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# Composition of Fish Communities on and off Mussel Beds in the Kiamichi River, Oklahoma

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**Abstract:** Fishes and mussels are prominent organisms in streams of eastern North America. Fish communities have large effects on mussel communities because mussels disperse as ectoparasitic larvae on fish hosts. Mussel communities influence the abundance and composition of algae and macroinvertebrates in streams by providing shell habitat and nutrient subsidies from their excreta, possibly influencing fish communities through these same mechanisms. To begin addressing this question, we asked if fish composition varied on and off mussel beds in the Kiamichi River in Southeastern Oklahoma. We also asked how any observed variation in fish composition between mussel and non-mussel sites was related to fish feeding and nesting traits. We quantitatively sampled 10 sites in summer 2013, including five with and five without large mussel beds. We found no significant differences in fish abundance, richness, or feeding guilds between mussel and non-mussel sites. However, mussel sites had a significantly higher proportion of nest building fish than non-mussel sites. Our study was limited by sample size, methodology and timing. To robustly address the question of whether mussel communities influence fish communities, we encourage further work that samples more sites, employs a variety of sampling methods, and includes behavioral observations.

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## Introduction

Freshwater fishes and mussels (Bivalvia: Unionidae) are dominant consumers in streams of eastern North America. Adult mussels are sedentary and mussel dispersal occurs largely through the movement of mussel larvae, which are obligate ectoparasites on fish (Barnhart et al. 2008; Vaughn 2012). Because of this host-parasite relationship, fish community structure can have a large influence on mussel community structure (Vaughn and Taylor 2000; Schwalb et al. 2013). However, little is known about how

mussels in turn might influence the composition and abundance of fish communities. There is anecdotal evidence that fish prefer sections of experimental tanks with mussels more than areas without mussels (Moy and Sparks 1991). Recently, American shad (*Alosa sapidissima*) have been found to deposit eggs in the body cavities of mussels (Wisniewski et al. 2013) and pacific lamprey grow faster in the presence of mussels (Limm and Power 2011).

Mussels typically occur as patchily distributed, dense, multispecies aggregations called mussel beds. Mussel beds have been shown to influence the distribution of other

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organisms primarily through two mechanisms. First, nutrients excreted by mussels fertilize algae (Allen et al. 2012) that is then consumed by primary consumer invertebrates (Atkinson et al. 2014), fish (Sansom, unpublished data), and even riparian spiders (Allen et al. 2012). Second, mussels provide structural habitat for benthic organisms both through the biogenic habitat provided by their shells and by altering sediment properties by their shells increasing surface roughness and/or through bioturbation (Spooner and Vaughn 2006; Vaughn et al. 2008; Allen and Vaughn 2011; Sansom et al. 2017). Mussels might influence the composition of fish communities by one or both of these mechanisms. Increased standing crops of benthic algae and higher abundances and richness of benthic macroinvertebrates resulting from mussel fertilization might lead to increased abundances of fish herbivores and insectivores. Increased substrate complexity provided by mussel shells can offer refuge from predation (Moy and Sparks 1991), and more stable stream sediment might provide preferential spawning and nesting habitat. For example, in previous field studies we have often observed centrarchid nests within mussel beds (C. Vaughn, personal observation).

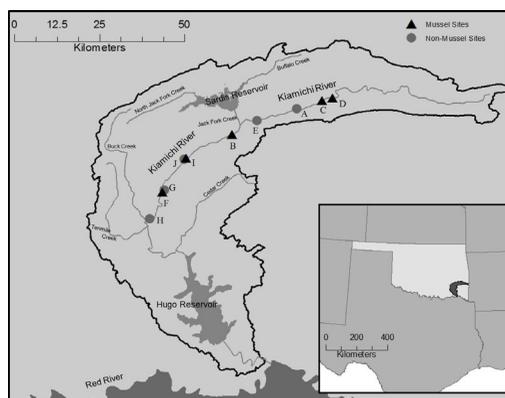
To begin addressing the question of whether mussels might influence fish communities we asked two questions: (1) does fish composition and abundance vary on and off mussel beds and (2) how is variation in fish composition on and off mussel beds related to their feeding and nesting traits?

## Methods

We conducted our study in the Kiamichi River, a major tributary of the Red River in southeastern Oklahoma with high mussel (31 species) and fish (86 species) biodiversity (Vaughn et al. 1996; Matthews et al. 2005). Based on previous knowledge of mussel distribution in the river (Galbraith et al. 2008) we selected 10 river reaches, five with large mussel beds and five with similar environmental conditions (Table 1), but without mussel beds (Fig. 1). All sites were a minimum of 500 m apart.

In the summer of 2013 we sampled fish, water quality and physical habitat variables at each site. Fish were collected with a backpack electroshocker (Smith-Root, Inc. Model 12-B) using pulsed direct current. Electrofishing began at the most downstream portion of the reach and continued upstream, going from bank-to-bank in a zigzag pattern. The shocking effort (cumulative time the shocker was engaged) was recorded and used to determine catch per unit effort (CPUE). Immediately after electroshocking, all fish were euthanized in MS222 and preserved in 80% ethanol for later identification.

We measured current velocity, water chemistry, and substrate heterogeneity along five transects at each site. Transects were located at the most downstream location of the site, 25%, 50%, and 75% of the site reach, and the most upstream location. Current velocity was measured in 1 m intervals along each transect, at 0.6 depth of the water column (March-McBirney FloMate). Dissolved oxygen, temperature, pH, and conductivity were measured at the right bank, river center, and left bank along each transect using a Hach meter (Hach, HQ36d: dissolved oxygen and temperature) and a PCSTestr Multi-Parameter (Oakton Instruments, PCSTestr 35 model WD-35425-10; pH, and conductivity). Finally, we conducted pebble counts of 20 pebbles per transect (Kondolf et al. 2003), pooled the substrate data from each transect per site, and used these data to derive sediment texture distribution and heterogeneity



**Figure 1.** Kiamichi River watershed showing the site locations that were sampled during 2013.

Table 1. Abiotic parameters measured for each site in the Kiamichi River, Oklahoma.

Site	Effort (minutes)	Site Length (m)	Mean Site Width (m)	Mean Temperature (C)	Mean pH	Mean Conductivity (uS)	Mean Total Dissolved Solids (ppm)	Mean Salinity (ppm)	Mean Dissolved Oxygen (mg/L)	Mean Dissolved Oxygen (%)	Substrate Heterogeneity	D50 (mm)	Mean Velocity (m/s)	Mean Depth (m)	
Mussel	B	29	75	19.5	31.0	7.2	51.9	37.0	32.1	7.0	96.2	4.1	80	0.24	0.44
	C	32	70	20.6	27.8	7.3	55.2	39.2	32.8	5.9	76.4	7.0	50	0.06	0.40
	D	37	100	31.4	30.0	7.4	55.8	39.7	33.5	7.0	94.4	4.5	80	0.04	0.51
	F	30	70	38.8	29.5	7.5	53.5	38.0	32.5	7.6	100.0	3.3	70	0.07	0.45
	I	26	50	19	28.0	7.5	54.3	38.5	32.4	7.2	91.7	4.0	40	0.03	0.47
Non-Mussel	A	29	100	22.6	30.7	7.7	46.4	33.0	29.8	8.1	109.8	4.0	80	0.29	0.34
	E	30	80	34.2	28.8	7.7	54.2	38.5	32.6	8.4	109.9	4.0	60	0.06	0.45
	G	20	64	24.8	30.0	7.5	53.6	38.1	32.6	7.4	99.2	4.0	70	0.16	0.32
	H	36	80	29.8	30.6	7.9	59.7	42.4	35.0	8.1	108.3	7.0	60	0.06	0.42
	J	23	40	10.7	29.5	7.5	54.3	38.6	32.7	7.6	100.0	4.0	80	0.16	0.36
Mean <sup>a</sup>	Mussel Sites	30.8	73	25.9	29.3 A	7.4 A	54.1	38.5	32.7	6.9 A	91.7	4.6	64	0.08 A	0.46 A
	Non-mussel Sites	27.6	72.8	24.4	30.0 B	7.6 B	52.8	37.5	32.2	7.9 B	106.3	4.6	70	0.13 B	0.39 B

<sup>a</sup>If applicable, total mean values obtained from average of entire data per mussel and non-mussel sites, not the average values per site seen above. Heterogeneity and D50 means were averaged from totals per site. Different letters indicate means are statistically different (alpha = 0.05).

Table 2. The fish species collected in the Kiamichi River, Oklahoma grouped according to family<sup>a</sup>, trophic guild, and spawning activity.

Species <sup>b</sup>	Family Group	Trophic Guild	Nest Builder
<i>Lepomis cyanellus</i>	Centrarchidae	General Invertivore	Yes
<i>Lepomis gulosus</i>	Centrarchidae	General Invertivore	Yes
<i>Lepomis humilis</i>	Centrarchidae	General Invertivore	Yes
<i>Lepomis macrochirus</i>	Centrarchidae	General Invertivore	Yes
<i>Lepomis megalotis</i>	Centrarchidae	General Invertivore	Yes
<i>Micropterus dolomieu</i>	Centrarchidae	Piscivore	Yes
<i>Camptostoma anomalum</i>	Cyprinidae	Herbivore/Detritivore	No
<i>Cyprinella whipplei</i>	Cyprinidae	Surface/Water Column Invertivore	No
<i>Notropis boops</i>	Cyprinidae	Surface/Water Column Invertivore	No
<i>Notropis suttkusi</i>	Cyprinidae	Benthic Invertivore	No
<i>Pimephales notatus</i>	Cyprinidae	Omnivore	Yes
<i>Noturus spp</i>	Ictaluridae	Benthic Invertivore	No
<i>Pylodictis olivaris</i>	Ictaluridae	Piscivore	Yes
<i>Etheostoma maculatum</i>	Percidae	Benthic Invertivore	Yes
<i>Etheostoma nigrum</i>	Percidae	Benthic Invertivore	Yes
<i>Etheostoma radiosum</i>	Percidae	Benthic Invertivore	No
<i>Percina caprodes</i>	Percidae	Benthic Invertivore	No
<i>Percina copelandi</i>	Percidae	Benthic Invertivore	No
<i>Percina maculata</i>	Percidae	Surface/Water Column Invertivore	No
<i>Percina phoxocephala</i>	Percidae	Benthic Invertivore	No
<i>Percina sciera</i>	Percidae	Benthic Invertivore	No
<i>Aplodinotus grunniens</i>	Other	Benthic Invertivore	No
<i>Lepisosteus oculatus</i>	Other	Piscivore	No
<i>Moxostoma erythrurum</i>	Other	Benthic Invertivore	No

<sup>a</sup>The family group “Other” was used to group fish species that did not have more than two species in a family.

<sup>b</sup>Fish species do not include the singleton species removed from the analysis.

( $D_{90} / D_{50}$ ) within each site (Williams 1980).

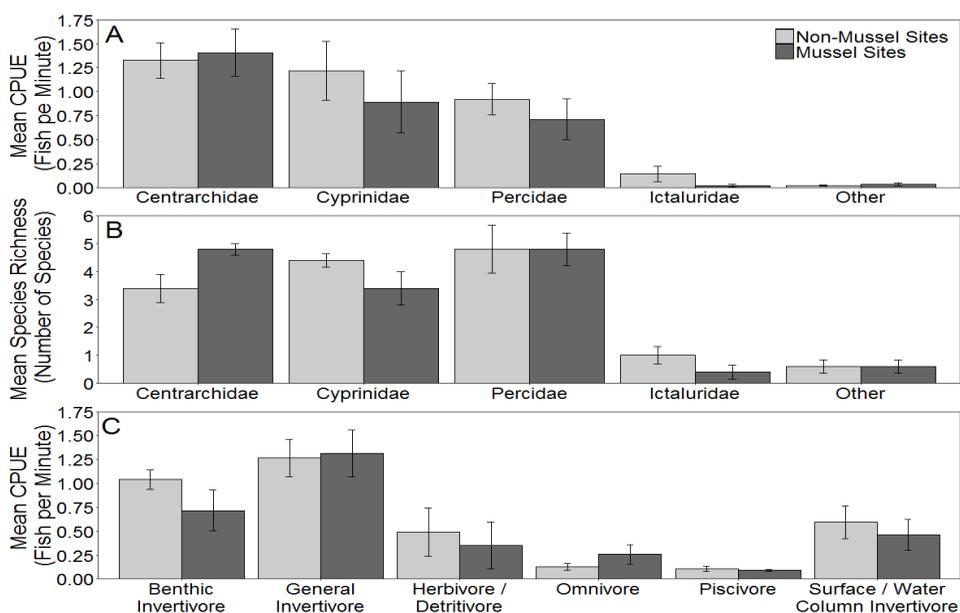
We estimated CPUE by dividing the total number of fish caught at each site by the time (in minutes) spent electrofishing. We first compared total fish abundance and species richness between mussel and non-mussel sites. We then classified fish by taxonomy, feeding guild, and nesting behavior and compared the abundance of these groups on and off mussel beds. We used non-parametric tests to analyze data as they did not meet normality requirements. We compared total abundance, total richness, and nesting behavior with the Wilcoxin signed-ranks test and differences among fish families and feeding groups with a Kruskal-Wallis test.

Fish families were Percidae, Cyprinidae, Centrarchidae, Ictaluridae, and 'other fish' (consisting of fish that did not have more than two species in a family). We assigned fish to feeding guilds (benthic invertivore, general invertivore, herbivore/detritivore, omnivore, piscivore, surface/water column invertivore

according to Poff and Allan (1995), Taylor and Warren (2001), Miller and Robison (2004), Gido and Franssen (2007), and Frimpong and Angermeier (2009; Table 2). Fish were classified as nest builders or non-nest builders following Frimpong and Angermeier (2009; Table 2). Singleton species, those species in which only one individual was found across all sites, were tallied, but were not used in further statistical analyses to avoid rare species bias (Cao et al. 1998; Cao et al. 2001).

## Results

All sites were sampled in riffle-run reaches during summer low-flow conditions. Overall, mussel and non-mussel sites had similar environmental conditions (Table 1). On average, sites were 72.9 m in length and 25.1 m in width. Minor but statistically significant differences were observed between mussel and non-mussel sites in mean temperature (0.7 °C), mean pH (0.2 pH units), mean dissolved oxygen (1.0 mg/L), mean current velocity (0.05 m/s) and mean



**Figure 2.** Mean CPUE for each fish family between mussel and non-mussel sites (A). Mean species richness for each fish family between mussel and non-mussel sites (B). Mean CPUE for each feeding guild between mussel and non-mussel sites (C). Error bars on each panel represent  $\pm$  SE.

depth (0.07 m) (Table 1).

We collected a total of 964 fish across 34 species. Ten of the 34 species occurred as singletons and were removed from further analyses (i.e. 10 singleton species). Neither total fish abundance (mussel =  $3.06 \pm 0.43$ , non-mussel  $3.63 \pm 0.43$ ,  $W = 2806$ ,  $P = 0.1862$ ) or species richness (mussel =  $14.0 \pm 0.63$ , non-mussel  $14.2 \pm 0.97$ ,  $W = 317.5$ ,  $P = 0.9292$ ) varied significantly between mussel and non-mussel reaches.

The abundance and species richness of fish families, and the abundance of fish feeding guilds also did not vary significantly between mussel and non-mussel sites (Fig. 2). Ten of the 24 species analyzed were classified as nest builders (Table 2). Mussel sites had a significantly higher proportion of nest building fish than non-mussel sites. On average,  $50\% \pm 0.02$  of the fish species found at mussel sites were nest builders, while only  $41\% \pm 0.03$  of the fish found at non-mussel sites were nest builders ( $W = 2.5$ ,  $P = 0.0439$ ).

## Discussion

It is well known that fish communities impact the abundance and species composition of mussel communities (Vaughn and Taylor 2000; Vaughn 2012; Schwalb et al. 2013). We asked if mussels, in turn, influence fish community composition. We found a significantly higher proportion of nest building fish on mussel sites as opposed to non-mussel sites. However, we found no significant differences in overall fish abundance, species richness, taxonomic composition, or feeding guilds between mussel and non-mussel sites. Thus, with the exception of potential effects on nesting behavior, we detected no effects of mussels on the abundance and composition of fish in the Kiamichi River.

Our finding of no influence of mussel communities on fish communities could be because there is indeed no effect, because of improper site selection, or be due to sampling error (time of sample collection and small sample size). Fish assemblages are greatly influenced by environmental and landscape

factors (Marsh-Matthews and Matthews 2000; Porter and Patton 2015), and these are likely the primary controls on fish composition in the river. To account for this, we attempted to minimize differences in environmental variables among mussel and non-mussel sites. We did, however, observe slight differences in water temperature, pH, dissolved oxygen, current velocity and depth among mussel and non-mussel sites (Table 1). Temperature, pH, and dissolved oxygen are typically spatially homogenous in a stream at any given time, and therefore not likely to influence fish community structure. Increases in water depth and in stream complexity associated with higher current velocity are both associated with an increases in fish species richness (Sheldon 1968; Taylor et al. 1993; Marsh-Matthews and Matthews 2000). However, both species richness and species composition were similar between mussel and non-mussel sites in our study (Figure 2). We don't think that the slight differences in depth (0.07 m) and velocity (0.05 m/s) that we observed between mussel and non-mussel sites influenced fish species composition.

Further, our study was conducted during a single field season and each site was only sampled one time, thus our results represent a static "snapshot in time", while highly mobile fishes move in and out of habitats temporally. Finally, our data indicate that we under sampled some components of the fish community. The Kiamichi River supports a diverse fish fauna of 86 species, but many of these species are relatively rare (Pyron et al. 1998; Matthews et al. 2005). During our limited survey of 10 sites using electrofishing, we collected 34 species or approximately 40% of the known fauna. We know that we under sampled some fishes because of their size or habitat preferences. For example, we visually observed freshwater drum (*Aplodinotus grunniens*) and spotted gar (*Lepisosteus oculatus*) at most of the sites, but failed to capture many individuals because of our sampling method. However, the majority of species we sampled are considered to be ubiquitous throughout the Kiamichi River (15 out of 24 species analyzed; Porter and Patton 2015), and we are confident that we sampled the majority of common species that were found in

mussel and non-mussel sites.

We found more species of nest building fish in mussel sites compared to non-mussel sites. Mussel shells provide biogenic habitat and mussel aggregations may act to stabilize stream sediments during high flow events (Strayer 1999; Zimmerman and De Szalay 2007). This alteration to the benthic habitat may be attractive to fish that need firm substrate in which to construct their dish-like nests (Danylchuk and Fox 1996). All of the Centrarchidae collected in our study were nest builders, and centrarchid nests are commonly seen within mussel beds in the Kiamichi River and other nearby rivers (C. Vaughn, personal observation). While not statistically significant, we did find slightly more species of Centrarchidae in mussel sites (mussel =  $4.8 \pm 0.2$ , non-mussel =  $3.4 \pm 0.5$ ). As discussed above, we don't think that the slight differences in depth and velocity observed among mussel and non-mussel sites influenced the distribution of nest-building fish.

Do mussel communities influence fish communities? With the exception of differences in the number of nest building species, we found no influence of mussel communities on the composition and abundance of fish in the Kiamichi River. However, our study was limited by sample size, methodology and timing. To robustly address this question we suggest further work should be done examining more sites, employing methods beyond electrofishing, and sampling fishes seasonally. Additionally, observational studies of fish movement and behavior on and off mussel beds would be useful.

## Acknowledgements

We thank the landowners who allowed us to use their property for river access. Funding for this work was provided by the Fisheries Division of the Oklahoma Department of Wildlife Conservation and the Oklahoma Biological Survey. We thank W.J. Matthews and E. Marsh-Matthews for their expertise and advice on fish sampling, and A. Geheber for help with fish identification. Fish were collected under permit number 5718 from the Oklahoma Department

of Wildlife Conservation. This manuscript benefited from reviews by G. Hopper, K.B. Gido and three anonymous reviewers. This project was completed as part of a master's thesis at the University of Oklahoma, and was approved by IACUC no. R12-013. This is a contribution to the program of the Oklahoma Biological Survey.

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Submitted July 19, 2017 Accepted November 28, 2017