Impact of Gravel Bar Scalping on Neosho Madtom (*Noturus placidus*) Populations from the Lower Neosho River, Kansas

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ABSTRACT

From 1996 to 2007 we sampled depositional point bars that were scalped for gravel harvesting and unharvested control sites in the Neosho River, Kansas to determine if scalping effected the abundance of the Neosho madtom (*Noturus placidus*) and other obligate benthic fishes. Mean relative abundance of the Neosho madtoms did not differ between scalped gravel scalped bars and control bars, but was greater in riffles and runs compared to deeper, low velocity point bars ($P<0.001$). Species diversity and richness of obligate benthic fishes tended to be similar between gravel scalped and control bars; however, some obligate benthic fishes [channel catfish (*Ictalurus punctatus*), freckled madtom (*Noturus nocturnus*), stonecat (*Noturus flavus*), orangethroat darter (*Etheostoma spectabile*), and suckermouth minnow (*Phenocobius mirabilis*)] were more likely to be present when the Neosho madtom was present ($P<0.001$). When combining additional data from other long-term monitoring from 1991 to 2007, Neosho madtom relative abundance in the Neosho River was positively related to mean annual flow ($r=0.61$, $P=0.01$). Scalping of gravel bars appeared to have less of an impact on Neosho madtom and other benthic obligate fishes than annual flow. However, other geomorphic metrics such as bedload transport were not measured in this study and, if affected by gravel scalping, may ultimately affect the fishes in the Neosho River.

INTRODUCTION

The Neosho madtom (*Noturus placidus*) is a small catfish (< 75 mm) occurring primarily in the mainstem of the Neosho River and Cottonwood River in Kansas (KS), and to a lesser extent in the South Fork Cottonwood (KS), Spring River (KS, Missouri, and Oklahoma), and the Neosho River in Oklahoma (Cross and Collins 1995, Luttrell et al. 1992, Wilkerson et al. 1996, Wilkerson and Fuselier 1997). The fish is a nocturnal benthic insectivore, typically inhabiting riffles and to a lesser extent depositional point bars with moderate currents and unconsolidated gravel (Moss 1983, Cross and Collins 1995). Neosho madtom typically only survives one year, spawning from May through July and dying shortly thereafter; only a small percentage survive to spawn a second summer (Fuselier and Edds 1994, Bulger and Edds 2001). The historical range of the Neosho madtom has been reduced by one-third due to the construction of multiple impoundments in Kansas and Oklahoma; therefore, it was listed federally as threatened in 1990 due to its vulnerability of becoming endangered (USFWS 1990). The species has been on the Kansas's Threatened and Endangered list since 1975.

The majority of the Neosho madtom's habitat loss is irreversible due to inundation and hypolimnetic releases from federal reservoirs; therefore, the attention of state and federal resource agencies has focused on more solvable problems to protect and improve

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Neosho madtom habitat. These efforts identified several threats to the species' status including mainstem impoundments, hypolimnetic releases from reservoirs, increases in permanent pool elevations at existing reservoirs, hydraulic alterations from headwater impoundment, pollution from feedlots and nonpoint sources, heavy metal contamination, prolonged droughts, and instream gravel removal (USFWS 1991).

Prior to 1990, gravel removal in the Neosho madtom's range was occurring both by dredging the river channel and bar scalping, primarily in the Neosho River. Dredging is the removal of gravel below the water surface; bar scalping is the removal of gravel above the water elevation from depositional (point) bars. At the time, there was information on destruction of Neosho madtom habitat resulting from historic dredging activity (Moss 1981, Fuselier and Edds 1995), and other research had documented the negative effects of gravel dredging on fish communities (Forshage and Carter 1973, Kanehl and Lyons 1992); however, there was no information on the effects of gravel bar scalping in warmwater rivers. In response, Kansas Department of Wildlife and Parks (KDWP) implemented a moratorium on state permits from 1991-1995 for all gravel harvesting within the Neosho madtom's range in Kansas. In 1995, the USFWS issued a biological opinion that allowed for limited gravel harvest by bar scalping only, provided a monitoring study was undertaken to evaluate the impacts of the activity, which began in 1996 by KDWP. The objectives of this study were to use this monitoring data to determine if gravel scalping reduced relative abundance of Neosho madtom and/or if it reduced species richness and diversity of other obligate benthic species, and to determine if other measured factors (e.g., flow) impacted Neosho madtom population abundance.

MATERIALS AND METHODS

Study area

The Neosho River drains approximately 31,000 km^2 of North American prairie beginning in the Flint Hills in Kansas and flowing southeast across the Central Irregular Plains and Ozark Highlands to its confluence with the Arkansas River in northeast Oklahoma (Fig. 1; USEPA 2007). The area is predominantly rural with most cities lying along the Neosho River or its tributaries. Land use is dominated by livestock grazing and row-crop agriculture, and rivers are generally bordered by riparian timber. Discharge is typically greatest during spring and early summer months when the basin receives approximately 75% of its annual precipitation (mean=92 cm/yr; Marcher et al. 1984). Approximately one-third of the Neosho River has been impounded, and federal reservoirs have altered hydrologic patterns to attenuate floods and provide hydroelectric power (USFWS 1991). Our study sites were within the portion of the Neosho River below John Redmond Dam to the Kansas-Oklahoma border (Fig. 1). The study reach is characterized by a valley slope of approximately 0.23 m/km, moderate to high sinuosity ranging from 1.41 to 1.83, and an entrenched channel with bank heights ranging from 4 to 10 m (Carswell and Hart 1985, Dutnell 1998). The river lies on Pennsylvanian bedrock (300 ma.) with a valley alluvium approximately 10 m in thickness and consisting primarily of silt and clay with a basal layer of sand and gravel averaging 1 m in thickness (Williams 1944, Juracek and Perry 2005). Bedload material is primarily chert gravel derived from the basal layer during erosion of the alluvium, thus forming the principal substrate material at depositional point bars and riffles throughout the Neosho River (Juracek and Perry 2005).

Site selection

Twenty separate gravel bars were sampled from 1996 to 2007 varying annually from 12 to 18 depending on gravel harvest activity. Gravel removal at treatment (gravel scalped) sites averaged 557 m^3 annually (range 62-1,206 m^3), while control sites had no gravel removal for a minimum five years prior to sampling. We selected two control sites for each treatment site, each located immediately up- and downstream from the respective treatment site. Separate gravel bars were selected as control sites (59%); however, due to accessibility constraints, 41% of control sites were actually located on the same bar on which the gravel harvest was occurring. In these cases, control sites were buffered 30 to 60 m from the harvest activity to minimize effect on adjacent benthic fauna.

All sites were depositional bars; however, there were notable differences in habitat characteristics between sites. We classified sites into four mesohabitat types- point bars, gravel riffles, gravel runs, and bedrock riffles. Sixty-five percent of our sites were point bars where the river did not have a substantial change in slope and had moderate flows. These depositional areas occurred opposite of outside bends and did not contain any riffle or run habitats. Point bar morphology reflected the river's meander, with flat, elongated bars occurring opposite of gradual bends in the river, while at sharp bends in the river gravel bars were piled high and were shorter in length. All point bars sloped from the riparian zone riverward, terminating on bedrock at approximately mid-channel. Riffles

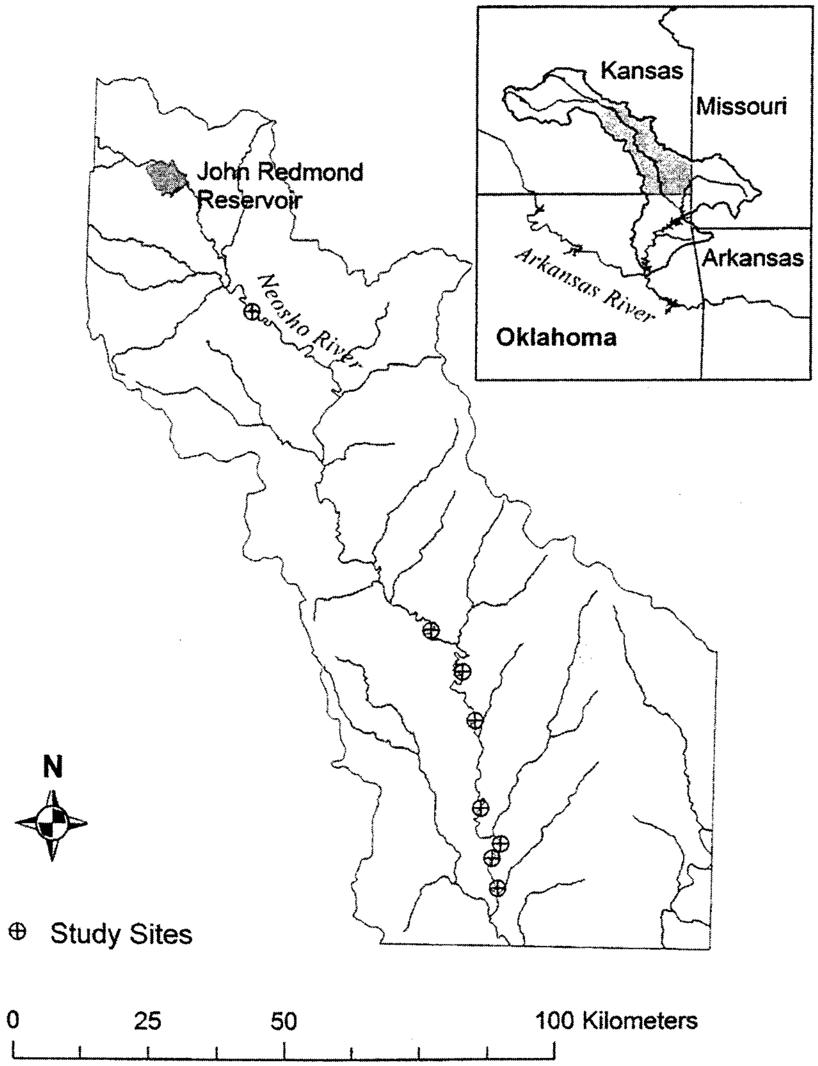

Figure 1. Map of the lower Neosho River in Kansas depicting the location of study sites. Inset map shows regional position of the study area including major reservoirs.

and runs occurred in association with depositional bars where the river underwent a change in bed elevation. Gravel riffles comprised 14% of our sites and were characterized as having moderate to swift currents, shallow depths, and gravel as the predominant substrate, whereas gravel runs (6%) occurred up- or downstream of gravel riffles, but were slightly deeper. Bedrock riffles (15%) were associated with depositional areas near limestone outcroppings and contained cobbles and boulders with pockets of chert gravel; flows were swift and depths shallow at these sites.

Gravel bar sampling

We sampled sites annually for eleven years from 1996 to 2007, with the exception of 2005 due to high water. Site length averaged 76 m (range 26-192 m) and was divided into five equally-spaced transects to encompass potential suitable habitat for Neosho madtom. Beginning downstream, transects were set perpendicular to the wetted channel and included up to five sample points along each transect spaced a minimum of 2 m apart. The number of sample points per transect depended on the presence of suitable gravel substrate and depths <1.2 m. All sample points were selected for the presence of chert gravel; however, substrate was not always homogeneous, often intermixed and at times dominated by fines (silt/sand), cobble, or bedrock. Each sample point (4.5 m^2) was kick-seined by two or three persons thoroughly disturbing the substrate 2 m upstream of a seine (2.4 m, 3 mm mesh; Wildhaber et al. 2000a and 2000b). All samples (n=5,611) were collected when the river was at base-flow (mean=49 m/s, range 37-667) during daytime in July (18%), August (66%), September (15%) and October (1%), following expected recruitment of age-0 Neosho madtom (Fuselier and Edds 1994, Bulger and Edds, 2001). Enumeration of benthic insectivores and total length of Neosho madtoms were recorded prior to release. Care was taken to insure fish were released a suitable distance from unsampled points to avoid duplicate collections. In addition, habitat metrics were recorded at each sample point including substrate, water depth, and current velocity, which was recorded at 60% depth with a current meter.

Hydrologic data

Daily mean flow data were obtained from the USGS gauge station east of Parsons, KS (37°20'24" N, 95°06'35" W). Mean annual discharge and daily discharge information were obtained for the period of record (1922-2007). Since the majority of Neosho madtoms collected were age-0 fish post-spawn, we assumed that fluctuations in mean annual discharge may determine success of madtom spawning and recruitment. When analyzing for hydrological relationships, we also obtained additional data from USFWS (V. Tabor, USFWS, Manhattan, KS, personal communication) and from Eberle and Stark (1995) for sampling that occurred in the lower Neosho River from 1990 to 2007. Sampling methods for these additional data were similar to our study, and combining the data sets extended the temporal scale when assessing the relationship between water flow and Neosho madtom populations.

Data analysis

Nesoho madtom catch per unit effort (CPUE) was calculated as the number of fish collected per 100 m^2 kick seined, which is a common metric used for Neosho madtom studies (Wildhaber et al. 2000a and 2000b, Bulger and Edds 2001). We used analysis of covariance (ANCOVA) with year as the covariate to determine if mean CPUE of Neosho madtoms differed at control and excavated sites. We also used ANCOVA with year as the covariate to determine if mean Neosho madtom CPUE differed by mesohabitat type, and to determine if mean depth, velocity, and substrate composition differed by mesohabitat type. Logistic regression with odds ratios (Stokes et al. 2000) was used to determine if the presence of a Neosho madtom was associated with the presence of other obligate benthic fishes. Shannon diversity index and species richness for obligate benthic fishes were calculated for each site, and an ANCOVA (with year as the covariate) was used to determine of mean species richness or diversity differed between control and scalped gravel sites. Finally, correlation analysis was used to relate Neosho madtom CPUE to mean annual flow and coefficient of variation of mean annual flows.

RESULTS

Mean Neosho madtom CPUE was highly variable, ranging from 0.4/100 m^2 in 1996 to 25.4/100 m^2 in 1999 (Fig. 2). Mean Neosho madtom density did not differ between scalped gravel bars (mean=5.96/100 m^2) and control sites (mean=7.62/100 m^2; P=0.17). In addition, differences were not consistent with treatment groups as higher CPUE occurred adjacent to bar scalping activities in 1998, while it tended to be higher on control sites most other years.

Mean Neosho madtom relative abundance was highest in gravel riffles and lowest in point bars (P<0.001; Table 1). Point bars were significantly deeper than other mesohabitats (P<0.001), had slower velocities (P<0.001), and contained gravel that was more likely to be embedded with fines (P<0.001). Control sites had more habitat heterogeneity than did treatment sites with only 54% of sample points occurring in point bar habitats, while at treatment sites 86% of sample points were from point bars, and no samples occurred in either gravel runs or bedrock riffles. Total Neosho madtom lengths averaged 34 mm and ranged from 14 to 79 mm (n=1,789). Adult fish collected post-spawn (>50 mm as described by Bulger and Edds 2001) comprised only 5% of the total catch; thus, the majority of madtoms collected were age-0 fish.

The proportional abundance of the benthic fish community for all sites combined consisted of channel catfish (*Ictalurus punctatus*; 59%), slenderhead darter (*Percina phoxocephala*; 23%), suckermouth minnow (*Phenocobius mirabilis*; 6%), and orangethroat darter (*Etheostoma spectabile*; 5%) with less common species occurring (by order of relative abundance), stonecat (*Noturus flavus*), logperch (*Percina caprodes*), gravel chub (*Erimystax x-punctatus*), river darter (*Percina shumardi*), flathead catfish

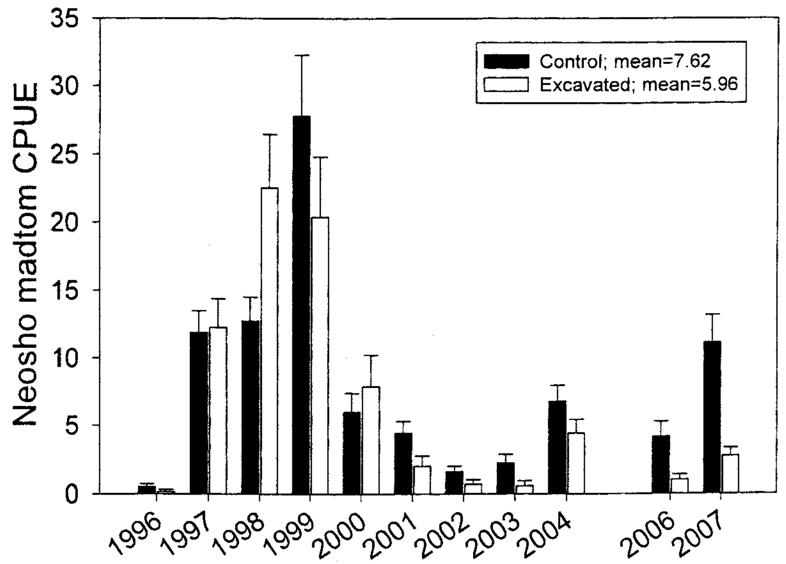

Figure 2. Mean relative abundance (number/100 m^2) of Neosho madtom at gravel scalped and control sites in the Neosho River, Kansas 1996-2007. Errors bars represent one standard error.

(*Plyodictis olivaris*), and freckled madtom (*Noturus nocturnus*). Logistic regression revealed that when Neosho madtom were present at a site, *I. punctatus*, *P. mirabilis*, *E. spectabile*, *N. flavus* and *N. nocturnus* were 1.6 to 10.8 times more likely to be collected at that site (P<0.001; Table 2).

Species diversity and richness of obligate benthic fishes tended to be similar between gravel scalped and control sites. Mean benthic species diversity ranged from 0.65 (SE=0.04) at scalped sites in 2002 to 0.81 (SE=0.03) at scalped sites in 2003. Overall, mean benthic species diversity did not differ between control sites (mean=0.72) and scalped sites (mean=0.74; P=0.08). Mean benthic species richness ranged from ranged from 2.41 (SE=0.05) at scalped sites in 2003 to 2.70 (SE=0.10) at scalped sites in 1997. Overall, mean benthic species diversity was lower at control (mean=2.38) sites compared to gravel scalped sites (mean =2.46; P=0.02), but this difference was likely not biologically meaningful. There was no evidence that gravel scalping reduced benthic species diversity or richness compared to control sites.

Neosho madtom CPUE typically increased with mean annual flow (r=0.61, P=0.01). The highest CPUE typically occurred when mean annual flow was at least 50% higher than the mean flow for the Parsons gauge station (Fig. 3). Coefficient of variation of mean annual flow tended to be lower at higher Neosho madtom relative abundance, but this relationship was not significant (r=-0.38, P=0.15).

Table 1. A comparison of Neosho madtom CPUE and mean depth, velocity, and percentage of substrate in each category among mesohabitat types. Values in parentheses are one standard error. Values with the same letter indicate significant difference for those mesohabitat types.

	Gravel riffle	Gravel run	Bedrock riffle	Point bar
N. placidus/100 m^2	[a]19.21 (1.92)	[b]14.44 (1.89)	[c]9.10 (1.11)	[d]3.21 (0.24)
Mean depth (m)	[a]0.41 (0.01)	[b]0.44 (0.01)	[c]0.32 (0.01)	[d]0.57 (0.05)
Mean velocity (m/s)	[a]0.31 (0.01)	[b]0.26 (0.01)	[c]0.38 (0.01)	[d]0.07 (0.00)
Clean gravel (%)	70	53	48	47
Gravel + fines (%)	25	35	8	39
Gravel + cobble (%)	6	11	40	12
Gravel + bedrock (%)	0	0	4	2
Control $_{(n=3794)}$ (%)	14	9	23	54
Treatment $_{(n=1817)}$ (%)	14	0	0	86

DISCUSSION

The results of our study suggest that scalping a gravel bar has minimal direct effect on the abundance of Neosho madtom adjacent to these mining activities. We hypothesized that gravel scalping may reduce Neosho madtom abundance because this fish would move onto the scalped bars during high flows as it prefers shallow habitats near the water-shore interface (Moss 1983, Fuselier and Edds 1994). One of the concerns was that periodically inundated portions of gravel bars might be critical to certain life history requirements for the Neosho madtom, such as spawning or recruitment, and that alterations to the this habitat, either by removal of gravel or compaction by heavy equipment, may be detrimental to madtom populations. Benthic species diversity and richness were not lower in gravel scalped sites compared to control sites, which is further evidence of no direct effect of gravel scalping on benthic fishes. Finally, other benthic species were more likely to be collected when the Neosho madtom was collected, which is similar to the results of Wildhaber et al. (1999) and suggests that other benthic fishes will likely respond to management actions that would improve Neosho madtom populations. Although many studies have documented the negative impacts to aquatic fauna from in-channel dredging (Kanehl and Lyons 1992, Brown et al. 1998, Meador and

Table 2. Logistic regression results demonstrating the odds of the presence of various benthic fishes when the Neosho madtom was present in the Neosho River, 1997-2007.

Species	Odds ratio	P value
Channel catfish (*Ictalurus punctatus*)	1.63	<0.001
Flathead catfish (*Plyodictis olivaris*)	0.39	0.06
Freckled madtom (*Noturus nocturnus*)	10.81	<0.001
Suckermouth minnow (*Phenocobius mirabilis*)	1.83	<0.001
Slenderhead darter (*Percina phoxocephala*)	1.11	0.25
Orangethroat darter (*Etheostoma spectabile*)	3.96	<0.001
River darter (*Percina shumardi*)	0.50	0.14
Logperch (*Percina caprodes*)	0.82	0.43
Gravel chub (*Erimystax x-punctatus*)	1.13	0.60
Stonecat (*Noturus flavus*)	4.82	<0.001

Layher 1998), there is little research assessing the impacts of gravel bar scalping on fish communities. Pauley et al. (1989) found reduced bar size and a loss of side-channel macrohabitats from gravel bar scalping in the Puyallup River, Washington. Our results of Neosho madtom abundance and benthic species richness and diversity suggest that properly managed gravel bar scalping operations may not directly influence the number or diversity of obligate benthic fishes.

Habitat preference and fish community composition were similar to previous studies (Moss 1983, Eberle 1996, Wildhaber et al. 1999, Bulger and Edds 2001). Although madtoms occurred at significantly higher densities in riffles and runs, nearly 30% of all madtoms collected during our monitoring were from deeper, slower habitat associated with point bars, at times in densities up to 44/100 m^2. Previous studies have found the Neosho madtom nearly exclusively in riffles (Bulger and Edds 2001, Fuselier and Edds 1994); however, Eberle and Stark (1995) made note of madtoms occurring on point bars not part of a riffle. Our data compliments their observations demonstrating that the Neosho madtom is not a riffle obligate but regularly occurs in nearly all habitats that have suitable substrate and depths within the Neosho River. In addition, the presence of a thin layer of silt and sand (fines) overlain on gravel did not seem to preclude madtom occurrences. Forty-one percent of sample points where madtoms were collected contained gravel overlain by fines, while 47% were identified as clean gravel, which supports observations by Moss (1981) that Neosho madtoms appear to be silt tolerant, provided gravel is present. As in other studies (Fuselier and Edds 1994, Bulger and Edds 2001), our length frequency histogram data indicate a predominantly annual turnover of the Neosho madtom population. Adult fish collected post-spawn (>50 mm; Bulger and Edds 2001) comprised only 5% of the total catch; thus, the majority of madtoms collected were young-of-year fish.

We found increased Neosho madtom abundance associated with higher mean annual flow, which is similar to Wildhaber et al. (2000a) who found positive correlations with Neosho madtom CPUE and higher minimum flow, particularly in the winter and spring months. In our study, Neosho madtom densities were high during much of the 1990's when abundant rainfall produced above-average flows but dwindled during the drought years of the first half of the current decade. Although water flow was above average in 2004, 2005, and 2007, mean madtom CPUE during these years (4.8/100 m^2) did not respond to the level of those documented in consecutively wet years from 1997 to 1999 (mean=17.0/100 m^2). Deacon (1961) noted that riffle-dwelling species, including the Neosho madtom, were slow to recover following the prolonged drought of the mid-1950's, and this may have occurred in our study. Mean annual discharge in the Neosho

River was below normal from 2000 to 2003 and again in 2006, when madtom CPUE averaged 3.4/100 m^2; therefore, our data may be reflecting a slow, but gradual increase in the madtom population following the drought of this decade. In addition, from 1996 to 1999, 57% of our sample points were from point bars compared to 67% from 2000 to 2007. A greater proportion of our samples from this lower-quality habitat may diminish the perception of madtom recovery following this period of drought.

Mean annual flow appeared to be more influential to Neosho madtom abundance than gravel bar scalping. These results concur with those of Wildhaber et al. (2000a); alteration of water flows by reservoirs may be a primary factor in Neosho madtom declines. Regulation of flows by reservoirs upstream of Neosho madtoms (e.g., John Redmond Dam) to mimic a more natural hydrograph would likely benefit this fish as well as other native benthic fishes. Although few differences in fish abundance and community composition at gravel scalped and control sites occurred during this study, other geomorphic factors not measured may be strongly affected by gravel bar scalping. Gravel removal, regardless of the method, results in a deficiency of bedload material in the river, thus creating a scenario where a river will work to equilibrate this deficiency by

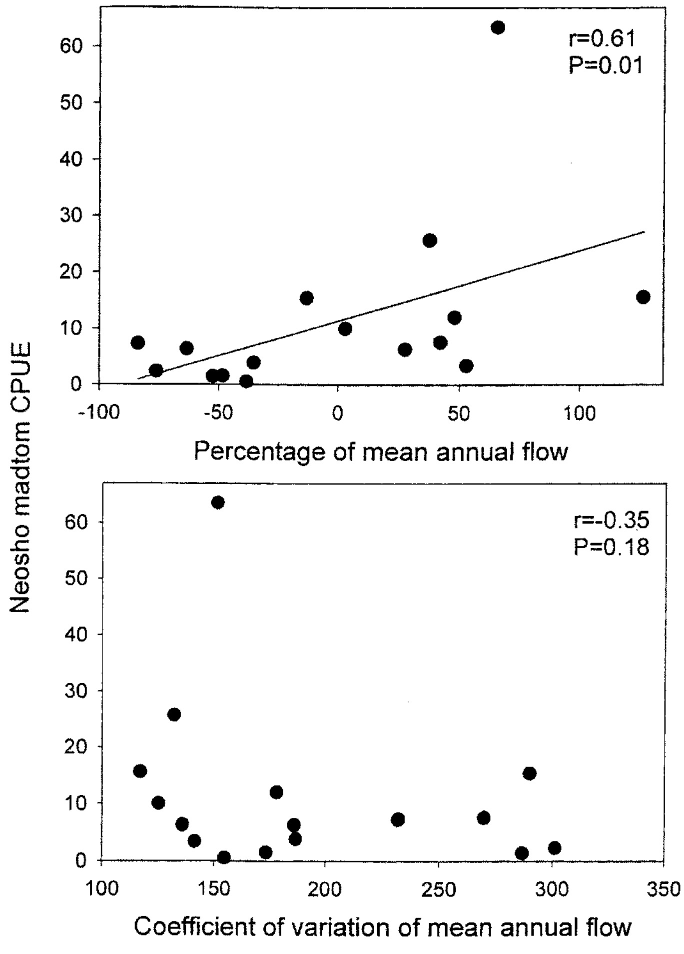

Figure 3. Relationship between annual madtom CPUE (number/100 m^2) and mean annual flow and coefficient of variation of mean annual flow in the Neosho River, 1991-2007.

eroding the sources of bedload (bed and banks) at an increased rate (Kondolf 1997, Juracek and Perry 2005). Excessive removal of bedload material will increase erosion rates and can result in damage to infrastructure, agricultural fields, and aquatic habitats (Kondolf 1997, Langer 2002) and may eventually impact the Neosho madtom or other native species. The majority of bedload material in the Neosho River comes from erosion of basal deposits in the alluvium (Juracek and Perry 2005); thus, bedload movement could be measured from erosion sources and depositional points along various reaches of the river in order to establish a "safe yield" of gravel removal without causing a significant deficiency. Therefore, future research on the geomorphic processes related to gravel scalping (and how these process may effect fishes) is needed. Proper management of gravel harvest operations in the Neosho madtom's range should continue to maintain suitable habitat conditions in order for the species to remain viable.

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