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FISH COMMUNITY STRUCTURE IN NATURAL AND ENGINEERED HABITATS IN THE KANSAS RIVER[†]

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ABSTRACT

We investigated fish assemblage structure in engineered (rip-rap) and natural habitats (log jams and mud banks) in the Kansas River USA to determine if natural structures had higher abundance and diversity of fishes at a local spatial scale. A total of 439 randomly selected sites were boat electrofished from May to August 2005 and 2006. Mean species diversity and richness were significantly higher in rip-rap than log jams and mud banks. Mean relative abundance (CPUE; number of fish collected per hour electrofishing) of six of the 15 most common fishes (>1% of total catch) were most abundant in rip-rap, two were most abundant in log jams, and none in mud banks. Rip-rap had the highest relative abundance of fluvial specialist and macrohabitat generalists, whereas mean CPUE of fluvial dependents was highest in log jams. Although a discriminant function analysis indicated that nine size classes (eight species) discriminated among three habitat types, the high misclassification rate (38%) suggested a high degree of fish assemblage overlap among the habitats. Although previous work has suggested that engineered structures (rip-rap) and urbanization are linked to reduced biotic diversity or reduced growth of fish species, our results suggest that at a local scale rip-rap may not have the same negative impacts on fish assemblages. Published in 2009 by John Wiley & Sons, Ltd.

KEY WORDS: rip-rap; habitat; river; diversity; urbanization

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INTRODUCTION

Human alteration has modified natural river systems throughout the world. Channelization, agriculture, urbanization, overharvesting and the creation of dams and reservoirs have significantly altered the majority of the world's large rivers (Dister *et al*., 1990; Gore and Shields, 1995). These activities have been linked to subsequent riverine species declines and homogenization of habitat types and fish assembalges (Shields, 1995; Barko and Herzog, 2003; Allan, 2004). However, the effects of instream and shoreline habitat alteration on riverine fishes may be scale dependent. At larger spatial scales such as river reaches and watersheds, habitat alteration lowers biotic integrity (Karr *et al*., 1985; Wang *et al*., 2001), decrease habitat availability through backwater and floodplain sedimentation (Gore and Shields, 1995; Shields *et al*., 1995) and is associated with reduced growth and abundance of fishes (Hess and Mestl, 1993; Galat *et al*., 2005; Paukert and Makinster, 2008). At smaller spatial scales, engineered structures such as rip-rap (artificial shoreline structures comprised of rocks of various sizes; Eitzmann *et al*., 2007) can be associated with increased abundance and biomass of riverine fishes and provide habitat for fishes that is similar to natural habitats such as woody debris (Shields *et al*., 1995; Barko *et al*., 2004).

Potential benefits of woody debris to fishes in large river systems include increased cover and increased macroinvertebrate density and diversity (Angermeier and Karr, 1984; Benke *et al*., 1985; Lehtinen *et al*., 1997). However, research examining the influence of rip-rap on riverine fishes has been mixed and focused primarily on

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salmonids or smaller stream systems (Fischenich, 2003). The relatively fewer studies examining effects of rip-rap on fishes in large rivers have suggested that it is associated with increased fish species richness at local scales (Barko *et al*., 2004) or supports fish assemblages different from those found in areas without rip-rap at river-reach scales (Madejczyk *et al*., 1998). Further, rip-rap may have positive effects on riverine ecosystems at smaller scales while simultaneously having negative effects at larger, river-reach scales (Shields *et al*., 1995).

Previous studies of Kansas River fishes have evaluated habitat associations of individual species (Quist *et al*., 1999; Eitzmann *et al*., 2007; Paukert and Makinster, 2008); however they have not investigated how fish assemblages differ among natural and engineered habitats. The objective of this study was to determine if fish assemblage structure during summer differs in engineered rip-rap and natural habitats (log jams and mud banks) in the Kansas River at a local spatial scale. We predicted that log jams, a habitat representing the least amount of river disturbance, would support (1) higher species richness and diversity and (2) a higher proportion of fluvial specialist and fluvial dependent species than rip-rap or mud bank.

METHODS

Study area

The Kansas River is a seventh-order large river and a tributary of the Missouri River (Galat *et al*., 2005) that flows 274 km from its beginning at the confluence of the Smokey Hill and Republican rivers east to its confluence with the Missouri River in Kansas City, Kansas. Like other large rivers around the world, it has been impacted by anthropogenic activities including channelization, increases in agriculture and urbanization, and instream sand dredging (Sanders *et al*., 1993; Paukert and Makinster, 2008). The Kansas River naturally has a shallow (typically less than 1.5 m), braided channel containing sand bars, log jams (piles of partially submerged woody debris along shorelines), and islands (Quist and Guy, 1999; Makinster, 2006). Approximately 16% of the Kansas River contains bank stabilization structures (Sanders *et al*., 1993), especially in the more channelized reaches near urban areas (Paukert and Makinster, 2008). However, rip-rap, mud banks and log jams are located throughout the entire Kansas River (Makinster, 2006), and thus the river contains a mix of engineered and naturally-occurring shoreline habitats. Common riparian woody vegetation includes deciduous, broadleaf species such as *Acer saccharinum*, *Populus deltoides*, *Salix* spp., *Platanus occidentalis* and *Celtis occidentalis* (Geyer *et al*., 2003).

Fish sampling

Fish communities were sampled throughout the Kansas River from May to August 2005 and 2006 using boat-mounted electrofishing. The river was divided into 16 segments, each ranging from 10 to 16 km in length (mean = 16.1 km) which could be sampled in one day. Each segment was then divided into 10 1.6 km sections, three of which were randomly selected for sampling (Eitzmann *et al*., 2007; Paukert and Makinster, 2008). Within each of these three 1.6 km sections, three shoreline sites were chosen for sampling. Shoreline habitat within each 1.6 km section was classified as mud bank, rip-rap or log jam (a partially submerged mass of woody debris $\geq$4.5 m in length and extending into the channel from shore; Eitzmann *et al*., 2007). All three habitats were sampled per 1.6 km section if present, but only one habitat was sampled per site within the 1.6 km section.

Sampling was conducted using a Coffelt Model VVP 15 electrofisher mounted to a 4.5 m boat using one netter on the bow (Paukert and Makinster, 2008). Electrofishing was achieved during the day downstream using a low frequency pulsed DC output with one anode array (1–6 A; 180–250 V; 15–20 Hz) for 5 min per site (Paukert and Makinster, 2008). Multiple 5 min sites were sampled within a 1.6 km section if all habitats were present (see above). We chose boat electrofishing as our sampling gear because it effectively collects many fishes from multiple, complex habitats and is commonly used for fish assemblage studies (e.g., Madejczyk *et al*., 1998). Shoreline seining was not used because of the difficulty in seining complex habitat such as woody debris and rip-rap (Hayes *et al*., 1996; Guy *et al*., In press), although using this gear may have resulted in a higher proportion of small-bodied fishes (Eitzmann and Paukert, In press). All collected fish were measured (total length to the nearest mm) and released near the capture site.

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Data analysis

To assess differences in fish species diversity and richness among the three habitat types, mean species diversity and richness were calculated for each habitat type. Species diversity for each sample was calculated using the Shannon index of diversity (Shannon and Weaver, 1949; Kwak and Peterson, 2007). Species richness was calculated as the total number of species per sample. Mean species richness and species diversity were calculated for each habitat type to determine if there were differences in these metrics among habitat type. Catch-per-unit-effort (CPUE; number of each species collected per hour of electrofishing) was used as an index of relative abundance. Only species comprising $>1\%$ of the catch were analysed. Large-bodied fishes comprising $>1\%$ of the catch were divided into juvenile and adult length classes based on Pflieger (1997) and Paukert and Makinster (2008) (Table I). All species comprising $>1\%$ of the catch were also divided into habitat guilds based on Becker (1983), Pflieger (1997), Galat *et al.* (2005) and Thomas *et al.* (2005). Fluvial dependent species require flowing water for a portion of their life cycle (commonly for reproduction), fluvial specialists require flowing water for most or all of their life cycle, and macrohabitat generalists are found in both lentic and lotic systems (Galat *et al*., 2005). Fluvial dependent and fluvial specialist species are considered habitat specialists. All CPUE data were log10 $(x+1)$ transformed to better meet assumptions of normality.

Table I. Number of fish collected (percentage), and mean catch per unit effort (standard error), of fish collected in three habitat types during summer 2005–2006 in the Kansas River. Habitat guilds were macrohabitat generalist (MG), fluvial dependent (FD) or fluvial specialist (FS). No juvenile (<550 fork length) shovelnose sturgeon or shortnose gar were collected. *p*-values are from testing if mean CPUE differed among habitats for each species

Species	*N* (%)	Mean CPUE (SE)			*p*-value	Habitat Guild
		Log jam	Mud bank	Rip-rap		
Flathead catfish (*Pylodictis olivaris*)						FD
Adult	84 (5.7)	1.5 (0.5)	1.6 (0.3)	3.0 (0.5)	<0.010	
Juvenile (<400 mm)	312 (21.2)	4.3 (1.3)	4.2 (0.6)	14.0 (1.7)	<0.001	
River carpsucker (*Carpiodes carpio*)						MG
Adult	154 (10.5)	5.4 (1.3)	3.4 (0.6)	3.8 (0.7)	0.280	
Juvenile (<275 mm)	73 (5.0)	1.3 (0.4)	2.2 (0.4)	1.6 (0.5)	0.195	
Red shiner (*Cyprinella lutrensis*)	166 (11.3)	2.5 (1.0)	2.8 (0.5)	6.6 (1.4)	0.035	MG
Freshwater drum (*Aplodinotus grunniens*)						MG
Adult	72 (4.9)	1.3 (0.4)	1.4 (0.3)	2.5 (0.4)	0.095	
Juvenile (<275 mm)	70 (4.8)	1.7 (0.6)	1.7 (0.4)	1.9 (0.5)	0.979	
Blue sucker (*Cycleptus elongatus*)						FS
Adult	62 (4.2)	3.3 (0.9)	1.2 (0.3)	1.3 (0.3)	0.017	
Juvenile (<500 mm)	5 (0.2)	0.3 (0.2)	0.1 (0.1)	0.1 (0.1)	0.299	
Longnose gar (*Lepisosteus osseus*)						FD
Adult	29 (2.0)	0.8 (0.4)	0.8 (0.2)	0.6 (0.2)	0.999	
Juvenile (<700 mm)	34 (2.3)	1.4 (0.5)	0.7 (0.2)	0.8 (0.3)	0.404	
Channel catfish (*Ictalurus punctatus*)						MG
Adult	41 (2.8)	0.7 (0.3)	0.9 (0.2)	1.3 (0.4)	0.875	
Juvenile (<250 mm)	11 (0.7)	0	0.4 (0.1)	0.2 (0.1)	0.274	
Fathead minnow (*Pimephales promelas*)	48 (3.3)	0.2 (0.2)	0.7 (0.2)	2.4 (0.5)	<0.001	MG
Bluegill sunfish (*Lepomis macrochirus*)	43 (3.0)	0.2 (0.2)	0.4 (0.2)	2.4 (0.5)	<0.001	MG
Smallmouth buffalo (*Ictiobus bubalus*)						MG
Adult	37 (2.5)	2.7 (0.8)	0.4 (0.1)	0.9 (0.3)	<0.001	
Juvenile (<400 mm)	1 (0.1)	0.0	0.1 (0.1)	0	0.473	
Adult shovelnose sturgeon (*Scaphirhynchus platorynchus*)	33 (2.3)	0.5 (0.3)	1.3 (0.3)	0.4 (0.2)	0.114	FS
Green sunfish (*Lepomis cyanellus*)	32 (2.2)	0	0.2 (0.1)	2.0 (0.1)	<0.001	MG
Adult shortnose gar (*Lepisosteus platostomus*) (>375 mm)	31 (2.1)	0.9 (0.5)	0.7 (0.2)	0.9 (0.4)	0.535	MG
Gizzard Shad (*Dorosoma cepedianum*)						MG
Adult	13 (0.9)	0	0.4 (0.2)	0.4 (0.2)	0.290	
Juvenile (<200 mm)	12 (0.8)	0	0.3 (0.1)	0.5 (0.3)	0.538	
White crappie (*Pomoxis annularis*)	22 (1.5)	0.3 (0.2)	0.4 (0.1)	0.9 (0.4)	0.902	MG

An analysis of covariance (ANCOVA) was used to determine if (1) mean species diversity, (2) mean species richness and (3) mean CPUE for each habitat guild differed by habitat. In addition, ANCOVA was also used to determine if mean CPUE for each species differed among the three habitats. In these analyses habitat was used as the main effect and river mile and year as covariates. Thus, any effects of river mile (spatial distribution) and year on mean species diversity and richness were accounted for in the ANCOVA. A least squares means test was used to identify where the means differed if the ANCOVA was significant. All statistical tests with $p < 0.10$ were considered statistically significant.

A stepwise discriminant function analysis (DFA) was used to assess if the CPUE of each species could be used to discriminate among the three habitat types. This statistical technique has been widely used in ecological studies, including fish ecology (Hawkes *et al*., 1986; Nelson *et al*., 1992; Poff and Allan, 1995). It is used to study the differences between two or more groups using several measured variables (i.e. mean CPUE of each species by habitat; Klecka, 1980). We used the DFA in a descriptive manner (canonical discriminant analysis CDA); deriving canonical axes based on combinations of the measured variables that maximally separate the pre-determined classes (i.e. the three habitat types; Poff and Allan, 1995). Only those species comprising >1% of the total catch were used in the analysis.

RESULTS

A total of 1469 fishes comprising 36 species were sampled from 439 sites. Fifteen species comprised >1% of the total catch (1385 total fishes). Flathead catfish (*Pylodictis olivaris*) and river carpsucker (*Carpiodes carpio*), were the species most frequently captured (see Table I). Of the 15 dominant species, two were fluvial specialists (blue sucker, *Cycleptus elongates,* and shovelnose sturgeon, *Scaphirhynchus platorynchus*), and two were fluvial dependents (longnose gar, *Lepisosteus osseus* and flathead catfish). The remaining species were considered habitat generalists (Table I).

Mean species diversity was highest in rip-rap (0.75) and lower in log jams (0.59) and mud banks (0.51; $F = 8.46$, numerator df = 2, denominator df = 434; $p = 0.0002$; Figure 1). Mean species richness was also highest in rip-rap

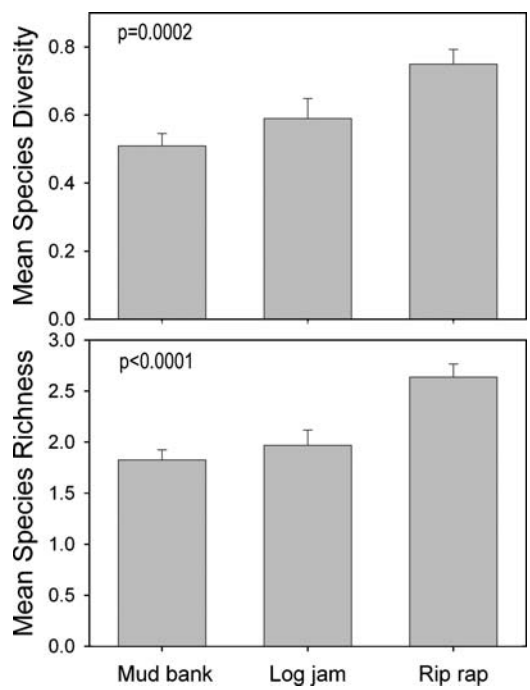

Figure 1. Mean species diversity (top panel) and richness (bottom panel) by habitat type for fish collected at three habitat types in the Kansas River during summer 2005–2006. Error bars represent one standard error of the mean

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(2.64) and lower in log jams (2.00) and mud banks (1.83; F = 12.46, numerator df = 2, denominator df = 434, $p < 0.0001$; Figure 1). Therefore, the highest number of species and the highest diversity was always found in rip-rap.

Mean CPUE for eight of the 23 dominant species and/or size classes differed among habitat types (Table I). Adult and juvenile flathead catfish, red shiner, adult freshwater drum, bluegill, green sunfish and fathead minnow were most abundant in rip-rap, whereas adult blue sucker and smallmouth buffalo were most abundant in log jams (Table I). No species or size class was significantly most abundant in mud banks. Mean CPUE of the remaining species did not differ among habitat types. The mean CPUE of fluvial specialists combined (blue sucker and shovelnose sturgeon) was higher in log jams compared to rip-rap and mud banks (F = 3.83, numerator df = 2, denominator df = 71, $p = 0.0263$). Fluvial dependent (flathead catfish and longnose gar) CPUE (F = 10.23, numerator df = 2, denominator df = 218, $p < 0.001$) and macrohabitat generalist CPUE (F = 6.11, numerator df = 2, denominator df = 307, $p = 0.0025$) was also highest in rip-rap (Figure 2).

Nine size classes (juvenile or adult) representing eight species discriminated among the three habitats based on a stepwise DFA: juvenile and adult flathead catfish, green sunfish, adult smallmouth buffalo, fathead minnow, bluegill, adult blue sucker, shovelnose sturgeon and juvenile river carpsucker (Table II; Figure 3). Axis one represented a gradient of sites with higher relative abundance of adult and juvenile flathead catfish, centrarchids (bluegill and green sunfish) and fathead minnows. Axis two differentiated among sites with high adult blue sucker and smallmouth buffalo abundances and low shovelnose sturgeon abundance (Wilks' Lambda = 0.736, F = 7.86, numerator df = 18, denominator df = 856, $p < 0.0001$). Centroids for each habitat indicated that log jams and mud banks had more similar fish assemblages than compared to rip-rap (Figure 3). Although the DFA was statistically

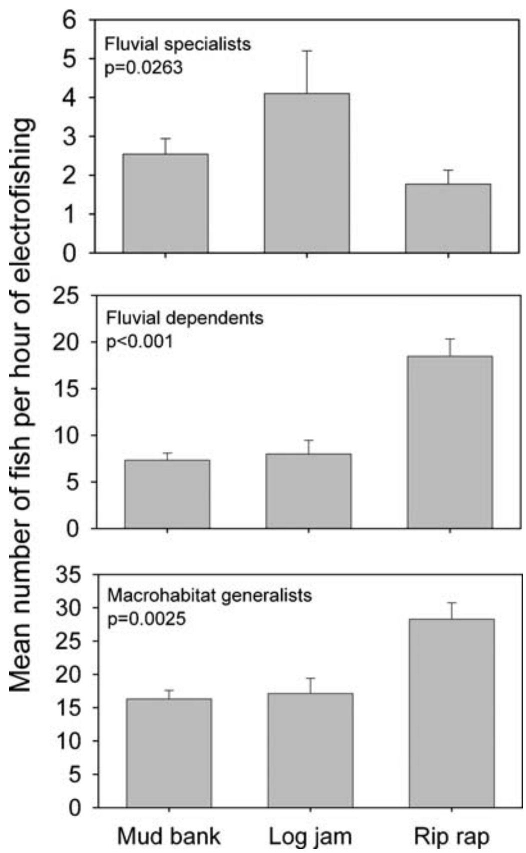

Figure 2. Mean number of fish collected per hour of electrofishing among mud bank, log jam, and rip-rap habitat in the Kansas River for species classified as fluvial specialists (top panel), fluvial dependents (middle panel), and macrohabitat generalists (bottom panel). Habitat guilds were from Becker (1983); Pflieger (1997); Galat *et al.* (2005); Thomas *et al.* (2005). Error bars represent one standard error of the mean

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Table II. Canonical coefficients for the discriminant function analysis to determine if fish assemblages differ among rip-rap, log jams and mud banks for fish collected in the Kansas River, summer 2005–2006

Species and size	Canonical Axis 1	Canonical Axis 2
Bluegill	0.287	−0.028
Adult blue sucker	−0.027	0.484
Fathead minnow	0.378	−0.152
Adult flathead catfish	0.242	−0.046
Juvenile flathead catfish	0.586	−0.002
Green sunfish	0.421	−0.067
Juvenile river carpsucker	−0.244	−0.083
Adult shovelnose sturgeon	−0.110	−0.377
Adult smallmouth buffalo	0.188	0.777

significant the misclassification rate was high (38.27%). Log jams had the highest misclassification rate (81.8%) followed by rip-rap (46.8%), and mud banks (18.3%).

DISCUSSION

Our study indicates that at a local scale, rip-rap had increased fish species richness and diversity, and did not have lower abundances of many fluvial specialist and dependent species, at least for the primarily large-bodied species collected in our study. At local scales, rip-rap may provide suitable habitat of similar quality to natural banks, but this likely depends on both its extent (e.g. intermittent or continuous) and the quality of riverine habitat it replaces (Shields *et al*., 1995). A review by Fischenich (2003) suggested that rip-rap generally provides a novel habitat type for fishes in warmwater systems where rivers tend to lack a coarse hard substrate, which may explain why our study indicated higher diversity, richness and (in some cases) fish abundance in rip-rap. Barko *et al.* (2004) also found that man-made rock structures (wing dikes) supported higher fish species richness than natural banks in the upper Mississippi River. However, Pennington *et al.* (1983) and Madejczyk *et al*. (1998) showed that fish species richness was not significantly higher at revetments or wing dikes in the Mississippi River.

In disturbed rivers complex natural habitats like woody debris are often intentionally removed or washed away by higher velocity flows due to channelization (Shields *et al*., 1995; Reich *et al*., 2003). The correlation of habitat complexity with species diversity is a well-established theory in ecology (Gorman and Karr, 1978; Benke *et al*., 1985), and rip-rap's complex structure may support more diverse habitat types and thus higher fish species diversity.

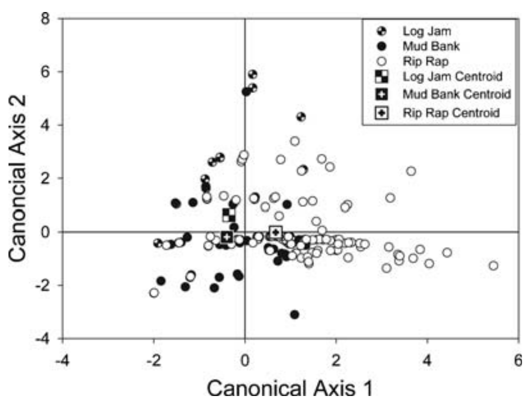

Figure 3. Canonical discriminant function analysis of fish assemblages at three habitat types in the Kansas River sampled using electrofishing during summer 2005–2006

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Rip-rap's coarse surfaces also support more dense and diverse invertebrate colonization than sandy or muddy substrate (Benke *et al*., 1985; Litvan *et al*., 2008), potentially increasing food resources that may support a greater diversity and abundance of fishes. Therefore, in disturbed systems rip-rap may replace some of the naturally-occurring complex habitat that has been eliminated.

Our hypothesis that natural habitats would have higher species diversity and abundance was unsupported, but the relationship may be scale dependent. At local spatial scales, both rip-rap and woody debris may function similarly to allow invertebrate colonization and a diversity of habitats and flows that support both lentic and lotic fishes when compared to sandy or muddy substrates (Angermeier and Karr, 1984; Benke *et al*., 1985; Lehtinen *et al*., 1997; Barko *et al*., 2004; Litvan *et al*., 2008). The high species richness and diversity in rip-rap in the Kansas River suggests that at a local scale in the Kansas River, rip-rap may provide higher-quality habitat for fishes than log jams. Although we did not test the mechanism for this relationship, perhaps greater stability in rip-rap habitat during changing flow regimes in the river allows more time for the establishment of invertebrate populations or provides more constant habitat for fishes. Further research is necessary to assess these more temporal and mechanistic questions.

The results of this study indicate that rip-rap did not support a distinct fish assemblage or a higher proportion of habitat generalists as expected. Although some species had higher abundances in specific habitats, there was substantial overlap in fish assemblage structure among habitats. This supports the conclusions of Barko *et al.* (2004) and Pennington *et al.* (1983) who found similar adult fish species assemblage structure in areas with and without wing dikes and revetments in the upper Mississippi River. In contrast, Madejczyk *et al.* (1998) found that greater than 40% of species collected were found in only one of three habitat types (wing dikes, woody snags, bare shore) in the upper Mississippi River, and Lehtinen *et al.* (1997) found that woody snags and bare shores supported dissimilar fish communities in Mississippi River main channel borders. In our study all but four species that comprised $>1\%$ of the catch (juvenile smallmouth buffalo, juvenile channel catfish, green sunfish, gizzard shad) were collected in all three habitats. The lack of discrimination of fish assemblages among habitats may be the result of a high proportion of habitat generalists in the Kansas River fish community, which is common in Great Plains streams (Bramblett and Fausch, 1991). Our study collected only four species that were not macrohabitat generalists (flathead catfish, blue sucker, longnose gar and shovelnose sturgeon). Flathead catfish, a fluvial dependent species, was more abundant in rip-rap, whereas all other species that had higher abundances in rip-rap were macrohabitat generalists (red shiner, adult freshwater drum, fathead minnow and green and bluegill sunfish). Flathead catfish use cover when resting and feed in riffles and rocky areas (Daugherty and Sutton, 2005; Pflieger, 1997), which is consistent with the findings of our study and another study on the Kansas River (Paukert and Makinster, 2008). In contrast, fish assemblages in other large rivers have higher proportions of habitat specialists than our study (Lehtinen *et al*., 1997; Madejczyk *et al*., 1998). Further, Madejczyk *et al.* (1998) noted that habitat specialists may have influenced fish assemblages at individual habitats in their study. In this study, only four of the 15 dominant species were habitat specialists, with the highest relative abundance of fluvial dependents found in rip-rap. The large number of habitat generalists may indicate that differences in habitat assemblages may not be as pronounced in the Kansas River.

Adult blue sucker (a fluvial specialist) and smallmouth buffalo (a macrohabitat generalist) were most abundant in log jams. These fish feed on invertebrates and detritus (Pflieger, 1997; Galat *et al*., 2005; Thomas *et al*., 2005), both available in log jams whose structure can trap detritus and support invertebrate colonization (Benke *et al*., 1985; Lehtinen *et al*., 1997; Litvan *et al*., 2008). Both species have been collected in areas of high flows in the Kansas River (Eitzmann *et al*., 2007) and therefore these log jams may also be associated with higher flows.

The impacts of rip-rap in riverine systems may be scale-dependent. Our study indicates that at local spatial scales, rip-rap may rival naturally-occurring shoreline fish habitats, and does not appear to be associated with reduced abundances of native riverine species. However, at larger spatial scales, rip-rap may have negative effects such as habitat alteration and increased sedimentation. Stream ecological theory stresses the importance of nutrient, sediment and organism exchange between the main channel of a river and its floodplains and backwaters during periodic flood pulses (Junk *et al*., 1989; Bayley, 1991). Channelization and bank stabilization using rip-rap structures constrains lateral migration of the main channel, increases sedimentation of previous backwaters, and results in the loss of lentic habitats, all of which can have negative effects on fishes (Karr *et al*., 1985; Hesse and Mestl, 1993; Gore and Shields, 1995). Urbanization at the landscape level decreases fish diversity (Wang *et al*., 1997), and at the river reach scale, increased rip-rap and urbanization may lead to reductions in flathead catfish growth (Paukert and Makinster, 2008). Construction of intermittent rip-rap may locally increase species richness and diversity and provide novel habitat for fishes. However, continuous rip-rap that constrains natural riverine processes still may be detrimental to riverine ecosystems at larger spatial scales.

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REFERENCES

Allan JD. 2004. Landscapes and riverscapes: the influence of land use on stream ecosystems. *Annual Review of Ecology, Evolution, and Systematics* **35**: 357–384. DOI:10.1146/annurev.ecolsys.35.120202.110122

Angermeier PL, Karr JR. 1984. Relationships between woody debris and fish habitat in a small warmwater stream. *Transactions of the American Fisheries Society* **113**: 716–726. DOI: 10.1577/1548-8659. (1984)13<716:RBWDAF>2.0.CO;2

Barko VA, Herzog DP. 2003. Relationship among side channels, fish assemblages, and environmental gradients in the unimpounded Upper Mississippi River. *Journal of Freshwater Ecology* **18**: 377–382.

Barko VA, Herzog DP, Hrabik RA, Scheibe JS. 2004. Relationship among fish assemblage and main-channel-border physical habitats in the unimpounded upper Mississippi River. *Transactions of the American Fisheries Society* **133**: 371–384. DOI: 10.1577/02-103

Bayley PB. 1991. The flood pulse advantage and the restoration of river-floodplain systems. *Regulated Rivers: Research and Management* **6**: 75–86.

Becker GC. 1983. The fishes of Wisconsin. University of Wisconsin Press: Madison, Wisconsin; 1052 pp.

Benke AC, Henry RL III, Gillespie DM, Hunter RJ. 1985. Importance of snag habitat for animal production in southeastern streams. *Fisheries* **10**: 8–13. DOI: 10.1577/1548-8446. (1985)10<0008:IOSHFA>2.0.CO;2

Bramblett RG, Fausch KD. 1991. Variable fish communities and the index of biotic integrity in a Western Great Plains River. *Transactions of the American Fisheries Society* **120**: 752–769.

Daugherty DJ, Sutton TM. 2005. Seasonal movement patterns, habitat use, and home range of flathead catfish in the Lower St. Joseph River, Michigan. *North American Journal of Fisheries Management* **25**: 256–269. DOI: 10.1577/M03-252.2

Dister E, Gomer D, Obrdilk P, Petermann P, Schneider E. 1990. Water management and ecological perspectives of the upper Rhine's floodplains. *Regulated Rivers: Research and Management* **5**: 1–15. DOI: 10.1002/rrr.3450050102

Eitzmann JL, Paukert CP. In press Longitudinal differences in habitat complexity and fish assemblage structure of a Great Plains river. *American Midland Naturalist.*

Eitzmann JL, Makinster AS, Paukert CP. 2007. Distribution and growth of blue sucker in a Great Plains USA river. *Fisheries Management and Ecology* **14**: 255–262. DOI: 0.1111/j.1365-2400.2007.00550.x

Fischenich JC. 2003. *Effects of Riprap on Riverine and Riparian Ecosystems, ERDC/EL TR-03-4, U.S.* Army Engineer Research and Development Center: Vicksburg, MS.

Galat DL, Berry CR Jr, Peters EJ, White RG. 2005. The Missouri River basin. In *Rivers of North America*, Benke AE, Cushing CE (eds). Elsevier Academic Press: San Diego, California; 427–480.

Geyer W, Brooks K, Neppl T. 2003. Streambank stability of two Kansas river systems during the 1993 flood in Kansas, USA. *Transactions of the Kansas Academy of Science* **106**: 48–53.

Gore JA, Shields FD. 1995. Can large rivers be restored? *BioScience* **45**: 142–152.

Gorman OT, Karr JR. 1978. Habitat structure and stream fish communities. *Ecology* **59**: 507–515.

Guy CS, Braaten PJ, Herzog DP, Pitlo J, Rogers RS. In press Warmwater fish in rivers. In *Standard methods for sampling North American freshwater fishes*, Bonar S, Willis DW, Hubert WA (eds). American Fisheries Society: Bethesda, Maryland; 59–84.

Hawkes CL, Miller DL, Layher WG. 1986. Fish ecoregions of Kansas: stream fish assemblages patterns and associated environmental correlates. *Environmental Biology of Fishes* **17**: 267–279.

Hayes DB, Ferreri CP, Taylor WW. 1996. Active fish capture methods. In *Fisheries techniques, second edition*, Murphy BR, Willis DW (eds). American Fisheries Society: Bethesda, Maryland; 193–220.

Hesse LW, Mestl GE. 1993. An alterative hydrograph for the Missouri River based on the precontrol condition. *North American Journal of Fisheries Management* **13**: 360–366. DOI: 10.1577/1548-8675. (1993)13<0360:AAHFTM>2.3.CO;2

Junk WJ, Bayley PB, Sparks RE. 1989. The flood pulse concept in river-floodplain systems. *Canadian Special Publication of Fisheries and Aquatic Sciences* **106**: 110–127.

Karr JR, Toth LA, Dudley DR. 1985. Fish communities of midwestern rivers: a history of degradation. *BioScience* **35**: 90–95.

Klecka WR. 1980. *Discriminant Analysis*. SAGE Publications, Inc.: Newbury Park, California; 7.

Kwak TJ, Peterson JT. 2007. Community indices, parameters, and comparisons. In *Analysis and Interpretation of Freshwater Fisheries Data*, Guy CS, Brown ML (eds). American Fisheries Society: Bethesda, Maryland; 677–764.

Lehtinen RM, Mundahl ND, Madejczyk JC. 1997. Autumn use of woody snags by fishes in backwater and channel border habitats of a large river. *Environmental Biology of Fishes* **49**: 7–19.

Litvan ME, Stewart TW, Pierce CL, Larson CJ. 2008. Effects of grade control structures on the macroinvertebrate assemblage of an agriculturally impact stream. *River Research and Applications* **24**: 218–233. DOI: 10.1002/rra.1063

Madejczyk JC, Mundahl ND, Lehtinen RM. 1998. Fish assemblages of natural and artificial habitats within the channel border of the upper Mississippi river. *American Midland Naturalist* **139**: 296–310.

Makinster AS. 2006. Flathead catfish population dynamics in the Kansas River. MS Thesis, Kansas State University, Manhattan, Kansas, USA.

Nelson RL, Platts WS, Larsen DP, Jenson SE. 1992. Trout distribution and habitat in relation to geology and geomorphology in the North Fork Humboldt River drainage, northeastern Nevada. *Transactions of the American Fisheries Society* **121**: 405–426.

Paukert CP, Makinster AS. Longitudinal patterns in flathead catfish relative abundance And length at age within a large river: effects of an urban gradient. *River Research and Applications.* DOI: 10.1002/rra.1089 (In Press)

Pennington CH, Baker JA, Potter ME. 1983. Fish population along natural revetted banks on the lower Mississippi river. *North American Journal of Fisheries Management* **3**: 204–211.

Pflieger WL. 1997. *The Fishes of Missouri, revised edition*. Missouri Department of Conservation: Jefferson City, Missouri.

Poff NL, Allan JD. 1995. Functional organization of stream fish assemblages in relation to hydrological variability. *Ecology* **76**: 606–627.

Quist MC, Guy CS. 1999. Spatial variation in population dynamics of shovelnose sturgeon in the Kansas River. *Prairie Naturalist* **31**: 65–74.

Quist MC, Tillma JS, Burlingame MN, Guy CS. 1999. Overwinter habitat use of shovelnose sturgeon in the Kansas River. *Transactions of the American Fisheries Society* **128**: 522–527.

Reich M, Kershner JL, Wildman RC. 2003. Restoring streams with large wood: a synthesis. In *The Ecology and Management of Wood in Rivers*, Gregory S, Boyer K, Gurnell A (eds). American Fisheries Society Symposium 37, American Fisheries Society: Bethesda, Maryland; 355–366.

Sanders R, Huggins MDG, Cross FB. 1993. The Kansas River system and its biota. In *Proceedings of the Symposium on Restoration Planning for the Rivers of the Mississippi and Missouri River Ecosystem*, Hesse LW, Stalnaker CB, Benson NG, Zuboy JR (eds). Report Number 19; U.S. National Biological Survey: Washington, DC; 295–326.

Shannon CE, Weaver W. 1949. *The Mathematical Theory of Communication*. University of Illinois Press: Urbana, Illinois.

Shields FD Jr. 1995. Fate of lower Mississippi River habitats associated with training dikes. *Aquatic Conservation: Marine and Freshwater Ecosystems* **5**: 97–108. DOI: 10.1002/aqc.3270050203

Shields FD Jr, Commer CM, Testa S III. 1995. Toward greener riprap: environmental considerations from microscale to macroscale. In *River, Coastal and Shoreline Protection: Erosion Control Using Riprap and Armourstone*, Thorne CR *et al*. (eds). John Wiley and Sons: Chichester; 557–574.

Thomas JA, Emery EB, McCormick FH. 2005. Detection of temporal trends in Ohio River fish assemblages based on lockchamber surveys. In *Historical Changes in Large River Fish Assemblages of the Americas*, Rinne JN, Hughes RM, Calamusso B (eds). American Fisheries Society: Bethesda, Maryland; 431–449.

Wang LZ, Lyons J, Kanehl P, Gatti R. 1997. Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams. *Fisheries* **22**: 6–12.

Wang L, Lyons J, Kanehl P. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. *Environmental Management* **28**: 255–266. DOI: 10.1007/s002670010222