Fish Community Structure and Zonation Related to Stream Habitat

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Abstract: Twenty-seven quantitative fish collections and site habitat analyses were performed from October 1985 to April 1988 in the Little Missouri River in Southwest Arkansas. Longitudinal addition of fish species (from 9 to 30) corresponded to downstream change in physical habitat. Species diversity increased from headwaters to midreaches and was positively correlated with increasing stream size, decreasing particle substrate size, depth, and development of alluvial riffle/pool morphology. The prime factor associated with the increasing fish species diversity was the corresponding increase in habitat diversity downstream. Fish feeding guild structure did not change from headwaters to midreaches. Insectivore/herbivore feeding guilds dominated all riffles and shallow pools. Insectivore/piscivore feeding guilds dominated all deep pools. Differences in species diversity among sample reaches progressing downstream was gradual. Diversity was affected by striped bass and spotted suckers migrating from a downstream impoundment on a seasonal basis and by stocked rainbow trout. This study demonstrated that single reach samples would not be adequate to characterize the stream system or its drainage basin when progressing through diverse geomorphology.

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Sampling of fish communities in stream reaches has been investigated as a means of characterizing stream systems. Fausch et al. (1984) suggested that fish assemblages changed gradually with stream order. From a biotic sense, 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 usually be addition of species rather than replacement (Evans and Noble 1979). Increase in diversity downstream has been greatest for those rivers with the most decrease in variability, and number of species in downstream sections was greater in rivers with more constant variables (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 (1979*a, b*) 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) and statewide within drainage regions (Matthews and Robison 1988).

Community structure of fish populations has been shown to change with habitat type and season (Barila et al. 1981, Karr 1981, Rose and Echelle 1981, Guillory 1982). Orth and Maughan (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 6 watersheds in the White River drainage of northwest Arkansas and southeast Missouri and found that the mutual abundance of 13 species of fish was no more structured than could be explained by random occurrence. The purpose of this study was to refine stream sampling procedures used to assess stream fish populations and instream and riparian habitat; determine the variation in fish species composition and diversity with longitudinal position and change in geology; and to evaluate the accuracy of reach samples in predicting entire stream fish assemblages, composition, and diversity.

Methods

The Little Missouri River drains the southwestern portion of the Ouachita Mountains (48,000 km^2) in westcentral Arkansas (Andrews 1970). Stream channels are relatively steep with narrow flood plains. The river in its headwaters is debris regulated, incised, well confined, and moderately entrenched with a boulder, cobble, and coarse grain substrate. In its midreaches, the river is moderately confined and slightly entrenched with a cobble and coarse grain substrate and alternating pools and riffles. Thirty-seven kilometers from its headwaters, the river is impounded, forming Lake Greeson. Below Lake Greeson, the river flows through the Gulf Coastal Plain into the Ouachita River. The study was conducted in the headwaters to midreaches of the river. Elevation dropped from 521 m at the headwaters to 314 m at the Albert Pike pool. All sample sites were located on the Ouachita National Forest, Montgomery County, Arkansas. Forest types in the study area consisted of oak-hickory and pine.

Stream segments were delineated into debris regulated headwater channels and riffle/pool midreach channels following morphological methods of Brussock et al.

(1985). Ten study reaches were selected, 5 sites in the debris regulated portion and 5 sites in the riffle/pool portion. Sites were sampled at least 3 times per year corresponding to Arkansas flow periods (Filipek et al. 1987). Each sample site was initially channel typed following the methods of D. L. Rosgen (unpubl. rep., U.S. Dep. Agric., For. Serv., 1965). Stream order for sample sections was determined using the counter crennulation method.

Population estimates were made from October 1985 to April 1988 resulting in 27 observations (18 riffles/9 pools). Sites were isolated with block nets (6.4 mm mesh) at the upstream and downstream ends prior to estimates to prevent movement of fishes into and out of the study area. Fishes were captured with either a bank generator coupled with a variable voltage pulsator (Coffelt VVP-2C) and hand held electrodes or a boat mounted generator, variable voltage pulsator (Coffelt VVP-2E), and boat mounted electrodes. Both shocking units used variable voltage, pulsed direct current, or alternating current. The boat mounted unit was used in large deep pools. Fishes were captured on 3 or more complete passes through the site and held outside the site in live wells or buckets. Fishes from each unit of effort were either identified to species, counted, weighed (gm), and measured (mm-TL) individually in the field, or preserved in 10% formalin and returned to the laboratory for similar analysis. Representative specimens were cataloged into the freshwater fishes collection, Arkansas Tech University, Russellville, Arkansas.

Population size for each species was estimated following Van Deventer and Platts (1985). Biomass was estimated for each species at each site by multiplying the population estimate by the mean individual weight. The surface area of each study site was measured and standing stocks were reported in kg/ha. Species diversity at each site was computed following methods outlined in Shannon and Weaver (1949).

All species were grouped according to feeding guild based on general food habitat descriptions (Buchanan 1973, Pflieger 1975). The structure of the fish community in each habitat type was summarized using feeding guild and percent composition by species.

Stream habitat was surveyed at each site. Transects at 10 m intervals and perpendicular to stream flow were examined for entire riffles or pools (Hankin 1986). On each transect, channel and water width were measured to the nearest decimeter and depth recorded to the nearest cm at 5 locations. Substrate along each transect was visually examined and percent composition of clay, silt, gravel, rubble, boulder, and bedrock estimated. Canopy closure was measured at 3 points on each transect line and averaged to a percent. Longitudinal cover and pool rating among numerous additional habitat parameters were also collected on each transect following the methods of D. J. Ebert et al (unpubl. rep., U.S. Dep. Agric., For. Serv., 1987) a modification of the line transect system of Platts et al. (1983), Fisheries Habitat Relationships (FHR) methods of Parsons (unpubl. rep., Colo-Wyo Chap. Am. Fish. Soc., 1984), General Aquatic and Wildlife System (GAWS) of J. G. McBride et al. (unpubl. rep., U.S. Dep. Agric., For. Serv., 1985) and riparian analysis methods of

Platts et al. (1987). Selected water quality and stream flow measurements were collected at each site.

Results

A total of 4,779 individuals comprising 9 families and 31 species were represented in the electrofishing samples. Number of species increased with longitudinal progression from headwaters to upper midreaches (Table 1). This progression was associated with addition of new species rather than species replacement. Sixty-two percent of species added with increasing stream order were either pool species or slow water, large channel species (Table 1). As the river progressed from headwaters to midreaches the channel widened (water width/channel width), mean substrate particle size decreased, stream type changed, canopy closure decreased and then increased, and mean depth in pools and riffles increased (Table 2).

Headwater fish fauna was characterized by riffle species, with minnows dominating. Yellow bullheads (*Ictalurus natalis*) and juvenile sunfish (*Lepomis sp.*) were also present in lower numbers. As the river progressed downstream percent composition by number for central stonerollers (*Campostoma anomalum*) remained stable. This species was the most numerous fish collected at all sites. Percent composition for creek chubs (*Semotilus atromaculatus*) and striped shiners (*Notropis chrysocephalus*) decreased with increasing longitudinal distance from headwaters, while longear sunfish (*L. megalotis*) and greenside darters (*Etheostoma blennioides*) increased in numbers. All of the 9 species collected at site 1 were found at other stations (Table 1). Species additions were related to an overall headwater-downstream increase, species number was not clearly correlated with stream order, and it increased regularly downstream within orders (Table 1). Relative abundance for an individual species in some cases showed a regular increase, in others a decrease, others remained constant. Two species, spotted sucker (*Minytrema melanops*) and striped bass (*Morone saxatilis*), were migrants from Lake Greeson, 37 kilometers downstream. Rainbow trout (*Salmo gairdneri*) were supplementally stocked annually from mid-December through early April.

The river, in second and third order sections, passed through a boulder/pool, debris regulated channel configuration. In this section, smallmouth bass (*Micropterus dolomieui*), rainbow trout, northern hogsucker (*Hypentilium nigricans*), and central stoneroller were more abundant than in other sections. Fish biomass and diversity increased through the debris regulated area. Species characteristic of pools dominated additions. When a riffle species was collected in fourth and fifth order sections it was characteristic of low gradient wide channels. Redfin (*E. whipplei*) and fantail (*E. flabellare*) darters represent such changes (Table 1). Striped shiner, abundant in headwaters, gradually declined in numbers, and bigeye shiner (*N. boops*) absent in swifter flowing headwater areas, increased with upper midreaches. Fish biomass and diversity was higher in lower reaches than headwaters (Table 1).

Habitat diversity increased with downstream progression. The stream channel

Table 1. Percent composition of fish based on stream order, Little Missouri River, Arkansas (1985–1988).

Common name	Scientific name	Guild[a]	Stream order 1–2	3	4	5
Orangebelly darter	*Etheostoma radiosum*	I	8.6	0.9	5.7	9.4
Central stoneroller	*Campostoma anomalum*	H	32.8	51.4	47.4	29.6
Creek chub	*Sematolis atromaculatus*	I	24.4	1.9	<0.5	<0.5
Striped shiner	*Notropis chrysocephalus*	I	17.7	10.3	9.4	1.3
Yellow bullhead	*Ictalurus natalis*	O	7.9	12.6	0.9	1.3
Longear sunfish	*Lepomis megalotis*	I	7.5	4.8	20.3	30.8
Greenside darter	*Etheostoma blennioides*	I	<0.5	<0.5	2.7	3.1
Redfin shiner	*Notropis umbratilis*	I	<0.5	<0.5	<0.5	0.7
Northern studfish	*Fundulus catenatus*	I	<0.5	1.9	2.4	5.9
Slender madtom	*Noturus exilus*	I	—	<0.5	0.5	<0.5
Smallmouth bass	*Micropterus dolomieui*	X	—	4.8	1.6	1.9
Rainbow trout	*Salmo gairdneri*	X	—	2.9	0.5	0.5
Northern hogsucker	*Hypentilium nigricans*	I	—	5.8	4.8	1.9
Ouachita shiner	*Notropis ouachitae*	I	—	<0.5	<0.5	<0.5
Shadow bass	*Ambloplites ariomus*	X	—	—	<0.5	0.8
Green sunfish	*Lepomis cyanellus*	X	—	—	<0.5	<0.5
Bigeye shiner	*Notropis boops*	I	—	—	2.0	4.9
Spotted sucker	*Minytrema menalops*	I	—	—	<0.5	<0.5
Bluntnose minnow	*Pimephales notatus*	O	—	—	<0.5	1.6
Logperch	*Percina caprodes*	I	—	—	<0.5	<0.5
Striped bass	*Morone saxatilis*	P	—	—	<0.5	<0.5
Redfin darter	*Etheostoma whipplei*	I	—	—	—	<0.5
Brook silverside	*Labidesthes sicculus*	I	—	—	—	1.9
Orangespotted sunfish	*Lepomis humilis*	I	—	—	—	<0.5
Blackspotted topminnow	*Fundulus olivaceus*	I	—	—	—	<0.5
Blackstriped topminnow	*Fundulus notatus*	I	—	—	—	1.5
Caddo madtom	*Noturus taylori*	I	—	—	—	<0.5
Juvenile darters	*Etheostoma spp.*	I	—	—	—	<0.5
Bluegill	*Lepomis macrochirus*	I	—	—	—	<0.5
Golden redhorse	*Moxostoma erythrurum*	I	—	—	—	<0.5
Largemouth bass	*Micropterus salmoides*	X	—	—	—	<0.5

[a]H = herbivore, I = insectivore, O = omnivore, P = piscivore, X = insectivore-piscivore.

Table 2. Selected habitat parameters for the Little Missouri River from headwaters to midreaches.

Head	STREAM ORDER 1–2	3	4	Midreach >5
Fish feeding guild	herbivore/ insectivore-piscivore			>
Substrate type	boulder/gravel	boulder	boulder/ gravel	boulder/ cobble/ gravel
Stream type	spring/riffle	boulder/ pool	boulder/ riffle/ pool	same
Canopy closure	89%	6%	31%	26%
Water width/ channel width (m)	8.6/12.6	9.8/26.5	11.7/31.9	18.6/31.4
N fish spp.	9	11	20	30
Average fish biomass (gm/m^2)	0.71	0.93	1.15	1.21
Average fish diversity	0.56	0.98	1.35	1.67
Mean depth riffle/ pool (m)	0.18/0	0.27/0.69	0.42/0.78	0.36/0.81

became wider (water width/channel width - 8.6/12.6 - 18.6/31.6 m), canopy closure decreased, substrate particle size became more heterogeneous (boulder/cobble/ gravel) and mean riffle/pool depth increased (0.18/0 - .36/81 m) (Table 2).

Fish feeding guild structure did not change from headwaters to upper midreaches. Herbivore and insectivore-piscivore feeding groups dominated all sites regardless of stream order. The central stoneroller, the most numerous species collected, was the only herbivore present in the stream. The striped bass was considered to be strictly piscivorous in the system. Bluntnose minnow (*Pimephales notatus*) and yellow bullhead were classified as omnivorous. All remaining species were insectivore or insectivore/piscivore (Table 1).

Discussion

Longitudinal succession by addition of stream fishes has been demonstrated by numerous investigators (Lotrich 1973, Horwitz 1978, Evans and Noble 1979). This investigation adds to that evidence. The principle of increase by addition of species may be considered valid for many geographic areas. This results from increase in habit diversity or habitat addition and stability with longitudinal distance from headwaters (Evans and Noble 1979).

Species additions in our study increased with longitudinal distance from the headwaters to upper midreaches. These additions were the result of greater habitat variability. Sheldon (1968), Deacon and Bradley (1972), Whiteside and McNatt (1972), Tramer and Rogers (1973), Gorman and Karr (1978), Foltz (1982), and Orth and Maughan (1984) have documented increased species diversity with habitat and substrate diversity. Orth and Maughan (1984) noted fish stocks higher in pools than riffles in midreaches of Glover Creek, Oklahoma, with insectivores dominating riffles and insectivores/piscivores dominating pools.

Fish species composition differed greatly among sites within the system, primarily based on stream order. Fish fauna of the stream can only be characterized through evaluation of many sample sites. Single sample sites in headwater areas would drastically underestimate overall species composition. Likewise, headwater or midreach samples alone might result in uncharacteristic biomass or diversity estimates. An appropriate method of stream evaluation would need to include both boulder-debris regulated and riffle-pool reaches. Garman et al. (1982) noted that single site sampling of Brumley Creek, Virginia, underestimated fish species composition. In our study, entire riffle or pool reaches were sampled following Hankin (1986). This method elevated the possibility of splitting populations. However, of 31 species captured in total, 72% were captured at the richest riffle reach and 48% captured at the richest pool site.

The fish fauna of the Little Missouri River was affected through introduction of supplementally stocked rainbow trout and migrating striped bass and spotted suckers from Lake Greeson 37 kilometers downstream. Although habitat modification appeared to be minimal in the watershed, single reach fish population sampling might have indicated modification. Spring sampling consistently indicated spotted suckers as codominants by weight in many pools and riffles. This species was not collected in summer or fall samples in riffles and very seldom in pools. Specific reach samples only collected during low flow summer months would not detect the presence of this species. Rainbow trout, abundant at stocking sites in the spring were seldom collected during the remainder of the year. Carryover of small numbers of trout was evident in the boulder regulated reaches of the stream. Competition of trout and smallmouth bass appeared to be minimal, due primarily to overall low carryover of trout and abundance of smallmouth bass in seasonal samples.

In evaluation of stream systems for biotic and abiotic factors we recommend: 1) inventory and physically type the study watershed to delineate the geomorphology and channel types of the river system, since abiotic characters usually control biotic populations; 2) sample distinct riffle or pool habitats, thus enabling the manager to assess entire biotic communities; 3) conduct multiple reach samples during representative yearly flow periods for at least 2 years, and do not rely solely on low flow samples; and 4) develop management recommendations based on acceptable biotic and abiotic information.

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