TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCE
Vol. 107, no. 1/2
p. 17-24 (2004)

Correlations among densities of stream fishes in the upper Neosho River, with focus on the federally threatened Neosho madtom *Noturus placidus*

JEREMY S. TIEMANN,[1a] DAVID P. GILLETTE,[1b] MARK L. WILDHABER[2] AND DAVID R. EDDS[1]

1. *Emporia State University, Department of Biological Sciences, Emporia, KS 66801*
2. *U.S. Geological Survey, Columbia Environmental Research Center, Columbia, MO 65201*

a) *Present address: Illinois Natural History Survey, Center for Biodiversity, Champaign, IL 61820 (jtiemann@inhs.uiuc.edu)*
b) *Present address: University of Oklahoma, Department of Zoology, Norman, OK 73019*

We sampled fishes monthly from November 2000 to October 2001 at four gravel bar sites along a 34-km stretch of the upper Neosho River in Lyon County, Kansas. We assessed the potential for interspecific competition among stream fishes, with focus on the federally threatened Neosho madtom, *Noturus placidus,* by using Pearson's correlation analysis with sequential Bonferroni correction of alpha to examine relationships among fish densities. Of the 19 fish species analyzed, there were six significant positive and no significant negative correlations. Abundance of *N. placidus* did not vary significantly with total abundance of fishes or with abundance of any of these potential competitors. The lack of significant negative correlations at these sites at this time might reflect an assemblage in equilibrium or one controlled abiotically rather than by ongoing active competition.

Keywords: interspecific competition, stream fishes, gravel bar, Neosho madtom, Noturus placidus, upper Neosho River, Kansas.

INTRODUCTION

Several studies have addressed competition in stream fish assemblages (e.g. Matthews 1982; Roell and Orth 1994; Grossman et al. 1998), but only one (Wildhaber, Allert and Schmitt 1999) has focused on potential interspecific competition with the federally threatened Neosho madtom *Noturus placidus*. This small (generally <75 mm in total length) ictalurid presently is distributed discontinuously in the Neosho (Grand) - Spring River system, which is located within the Prairie Parkland Province and Ozark Upland Province ecoregions in Kansas, Missouri and Oklahoma (Wildhaber, Allert and Schmitt 1999). Individuals typically are found in riffles and sloping gravel bars in moderate current, and prefer deposits of loosely compacted gravel where they nocturnally feed on insects (USFWS 1991; Cross and Collins 1995). The U.S. Fish and Wildlife Service (USFWS) listed *N. placidus* as threatened in 1991 (55 FR 21148), and suggested that populations might be limited by competition for resources (e.g. food and habitat) with other fishes (USFWS 1991). To address this question, Wildhaber, Allert and Schmitt (1999) sampled 12 gravel bars in the Neosho (from near the confluence with the Cottonwood to the Grand Lakes of the Cherokees) and Cottonwood (near Emporia, Kansas) rivers, and 20 gravel bars in the Spring River (downstream from its confluence with its North Fork to the Grand Lakes of the Cherokees). They concluded that interspecific competition was not limiting *N. placidus* populations based on positive correlations between densities of *N. placidus* and other stream fishes with habitat preferences similar to those of *N. placidus* (e.g. suckermouth minnow *Phenacobius mirabilis*, juvenile channel catfish *Ictalurus punctatus*, and slenderhead darter *Percina phoxocephala*).

Many fishes inhabiting the Neosho River system potentially are interspecific competitors for resources (Wildhaber, Allert and Schmitt 1999), and their presence suggests that competition could limit *N. placidus* populations. *Noturus placidus* densities are generally higher in the Cottonwood and Neosho rivers than in the Spring River (Wilkinson et al. 1996; Wildhaber, Allert and Schmitt 1999); within the Neosho River, densities are higher in the upper Neosho (upstream from its confluence with the Cottonwood) than in the lower Neosho (Wildhaber, Tabor et al. 2000). We asked whether the patterns observed by Wildhaber, Allert and Schmitt (1999) would hold for the upper portion of the Neosho River based on the premise that higher densities result in greater potential for interspecific competition (Strange, Moyle and Foin 1992). We examined correlations among densities of stream fishes, with focus on *N. placidus*, in the upper Neosho River. Little is known of potential interspecific competition with *N. placidus* in the upper Neosho; therefore, this study could aid the species' recovery.

Materials and Methods

We sampled fishes monthly from November 2000 to October 2001 on four gravel bars along a 34-km stretch of the upper Neosho River in Lyon County, Kansas (Fig. 1). This segment of the Neosho River lies within the Prairie Parkland Province Ecoregion

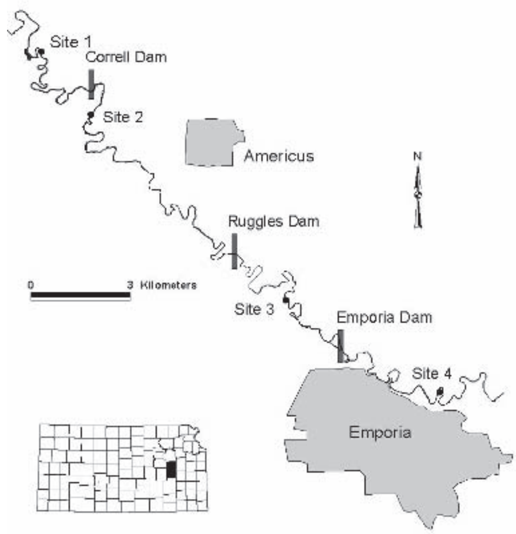

Figure 1. Sampling sites along the Neosho River in Lyon County, Kansas.

(Chapman et al. 2001), and is a 5th order stream with a mean gradient of 0.54 m/km. To maximize the probability that *N. placidus* would be collected, collection sites were selected based on the presence of a gravel bar composed mainly of gravel < 64 mm in size (Fuselier and Edds 1994; Wildhaber, Allert and Schmitt 1999).

Depending on depth (depths >1.25 m were not sampled) and landowner permission, three to five cross-channel transects perpendicular to the river channel were spaced equally along each gravel bar, and up to five sampling points were spaced equally along each transect. At each point, we collected fishes from a 4.5 m^2 area by disturbing the gravel substrate 3 m upstream from a stationary 1.5 m long, 3 mm mesh seine. To minimize disturbance, we sampled transects from downstream to upstream, and points from near shore to far shore. All fishes were identified and counted upon completion of a point, and were released upon completion of a site.

We pooled point data for each month at each site, and calculated mean total abundance of fishes per 100 m^2, in addition to mean abundance of individual fish species per 100 m^2. We assumed that potential competitors were equally vulnerable to capture by our sampling method (Wildhaber, Allert and Schmitt 1999). We eliminated fishes occurring in < 5% of the samples (< two samples) from analyses (Gauch 1982). We compared densities at the site level to assess potential competition among fish species. Because of multiple tests, sequential Bonferroni correction of a standard $\alpha = 0.05$ was applied to help control overall experimental Type I error (Rice 1989). All statistical tests were conducted using SYSTAT for Macintosh, Version 5.2 (SYSTAT, Inc., Evanston, IL). Distribution of means was evaluated for normality using the Shapiro-Wilk test (Zar 1999), and for homogeneity of variance using Levene's test (Milliken and Johnson 1984); non-normal variables were log10 transformed (Zar 1999). We used one-way analysis of variance (ANOVA) to test for differences in mean fish abundance among sites, and Pearson's correlation analysis to assess correlations among non-zero fish densities (Wildhaber, Allert and Schmitt 1999).

Results

We collected 26 fish species representing 15 genera and nine families from 45 samples (Site 3 was frozen in December, January, and February). Seven species occurred in < two samples, leaving 19 species for analysis (Table 1). Mean total abundance of fishes was 315.1 (SE = 464.0) fish per 100 m^2. Mean individual species' abundance ranged from 1.2 (SE = 0.2) per 100 m^2 (longear sunfish *Lepomis megalotis*) to 120.1 (SE = 223.7) per 100 m^2 (red shiner *Cyprinella lutrensis*); mean *N. placidus* abundance was 3.6 (SE = 1.8) per 100 m^2 (Table 1).

ANOVAs did not indicate significance by site for total abundance of fishes or for any of the 19 species, thus allowing meaningful comparisons by Pearson's correlation analysis. With sequential Bonferroni adjustment of alpha, there were six significant positive and no significant negative correlations (Table 2). At $\alpha = 0.05$, there were an additional 12 (nine positive and three negative) correlations (Table 2). There were no significant correlations between *N. placidus* abundance and total abundance of fishes or with abundance of any of the other 18 fish species (range: P = 0.14 to P = 0.96).

Discussion

Even though some degree of competition among fishes undoubtedly occurs on a gravel bar, and changes with differing physical conditions (Fausch and White 1986), coexisting species can segregate into distinct microhabitats and partition resources (Ross 1986; Matthews 1998). Strange, Moyle and Foin (1992) suggested that deterministic (density-dependent) factors, including interspecific competition, occur when stochastic (density-independent) factors, including natural and anthropogenic disturbances, are not occurring. In our study, the only significant correlations were positive, suggesting limited interspecific competition among stream fishes at these sites at this time. All 11 species having significant correlations (Table 2) inhabit streams with permanent flow, moderate gradient, and gravel substrate, but can utilize different resources (Cross and Collins 1995; Pflieger 1997). Through coexistence, the fish assemblage might have evolved to where each species now demonstrates slight differences in food (e.g. size or timing of food eaten) or habitat preferences (e.g. velocity or substrate composition), thus reducing the level of competition (Matthews 1998). The lack of significant negative correlations likely reflects abiotic control (Grossman, Moyle and Whitaker 1982) or an evolved equilibrium (e.g. non-linear competitive hierarchies) in resource partitioning among members of the

Table 1. Fish species and their mean abundances per 100 m^2 (standard error) collected in the upper Neosho River, November 2000 to October 2001. Asterisks (*) indicate species that occurred in < 5% of the 45 samples (< two samples) and were excluded from analysis.

Family	Scientific name	Common name	Mean abundance
Family Cyprinidae	*Campostoma anomalum*	Central stoneroller	5.1 (4.9)
	*Cyprinella camura**	Bluntface shiner	0.0 (0.0)
	Cyprinella lutrensis	Red shiner	120.1 (223.7)
	Notropis buchanani	Ghost shiner	38.9 (50.7)
	Notropis stramineus	Sand shiner	9.6 (9.6)
	Phenacobius mirabilis	Suckermouth minnow	4.8 (4.5)
	Pimephales notatus	Bluntnose minnow	33.4 (39.8)
	Pimephales tenellus	Slim minnow	12.4 (8.5)
	Pimephales vigilax	Bullhead minnow	25.0 (46.9)
Family Catostomidae	*Moxostoma erythrurum**	Golden redhorse	0.0 (0.0)
Family Ictaluridae	*Ictalurus punctatus*	Channel catfish	6.5 (9.3)
	Noturus placidus	Neosho madtom	3.6 (1.8)
	Noturus flavus	Stonecat	2.4 (1.7)
Family Fundulidae	*Fundulus notatus**	Blackstripe topminnow	0.0 (0.0)
Family Poeciliidae	*Gambusia affinis**	Western mosquitofish	0.0 (0.0)
Family Moronidae	*Morone chrysops**	White bass	0.0 (0.0)
Family Centrarchidae	*Lepomis cyanellus*	Green sunfish	6.4 (5.3)
	Lepomis humilis	Orangespotted sunfish	16.9 (30.2)
	Lepomis macrochirus	Bluegill	2.2 (1.0)
	Lepomis megalotis	Longear sunfish	1.2 (0.2)
Family Percidae	*Etheostoma spectabile*	Orangethroat darter	8.5 (8.8)
	*Etheostoma flabellare**	Fantail darter	0.0 (0.0)
	Percina caprodes	Logperch	2.8 (1.8)
	Percina copelandi	Channel darter	3.6 (2.2)
	Percina phoxocephala	Slenderhead darter	12.0 (13.1)
Family Sciaenidae	*Aplodinotus grunniens**	Freshwater drum	0.0 (0.0)

Fish species combination	r (P-value)
Pimephales vigilax *Lepomis humilis*	0.98 (<0.0001) *
Campostoma anomalum *Phenacobius mirabilis*	0.89 (0.0001) *
Pimephales notatus *Percina phoxocephala*	0.82 (0.001) *
Pimephales tenellus *Lepomis megalotis*	0.79 (0.002) *
Percina caprodes *Notropis buchanani*	0.78 (0.003) *
P. mirabilis *Noturus flavus*	0.77 (0.004) *
C. anomalum *N. flavus*	0.74 (0.006)
P. notatus *P. tenellus*	0.72 (0.009)
P. tenellus *Percina copelandi*	0.70 (0.01)
P. notatus *P. copelandi*	0.70 (0.01)
C. anomalum *P. caprodes*	0.68 (0.02)
P. mirabilis *N. buchanani*	0.66 (0.02)
C. anomalum *N. buchanani*	0.64 (0.03)
P. notatus *L. megalotis*	0.63 (0.03)
Ictalurus punctatus *Lepomis macrochirus*	0.59 (0.04)
Etheostoma spectabil *P. caprodes*	-0.58 (0.04)
E. spectabile *P. copelandi*	-0.58 (0.04)
E. spectabile *P. notatus*	-0.58 (0.04)

⇦ Table 2. Pearson's correlation analysis [r (P-value)] between mean site densities of significant fish species combinations collected in the upper Neosho River, November 2000 to October 2001. Asterisks (*) indicate correlations significant at sequential-Bonferroni adjusted alpha value.

assemblage (Connell 1980) rather than ongoing active competition. Differentiation between these two premises was beyond the scope of the present study.

Wildhaber, Tabor et al. (2000) reported greater mean overall densities of *N. placidus* (number per 100 m^2) in the upper Neosho (19.8) than in the lower Neosho (5.6). Their collections were made between August and October, a time when *N. placidus* densities are typically highest due to young-of-year recruitment (Moss 1983; Wilkinson et al. 1996). Our mean density of 3.6 was calculated from monthly collections throughout the year. Fuselier and Edds (1994), sampling throughout the year, reported a density of 3.3 in the Cottonwood River. Bulger and Edds (2001), sampling from April to October, recorded a density of 4.5 in the upper Neosho and 1.9 in the Cottonwood. Other reports of *N. placidus* densities in the Neosho River mainstem did not differentiate upper and lower portions of the river, including Moss (1983) with 11.7 from July to October, Wenke et al. (1992) with 6.8 in December and March, Eberle and Stark (1995) with 22.3 in October, and Wildhaber, Allert and Schmitt (1999) with 12.0 from August through October. Densities in Spring River are generally lower (Edds and Dorlac 1995 with 0.9; Wilkinson et al. 1996 with 2.4; Wildhaber, Allert and Schmitt 1999 with 3.3.). Differences in densities reported in these studies could be attributed to seasonal or annual variation, or to differences in collectors, sampling efficiency, quadrat size, or habitat quality.

Given the lack of significant negative correlation, interspecific competition does not appear to be limiting *N. placidus* populations at these sites at this time in the upper Neosho River, contrary to the hypothesis of the USFWS (1991). This finding is similar to that of Wildhaber, Allert and Schmitt (1999), who found significant positive correlations between *N. placidus* and three fishes with habitat preferences similar to those of *N. placidus* (*P. mirabilis, I. punctatus*, and *P. phoxocephala*) in the Neosho, Cottonwood, and Spring rivers combined. However, they found significant negative correlations between *N. placidus* and three fishes (bluntnose minnow *Pimephales notatus*, slim minnow *P. tenellus*, and bullhead minnow *P. vigilax*) with habitat preferences dissimilar to those of *N. placidus*, whereas we found no significant negative correlations. Ross (1986) suggested that more distantly related species (similar to *Pimephales* sp. and *N. placidus* in Wildhaber, Allert and Schmitt 1999) segregated more on resources (e.g. space or time) than did closely related species.

For two species to coexist, they need to segregate along one or more resources (e.g. separation of feeding activity), which would reduce competition to a level at which both species could persist (Gause 1934). For example, *Noturus* species are dominant food consumers during the night, whereas other fishes (e.g. minnow and darters) are dominant food consumers during the day, thus avoiding direct competition for food resources (Burr and Stoeckel 1999). *Noturus placidus* abundance was positively correlated with macroinvertebrate abundance along the same stretch of river, but was limited by habitat, as was macroinvertebrate abundance (Tiemann 2002). Previous research on *N. placidus* has suggested that anthropogenic factors, including impoundments (Wildhaber, Tabor et al. 2000; Tiemann 2002), and environmental contaminants (Wildhaber, Allert et al. 2000), are limiting *N. placidus* populations, and might reduce opportunities for deterministic biotic interactions, including competition. Given the influence of these stochastic factors, it is difficult to assess effects of deterministic factors on *N. placidus* populations in the field; however, additional research could be conducted in the laboratory and field to better understand effects of deterministic factors on *N. placidus*.

Acknowledgements

This research was supported by the U.S. Geological Survey (USGS), Department of Interior, under USGS Cooperative Agreement No. 00CRA0025, with addition funding from an Emporia State University (ESU) Faculty Research and Creativity Grant and the ESU Department of Biological Sciences. K. Cummings, G. Levin, T. Rice, C. Taylor, and D. Thomas, of the Illinois Natural History Survey provided comments and suggestions, and the Kansas Department of Wildlife and Parks and the U.S. Fish and Wildlife Service issued collecting permits. Landowners (G. Gulde, P. and D. Matile, L. Schlesener, and ESU Natural Areas) allowed access to the river on their property. D. Moore and D. Zelmer of ESU gave statistics and study design advice, R. Sleezer and L. Sneed of ESU helped create the map of the study site, and ESU students B. Chance, J. Dean, B. Harkins, and S. Sherraden assisted with fieldwork.

Literature cited

Bulger, A.G. and Edds, D.R. 2001. Population structure and habitat use in Neosho madtom (*Noturus placidus*). Southwestern Naturalist 46(1), p. 8-15.

Burr, B.M. and Stoeckel, J.N. 1999. The natural history of madtoms (Genus *Noturus*), North America's diminutive catfishes. In Irwin, E.R., Hubert, W.A., Rabeni, C.F., Schramm, H.L. Jr. and Coon, T. (eds.), Catfish 2000: Proceedings of the international ictalurid symposium, p. 51-

101. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Chapman, S.S., Omernik, J.M., Freeouf, J.A., Huggins, D.G., McCauley, J.R., Freeman, C.C., Steinauer, G., Angelo, R.T and Schlepp, R.L. 2001. Ecoregions of Nebraska and Kansas (color poster with map, descriptive text, summary tables, and photographs). U.S. Geological Survey, Reston, Virginia.

Connell, J.H. 1980. Diversity and the coevolution of competitors, or the ghost of competition past. Oikos 35(2), p. 131-138.

Cross, F.B. and Collins, J.T. 1995. Fishes in Kansas, 2nd ed. University Kansas Museum of Natural History, Lawrence, 315 p.

Eberle, M.E. and Stark, W.J. 1995. Distribution and abundance of the Neosho madtom (*Noturus placidus*) in Kansas, with an assessment of the amount of suitable habitat. Unpub. Report to the Kansas Department of Wildlife and Parks, Pratt, 10 p.

Edds, D.R. and Dorlac, J.H. 1995. Survey of the fishes of the Spring River Basin in Missouri, Kansas, and Oklahoma, with emphasis on the Neosho madtom. Unpub. Report to the Kansas Department Wildlife and Parks, Pratt, 43 p.

Fausch, K.D. and White, R.J. 1986. Competition among juveniles of coho salmon, brook trout, and brown trout in a laboratory stream, and implications for Great Lakes tributaries. Transactions American Fisheries Society 155(3), p. 363-381.

Fuselier, L. and Edds, D.R. 1994. Seasonal variation in habitat use by the Neosho madtom (Teleostei: Ictaluridae: *Noturus placidus*). Southwestern Naturalist 39(3), p. 217-223.

Gauch, H.G. Jr. 1982. Multivariate analysis in community ecology. Cambridge University Press, Cambridge, United Kingdom, 298 p.

Gause, G.F. 1934. The struggle for existence. Macmillan (Hafner Press), New York, 163 p.

Grossman, G.D., Moyle, P.B. and Whitaker, J.O. Jr. 1982. Stochasticity in structural and functional characteristics of an Indiana stream fish assemblage: A test of community theory. American Naturalist 120(4), p. 423-454.

Grossman, G.D., Ratajczak, R.E. Jr., Crawford, M. and Freeman, M.C. 1998. Assemblage organization in stream fishes: effects of environmental variation and interspecific interactions. Ecological Monographs 68(3), p. 395-420.

Matthews, W.J. 1982. Small fish community structure in Ozark (Arkansas and Missouri, USA) streams: Structured assembly patterns or random abundance of species? American Midland Naturalist 107(1), p. 42-54.

Matthews, W.J. 1998. Patterns in freshwater fish ecology. Kluwer Academic Publishers, Norwell, Massachusetts, 756 p.

Milliken, G.G. and Johnson, D.E. 1984. Analysis of messy data, Volume I: Designed experiments. Wadsworth, Inc., Belmont, California, 473 p.

Moss, R.E. 1983. Microhabitat selection in Neosho River riffles. Unpub. Doctoral dissertation, University of Kansas, Lawrence, 287 p.

Pflieger, W.L. 1997. The fishes of Missouri, 2nd ed. Missouri Department of Conservation, Jefferson City, 372 p.

Rice, W.R. 1989. Analyzing tables of statistical tests. Evolution 43(1), p. 223-225.

Roell, M.J. and Orth, D.J. 1994. The roles of predation, competition, and exploitation in the trophic dynamics of a warmwater stream: a model synthesis, analysis, and application. Hydrobiologia 291(3), p. 157-178.

Ross, S.T. 1986. Resource partitioning in fish assemblages: a review of field studies. Copeia 1986(2), p. 352-388.

Strange, E.M., Moyle, P.B. and Foin, T.C. 1992. Interactions between stochastic and deterministic processes in stream fish community assembly. Environmental Biology Fishes 36(1), p. 1-15.

Tiemann, J.S. 2002. Effects of lowhead dams on fish and benthic invertebrate assemblage structure in the Neosho River, with comments on the threatened Neosho madtom, *Noturus placidus*. Unpub. Master's thesis, Emporia State University, Emporia, Kansas, 71 p.

United States Fish and Wildlife Service. 1991. Neosho madtom recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado, 42 p.

Wenke, T.L., Eberle, M.E., Ermsting, G.W. and Stark, W.J. 1992. Winter collections of the Neosho madtom (*Noturus placidus*). Southwestern Naturalist 37, p. 330-333.

Wildhaber, M.L., Allert, A.L. and Schmitt, C.J. 1999. Potential effects of interspecific competition on Neosho madtom (*Noturus placidus*) populations. Journal Freshwater Ecology 14(1), p. 19-30.

Wildhaber, M.L., Allert, A.L., Schmitt, C.J., Tabor, V.M., Mulhern, D.W., Powell, K.L. and Sowa, S.P. 2000. Natural and anthropogenic influences on the distribution of the threatened Neosho madtom in a midwestern warmwater stream. Transactions American Fisheries Society 129(1), p. 243-261.

Wildhaber, M.L., Tabor, V.M., Whitaker, J.E., Allert, A.L., Mulhern, D.W., Lamberson, P.J. and Powell, K.L. 2000. Ictalurid populations in relation to the presence of a main-stream reservoir in a midwestern warmwater stream with emphasis on the threatened Neosho madtom. Transactions American Fisheries Society 129(6), p. 1264-1280.

Wilkinson, C., Edds, D.R., Dorlac, J., Wildhaber, M.L., Schmitt, C.J. and Allert, A. 1996. Neosho madtom distribution and abundance in the Spring River. Southwestern Naturalist 41(1), p. 78-81.

Zar, J.H. 1999. Biostatistical analysis, 4th ed. Prentice-Hall, Upper Saddle River, New Jersey, 663 p.