic organisms by number identified from Surber samples of two sites in headwater riffles, Illinois River System, Washington County, Arkansas.

Organism	Otter Creek Head	Otter Creek Tail	Great House Spring Head	Great House Spring Tail
Diptera	24.3	19.3	42.7	17.2
Ephemeroptera	44.3	22.7	33.0	41.3
Tricoptera	5.2	7.6	5.6	3.4
Decapoda	0.8	0.8	0.8	10.3
Amphipoda	9.6	18.5	0	0
Isopoda	0.8	2.5	0	0
Annelida	0	4.2	0	10.3
Odonata	13.9	17.6	8.1	0
Megaloptera	0	0	1.6	0
Coleoptera	0	0	0.8	13.8
Mollusca	0	0	5.6	3.4
Unidentified	0.8	3.4	0	0

of head areas was substantially less than tails. Dissolved oxygen, specific conductance and canopy closure did not change through study sites (Table 6). Steambank erosion was great, canopy closure and instream cover were lacking in several sample reaches.

Table 6. Physical and chemical parameters for selected riffles (1st - 3rd order) of the Illinois River System, Washington County, Arkansas.

3rd order----------)----------)----------)---------) 1st order

	Hwy 31		Savoy Road		Harmon Road		Great House		Small Trib.	
	H	T	H	T	H	T	H	T	H	T
Channel Width (m)	17.6	14.3	24.4	29.5	---	---	21.2	25.5	---	--
Water Width (m)	17.6	14.3	22.3	7.4	32.0	32.0	17.5	7.3	4.2	6.3
Depth 1/4	0.5	1.3	1.3	3.1	---	---	1.4	1.5	0.3	0.5
(ft) 1/2	1.1	2.1	1.4	1.9	---	---	1.5	1.0	0.5	0.8
3/4	1.2	1.4	1.3	0.7	---	---	1.1	1.5	0.4	0.7
Substrate	gr/cb	gr/cb	gr/cb	gr	gr	bd	gr/cb	gr/cb	gr	gr
Length (m)	29.0	43.0	12.0	21.4	60.0	60.0	8.1	30.0	7.0	30
Dissolved Oxygen (mg/1)	8.7	8.7	8.7	8.7	8.2	8.2	8.3	8.3	8.6	8.6
Specific Conductance (umhos)	230	224	228	230	218	226	232	228	224	230

DISCUSSION

Stream fish distribution, species number and diversity have been found to increase with longitudinal distances from headwaters. Increase in species number has been attributed to addition rather than replacement of species (Evans and Noble, 1979). Increase in diversity has been highest with highest decrease in variability (Horwitz, 1978). In biologically diverse streams, such as the Illinois River system, distribution of fish species has been found to be constrained by environmental tolerances, competition and preditor-prey interactions (Smith and Powell, 1971); and habitat and food preference (Matthews and Hill, 1979a, 1979b; Orth and Maughn, 1984). In this investigation bottom dwelling insectivorous, and herbivorous fish species preferred riffle heads over tails. Lotrich (1973) and Todd and Stewart (1985) have documented the selective feeding of sculpins (Cottidae) and darters (Percidae) on mayflies (Ephemeroptera) and chironomids (Diptera). Todd and Stewart (1985) further stated that primary food sources of *E. spectabile* and *C. carolinae* in Flint Creek, Oklahoma were mayflies, chironomids, amphipods and crustaceans. Both of these fish were primary species in every riffle head collection of this investigation.

Food analysis of *C. carolinae* stomach contents confirmed findings of both investigations, however we found large *C. carolinae* to contain a high amount (43.5%) of fish material in their stomach contents. In 40% of large-size *C. carolinae* fish and Decopoda were sole food items. This suggests that large-size *C. carolinae* preferred fish and Decopod crustaceans over smaller food items and may indicate a greater availability of food items (fish and macrobenthos) in riffle heads. There was also a noticeable difference in the preference for food items between the two size classes of *C. carolinae. No Diptera larvae were found in the larger-size class of C. carolinae,* this group was the dominant food of small-size individuals. Daiber (1956) reported that chironomids decrease as a food source for sculpins as the sculpins increase in size. Larger food items such as fish and Decopoda represent a high energy food source, and may be correlated with increased mouth size in large-size sculpins. Food habit studies concerning sculpins have generated conflicting results, Gill (1905) described sculpins as omnivores; Todd and Stewart (1985) described sculpins as insectivores; Northcote (1954), Yoshiyama (1980), and Bailey (1952) stated that young sculpins feed an aquatic insects, their food habits changing with increasing size. Northcote (1954) stated that food items of large-size sculpins are primarily fish, due in part to large mouth-size. Food preference of *C. carolinae* in headwater areas of the Illinois River system is vital in understanding the fish community structure because riffle fish populations are stable over all seasons. *C. carolinae* may represent the top carnivore of headwater riffles in the Illinois River system.

Brown and Brown (1984) found several species of Ephemeroptera, Trichoptera, and Diptera (Chironomidae) to be positively attracted to riffle heads in the Brazos River, Palo Pinto County, Texas. Brown (per. comm.) has noted similar tendencies of these groups in Clear Creek, Washington County, Arkansas, a 3rd order tributary of the Illinois River. It appears that high populations of macrobenthic invertebrates, especially insects, in head portions of riffles attract darters, sculpins, and madtom catfish all of which are insectivores at various life stages.

C. anomalum was the most abundant species in 60% of sample stations, and occurred in highest numbers in riffle head areas (50%/29%). Orth and Maughn (1984), Pflieger (1975), and Sewell *et al.* (1980) consider this species to be herbivorous. Bottom substrate in all sample sites was covered with periphyton. Although there was no visual difference in periphyton coverage between riffle heads or tails, Brown and Todd (per. comm.) have found greater concentrations of periphyton in riffle heads in the Illinois River based on dry weight, ATP, and chlorophyll a analyses. Position of *C. anomalum* in riffle heads may have been due to abundance of periphyton, current, depth, positive rehotaxis, or a combination of factors.

In this investigation fish biomass was highest in head areas of riffles (0.58-6.6/0.28-2.0 g/m^2). This concentration of insectivores and herbivores did not carry through to riffle tails. In tail areas more general feeders insectivores, insectivores-piscivores and omnivores dominated populations. Centrarchids and cyprinids, preferred slower flowing, deeper riffle tail areas.

Although numerous studies have been conducted on fish habitat preferences in stream systems on a holistic basis, no intensive studies have dealt with riffle habitat partitioning or preference by species or groups of fish. This investigation indicated that riffle fish species were partitioned on food and microhabitat preference. There was a distinct tendency for bottom dwelling darters, sculpins, and madtom catfish to be located in riffle head areas where macrobenthic invertebrates may be concentrated. More general feeders, minnows and sunfishes preferred less turbulent, slower flowing, deeper tail water areas. This investigation raises the question whether day/night riffle partitioning is similar and to what extent seasonality affects riffle species composition and feeding guild structure.

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LITERATURE CITED

BAILEY, J. F. 1952. Life history and ecology of the sculpin *Cottus bairdi punctulatus* in southwestern Montana. Copeia 1952:243-255.

BAKER, J. A. and S. T. ROSS. 1981. Spatial and temporal resource utilization by southeastern cyprinids. Copeia 1981:178-189.

BORENGASSER, M. J. 1968. The physical geography of Washington County, Arkansas. M.S. thesis, Univ. of Arkansas, Fayetteville, AR. 113 pp.

BROWN, A. V. (per. comm.). Clear Cr. site specific data for macrobenthic invertebrate populations - Stream Ecology class field trips.

BROWN, A. V. and K. B. BROWN. 1984. Distribution of insects within riffles of streams. Freshwater Invert. Biol. 3:2-11.

BROWN, A. V. and C. S. TODD. (per. comm.). Ongoing studies of periphyton populations in the Illinois River, Arkansas.

BRUSSOCK, P. P. 1986. Microdistribution and movements of benthic macroinvertebrates in relation to stream geomorphology. Ph.D. Dissertation. Univ. of Arkansas, Fayetteville, AR. 160 pp.

BUCHANAN, T. M. 1973. Key to the Fishes of Arkansas. Arkansas Game and Fish Comm., Little Rock, AR. 68 pp.

DAIBER, F. C. 1956. A copmaritive analysis of the winter feeding habits of two benthic stream fishes. Copeia 1956:141-151.

DEWEY, M. R. 1981. Seasonal abundance, movement and diversity of fishes in an Ozark stream. Proc. Ark. Acad. Sci. 35:33-39.

EVANS, J. W. and R. L. NOBLE. 1979. The longitudinal distribution of fishes in an east Texas stream. Amer. Midl. Nat. 101:333-343.

FELLEY, J. D. and L. G. HILL. 1983. Multivariate assessment of environmental preferences of cyprinid fishes of the Illinois River, Oklahoma. Amer. Midl. Nat. 109:209-221.

GERKING, S. D. 1959. The restricted movements of fish populations. Biol. Rev. 34:221-242.

GILL, T. 1905. The sculpin and its habits. Smithsonian Miscellaneous Collections 47:348-387.

HOOVER, J. J. 1985. Feeding ecology of some small Ozark stream fishes. Great Plains Limno. Conf., Fayetteville, AR.

HORWITZ, R. J. 1978. Temporal variability patterns and the distributional pattern of stream fishes. Ecol. Monogr. 48:307-321.

HYSLOP, E. J. 1980. Stomach contents analysis - A review of methods and their application. J. Fish. Biol. 17:411-429.

LIMBECK, R. L. 1986. Zooplankton dynamics in headwaters and midreaches of the Illinois River, Arkansas. M.S. thesis, Univ. of Arkansas, Fayetteville, AR.

LOTRICH, V. A. 1973. Growth, production, and community composition of fishes inhabiting a first, second, and third order stream of eastern Kentucky. Ecol. Monogr. 43:377-397.

MATTHEWS, W. J. 1982. Small fish community structure in Ozark streams: structured assembly patterns or random abundance of species? Amer. Midl. Nat. 107:42-54.

MATTHEWS, W. J. and L. G. HILL. 1979a. Age specific differences in the distribution of red shiners *(Notropis lutrensis)* over physiochemical ranges. Amer. Midl. Nat. 101:366-372.

MATTHEWS, W. J. and L. G. HILL. 1979b. Influence of physicochemical factors on habitat selection by red shiners *Notropis lutrensis* (Pisces, Cyprinidae). Copeia 1979:70-81.

MATTHEWS, W. J. and L. G. HILL. 1979b. Influence of physicochemical factors on habitat selection by red shiners *Notropis lutrensis* (Pisces, Cyprinidae). Copeia 1979:70-81.

MATTHEWS, W. J. and J. D. MANESS. 1979. Critical thermal maxima, oxygen tolerances, and success of cyprinid fishes in a southeastern river. Amer. Midl. Nat. 102:374-377.

MERRITT, R. W. and K. W. CUMMINS. 1984. An introduction to the aquatic insects of North America. 2nd ed. Kendall-Hunt Pub. Co., Dubuque, IA. 722 pp.

NORTHCOTE, T. G. 1954. Observations on the comparative ecology of two species of fish, *Cottus asper* and *Cottus rhotheus*, in British Columbia. Copeia 1954:25-28.

ORTH, D. J. and O. E. MAUGHN. 1984. Community structure and seasonal changes in standing stocks of fish in a warmwater stream. Amer. Midl. Nat. 112:369-378.

PFLIEGER, W. L. 1975. The fishes of Missouri. Missouri Dept. Conserv., Springfield, MO. 343 pp.

PLATTS, W. S., W. F. MEGHAN and G. W. MINSHALL. 1983. Methods for evaluating stream, riparian and biotic conditions. U.S. Dept. Agr., Forest Service Gen. Tech. PUbl. Rept. INT-138, Ogden, UT. 70 pp.

REED, R. 1968. Mark and recapture studies of eight species of darters in three streams in northwestern Pennsylvania. Copeia 1968:172-175.

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

SMITH, C. L. and C. R. POWELL. 1971. The summer fish community of Brier Creek, Marshall County, Oklahoma. Amer. Mus. Novit. 2458:1-30.

SWELL, S. A., J. K. BEADLES and V. R. McDANIEL. 1980. The systematic status of the fishes of the genus *Campostoma* (Cyprinidae) inhabiting the major drainages of northern Arkansas. Proc. Arkansas Acad. Sci. 34:97-100.

TODD, C. S. and K. W. STEWART. 1985. Food habits and dietary overlap of nongame insectivorous fishes in Flint Creek, Oklahoma, a western Ozark foothills stream. Great Basin Natr. 45:721-733.

USINGER, R. L. (ed.) 1956. Aquatic insects of California. Univ. Calif. Press, Berkeley, CA. 508 pp.

WINN, H. F. 1958. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae). Ecol. Monogr. 28:155-191.

YOSHIYAMA, R. M. 1980. Food habits of three species of rocky intertidal sculpins (Cottidae) in central California. Copeia 1980:515-525.