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Potential Effects of Interspecific Competition on Neosho Madtom *(Noturus placidus)* Populations

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ABSTRACT

Previous research on the distribution of Neosho madtoms, which are Federally-listed as threatened, indicated a positive relationship between density of Neosho madtoms and cumulative density of other riffle-dwelling benthic fishes. This suggested that interspecific competition was not limiting Neosho madtom populations. We provide further evidence that interspecific competition is not limiting Neosho madtom populations. Densities of fishes with habitat preferences similar to those of the Neosho madtom were positively correlated with Neosho madtom densities, whereas densities of fishes with different habitat preferences were negatively correlated. Slenderhead darter, suckermouth minnow, and juvenile channel catfish densities were positively correlated with Neosho madtom densities. Like the Neosho madtom, these species are found most often over gravel substrate with moderate flows; the suckermouth minnow is tolerant of high turbidities. Bluntnose minnow, western slim minnow, and bullhead minnow densities were negatively correlated with Neosho madtom densities. In contrast to the Neosho madtom, these species are found most often in pools or sluggish backwaters.

INTRODUCTION

The Neosho madtom (*Noturus placidus*) is a small ictalurid that is generally < 75 mm in TL (U.S. Fish and Wildlife Service [U.S. FWS] 1991). The Neosho madtom was first described as a species in 1969 (Taylor 1969). Due to apparent low densities and concerns over population status, the Neosho madtom was listed as "threatened" by the U.S. FWS (1991). Currently, the Neosho madtom is found in the mainstems of the Neosho River, Cottonwood River, and Spring River in Kansas, Missouri, and Oklahoma (Luttrel et al. 1992, Wenke et al. 1992, Cross and Collins 1995, Wilkinson et al. 1996) (Figure 1). The Neosho madtom has been found in the greatest numbers in riffles during daylight in late summer and early fall (Moss 1983, Luttrel et al. 1992, Wenke et al. 1992, Fuselier and Edds 1994, 1995).

Population densities of the Neosho madtom are much greater in the Neosho and the Cottonwood rivers (Neosho River system) than in the Spring River (Moss 1983, Wilkinson et al. 1996). The physical-chemical makeup of the Spring River differs from that of the Neosho River system (Moss 1983), and as Wildhaber et al. (in press) suggest, may be one factor contributing to differences in Neosho madtom densities between river systems.

Cross and Collins (1995) described the Spring River drainage as one of the most diverse drainages in Kansas; it contains 20 species found nowhere else in Kansas. Wildhaber et al. (1996) collected 35 fish species in the Neosho River

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system and 46 in the Spring River. Wildhaber et al. (in press) found that fish species richness of Spring River sites without Neosho madtoms was less than that of sites with Neosho madtoms as a result of lower overall fish densities at sites without Neosho madtoms. There was no difference in species richness between Spring River sites with and without Neosho madtoms after species richness was adjusted for density using rarefraction calculations (Hurlbert 1971).

Differences in species richness between the Neosho River system and the Spring River are likely a result of the type of area drained (Wildhaber et al. in press). Although the mainstem reaches we sampled in these three rivers are all found in the Prairie Parkland Province ecoregion, the upper reach and many of the tributaries of the Spring River drain a very different ecoregion, the Ozark Uplands Province (Bailey 1995). The Ozark Uplands Province was described by Pflieger (1975) as predominantly limestone with streams containing large quantities of unconsolidated chert that filter the water; many streams are spring fed. Wildhaber et al. (in press) documented that gravel bars in Neosho River system are characterized by: smaller substrate; higher turbidity, hardness, alkalinity, and conductivity; and warmer water temperatures than the Spring River. Furthermore, Pflieger (1975) noted that more than one-third of Missouri's fishes have their distribution centered in the Ozark Uplands Province where many Spring River tributaries originate.

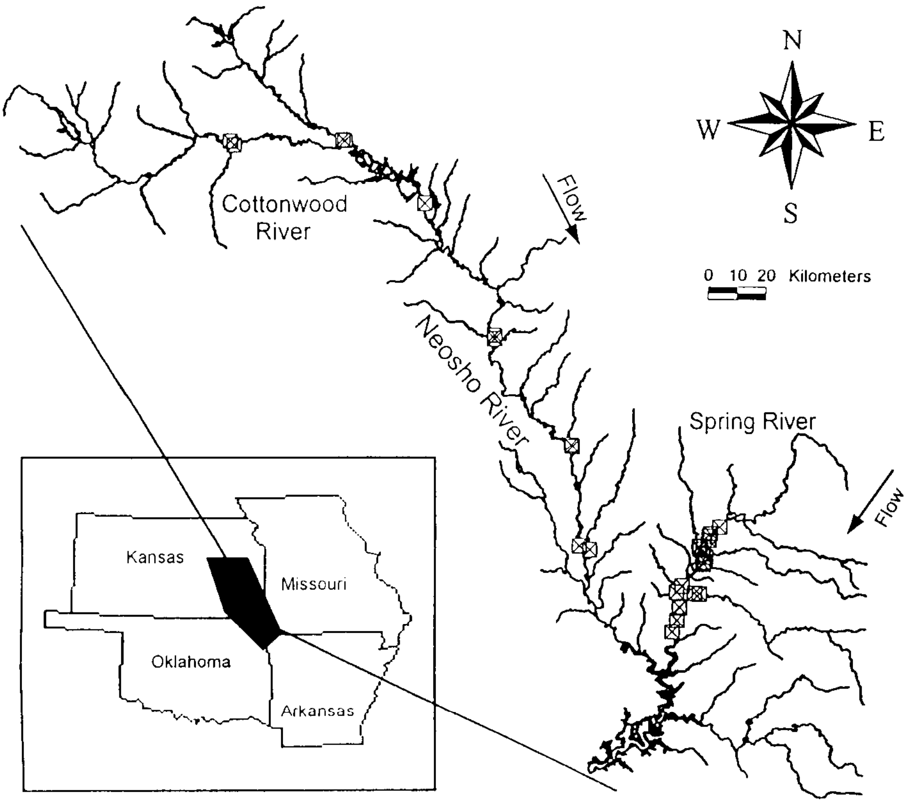

Figure 1. Sampling sites (boxes) in the Neosho River system and Spring River.

The Spring River and its tributaries also drain watersheds of the Tri-State Mining District, where increased concentrations of cadmium, lead (Pb), and zinc (Zn) have been found (Spruill 1987). Neosho madtoms have only been collected in the central reach of the Spring River, except for one known population just north of Baxter Springs, Kansas (Pflieger 1975, Wilkinson et al. 1996). Most Spring River Neosho madtoms are found upstream of the primary sources of mining-derived pollution to the Spring River (Barks 1977). Wildhaber et al. (in press) found a strong negative relationship between Neosho madtom populations and metal contaminants from Pb-Zn mining within the Spring River.

One of the factors the U.S. FWS (1991) listed as possibly limiting Neosho madtom populations was interspecific competition with other riffle-dwelling benthic fishes, as suggested by Moss (1983). Many of the fishes inhabiting the Neosho River system and the Spring River are potential competitors for resources (e.g., food, space, nesting sites) (Pflieger 1975). The presence of many of these species on the same gravel bars with Neosho madtoms (Moss 1983, Wildhaber et al. in press) further suggests that interspecific competition could limit Neosho madtom populations. However, Wildhaber et al. (in press) demonstrated a strong positive relationship between populations of Neosho madtoms and the group of riffle-dwelling benthic fishes that were assumed potential competitors to Neosho madtoms (potential competitors; Table 1) in the Neosho River, the Cottonwood River, and the Spring River. This positive relationship suggests that competition is not likely a primary factor limiting Neosho madtoms in the Spring River. The objective of this work was to determine the potential competitive impact of individual benthic fish species on Neosho madtom populations and thus better assess the impact of interspecific competition on Neosho madtom populations.

METHODS

Study Area

Our study area included the mainstems of the Neosho River and the Cottonwood River (Neosho River system) and the Spring River in Kansas, Missouri, and Oklahoma (Figure 1). Part or all of the mainstems of all three rivers are located in the Prairie Parkland Province ecoregion (Bailey 1995) and all are a part of the Arkansas River basin. The upper reach of the Spring River is located in the Ozark Uplands Province ecoregion. The Neosho River and the Cottonwood River drain mainly mixed-grass prairie with mature riparian vegetation along some sections, whereas the upper reaches of the Spring River and many of its tributaries primarily drain deciduous forests of the Ozark Uplands (Moss 1983). The Spring River drains approximately half the area, has 70% of the discharge, and has 1.7 times the gradient of the Neosho River system; however, all three rivers possess similar riffle-pool habitats (Moss 1983, Putnam et al. 1995, Kiner et al. 1997). The Neosho and Cottonwood rivers are regulated by reservoirs. The Spring River is essentially unregulated except for a powerplant cooling reservoir on one of its lower reaches.

Gravel Bar Sampling

Collection sites were selected to maximize the probability that Neosho madtoms would be collected. Twelve gravel bars (i.e., shoreline accumulations of stone, gravel, and sand generally < 38 mm in diameter which extended into the river) known to harbor Neosho madtoms were selected for study in the Neosho River system from Emporia, Kansas, to Grand Lake of the Cherokees (U.S. FWS 1991). In the Spring River, downstream from its confluence with its North Fork to Grand Lake of the Cherokees, 20 gravel bars were selected based on habitat characteristics favorable for Neosho madtoms (Moss 1983, U.S. FWS 1991, Wenke et al. 1992, Fuselier and Edds 1994). Collections at all sites occurred during daylight from August through October, after Neosho madtom young-of-year begin to be found on gravel bars (Fuselier and Edds 1994).

Before sampling, three to five cross-channel transects perpendicular to the river channel were spaced equally along each gravel bar. In most instances, five stations were spaced equally along a transect with a minimum distance of 2 m between adjacent stations. Fewer than five stations were established when the river channel was less than 10 m wide or when a station occurred at an unseinable depth of > 1.25 m. We collected fish from a 1.5-m wide area by disturbing the gravel substrate. We started 3 m upstream of a stationary 3.0-mm mesh seine and proceeding toward the seine (i.e., 4.5 m^2 area). On each transect, stations were sampled in order of their distance from the gravel bar, with collections generally proceeding from the downstream transect. All ictalurids and other identifiable fishes were counted and immediately released back into the river. Non-ictalurid voucher specimens and unidentifiable fishes were preserved in ethanol.

We wanted to test relationships between Neosho madtoms and Neosho madtom potential fish competitors. We assumed that fishes that were considered potential competitors to Neosho madtoms were equally vulnerable to capture by our sampling method. For most of the species that spend time stationary on the bottom, especially the small catfishes and darters, the density estimates were probably very comparable. For free-swimming species such as minnows we may have underestimated densities due to an avoidance response to the kick-seine. The primary intent of this study was to test relationships between Neosho madtoms and potential fish competitors. Although the efficiency of capture may have varied among species, by collecting every species of fish using the same technique at all sites density estimates of each species were consistent across sampling sites. This supports the validity of any relationships observed between Neosho madtoms and potential competitors.

Statistical Analyses

We analyzed fish densities at the site level to assess differences between the Neosho River system and the Spring River and between Spring River sites with and without Neosho madtoms. We calculated mean site densities of Neosho madtoms and each potential competitor by dividing the total number of each species collected at a site by the total area sampled with the kick seine. The list of potential fish competitors to Neosho madtoms (Table 1) was based on habitat preferences and feeding habits of each species as described by Pflieger (1975).

The statistical methods used to make the primary comparisons included analysis of variance (ANOVA), Fisher's Exact Test, and correlation analysis (SAS 1990). Separate one-way ANOVAs were performed to test differences

Table 1. Riffle-dwelling fish taxa collected in the Neosho River system and Spring River assumed to be potential competitors of the Neosho madtom based on habitat usage and feeding descriptions given by Pflieger (1975).

Ictaluridae	**Percidae**
Ictalurus punctatus (channel catfish)	*Etheostoma blennioides* (greenside darter)
Noturus exilis (slender madtom)	*Etheostoma f flabellare* (barred fantail darter)
Noturus flavus (stonecat)	*Etheostoma nigrum* (johnny darter)
Noturus miurus (brindled madtom)	*Etheostoma stigmaeum* (speckled darter)
Noturus nocturnus (freckled madtom)	*Etheostoma s spectabile* (northern orangethroat darter)
Pylodictis olivaris (flathead catfish)	*Etheostoma whipplei* (redfin darter)
Cyprinidae	*Etheostoma zonale* (banded darter)
Erimystax x-punctatus (gravel chub)	*Percina copelandi* (channel darter)
Notropis spp./*Pimephales* spp.	*Percina caprodes fulvitaenia* (Ozark logperch)
Phenacobius mirabilis (suckermouth minnow)	*Percina phoxocephala* (slenderhead darter)
Pimephales notatus (bluntnose minnow)	*Percina shumardi* (river darter)
Pimephales t tenellus (western slim minnow)	**Catostomidae**
Pimephales vigilax (bullhead minnow)	*Cycleptus elongatus* (blue sucker)
Sciaenidae	*Hypentelium nigricans* (northern hog sucker)
Aplodinotus grunniens (freshwater drum)	*Moxostoma duquesnei* (black redhorse)
Cottidae	*Moxostoma erythrurum* (golden redhorse)
Cottus carolinae (banded sculpin)	*Moxostoma macrolepidotum* (shorthead redhorse)
	Moxostoma spp.

between site means for river systems and for Spring River sites with and without Neosho madtoms. Before ANOVA could be performed, a species needed to be collected at a minimum of three sites with at least one site in each river system for river system comparisons and one site in Spring River sites with and without Neosho madtoms for within Spring River comparisons. Fisher's Exact Test was used to test the pairings of presence and absence of individual fish species with Neosho madtom presence and absence within the Spring River. For inclusion in Fisher's Exact Test, a fish species had to have been collected at nine or more sites in the Spring River for a valid comparison with Neosho madtom which were collected at nine sites in the Spring River. Correlation analyses were used to assess relationships between non-zero Neosho madtom densities and non-zero densities of other fish species. For correlation analyses to be acceptable, a fish species had to co-occur with the Neosho madtom at three or more sites.

The distribution of site means for each fish species was evaluated for normality using SAS (1990); all fish densities were $\log_{10}$ transformed. The issue of homogeneity of variance for river system differences was addressed using Levene's test as recommended by Milliken and Johnson (1984). For comparison between Spring River sites with and without Neosho madtoms, we accepted the premise that F-statistics and *t*-tests used to compare means of normally distributed variables are effective whether or not variances were equal, especially when sample sizes were equal or almost so (Milliken and Johnson 1984). There were nine sites with and 11 sites without Neosho madtoms in the Spring River. For the Spring River, having 11 sites with zero Neosho madtom densities precluded normal transformation of the full set of observations and forced us to restrict correlations to sites with Neosho madtoms.

RESULTS

Neosho River System Versus Spring River

Many of the fishes considered potential Neosho madtom competitors were collected in the Neosho River system and the Spring River; however, many other species were found in only one of the two river systems (Table 2). The freshwater drum (*Aplodinotus grunniens*), juvenile flathead catfish (*Pylodictis olivaris* —100 mm total length largest collected), golden redhorse (*Moxostoma erythrurum*), blue sucker (*Cycleptus elongatus*), and freckled madtom (*Noturus nocturnus*) were only found in the Neosho River system. The greenside darter (*Etheostoma blennioides*), speckled darter (*Etheostoma stigmaeum*), banded darter (*Etheostoma zonale*), river darter (*Percina shumardi*), barred fantail

Table 2. Number of sites at which riffle-dwelling benthic fishes assumed to be Neosho madtom potential competitors were collected. Eleven sites for the Neosho River system and 20 sites for the Spring River; 9 sites with and 11 sites without Neosho madtoms in the Spring River.

Fish species	Neosho River system	Spring River	Spring River with Neosho madtoms	Spring River without Neosho madtoms
Banded darter	0	19	9	10
Banded sculpin	0	2	0	2
Barred fantail darter	0	14	8	6
Black redhorse	0	2	2	0
Blue sucker	2	0	0	0
Bluntnose minnow	6	13	8	5
Brindled madtom	0	1	1	0
Bullhead minnow	6	1	0	1
Channel catfish	11	9	5	4
Channel darter	1	4	1	3
Flathead catfish	3	0	0	0
Freckled madtom	1	0	0	0
Freshwater drum	10	0	0	0
Golden redhorse	1	0	0	0
Gravel chub	5	11	8	3
Greenside darter	0	16	8	8
Johnny darter	0	2	0	2
Northern hogsucker	0	7	2	5
Northern orangethroat darter	8	14	8	6
Ozark logperch	10	18	8	10
Redfin darter	0	2	1	1
River darter	0	5	1	4
Shorthead redhorse	0	4	2	2
Slender madtom	1	14	8	6
Slenderhead darter	11	15	8	7
Speckled darter	0	15	7	8
Stonecat	10	11	6	5
Suckermouth minnow	11	10	6	4
Western slim minnow	6	15	8	7

darter (*Etheostoma f flabellare*), shorthead redhorse (*Moxostoma macrolepidotum*), northern hogsucker (*Hypentelium nigricans*), black redhorse (*Moxostoma duquesnei*), banded sculpin (*Cottus carolinae*), johnny darter (*Etheostoma nigrum*), redfin darter (*Etheostoma whipplei*), and brindled madtom (*Noturus miurus*) were only found in the Spring River.

The differences in fish densities between the Neosho River system and the Spring River illustrate other major differences in the fish communities of the two river systems (Table 3). As noted by Wildhaber et al. (in press), Neosho madtom densities were higher in the Neosho River system than in the Spring River. Neosho madtoms were collected at only 9 of 20 Spring River sites as opposed to 10 of 11 sites in the Neosho River system. There were also higher densities of suckermouth minnows (*Phenacobius mirabilis*), juvenile channel catfish (*Ictalurus punctatus*—203 mm in total length largest collected), stonecats (*Noturus flavus*), slenderhead darters (*Percina phoxocephala*) in the Neosho River system than in the Spring River. There were higher densities of Ozark logperch (*Percina caprodes fulvitaenia*) and slender madtoms (*Noturus exilis*) in the Spring River than in the Neosho River system.

Correlation analyses indicated significant relationships between non-zero densities of Neosho madtoms and potential competitors (Table 4). At a Bonferroni adjusted α of 0.0029 (i.e., correlation tests of Neosho madtom densities with the densities of 17 potential competitor species or 0.05/17 = 0.0029), non-zero Neosho madtom density had the highest positive correlations with non-zero slenderhead darter density (Table 4). At an α of 0.05, non-zero Neosho madtom density was correlated with non-zero densities for five other

Table 3. Mean density of fish per site and one-way analysis of variance test results for between rivers comparisons. Table 2 gives number of sites included in each mean. Species not collected at a minimum of three sites, in one of the river systems, or both could not be analyzed.

Fish species	**Neosho River system ($\bar{x}$/100 m^2)**	**Spring River ($\bar{x}$/100 m^2)**	**Analysis of variance P value (F)**
Bluntnose minnow	9.43	10.52	0.04 (0.85)
Bullhead minnow	9.27	2.78	0.94 (0.38)
Channel catfish	22.90	3.04	0.0002 (22.17)
Channel darter	2.61	4.11	0.29 (0.63)
Gravel chub	3.64	4.71	0.46 (0.51)
Neosho madtom	12.00	3.26	0.042 (4.83)
Northern orangethroat darter	4.88	10.39	0.062 (3.90)
Ozark logperch	2.41	6.33	0.0077 (8.34)
Slender madtom	0.93	6.49	0.048 (4.77)
Slenderhead darter	55.04	6.67	0.0001 (46.88)
Stonecat	6.03	1.79	0.012 (7.67)
Suckermouth minnow	13.8	3.09	0.0024 (12.25)
Western slim minnow	2.42	5.47	0.0548 (4.19)

fish species: positive for suckermouth minnow and juvenile channel catfish, and negative for bluntnose minnow (*Pimephales notatus*), western slim minnow (*Pimephales t tenellus*), and bullhead minnow (*Pimephales vigilax*). The same positive or negative correlations were seen within river systems for all fish species except the suckermouth minnow (Table 4); however, within-system correlations were generally not significant for these 17 fish species even at the $\alpha = 0.05$ level.

Sites With Neosho Madtoms Versus Sites Without in the Spring River

Many potential competitor species were collected both at sites with and without Neosho madtoms; however, some species were found only with or without Neosho madtoms (Table 2). The black redhorse and brindled madtom were found exclusively at sites with Neosho madtoms, whereas banded sculpins and johnny darters were found only at sites without Neosho madtoms. There were no fish species with the same presence/absence pattern as the Neosho madtom based on Fisher's Exact Test at a significance level of 0.0028 (Bonferroni α based on 18 species present at equal to or greater than the

Table 4. Correlations between mean site densities of riffle-dwelling fishes (non-zero densities) assumed to be benthic competitors of the Neosho madtom with non-zero Neosho madtom mean site densities. Analyses done for species collected at more than two sites with Neosho madtoms.

Fish species	**Neosho River system and Spring River combined r value *(P, N)***	**Neosho River *r* value *(P, N)***	**Spring River *r* value *(P, N)***
Banded darter	0.31 (0.41, 9)	(, 0)	0.31 (0.41, 9)
Barred fantail darter	-0.35 (0.41, 8)	(, 0)	-0.35 (0.40, 8)
Bluntnose minnow	-0.56 (0.049, 13)	-0.60 (0.29, 5)	-0.56 (0.15, 8)
Bullhead minnow	-0.91 (0.035, 5)	-0.91 (0.035, 5)	(, 0)
Channel catfish	0.61 (0.017, 15)	0.52 (0.12, 10)	0.08 (0.90, 5)
Flathead catfish	-0.28 (0.82, 3)	-0.28 (0.82, 3)	(, 0)
Freshwater drum	0.56 (0.12, 9)	0.56 (0.12, 9)	(, 0)
Gravel chub	0.27 (0.38, 13)	0.68 (0.20, 5)	0.00 (0.99, 8)
Greenside darter	-0.24 (0.57, 8)	(, 0)	-0.24 (0.56, 8)
Northern orangethroat darter	0.01 (0.99, 15)	0.11 (0.87, 7)	0.52 (0.19, 8)
Ozark logperch	-0.26 (0.30, 18)	0.19 (0.60, 10)	-0.78 (0.023, 8)
Slenderhead darter	0.66 (0.0027, 18)	0.55 (0.10, 10)	0.15 (0.72, 8)
Slender madtom	-0.38 (0.31, 9)	(, 1)	0.21 (0.61, 8)
Speckled darter	-0.18 (0.70, 7)	(, 0)	-0.18 (0.70, 7)
Stonecat	0.33 (0.22, 16)	0.10 (0.79, 10)	0.68 (0.14, 6)
Suckermouth minnow	0.62 (0.011, 16)	0.61 (0.06, 10)	-0.58 (0.23, 6)
Western slim minnow	-0.58 (0.029, 14)	-0.68 (0.14, 6)	-0.35 (0.40, 8)

number of sites at which Neosho madtoms were present or 0.05/18 = 0.0028). The gravel chub (*Erimystax x-punctatus*) was the only fish species to show a significant presence/absence relationship with the Neosho madtom at $P < 0.05$ ($P < 0.0098$, $N = 20$); 16 of the 20 sites had the same presence/absence pattern for the two species. Only banded darter densities were significantly different between sites with and without Neosho madtoms (Table 5); densities were greater at sites with Neosho madtoms.

DISCUSSION

The observed fish community patterns indicate that interspecific competition is not limiting either Neosho madtoms or potential competitors of Neosho madtoms; this is contrary to what the U.S. FWS (1991) suggested. The only highly significant relationship between Neosho madtom densities and potential competitor species observed indicated that Neosho madtom densities

Table 5. Mean density of fish per site and one-way analysis of variance test results for between sites in the Spring River with and without Neosho madtoms. Table 2 gives number of sites included in each mean. Species not collected at a minimum of three sites, at either sites with or without Neosho madtoms, or both could not be analyzed.

Fish species	Spring River with Neosho madtoms ($\bar{x}$/100 m²)	Spring River without Neosho madtoms ($\bar{x}$/100 m²)	Analysis of variance *P* value *(F)*
Banded darter	100.63	24.07	0.0025 (12.58)
Barred fantail darter	7.53	6.05	0.50 (0.49)
Bluntnose minnow	8.49	14.83	0.37 (0.89)
Channel catfish	3.10	2.97	0.93 (0.01)
Channel darter	2.96	4.59	0.71 (0.18)
Gravel chub	5.27	3.48	0.21 (1.81)
Greenside darter	7.69	4.42	0.22 (1.64)
Northern hogsucker	1.59	2.66	0.22 (1.96)
Northern orangethroat darter	9.89	11.10	0.78 (0.08)
Ozark logperch	5.75	6.84	0.66 (0.20)
River darter	1.48	17.48	0.089 (6.17)
Shorthead redhorse	1.48	1.21	0.53 (0.55)
Slender madtom	7.25	5.59	0.60 (0.30)
Slenderhead darter	5.99	7.55	0.40 (0.75)
Speckled darter	8.74	4.05	0.18 (1.98)
Stonecat	2.22	1.39	0.28 (1.31)
Suckermouth minnow	2.12	5.24	0.12 (2.99)
Western slim minnow	5.12	5.89	0.75 (0.11)

increase as the density of other fish species increase. Further, given the description of habitat usage of potential competitors by Pflieger (1975), even minimally-significant observed relationships can be explained. Positive relationships were found between the Neosho madtom and slenderhead darter, suckermouth minnow, and juvenile channel catfish. Each of these species is found most often over gravel with moderate flows. The Neosho madtom is also found in and the suckermouth minnow is tolerant of high turbidities (Pflieger 1975). If interspecific competition with these species was limiting Neosho madtom populations, their relationships with Nsosho madtoms should have been negative. Unlike the Neosho madtom, the bluntnose minnow, western slim minnow, and bullhead minnow are found most often in pools or sluggish backwaters (Pflieger 1975). Our data indicated that the densities of these species are negatively correlated with Neosho madtom densities, reflective of their different habitat preferences.

Previous research has both documented the presence of (Gilliam et al. 1993, Winston 1995) and lack of (Angermeier 1982, Mathews 1982, Grossman and Freeman 1987) interspecific competition as a determinant of the structure of fish communities in streams. A postulated cause of fish community structure is alternating interspecific competition, which is density dependent, and environmental impacts such as flooding or pollution, which are density independent (Strange et al. 1992). Interspecific competition becomes important in limiting fish populations when density-independent factors are not limiting (Strange et al. 1992). Currently, all available evidence suggests that the primary limitations on Neosho madtom populations are anthropogenic or density-independent factors, not ecological interactions such as interspecific competition (Wildhaber et al. in press). Wildhaber et al. (in press) provide strong evidence that Neosho madtom populations in the Spring River are limited by suboptimal habitat, including environmental contamination. They determined that the portion of the Spring River most impacted by environmental contamination, where there are few or no Neosho madtoms, could support more Neosho madtoms than the unimpacted portion where the species is currently most abundant. In the Neosho River system, Cross and Braasch (1969) presented strong evidence to suggest that fish populations in the Neosho River system were heavily impacted by reservoir construction.

What is unknown about the relationship of Neosho madtoms and their potential competitors is at what densities interspecific competition, or other density-dependent factors, would limit Neosho madtom populations. Interspecific competition may not currently be limiting Neosho madtoms populations due to the effects of other environmental factors such as predation and anthropogenic impacts. Little is known about the effects of predation on Neosho madtom populations except that the species of predators present are similar throughout the distribution of the Neosho madtom (Lee et al. 1980, Cross and Collins 1995). From Wildhaber et al. (in press), we know that anthropogenic factors seem to be limiting Neosho madtom populations in the Spring River. If current anthropogenic stresses (e.g., mining-derived waste) are removed from areas where Neosho madtom exist, would species densities increase, as our data suggests, and interspecific competition become an important factor controlling Neosho madtom populations? Additional research, both in the field and laboratory, is needed to understand community interactions, and to predict how specific management decisions will effect Neosho madtom populations.

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