SPATIAL HABITAT VARIATION IN A GREAT PLAINS RIVER: EFFECTS ON THE FISH ASSEMBLAGE AND FOOD WEB STRUCTURE

by

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ABSTRACT

We investigated spatial variation in fish assemblage and food web structure in the Kansas River, USA in relation to habitat changes. Fishes were collected at ten sites throughout the Kansas River for assessing assemblage structure in summer 2007 using fish community metrics and at 3 sites in 2006 for food web structure using stable isotope analysis. Satellite imagery indicated riparian habitat on the Kansas River was dominated by agriculture in the upper reaches (>35%) and tended to increase in urban land use in the lower reaches (>58%). Instream habitat complexity also decreased with increased urban area (<25%) becoming more channelized. Jaccard's similarity and percent similarity indices suggested that large-bodied fishes show changes in species presence and composition longitudinally within the river. Also, reaches directly above Bowersock Dam in Lawrence, Kansas and below the Johnson County Weir, near Kansas City, Kansas had low percent similarity compared to other reaches, suggesting the dam and the weir affect community composition. Canonical correspondence analysis indicated that species that prefer high velocity flows and sandy substrate (blue sucker and shovelnose sturgeon) are associated with the upper river reaches. Also, there was a higher abundance of omnivorous and planktivorous fish species in the lower more channelized river. The lower reaches contain more tolerant, macrohabitat generalist species and the upper river contained more intolerant, fluvial specialist species. Fish, macroinvertebrates, and detritus were collected at three river reaches classified as the heterogeneous instream habitat (>40% grass islands and sand bars) intermediate (22% grass islands and sand bars), and homogeneous (6% grass islands and sand bars) instream habitat reaches in June 2006. Riparian land use (proportion as agricultural and urban) was related to instream habitat with homogeneous areas having more urban riparian area compared to the heterogeneous and intermediate reaches. The heterogeneous habitat reach had

higher variability in $\delta^{13}C$ for fish classified as piscivores/invertivores (P=0.029) and macroinvertebrates (P=0.004) suggesting the complex habitat in the heterogeneous habitat reach provided more variable food sources. The $\delta^{15}N$ values also indicated that ten of the twelve fish species tended to consume prey at higher trophic levels in the heterogeneous habitat reach suggesting a more complex food web. Land use practices are leading to homogenization of instream habitat and this homogenization of habitats may be related to food web diversity and trophic position of fishes. Conserving intolerant, native species in the Kansas River may require maintaining suitable habitat for these species and restoration of impacted areas of the river.

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PREFACE

This thesis is my own personnel work, but has been written in third person because it is written for submission into the peer-reviewed journal *River Research and Applications*.

Chapter 1

Longitudinal differences in habitat complexity and fish assemblage structure of a Great Plains River.

ABSTRACT

We investigated the spatial variation in the fish assemblage in the Kansas River, USA to study how the fish community structure changes with habitat complexity in a large river. Fishes were collected at ten sites throughout the Kansas River for assessing assemblage structure in summer 2007. Satellite imagery indicated riparian land use in the Kansas River was dominated by agriculture in the upper reaches (>35%) and tended to increase in urban land use in the lower reaches (>58%). Instream habitat complexity (number of braided channels, islands, etc.) also decreased with increased urban area (<25%). Jaccard's similarity and percent similarity indices suggested that large-bodied fishes show changes in species presence and composition longitudinally within the river. Also, reaches directly above Bowersock Dam in Lawrence, Kansas and below the Johnson County Weir, near Kansas City, Kansas had low percent similarity compared to other reaches, suggesting the dam and the weir affect community composition. Canonical correspondence analysis indicated that species that prefer high velocity flows and sandy substrate (blue sucker and shovelnose sturgeon) are associated with the upper river reaches. Also, there was a higher abundance of omnivorous and planktivorous fish species in the lower river. Principal components analysis indicated the lower reaches contain more tolerant, macrohabitat generalist species and the upper river contained more intolerant, fluvial specialist species. Conserving intolerant, native species in the Kansas River may require maintaining suitable habitat for these species and restoration of impacted areas of the river.

INTRODUCTION

Habitat alteration has had a substantial effect on river fishes throughout the world and has caused the decline of many native fishes and the homogenization of fish communities within rivers. The major anthropogenic affects that have caused the reduction of habitat in streams and rivers includes agriculture, urbanization, channelization, creation of dams, removal of snags, and pollution (Miller et al., 1989; Sheehan and Rasmussen, 1993; Gore and Shields, 1995; Johnson et al., 1995; Ligon et al., 1995; Sparks, 1995; Kanehl et al., 1997; Richter et al., 1997; Ricciardi and Rassmussen, 1999; Warren et al., 2000; Paukert and Makinster, In press). Many specialist species in Great Plains rivers have been extirpated because of these anthropogenic disturbances (Karr et al., 1985; Pegg and McClelland, 2004; Galat et al., 2005; Haslouer et al., 2005; Simon et al., 2005; McClelland et al., 2006). For example, seventeen species have been extirpated from the Maumee River, Ohio and eight species from the Illinois River, Illinois and planktivores and omnivores have become the dominant mid-river species, due to human influences on the watersheds (Karr et al., 1985). The reduction of specialist species has led to the homogenization of river fish communities which makes it difficult to determine the more recent effects of different disturbances on the fish communities (Rahel, 2000; 2007). Bramblett and Fausch (1991a) found that it is difficult to determine the status of the fish communities for Great Plains streams and rivers because many of the species within the systems are tolerant generalists that occupy many different habitats and can withstand many types of disturbances.

Although many rivers have homogenized communities, some still have community shifts spatially usually due to distinct habitat changes (e.g. dams, weirs, channelization; Karr et al., 1985; Pegg and McClelland, 2004; Pyron and Lauer, 2004; Galat et al, 2005; Gillette et al., 2005; McClelland et al., 2006). The Missouri and Illinois Rivers have suffered from various human alterations, but species richness is highest in mid-river to downriver reaches, which is related to more diverse tributaries in the lower Missouri River and the less impacted lower reaches of the Illinois River (Galat et al., 2005; Pegg and McClelland, 2004). In the upper reaches of the Missouri River invertivores and herbivores are the most abundant trophic guilds, whereas omnivores and benthic invertivores become more abundant downstream (Pegg and Pierce, 2002; Galat et al., 2005). The species that prefer moderate to high velocity flows and specific habitats (shovelnose sturgeon, *Scaphirhynchus platorynchus*, blue sucker, *Cycleptus elongatus*; Quist and Guy, 1999; Eitzmann et al., 2007) were also more abundant in the upper Missouri River which is the relatively unimpacted area of the river, and the generalist fishes that prefer slow water (bigmouth buffalo, *Ictiobus bubalus*, river carpsucker, *Carpiodes carpio*, and freshwater drum, *Aplodinotus grunniens*) appear to be found in the highly impacted, channelized lower river (Galat et al., 2005). McClelland et al. (2006) found the community in the lower Illinois River consisted of mostly generalist species not affected by sediment loads and the upper river contained both generalist and specialist species. They also noted that predator abundance in the lower river was higher and forage fish abundance was higher in the upper reaches of the Illinois River. Although, Karr et al. (1985) noted that mid-river omnivores have become the dominate fishes in the Illinois River. Therefore, highly impacted areas of rivers tend to be dominated by omnivorous and generalist species.

The Kansas River has also been highly impacted by human alteration such as agriculture, channelization, levees, dredging, and urbanization (Sanders et al., 1993, Paukert and Makinster, In press), but little research has been conducted to determine how these disturbances have altered the fish community within the river. Within the Kansas River there are 14 species that are listed of special concern, threatened or endangered. Of the 14 listed species, seven are believed to be extirpated from the river or not reproductively viable in the river (Cross and Collins, 1995; Haslouer et al., 2005), suggesting declines in native, fluvial specialist species. In the 1950s species such as the speckled chub, *Macrohybopsis aestivalis*, plains minnow, *Hybognathus placitus*, and western silvery minnow, *Hybognathus argyritis*, were among the top ten most abundant species in the lower Kansas River, but declined to relatively few numbers by 1980 (Cross and Moss, 1987). Many other species also declined or disappeared from the lower Kansas River from 1950-1980 (e.g. pallid sturgeon, *Scaphirhynchus albus*, flathead chub, *Macrhybopsis gracilis*, sicklefin chub, *Macrhybopsis meeki*, sturgeon chub, *Macrhybopsis gelida*, etc., Cross and Moss, 1987). Therefore, the objective of this study is to determine the fish community structure within the Kansas River and how the structure differs spatially and may relate to anthropogenic disturbance. We predict species richness will increase in the lower river similar to the Illinois and Missouri Rivers. Also, the community structure above the Johnson County Weir and Bowersock Dam will consist of mostly macrohabitat generalist and tolerant species that can inhabit fast and slow moving water due to distinct habitat changes and creation of reservoir-like environments upstream of these structures (Gillette et al., 2005; Falke and Gido, 2006). We also hypothesized the Kansas River will be similar to the Missouri River with more herbivores and invertivores in the upper, less impacted reaches and the channelized lower portions of the river will contain more omnivores and benthic invertivores. The lower, channelized river reaches will contain more macrohabitat generalist species, and the upper, relatively less impacted river will contain more fluvial specialist species.

MATERIALS AND METHODS

Study area

The Kansas River is a shallow (typically <1.5 m depth), sand bed river that begins near Junction City, Kansas and flows east 274 km to the Missouri River (Makinster and Paukert, 2008). The Kansas River watershed contains eighteen federal reservoirs (>650 ha) and about 13,000 small impoundments that have caused more stable flows and a decrease in sediment loading downstream (Sanders et al., 1993). However, Bowersock Dam (a low-head dam at river kilometer, rkm 83) is the only dam partially restricting the movement of fish on the main channel of the Kansas River (Quist and Guy, 1999), and created a low velocity, reservoir environment for about 5-6 km upstream. Although, Johnson County Weir (a small rock water intake structure used to divert river flows) at rkm 27 may also restrict fish movement at low discharge (Eitzmann et al., 2007) and also creates a reservoir environment for about 5-6 km upstream. The river is braided with many shallow side channels, and sandy islands usually overgrown with willows and grasses (Quist et al., 1999; Eitzmann et al., 2007).

Riparian and instream habitat

Ten reaches of the Kansas River were sampled throughout the study (Table 1.1; Fig. 1.1). Each reach was approximately 32 km apart throughout the river (except for at Bowersock Dam where one reach was directly above the dam and another reach was directly below the dam) and were selected to represent the entire Kansas River. Within each reach, all sampling was conducted within a 6 km section (Table 1.1).

To identify instream (stream width, number of channels, and proportion as channel, grass islands, and sand bars) and riparian (proportion as agriculture, forest, and urban land use) habitat in each reach, we used 1-m resolution satellite imagery from images taken on September 24, 2006 (Paukert and Makinster, In press). Imagery from 2007 was not available and we assumed in one year that instream and riparian habitat would not significantly change. Transects were created perpendicular to the river channel at 0.8 km intervals within the ten reaches, and riparian habitat (200 m on each side of the bankfull height) was measured along the transect. ArcGIS was used to calculate the length of each transect that was agriculture (pasture grassland and row cropland), forested (larger trees and vegetation), and urban land (obvious roads, paved parking lots, sand pits, and other man-made disturbances; Paukert and Makinster, In press). Bankfull width (m) was calculated as distance between the two most distinct banks along the transect (Armantrout 1998; Paukert and Makinster In press). Within the bankfull width, the number of channels (areas containing flowing water), grass islands (grass and forested areas surrounded by water), and sand bars (sand and vegetated areas between the bankfull mark and the channel) were calculated. Bankfull width was then used to estimate the proportions of the different instream habitats.

Field collections

The ten reaches were sampled for fishes and instream environmental variables from June 26 to August 22, 2007. Boat electrofishing and shoreline seining were used to assess the fish community as these gears collected >90% of the species available (Eitzmann and Paukert, 2007). An attempt was made to have consistent effort in each reach for each gear to facilitate comparisons among reaches. Electrofishing was conducted in three habitats (main channel border, rock eddy, and channel crossover) and seining was conducted in two habitats (main channel border and backwater) in each reach. Six randomly selected samples were taken in each habitat with each gear at all reaches unless habitat was limited in which case all available habitat was sampled. Daytime pulsed DC electrofishing (7-11 A, 400-500 V, 40-60 pulses s^{-1}) was conducted for approximately 300 seconds for each sample in all habitats using a Coffelt Model VVP 15 electrofisher powered by a 5,000-watt, single phase, 240-volt AC generator with a Wisconsin ring electrode with 8 droppers attached to one boom. All electrofishing was conducted in one day at each reach. A 6.0 m long and 1.2 m deep straight seine with 0.64 cm mesh was fished parallel to shore for 25 m in all habitats to collect small-bodied fish. All seining was conducted in one day in each reach. Fish collected with seines were fixed with 10% formalin and identified in the laboratory. A sub sample of 25 fish of each species in each sample were measured (total length, TL, mm) in the laboratory. All fish collected with electrofishing were identified, measured and released in the field near the site of collection.

We collected instream and shoreline environmental variable data at each site sampled with electrofishing and seining. The instream environmental variables collected include conductivity (μS), depth (m), flow (bottom, middle, surface flow; m sec^{-1}), Secchi depth (cm), substrate penetration (cm), and temperature (^{o}C). Shoreline environmental variables included visual proportion (within seine haul and electrofishing sites) of shoreline as mud bank, rip-rap, vegetation, or woody debris. Depth, flow, and substrate penetration data was collected on three transects perpendicular to shore and three points were measured along each transect. Substrate penetration was measured by suspending a 3 meter long, 1.3 cm diameter rebar 30 cm above the substrate, releasing it, and then measuring the distance the rebar penetrated the substrate. Conductivity, Secchi depth, and temperature were only taken at the beginning of each sample. Shoreline habitat was based on the shoreline present within each sample.

Data analysis

A multivariate analysis of variance (MANOVA) was used to test if mean proportion of riparian and instream habitat differed among reaches. If the MANOVA was significant an analysis of variance (ANOVA; Proc Mixed in SAS) was used to test which habitat variables differed among sites (Littel et al., 1996). Statistical significance was declared at $P \leq 0.10$, and least squares means tests were used to determine where means differed if the ANOVA was significant.

Catch per unit of effort (CPUE) was calculated as catch per unit of area (e.g. fish m^{-2}) for seines and catch per hour of electrofishing (e.g. fish $hour^{-1}$). Shannon-Weiner diversity (diversity) was calculated using CPUE from each individual sample for electrofishing and seining data separately. An ANOVA was used to test if mean species richness or diversity differed among reaches for each gear. Least squares means tests were used to determine where means differed if the ANOVA was significant.

Jaccard's similarity and percent similarity indices (PSI) were calculated for every combination of pairs of reaches for both the electrofishing and seining data separately to test how similar the community composition was among reaches. A two-way Mantel test (Mantel, 1967) was used to determine if distance between sites and similarity values were associated for both similarity indices. A significant, negative correlation would indicate that sites farther apart were less similar in species presence (Jaccard's) or composition (PSI). We also wanted to test if reaches impacted by the Bowersock Dam (reaches 7 and 8) and the Johnson County Weir (reaches 9 and 10) were less similar to other reaches so similarity of those sites to all other sites was compared to the mean similarity of all other sites combined using an ANOVA.

Canonical correspondence analysis (CCA) was used to compare species CPUE for each individual site to the 13 environmental variables, the proportion of instream and riparian habitat, and distance from the Missouri River confluence (rkm). This analysis was done separately for seining and electrofishing. Only the species that accounted for >1% of the total catch for each gear were used in the analysis (Ostrand and Wilde, 2002). The manual forward selection procedure in CANOCO 4.5 was used to decrease the number of environmental variables by only including the environmental variables that account for a significant amount of the variation ($P<0.10$) within the data set (ter Braak and Smilauer, 2002). The final CCA used the log transformed fish community data and the set of selected environmental variables. A CCA was also used to determine if feeding guild abundance was associated with environmental variables in the Kansas River. Species were assigned a feeding guild based on Pflieger (1997) and Thomas et al. (2005; Table 1.2). Methods used for the CCA are the same as listed above.

Principal components analysis (PCA) was conducted to determine which environmental variables best characterize the ten reaches. Species were assigned a habitat and tolerance guild based on Pflieger (1997), Galat et al. (2005), and Thomas et al. (2005; Table 1.2). As with the CCA, analysis of seining and electrofishing data was conducted separately. A t-test was conducted to determine if mean principal component scores differed when fish in habitat and tolerance guilds were present or absent.

RESULTS

Riparian and instream habitat

Riparian and instream habitats differed among reaches (Wilks' lambda = 0.193, d.f. = 36, 327, $P < 0.001$), with the upper reaches (1-3 and 5) of the river dominated by agriculture and forested areas with less than 10% urban area (Fig. 1.2A). Agricultural crop land decreased from upriver to downriver with reach 10, near the urban areas of Kansas City, Kansas not containing any agricultural crops (Fig. 1.2A). Urban areas generally increased downstream (reaches 6-10), with reaches 1-3 having <5% urban but reaches 7, 9, and 10 have >20% urban land (Fig. 1.2A). In reaches 1-5, the amount of instream habitat (grass islands and sand bars) ranged from 25 to 40% and in reaches 6-10 instream habitat ranged from 2 to 25% (Fig. 1.2B). Mean channel width and the mean number of channels available were also greater in the upper reaches of the river. Mean channel width and number of channels ranged from 171 to 332 m and 1.4 to 1.8 channels in reaches 1-5 and was 156 to 267 m and 1.0 to1.4 channels in reaches 6-10 (Fig. 1.2C). In the reach immediately above Bowersock Dam (reach 7) the area had increased urban land use compared to adjacent reaches (Fig. 1.2A). A decrease in instream habitat was also evident in reach 7 with relatively few secondary channels (Fig. 1.2B, C). Between Bowersock Dam and the Johnson County Weir there was an increase in the number of channels and mean channel widths similar to the upriver reaches 3 and 4 (Fig. 1.2C). Below the Johnson County Weir the riparian area was dominated by urban land use, and the instream habitat was almost non-existent with a narrow and relatively unbraided channel (Fig. 1.2).

Field collections

A total of 334 fishes were captured in the electrofishing samples (21 species, 146 electrofishing sites; Table 1.3) and 13,490 fishes were captured in seine samples (30 species, 83 seine hauls; Table 1.3) in the Kansas River in summer 2007. Electrofishing captured 8 unique (species only captured with this gear) species and seines captured 18 unique species (Table 1.3). Electrofishing consisted of 85.3% large-bodied individuals (TL>100 mm) and seine samples consisted of 99.8% small bodied individuals (TL<100 mm). The dominant species captured with electrofishing (75.1% of the total catch) included common carp, *Cyprinus carpio*, flathead catfish, *Pylodictis olivaris*, freshwater drum, river carp sucker, and white crappie, *Pomoxis annularis*. The dominant species captured with the seine (91.5% of the total catch) include bullhead minnow, *Pimephales vigilax*, river carpsucker, red shiner, *Cyprinella lutrensis*, and sand shiner, *Notropis stramineus*.

Electrofishing mean species richness ranged from 1.00 to 1.65 but did not differ among reaches (ANOVA; F=0.76, d.f.=9, 136, P=0.653). Species diversity averaged 0.32 (range: 0.17 to 0.48) and did not differ (F=0.89, d.f.=9,136, P=0.538, Fig. 1.3) throughout the reaches in the Kansas River. Mean species richness differed throughout the Kansas River for the seine hauls (F=2.35, d.f.=9, 73, P=0.022; Fig. 1.3) with mean species richness highest in reaches 1 and 5 (Fig. 1.3). Seine haul species diversity ranged from 0.68 to 1.22 and did not differ across reaches (F=1.06, d.f.=9, 73,P=0.400).

The Mantel test showed no correlation with the distance between sites for Jaccard's similarity (r=0.100, P=0.738) or PSI values (r=-0.181, P=0.140) for the seining data. However for the electrofishing data Jaccard's similarity (r=-0.208, P=0.097) and PSI (r=-0.220, P=0.087) were correlated with distance between site. There was higher similarity for large bodied species presence and composition for sites that were closer together. The mean PSI values for electrofishing and seining comparing all reaches are 0.49 and 0.62, respectively, and the mean Jaccard's similarity values for electrofishing and seining comparing all reaches are 0.45 and 0.52, respectively, suggesting that sites are about 50% similar throughout the river. Reach 7 had a mean PSI of 0.27 when compared to all other sites and reach 10 had a mean PSI of 0.47 in species composition when compared to all other sites for the seining data. This was due to the low abundance of red shiner in both reaches. Reach 7 and 10 consisted of <20% red shiner, whereas all other reaches were >44% red shiner (Table 1.3). Excluding reaches 7 and 10, all other sites had a mean PSI of 0.78 for fishes collected by seines.

Total variation explained by all CCA axis from the electrofishing species data was 28.1%, with axis one explaining 8.3% of the variation and axis 2 explaining 7.2% of the variation (Fig. 1.4). Species associated with areas with more agricultural land use included blue sucker, shovelnose sturgeon, and smallmouth buffalo, *Ictiobus bubalus*. These areas consisted of areas of increased sand bars, conductivity, and higher velocity flows (Table 1.1; Fig. 1.4). The lower river had a higher proportion of channel catfish, *Ictalurus punctatus*, common carp, freshwater drum, and longnose gar, *Lepisosteus osseus*. These reaches were characterized by less sand bars and deeper, more channelized areas (Table 1.1; Fig. 1.4). Total variation explained by the species data for the seine samples CCA was 34.7%, with axis 1 explaining 12.6% and axis 2 explaining 9.1% of the variation in the species data. Gizzard shad, *Dorosoma cepedianum*, were found in areas highly characterized with rip-rap banks and an increase in urban land use. Sand shiners were the dominate species in many lower river reaches. The up-river consisted mostly of red shiners, Western mosquitofish, *Gambusia affinis*, bluntnose minnow, *Pimephales notatus*, and bullhead minnow. These sites were characterized with greater proportion of agricultural land and instream habitat (Fig. 1.4). The lower reservoir like reach (7) and the highly modified reaches (9 and 10) were more characterized by rip-rap banks, and urban and channelized areas (Fig. 1.2). Reach 8 (directly below Bowersock Dam) consisted of both urban and agricultural land and was intermediate in the proportion of that reach that was channelized and containing sand bars (Fig. 1.2)

The proportional abundance of feeding guilds collected by electrofishing indicated that omnivorous species were more associated with the lower, more impacted reaches (Fig. 1.5).

Total variation explained in the CCA by the feeding guild data for the electrofishing samples was 14.3%, with axis 1 explaining 6.5% and axis 2 explaining 5.4% of the variation in the species data (Fig. 1.5). The omnivores were associated with the reaches with more urban land use and higher proportion of channelization (Fig. 1.5). The invertivores tended to be associated with higher proportions of sand bars but appeared to be found throughout the river (Fig. 1.5). Piscivores and detritivores were associated more with the upper river reaches with more diverse habitat (Fig. 1.5). The seining data CCA also showed similar patterns (Fig. 1.5). Total variation explained by the feeding guild data for the seine samples was 34.8%, with axis 1 explaining 20.4% and axis 2 explaining 9.7% of the variation in the species data (Fig. 1.5). Planktivores were associated with the reaches with more urban land use and higher bottom water level flows (Fig. 1.5) that tended to be near down river reaches. Herbivores, invertivores, and piscivores were more associated with the upper river reaches and areas with increased number of channels available (Fig. 1.5). Detritivores were also associated with the upper river and areas of high conductivity (Fig. 1.5). Therefore, omnivores (electrofishing) and planktivores (seining) were associated with more impacted areas with increased urbanization and channelization.

The habitat PCA of electrofishing data indicated that PC1 was an index of increased flows, sand bar habitat, and conductivity and accounted for 25% of the variation among sites (Table 1.4). Sites with high component loadings on axis 2 consisted of high proportion of log jams, increased Secchi depth, and deeper substrate penetration and explained 16% of the variation among sites electrofished (Table 1.4). Mean PC1 score was higher when fluvial specialists were present (P=0.014) and when intolerant species were present (P=0.002; Fig. 1.6). Fluvial specialist and intolerant species were present in sites with increased flow, sand bars, and conductivity (Fig. 1.6). Mean PC1 was lover when macrohabitat generalists were present

(P=0.051) and when tolerant species were present (P=0.009; Fig. 1.6). Macrohabitat generalists and tolerant species typically were found in areas with increased temperature and deeper water (Fig. 1.6).

The habitat PCA of the seining data showed that sites that scored high on PC1 consisted of high flows, rip-rap habitat, and Secchi depth and accounted for 22% of the variation among sites (Table 1.4). The number of sand bars had the only high component loadings associated with axis 2 (Table 1.4). Mean PC1 was lower when fluvial specialist species were absent (P<0.001), whereas mean PC1 was lower when tolerant species were present (P=0.008; Fig. 1.6). Fluvial specialist species were in areas of increased flow, rip-rap banks, and conductivity (Fig. 1.6). Macrohabitat generalists were present in every site (Fig. 1.6). Intolerant species were associated with increased sand bars though mean PC score did not significantly differ from when species were absent (P=0.140; Fig.1.6).

DISCUSSION

Land use and instream habitat alterations can cause significant changes in fish community structure (Karr et al., 1985; Roth et al., 1996; Poulton et al., 2003; Galat et al., 2005; McClelland et al., 2006) and it is important for conservation and management to determine what habitat alterations have the greatest effect on the fish community. In the Kansas River instream and riparian habitat differed longitudinally changing from diverse habitat areas to channelized, urban-dominated areas. In the lower river, deeper and narrower channels with fewer braided channels and islands were present, which is consistent with Paukert and Makinster (In press) who documented homogeneous habitats in the urban reaches of the Kansas River. The reduction of instream habitat in mid to lower reaches of the Kansas River suggests homogenization of the habitats, which is consistent with other studies (Lenat and Crawford, 1994; Schueler, 1994; Arnold and Gibbons, 1996; Booth and Jackson, 1997; May et al., 1997; Yoder et al., 1999; Paukert and Makinster, In press) and was linked to the fish community differences within the Kansas River.

Great Plains river fish communities consist of many species that are tolerant or moderately tolerant to a wide range of physicochemical conditions (Cross et al., 1986; Cross and Moss, 1987; Matthews, 1988; Bramblett and Fausch, 1991a; b; Fausch and Bramblett, 1991). However, our study found changes in habitat was associated with changes in fish communities even within this relatively homogeneous assemblage. Species richness and diversity in the Kansas River varied little throughout the Kansas River, which is consistent with Gillette et al. (2005) who also found no change in species richness throughout the Neosho River, Kansas. However, large-bodied fish presence and composition tended to vary longitudinally and also, localized disturbances such as Bowersock Dam (reach 7) and the Johnson County Weir (reach 10) in the lower urban area near Kansas City, Kansas had lower similarity of small-bodied fishes, suggesting that these barriers are affecting the fish community within those reaches. Low-head dams cause localized reservoir affects above dams and therefore causes the fish community directly above dams to consist of lentic fish species (Gillette et al., 2005). The fish community in the reaches in between Bowersock Dam and the Johnson County Weir were similar to the upper Kansas River which is likely due to more variable habitat and the increase in the number of secondary channels within these reaches. The site below the Bowersock Dam serves as a reset point, changing the fish community to more riverine species below the dam, which was similar to the prediction by Ward and Stanford (1983). The presence of the low-head dam altered stream characteristics such as flow, number of channels, and availability of instream habitat above the dam, which likely caused the differences in the fish communities in these areas (Gillette et al., 2005).

There still were subtle longitudinal differences in fish communities that may be related to habitat modification. The lower Kansas River consisted of channel catfish, freshwater drum, common carp, longnose gar and white crappie, which are species that prefer low velocity habitats (Cross and Collins, 1995; Pflieger, 1997). Species that preferred low velocity habitats in the Missouri River were most abundant in the lower highly impacted areas of the river (Galat et al., 2005), which is consistent with this study. The upper Kansas River reaches consisted of mostly blue sucker, river carpsucker, smallmouth buffalo, shovelnose sturgeon, bluntnose minnow, bullhead minnow, red shiners, and western mosquitofish. Shovelnose sturgeon and blue sucker prefer high velocity habitats (Galat et al., 2005) and showed highest abundances in the upriver reaches suggesting the diverse habitat and fast flows in the upper river is beneficial to these species (Quist and Guy, 1999; Eitzmann et al. 2007). Also, in the Wabash River, Indiana, fish species that preferred sand substrates and had body morphologies suitable for fast water were found in higher abundance in the upper, less impacted portions of the river (Pyron and Lauer, 2004). Smallmouth buffalo, bluntnose minnow, bullhead minnow, red shiners, and western mosquitofish tend to inhabit many different areas but prefer habitats of lower velocity (Cross and Collins, 1995; Pflieger, 1997), also suggesting that habitat in the upper reaches is more diverse allowing for higher abundance of many native riverine species.

Omnivores were highly associated with the lower channelized reaches of the Kansas River. In highly impacted rivers, different feeding guilds tend to occupy different areas of the river (Karr et al., 1985; Pegg and Pierce, 2002; Pyron and Lauer, 2004; Galat et al., 2005; McClelland et al., 2006) suggesting that loss of habitat in the impacted areas affects species and guild composition in large rivers. In the Missouri River herbivores and invertivores are in higher abundance in the upper unchannelized river and omnivores and benthic invertivores are in higher abundance in the lower highly impacted area of the river (Pegg and Pierce, 2002; Galat et al., 2005), which is similar to our study.

Moderately tolerant and tolerant fish species comprise 87% of the fish community in the Kansas River with 71% of the tolerant species sampled were considered macrohabitat generalist species. However the relatively few intolerant fish species were typically associated with upper reaches of the river with more sand bars and high velocity habitats, suggesting these areas are important to intolerant species. Also, within the Kansas River 14 species are listed as state or federally endangered, threatened, or of special concern (Cross and Collins, 1995; Haslouer et al., 2005). Of the listed species only one (blue sucker) was collected, suggesting the other species have been extirpated from the river or are in relatively low abundance. Ten of the fourteen species historical range in the Kansas River only consisted of the lower river, which is the most impacted segment of the Kansas River. Therefore, it was not surprising to have collected none of these species in our study. Of the species that were among the top 10 most abundant fishes in 1950 (plains minnow, speckled chub, and western silvery minnow; Cross and Moss, 1987), we did not capture any. The channelized lower river impacts created a homogeneous fish community of more tolerant generalist species. These habitat changes, coupled with species introductions, play a large part in the homogenization of fish faunas (Rahel, 2000). Currently the two intolerant species (blue sucker and shovelnose sturgeon) that were captured in high abundance in the river were captured in the upper river reaches that were less impacted by urbanization and channelization. Therefore, preserving the upper river may be important for the survival of these species. However, restoration efforts in the lower river need to be considered in the context of high urbanization and invasive species introductions.

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Table 1.1. Mean and range of instream environmental variables measured in the Kansas River in summer 2007. Rkm is river km from confluence of Missouri River.

		Depth (m)		Channel width (m)		Flow (m sec^{-1})		Secchi (m)		Substrate Penetration (m)		Conductivity (µS cm^{-1})		Temperature (C)	
Reach	**Rkm**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**
1	269-274	1.14	0.13-2.72	96	90-109	0.54	0.02-0.70	0.25	0.15-1.70	0.21	0.08-0.32	1992	550-2689	25.5	21.9-26.4
2	229-235	1.28	0.17-4.00	153	90-206	0.29	0.03-0.64	0.22	0.20-0.25	0.17	0.00-0.35	1502	326-1703	24.2	22.7-25.1
3	216-222	0.79	0.18-1.43	160	127-187	0.31	0.02-0.55	0.31	0.30-0.32	0.10	0.00-0.23	1592	1410-1676	27.2	26.1-28.1
4	202-208	1.05	0.19-1.69	132	115-150	0.38	0.08-0.58	0.32	0.17-0.35	0.14	0.03-0.57	1175	1039-1531	28.5	26.7-29.7
5	167-173	0.91	0.16-1.57	202	166-241	0.33	0.03-0.56	0.22	0.21-0.25	0.14	0.01-0.25	1083	928-1152	27.4	25.8-29.1
6	120-126	1.33	0.20-2.46	147	114-194	0.32	0.02-0.46	0.20	0.17-0.27	0.15	0.05-0.40	827	727-1031	29.9	29.5-30.9
7	83-89	1.16	0.21-2.57	212	137-279	0.28	0.01-1.66	0.22	0.22-0.22	0.19	0.03-0.33	1027	968-1131	27.0	25.2-29.5
8	76-82	1.02	0.25-2.03	178	163-205	0.23	0.02-0.44	0.24	0.22-0.30	0.10	0.00-0.33	968	942-979	26.8	26.1-27.0
9	24-60	1.27	0.14-2.62	220	181-251	0.11	0.01-0.26	0.45	0.45-0.50	0.14	0.00-0.33	1166	1085-1212	28.4	27.6-29.4
10	3-9	1.31	0.25-2.58	146	114-207	0.21	0.01-0.66	0.50	0.45-0.55	0.07	0.00-0.15	1101	972-1182	30.0	29.5-30.7

Table 1.2. Habitat guild, feeding guild and tolerance level of all species captured in seine and electrofishing sites in the Kansas River in summer 2006 (Pflieger 1997, Galat et al. 2005, Thomas et al. 2005). Species codes are given for the species used in canonical correspondence analysis.

Species	Species Code	Habitat Guild	Feeding Guild	Tolerance
Bigmouth buffalo		Macrohabitat generalist	Planktivore	
Black crappie		Macrohabitat generalist	Invertivore	
Blue catfish		Fluvial specialist	Omnivore	
Bluegill		Macrohabitat generalist	Invertivore	
Blue Sucker	Cycelo	Fluvial specialist	Invertivore	Intolerant
Bullhead minnow	Pimvig	Macrohabitat generalist	Omnivore	
Bluntnose minnow	Pimnot	Macrohabitat generalist	Detritivore	Tolerant
Creek chub		Macrohabitat generalist	Invertivore	Tolerant
Channel Catfish	Ictpun	Macrohabitat generalist	Omnivore	
Common Carp	Cypcar	Macrohabitat generalist	Detritivore	Tolerant
Central stoneroller		Fluvial specialist	Herbivore	
Emerald shiner	Notath	Macrohabitat generalist	Planktivore	
Fathead minnow		Macrohabitat generalist	Detritivore	Tolerant
Flathead Catfish	Pyloli	Fluvial dependent	Piscivore	
Freshwater drum	Aplgru	Macrohabitat generalist	Invertivore	
Goldeye		Fluvial dependent	Invertivore	Intolerant
Green sunfish		Macrohabitat generalist	Invertivore	Tolerant
Gizzard shad	Dorcep	Macrohabitat generalist	Detritivore	
Johnny darter		Macrohabitat generalist	Invertivore	
Longear sunfish		Macrohabitat generalist	Invertivore	
Largemouth bass		Macrohabitat generalist	Piscivore	
Longnose gar	Leposs	Fluvial dependent	Piscivore	
Orangespotted sunfish		Macrohabitat generalist	Invertivore	
Quillback		Macrohabitat generalist	Detritivore	
River carpsucker	Carcar	Macrohabitat generalist	Detritivore	
Redfin shiner		Fluvial specialist	Invertivore	Intolerant
Red shiner	Cyplut	Macrohabitat generalist	Omnivore	
Smallmouth bass		Macrohabitat generalist	Piscivore	Intolerant
Smallmouth buffalo	Ictbub	Macrohabitat generalist	Detritivore	
Shorthead redhorse		Fluvial dependent	Invertivore	
Shortnose gar		Macrohabitat generalist	Piscivore	
Shovelnose sturgeon	Scapla	Fluvial specialist	Invertivore	Intolerant
Suckermouth minnow	Phemir	Fluvial specialist	Invertivore	
Sand shiner	Notstr	Fluvial specialist	Omnivore	
White bass	Morchy	Fluvial dependent	Piscivore	
White bass hybrid	Morchy hyb	Fluvial dependent	Piscivore	
White crappie	Pomann	Macrohabitat generalist	Piscivore	
White sucker		Fluvial dependent	Detritivore	Tolerant
Western mosquitofish	Gamaff	Macrohabitat generalist	Invertivore	

Table 1.3. Total species captured in seining and electrofishing sites, sampled in the Kansas River in summer 2006. The number in parenthesis represents individuals captured in the electrofishing samples, whereas the adjacent number is the individuals captured by seining.

Species\Reach	1	2	3	4	5	6	7	8	9	10	Total
Bigmouth buffalo	0	0	0	0	0	0	0	0	0(1)	0	(1)
Black crappie	1	0	0	0	0	0	0	0	0	0	1
Blue catfish	0	0	0	0	0(1)	0	0	0	0	0(1)	(2)
Bluegill	2	0	0	2	2	0	1(2)	0	5	2	14(2)
Blue Sucker	0	0	0(3)	0(1)	0	0	0	0	0(1)	0(1)	(6)
Bullhead minnow	61	28	89	47	217	49	10	31	13	3	548
Bluntnose minnow	24	32	1	3	45	14	0	1	1	0	121
Creek chub	1	0	0	1	0	1	1	0	0	0	4
Channel Catfish	0	0(1)	1(1)	0	1(4)	3	2(2)	0(2)	0(3)	0(3)	7(16)
Common Carp	0(4)	0	1	0(10)	0(9)	0(6)	0(14)	0(1)	0(1)	0(2)	1(47)
Central stoneroller	0	0	1	0	3	0	0	0	1	0	5
Emerald shiner	4	8	1	7	0	84	11	94	2	24	235
Fathead minnow	0	3	1	0	8	0	1	0	0	0	13
Flathead Catfish	0(10)	0(3)	0(13)	0(13)	0(9)	0(24)	0(9)	0(11)	0(7)	0(4)	(103)
Freshwater drum	4(3)	0(1)	0(4)	1(2)	49(4)	0(2)	5(5)	0(7)	1(1)	0(3)	60(32)
Goldeye	2(1)	0	0	0	0	0	0	0	0	0	2(1)
Green sunfish	0	0	0	0	2	0(1)	0	0	2	0	4(1)
Gizzard shad	100	32	0	13	42	2	12	2	59	81	343
Johnny darter	1	0	0	0	1	0	0	0	0	0	2
Longear sunfish	0	0	0	0	0	0	0	1	0	0	1
Largemouth bass	3	0	0	3	5	0	0	0	3	0	14
Longnose gar	0(2)	0(3)	1	0	0(3)	0	0	1(2)	0	0	2(10)
Orangespotted sunfish	0	0	0	13	6	4	2	0	1	0	26
Quillback	0	0	0	0(1)	0	0	0	0	0	0	(1)
River carpsucker	444(4)	14(9)	257(29)	96(5)	87(2)	37	4(1)	4(3)	8(1)	60	1011(51)
Redfin shiner	1	0	0	0	0	0	0	0	0	0	1
Red shiner	686	1433	977	833	1319	1148	84	540	795	60	7875
Smallmouth bass	0	0(1)	0	0	0	0	0	0	0	0	(1)
Smallmouth buffalo	0(1)	0(4)	5(1)	1(4)	0	0	0(2)	0	1(1)	0(2)	7(15)
Shorthead redhorse	0	0(2)	0	0	1	0	0	0	0	0	1(2)
Shortnose gar	0	0	0	0	0	0	0	0	0	0(1)	(1)
Shovelnose sturgeon	0	(2)	(4)	(3)	(1)	(1)	0	0	0	0	(11)
Suckermouth minnow	29	4	0	11	51	1	7	0	1	0	104
Sand shiner	170	230	161	104	367	353	1018	144	304	63	2914
White bass	13(1)	20	2	5	11(1)	2	6	4(2)	0(1)	3(3)	66(8)
White bass hybrid	0(5)	0	0	0	0	0	0	0	0	0	(5)
White crappie	0	0(1)	2(4)	7(1)	8(1)	0	7(10)	0(1)	8	0	32(18)
White sucker	0	0	0	0	0	0	1	0	0	0	1
Western mosquitofish	6	12	17	19	2	7	4	0	2	6	75
Total	1553(31)	1818(24)	1520(59)	1170(40)	2232(35)	1711(34)	1183(45)	830(29)	1216(17)	312(20)	13490(334)

Table 1.4. Component loadings from two principal components analyses (PCA) using shoreline and instream environmental variables collected in the Kansas River in summer 2007. Separate PCAs were conducted for electrofishing and seining.

	Electrofishing		Seining	
Variable	Habitat 1	Habitat 2	Habitat 1	Habitat 2
Proportion shoreline rip-rap	-0.355	-0.453	0.333	-0.278
Proportion shoreline log jam	0.006	0.465	-0.117	0.018
Proportion shoreline sand bar	0.403	-0.016	-0.328	0.461
Depth (m)	-0.334	-0.082	-0.084	-0.253
Bottom flow (m/s)	0.361	-0.326	0.478	0.480
Mid-water flow (m/s)	0.274	0.041	0.487	0.462
Secchi depth (m)	0.014	0.424	0.394	-0.363
Substrate penetration (m)	0.300	0.388	-0.132	-0.031
Temperature (C)	-0.372	0.265	0.306	-0.196
Conductivity (µS/cm)	0.407	-0.251	-0.172	0.176
Eigenvalues	2.54	1.65	2.17	1.87
Variance Explained (%)	25	16	22	19

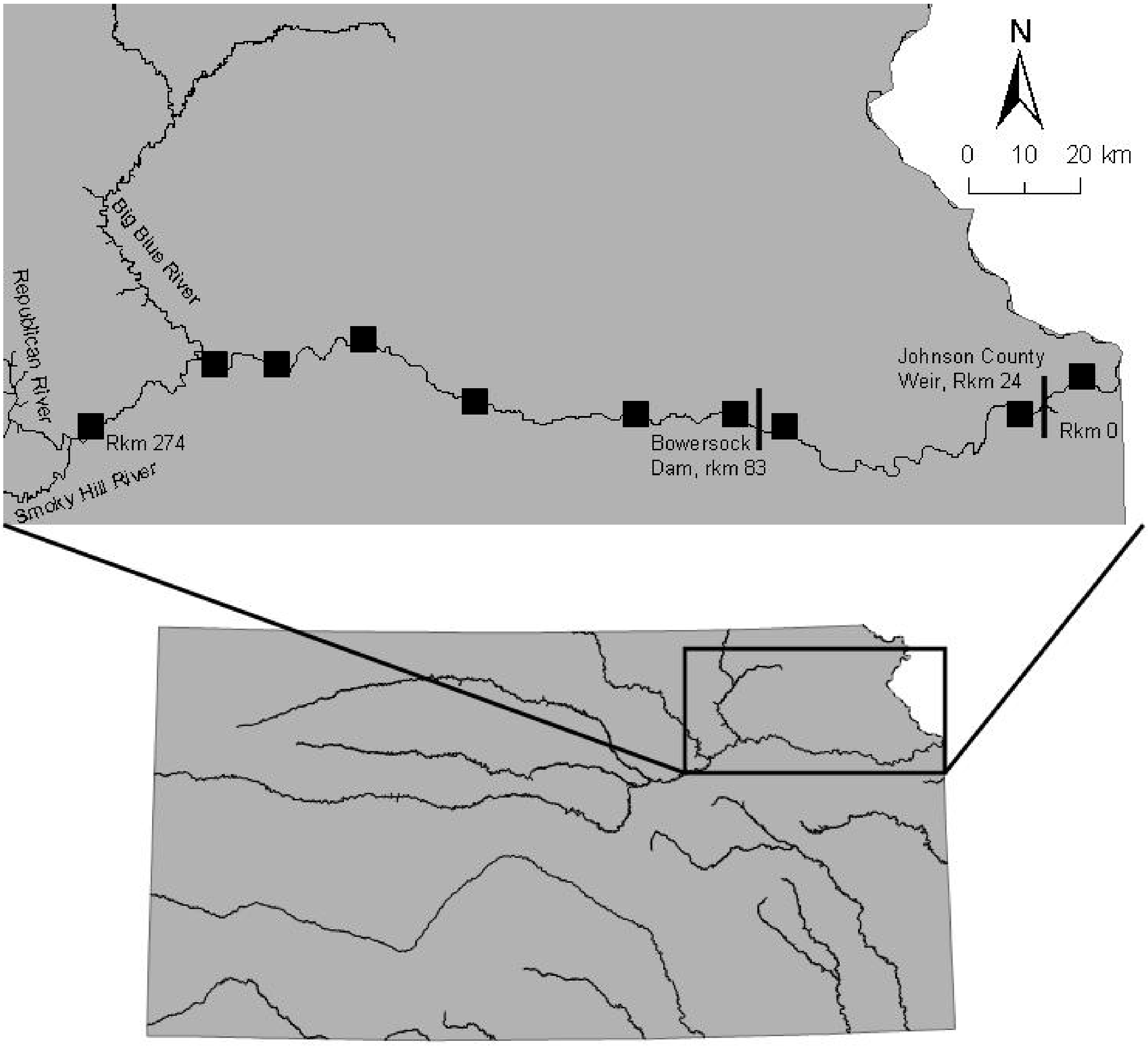

N
0 10 20 km
Big Blue River
Republican River
Smoky Hill River
Rkm 274
Bowersock Dam, rkm 83
Johnson County Weir, Rkm 24
Rkm 0

Figure 1.1

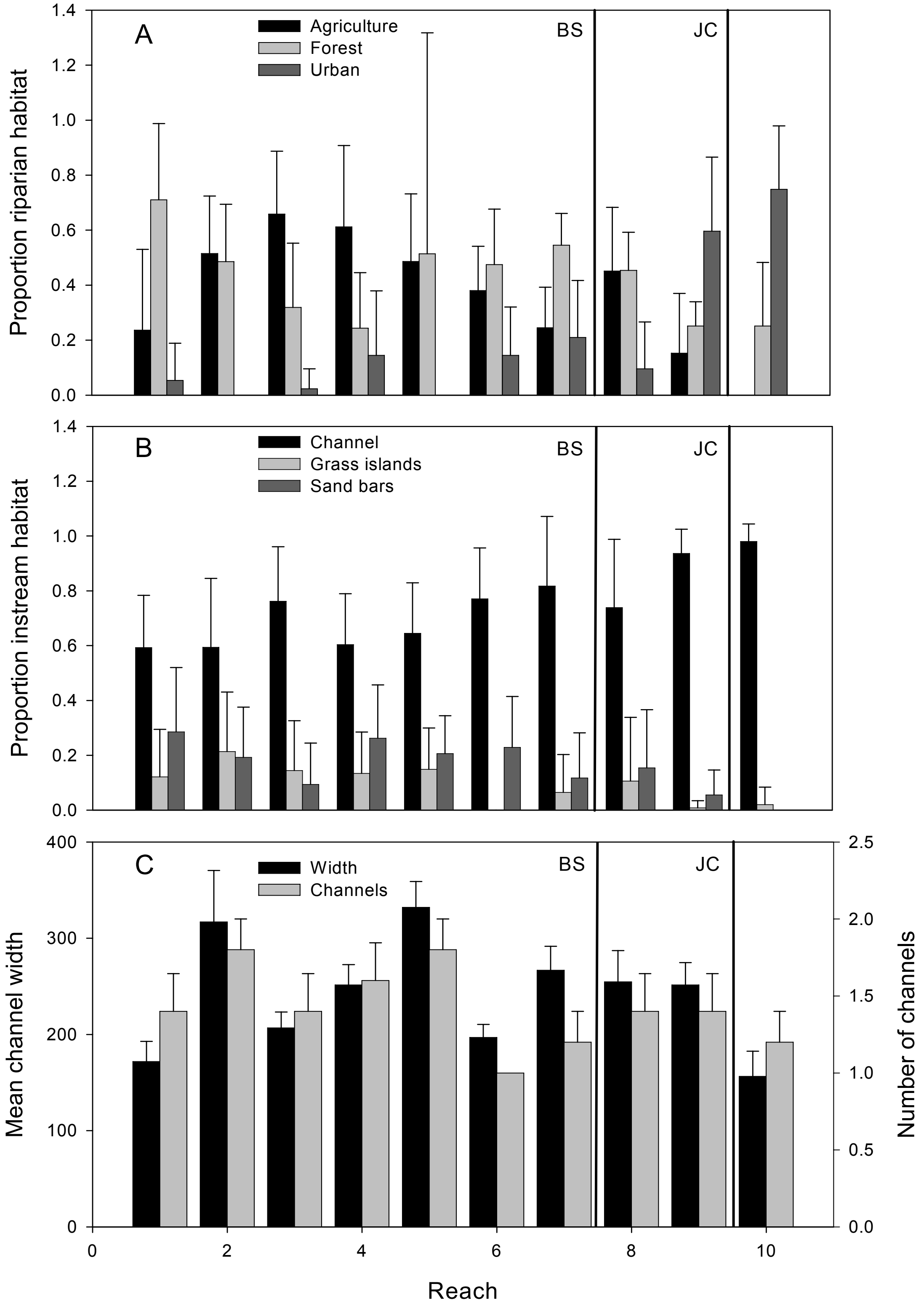
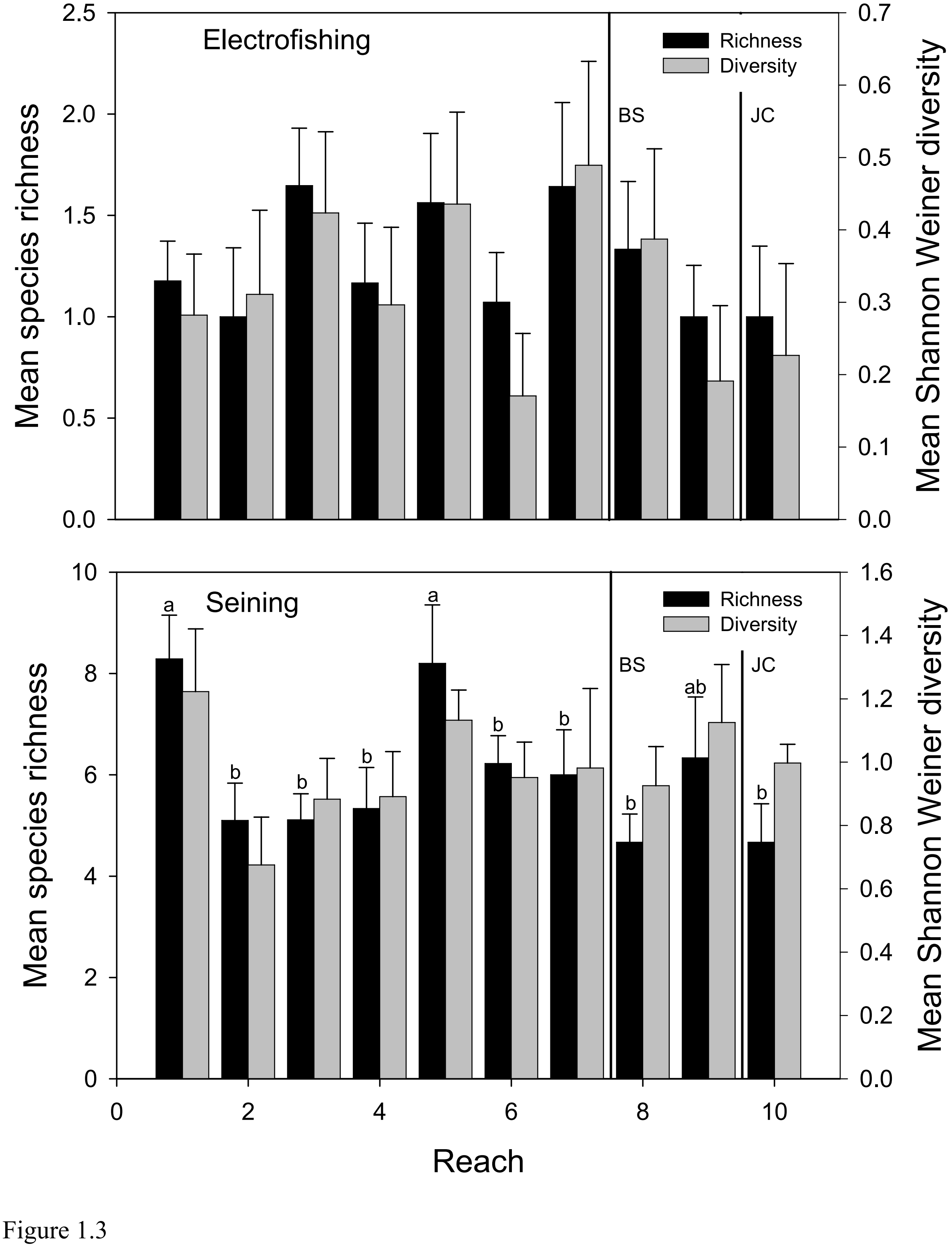

A
Agriculture
Forest
Urban
BS
JC
Proportion riparian habitat
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
B
Channel
Grass islands
Sand bars
Proportion instream habitat
C
Width
Channels
Mean channel width
400
300
200
100
0
Number of channels
2.5
2.0
1.5
1.0
0.5
0.0
Reach
0
2
4
6
8
10

Figure 1.2



Electrofishing
Richness
Diversity
BS
JC
Mean species richness
Mean Shannon Weiner diversity
0.0
0.5
1.0
1.5
2.0
2.5
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Seining
a
b
b
b
a
b
b
b
ab
b
0
2
4
6
8
10
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Reach

Figure 1.3

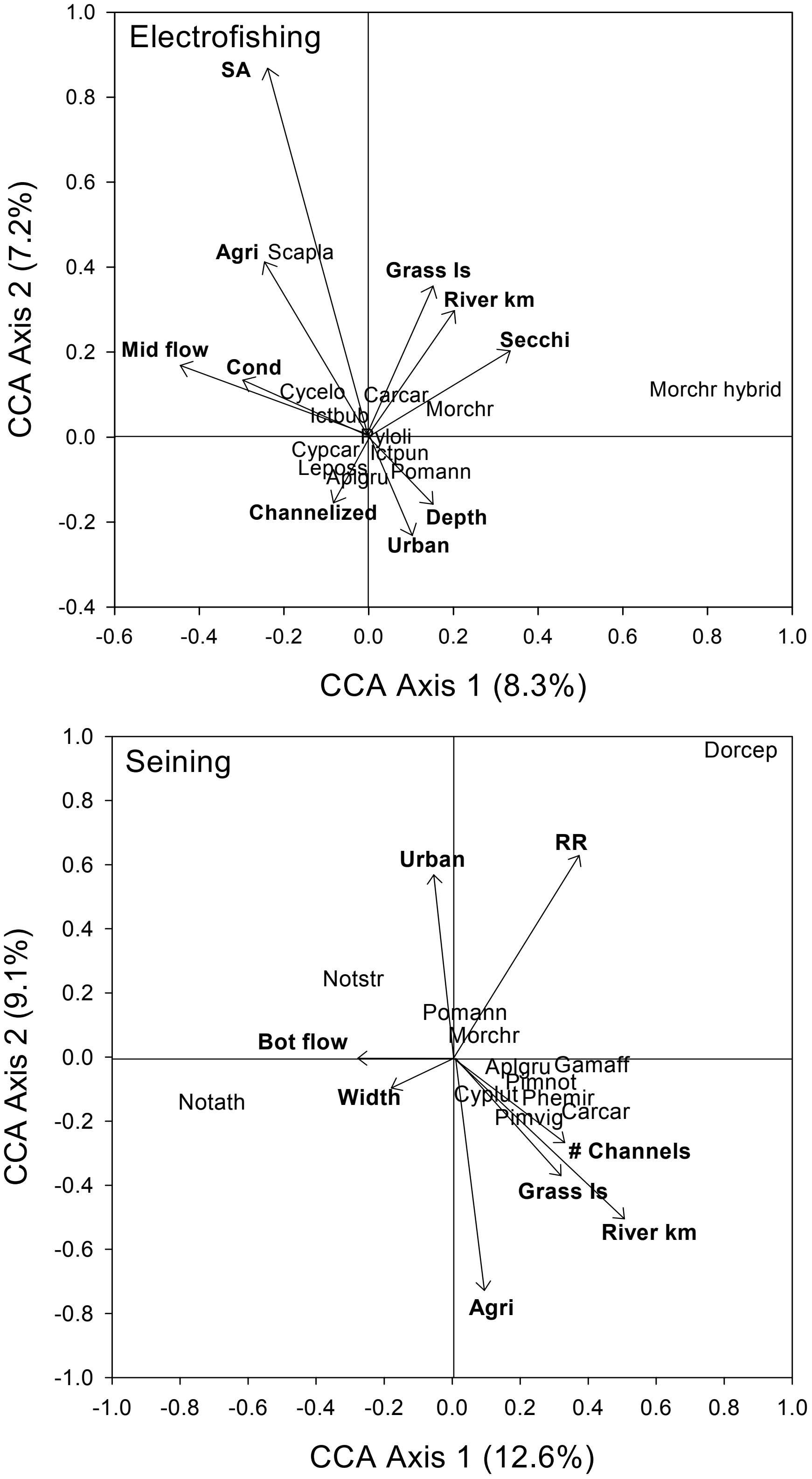

Electrofishing
CCA Axis 2 (7.2%)
CCA Axis 1 (8.3%)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
SA
Agri
Scapla
Grass ls
River km
Secchi
Mid flow
Cond
Cycelo
Carcar
Ictbub
Morchr
Morchr hybrid
Pyloli
Cypcar
Ictpun
Leposs
Aplgru
Pomann
Channelized
Depth
Urban
Seining
CCA Axis 2 (9.1%)
CCA Axis 1 (12.6%)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Dorcep
RR
Urban
Notstr
Pomann
Morchr
Bot flow
Aplgru
Gamaff
Pimnot
Phemir
Notath
Width
Cyplut
Carcar
Pimvig
Channels
Grass ls
River km
Agri

Figure 1.4

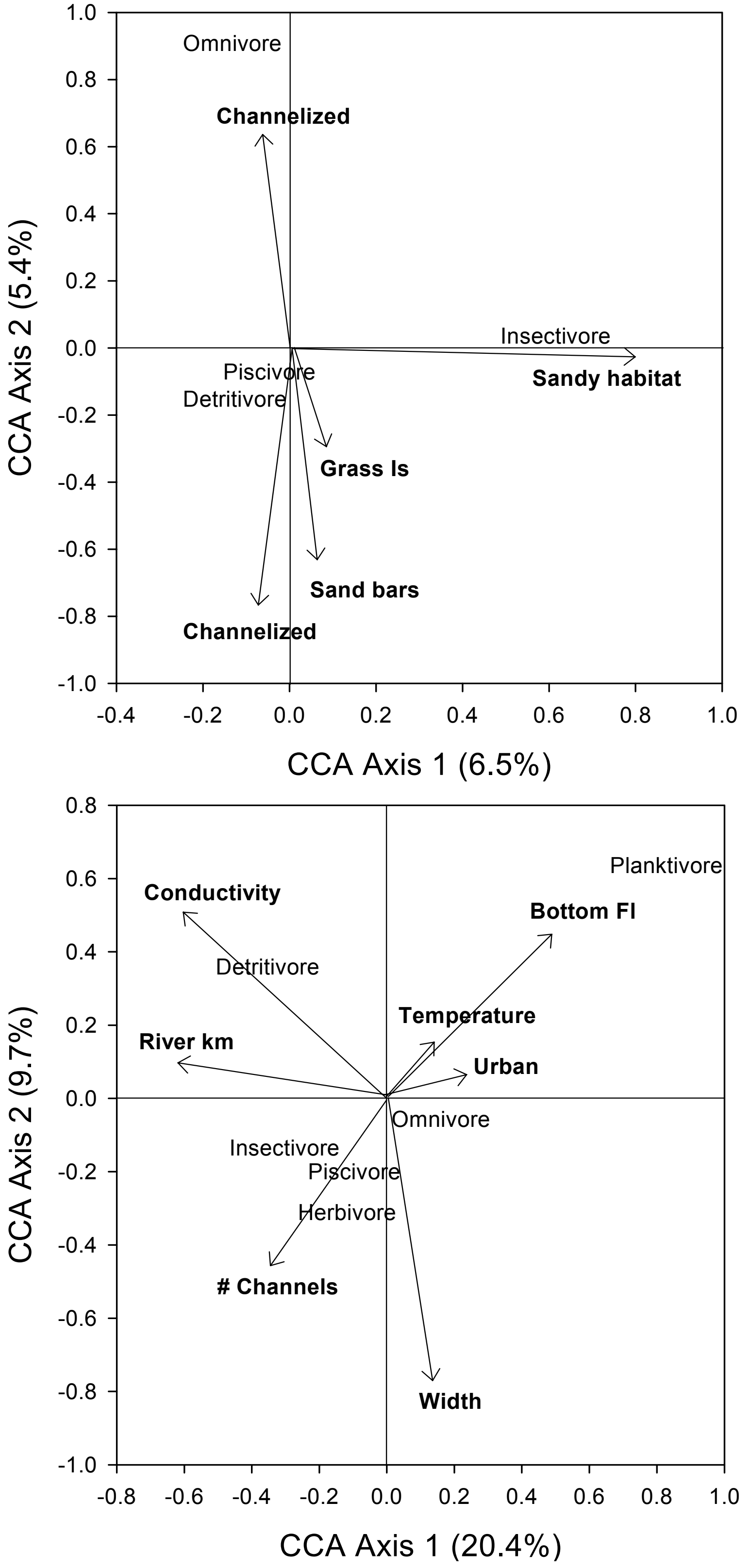
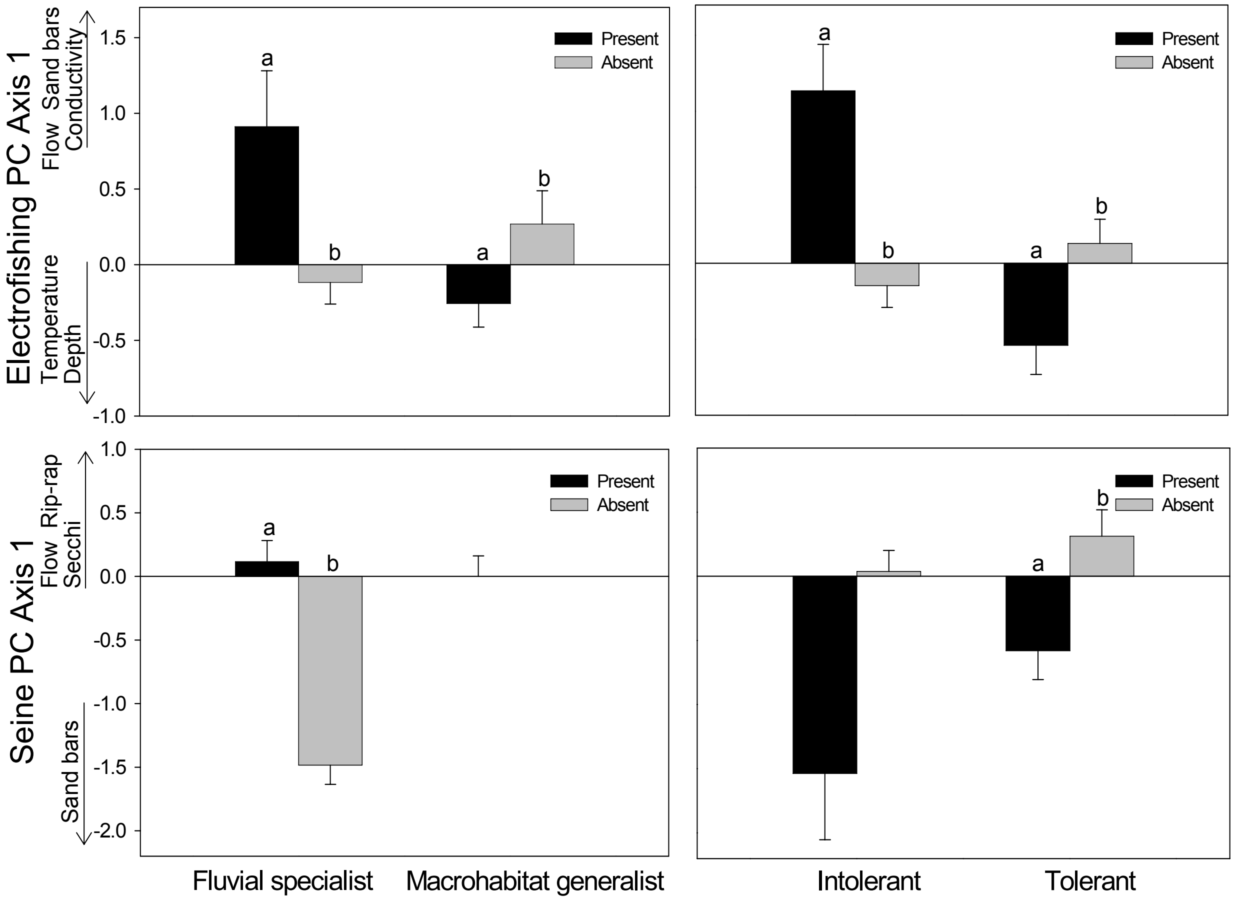

1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
CCA Axis 2 (5.4%)
CCA Axis 1 (6.5%)
Omnivore
Channelized
Insectivore
Sandy habitat
Piscivore
Detritivore
Grass Is
Sand bars
Channelized
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
CCA Axis 2 (9.7%)
CCA Axis 1 (20.4%)
Planktivore
Conductivity
Bottom FI
Detritivore
Temperature
River km
Urban
Omnivore
Insectivore
Piscivore
Herbivore
Channels
Width

Figure 1.5



Electrofishing PC Axis 1
Flow Sand bars Conductivity
Temperature Depth
Seine PC Axis 1
Flow Rip-rap Secchi
Sand bars
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
Present
Absent
a
b
Fluvial specialist
Macrohabitat generalist
Intolerant
Tolerant

Figure 1.6

Chapter 2

Spatial variation in habitat: effects on food web structure of a Great Plains River.

ABSTRACT

We investigated the spatial variation of habitat and food web structure of the fish community at three reaches in the Kansas River, USA to determine if δ^{13}C variability and δ^{15}N values differ longitudinally and are related to riparian land use practices and instream habitat. Fish, macroinvertebrates, and detritus were collected at three river reaches classified as the heterogeneous habitat (>40% grass islands and sand bars), intermediate (22% grass islands and sand bars), and homogeneous habitat (6% grass islands and sand bars) reaches in June 2006. Riparian land use (proportion as agricultural and urban) was related to instream habitat with homogeneous habitat areas having more urban riparian area compared to the heterogeneous habitat and intermediate reaches. The heterogeneous habitat reach had higher variability in δ^{13}C for fish classified as piscivores/invertivores (P=0.029) and macroinvertebrates (P=0.004) suggesting the complex habitat provided more variable food sources. The δ^{15}N values also indicated that fish species tended to consume prey at higher trophic levels in the heterogeneous habitat reach suggesting a more complex food web. Channelization and reduction of habitat is leading to homogenization of instream habitat and this homogenization of habitats may be related to food web diversity and trophic position of fishes.

INTRODUCTION

Anthropogenic influences have had major effects on streams and rivers worldwide (Ward and Stanford, 1989). Agriculture impacts in the United States are prominent, and six major river basins in North America (Lower Mississippi, Upper Mississippi, Southern Plains, Ohio, Missouri, and Colorado) have over 40% of the land area as agriculture (Allan, 2004). The Kansas River is no different with about 53% of the watershed as agricultural row crop and 43% cattle grazed pastures (US Geological Survey, 1994). The primary impacts from agriculture include increased pollutants, sediments, nutrients, and pesticides, but can also cause reduction of riparian and stream channel habitat and altered flows (Lenat, 1984; Osborne and Wiley, 1988; Cooper, 1993; Johnson et al., 1997; Allen, 2004). Therefore, these agricultural effects also may affect fishes in these areas. Roth et al. (1996) found that the proportion of agricultural land in the watershed was negatively correlated with Index of Biotic Integrity scores in a Midwestern watershed. Berkman and Rabeni (1987) also determined that increase in sedimentation from agriculture reduced aquatic insect diversity and density which negatively influenced the feeding and reproductive strategies of specialized fish species. Karr et al. (1985) noted that agriculture has the broadest impact on riverine communities but localized urban effects can be more intense.

Urbanization occupies only small percentages of land along streams and rivers (10% or more of the catchment area in 10 of the 150 large river basins in North America; Benke and Cushing, 2004), but has been shown to have pronounced effects on streams and rivers relative to land area (Allan, 2004). Urbanization causes river degradation due to the amount of impervious surface area (Paul and Meyer, 2001), which causes increased erosion, channel destabilization and widening, which leads to loss of habitat from channelization, excessive sedimentation, increases in temperature, and reduction in large woody debris in streams (Lenat and Crawford, 1994; Schueler, 1994; Arnold and Gibbons, 1996; Booth and Jackson, 1997; May et al., 1997; Yoder et al., 1999; Wang and Kanehl, 2003; Paukert and Makinster, In press) causing more homogeneous instream habitats. Fish and macroinvertebrate diversity and density tends to decrease with increase in impervious surface cover and urban areas (Klein, 1979; Jones and Clark, 1987; Steedman, 1988; Limburg and Schmidt, 1990; Horner et al., 1997; Wang et al., 1997; Yoder et al., 1999; Whiles and Dodds, 2002). Also, Poulton et al. (2003) found that macroinvertebrate diversity and the percent of large river fish specialists tends to decrease with increase in urbanization in the channelized portions of the Missouri River. These alterations to the habitat and macroinvertebrate community also affect fishes. Yoder et al. (1999) found a decrease in abundance of invertivorous fish with an increase in urbanization and suggested this was due to a disruption in the aquatic food web. In the Illinois River Karr et al. (1985) found all feeding guilds have species declining in abundance except for omnivores and relates this to habitat modifications due to urban areas. Also, growth of flathead catfish (*Pylodictis olivaris*) is slower in areas with less instream habitat diversity, which suggests less food available or an increase in intraspecific competition in areas of homogeneous habitats (Paukert and Makinster In Press). Also, fish growth of two Great Plains River fishes was related to habitat and substrate affects on macroinvertebrate abundance (Quist and Guy, 1998; Quist and Guy, 1999).

Carbon stable isotope signature in fishes can be related to flow longitudinally (Finlay et al., 1999; Fry, 2002) and laterally (Gido et al., 2006) within rivers. Finlay et al. (1999) determined that $\delta^{13}C$ varied with current velocity, and noted that isotopic distinction among habitats could be useful when determining the affects of different anthropogenic effects. Gido et al. (2006) determined $\delta^{13}C$ values in secondary channels of the San Juan River, New Mexico and Utah were less variable than primary channels, suggesting fishes in secondary channels converge on the same resources, and habitat homogenization in the secondary channels may be related to the less variable $\delta^{13}C$ values. Therefore using $\delta^{13}C$ values may be a useful tool to determine if fish and macroinvertebrates are affected by urbanization and agricultural land uses, which likely decrease riparian and instream habitat heterogeneity.

Stable isotope $\delta^{15}N$ values are used to determine trophic position (TP) of organisms as well as food sources. Trophic position is determined by the concentration of $\delta^{15}N$ in fish tissue relative to that in basal food sources, and is assumed to be greatest in fishes that consume high trophic level prey items with an enrichment of 3.4‰ per trophic level (Cabana and Rasmussen, 1996). The $\delta^{15}N$ values in fish tissue have been shown to increase with increase in agricultural land, but tend to increase at all trophic levels at the same rate (Anderson and Cabana, 2005). Therefore, $\delta^{15}N$ values can be used to test if trophic position of species differs across different land uses and if agricultural land use has any affects on $\delta^{15}N$ enrichment.

Density dependent processes may also affect food habits of fishes. Olson et al. (2003) found in two populations of bluegill that low density populations tended to be specialist feeders and the high density populations tended to forage on a wider range of prey and suggested that high-density populations need to be less selective in their prey choice. If increased species or feeding guild density is causing competition at the reaches we would expect to see less enrichment of $\delta^{15}N$ or lower TP due to the species having to eat lower quality (i.e., less $\delta^{15}N$ enriched) prey items.

The objectives of this study were to determine if habitat differs spatially within the Kansas River and are the differences related to land use. Also, does trophic structure differ by anthropogenic disturbances (e.g. land use and instream habitat) or fish density within a large river. We hypothesized that 1) reduction of instream habitat would be related to increased channelization due to urban land use, 2) trophic position of individual fish species would increase in areas with more instream habitat, 3) fish in areas of high habitat heterogeneity would have higher variability in $\delta^{13}C$ values, and 4) increased fish density would result in lower trophic position because of increased competition for food resources.

MATERIALS AND METHODS

Study area

The Kansas River begins near Junction City, Kansas at the confluence of the Smoky Hill and the Republican rivers and flows east 274 km where it joins the Missouri River. The Kansas River drainage area is approximately 155,000 km^2, running from the High Plains of Eastern Colorado westward to Kansas City, Kansas (Colby et al., 1956) and consists of about 12% of the Missouri River watershed (Metcalf, 1966). The Kansas River watershed contains eighteen federal reservoirs and about 13,000 small impoundments that affect discharge in the river system causing more stable flows and a decrease in sediment loading downstream (Sanders et al., 1993). Bowersock Dam (a low-head dam at river kilometer, rkm, 83) is the only dam restricting the movement of fish on the main channel of the Kansas River (Quist and Guy, 1999; Eitzmann et al., 2007). Sand is the dominant substrate throughout the river with few gravel beds. The river consists of many shallow side channels, and sandy islands usually overgrown with willows and grasses (Quist et al., 1999) particularly in upriver reaches. Mean depth is typically <1.5 m throughout the river most of the year (Makinster and Paukert, 2008).

Three reaches of the Kansas River were sampled for fishes, riparian and instream habitat, and macroinvertebrates. The fish and macroinvertebrates were collected from June 12th to June 29th, 2006, and the riparian and instream habitat was collected from satellite imagery from images taken on September 24, 2006. The reaches were chosen as representative of reaches throughout the Kansas River and are classified as the reach 1 (rkm 230 to 236), reach 2 (rkm 120 to 126), and reach 3 (rkm 25 to 31).

Riparian and instream habitat

We used 1-m resolution satellite imagery to classify instream and riparian habitat in each reach (Paukert and Makinster, In press). Transects were created perpendicular to the river channel at 1.6 km intervals within the three reaches and addition 9.6 km above each reach, and riparian habitat (200 m on each side of the bankfull height) was measured along the transect. The length of the transect that was agriculture (row cropland and pasture grassland), forested (larger trees and vegetation), and urban land (obvious roads, paved parking lots, sand pits, and other man-made disturbances, Paukert and Makinster, In press) was calculated for each transect using ArcGIS 9.0. Bankfull width (m) was calculated as distance between the two most pronounced banks along the transect (Armantrout, 1998; Paukert and Makinster, In press). Within the bankfull width, the number of channels (areas containing flowing water), grass islands (grass and forested areas with a channel present on each side), and sand bars (sand and vegetated areas between the bankfull mark and the channel) were recorded. The proportion of each instream habitat was calculated as the proportion of each transect within bankfull width in each habitat. We estimated the proportions of the different instream habitats by using the bankfull width.

Field collections

Multiple gears were used in each reach to collect all fishes at each location. The gears used in collection included daytime boat electrofishing (7-11 A; 400-500 V; 40-60 pulses), gill nets (30.5 m x 1.8 m deep, 4-7.62 m panels of 1.9, 3.8, 5.1, and 7.6 cm bar meshes), large hoop nets (1.1 m diameter, 3.8 cm bar mesh), small hoop nets (0.6 m diameter, 0.48 cm bar mesh), and a straight seine (4.5 m x 1.2 m, 0.64 cm mesh). All species were collected from the main channel and main channel border areas and depth (m) was recorded at each site sampled. Sample sites within each reach were selected randomly unless habitat was limited in which case all available habitat was sampled.

Stomachs and dorsal muscle tissues were removed in the field from the large-bodied adult fish and placed in ice and transported to the laboratory. The smaller bodied adult fish were kept whole, placed in ice in the field, and the dorsal muscle and stomachs were removed in the laboratory. Muscle and stomachs were taken from an average of 4 adult fish (range 1-6) of each species at each reach for stable isotope and stomach content analysis. Only adults were used to account for any possible diet shifts between age classes.

Macroinvertebrates were collected opportunistically within each reach using macroinvertebrate nets and sieves to capture all available taxa. Macroinvertebrates were taken from the substrate and from woody debris in the main channel and main channel border. All aquatic macroinvertebrate taxa available at each reach were collected and classified to order. Jardine et al. (2005) determined that gut contents should be removed from predatory macroinvertebrates before conducting stable isotope analysis. Therefore, all macroinvertebrates were kept alive for 24 hours to allow them to expel unwanted material.

Stable Isotope Analysis

White dorsal muscle was used for stable isotope analysis because it best represents the isotope signature of fish (Rounick and Hicks, 1985; Hesslein et al., 1993), has the lowest variability with respect to diet of $\delta^{13}C$ and $\delta^{15}N$, and does not require the removal of inorganic carbonates (Pinnegar and Polunin, 1999). All samples of muscle and macroinvertebrates were dried at a constant temperature (60 °C) for 48 h prior to grinding into a fine powder with a mortar and pestle or a coffee grinder. All fish and macroinvertebrate stable isotope analysis was conducted in the Stable Isotope Mass Spectrometry Laboratory (SISML) at Kansas State University or at North Carolina State University in the Analytical Services Lab - Stable Isotope Mass Spectrometry (ASL-SIMS) with a Thermo-Finnigan Delta Plus mass spectrometer with a CE 1110 elemental analyzer and Conflo II interface in continuous flow mode (CF-IRMS). Stable isotope ratios were calculated in standard notation:

$$\delta^{15}N = [({}^{15}N/{}^{14}N_{sample}/{}^{15}N/{}^{14}N_{standard})-1 \times 1000]$$

$$\delta^{13}C = [({}^{13}C/{}^{12}C_{sample}/{}^{13}C/{}^{12}C_{standard})-1 \times 1000]$$

Data are reported on a per million (‰) basis.

Although $\delta^{15}N$ values primary consumers may vary across site, Anderson and Cabana (2005) showed that trophic levels vary similarly across sites, and support the use of primary consumers as a baseline source for calculating trophic position (TP). Therefore, TP was calculated similar to methods in Cabana and Rasmussen (1996) by using a dominant primary consumer as the baseline, assuming a 3.4‰ increase in $\delta^{15}N$ with an increase of one trophic level (Minigawa and Wada, 1984; Post, 2002):

$$TP = [(\delta^{15}N_{\text{fish}} - \delta^{15}N_{\text{primary consumer}})/3.4] + 2$$

We chose chironomids as our baseline primary consumer because they were abundant in all three reaches and were similar to other primary consumers (i.e., ephemopterans; Gido and Franssen, 2007), and the baseline $\delta^{15}N$ value was based off the chironomid samples taken in each reach.

Stomach Content Analysis

Stomach contents were analyzed for all fishes to the lowest possible taxon. Contents of the stomachs were allowed to dry at 60° C for 24 hours, and each individual item was weighed to obtain a percent diet by dry-weight for each item for each individual fish. Data were summarized as mean percent by dry weight of each diet item for each species at each reach. In addition, diet data were summarized by fish feeding guilds from Plieger (1997; Table 2.1).

TP was also calculated using the diet items found in each individual fish. In order to calculate TP, each diet item was identified as detritus and plant matter (TP=1), macroinvertebrates (TP=2), and fish (TP=3). TP was then calculated using the equation in Vander Zanden et al. (1997)

$$\mathrm{TP}_{\mathrm{diet}} = \sum (V_i T_i) + 1$$

where V_i is the percent dry weight of the ith prey item and T_i is the TP of the ith prey item.

Data Analysis

A multivariate analysis of variance (MANOVA) was used to test if mean proportion of riparian and instream habitat differed among reaches with measurements from each river km as the replicates. If the MANOVA was significant an analysis of variance (ANOVA; Proc Mixed in SAS) was used to test which habitat variables differed among reaches (Littel et al., 1996). Statistical significance was declared at $P \leq 0.10$, and least squares means tests were used to test where means differed if the ANOVA was significant.

Biplots of mean $\delta^{13}C$ and $\delta^{15}N$ values for each fish species and macroinvertebrate taxa were plotted to assess the trophic structure of fishes among the three reaches. Coefficients of variation (CV), range, and standard error of the $\delta^{13}C$ and $\delta^{15}N$ values were calculated by the different trophic levels of macroinvertebrates and fishes among all locations. An ANOVA was conducted to test if mean $\delta^{13}C$ and $\delta^{15}N$ values differed among reaches for each feeding guild to test where enrichment was highest. To test if variance in $\delta^{13}C$ and $\delta^{15}N$ differed across reaches for the different feeding guilds a Levene's test for homogeneity of variance was used. An ANOVA was also used to test if mean stable isotope TP differed among reaches for the different feeding guilds collected in all reaches.

Linear regression was used to test if stable isotope TP of all species from all sites and stomach content TP of all species were associated. A slope of 1 would indicate that TP for both methods was the same. Due to only having three reaches we visually assumed how TP was related to fish density. Abundance of individuals was calculated by taking the catch per unit of effort (CPUE) for each guild and multiplying it by a standard amount of effort making effort equal across locations (since effort was relatively equal for each gear in each reach). For example, if total abundance of a species was 10 and effort was 10 minutes of electrofishing at that reach, then CPUE at that reach would be 1 fish per minute. After calculating CPUE at all reaches we can standardize the effort and then calculate the estimated total abundance with standardized effort. Therefore if our standardized effort was 5 minutes of electrofishing the estimated abundance of the species would be 5 from the example.

RESULTS

Riparian and instream habitat

Riparian and instream habitats differ among reaches (Wilks' lambda=0.193, d.f.=14, 42, P<0.001). Riparian habitat consisted of 46% agricultural land in reach 1 which tended to have more agricultural land than reach 2 (37%) and reach 3 (30%; Fig. 2.1A). Reach 1 had significantly more forested area (49%) and less urban land (5%) than reach 3 (28% forested, 41% urban; Fig 2.1A) . Reach 2 did not significantly differ from reach 1 or reach 3 in the amount of agricultural, forested or urban land use (Fig. 2.1A).

Instream habitat also differed among reaches with the reach 1 having a higher proportion of bankfull width as islands and sandbars (Fig. 2.1B). Reach 2 was narrower and has fewer channels than reach 1 and reach 3, although reach 3 had the greatest mean depth. Reach 1 also had less main channel area (59%) than reach 2 (77%) and reach 3 (93%). Reach 1 also has more grass islands (21%) than reach 2 (0%) and reach 3 (1%; Fig. 2.1B). Reach 1 and reach 2 appeared to have more variable instream habitat than the reach 3 (Fig. 2.1B). Therefore, the reach 1 has more islands and sand bars and will now be referred to as the heterogeneous habitat reach, whereas reach 3 was homogeneous with few braided channels or islands in its instream habitat and was deeper and more channelized and will be referred to as the homogeneous habitat reach. Reach 2 had less instream habitat than the heterogeneous habitat reach but had more than the homogeneous habitat reach and will be considered the intermediate reach.

Fish and Macroinvertebrate collection

A total of 157 individuals accounting for 12 species were used for stable isotope analysis. We captured at least 3 individuals of each species in each reach except for blue sucker, *Cycleptus elongatus*, in the intermediate reach (1 fish), emerald shiner, *Notropis atherinoides*, in the heterogeneous habitat reach (2 fish) and the homogeneous habitat reach (1 fish), and shovelnose sturgeon, *Scaphirhynchus platorynchus*, in the homogeneous habitat reach (2 fish). Woody debris contained many of the macroinvertebrate taxa (Chironimidae, Ephemeroptera, Hemiptera, Megaloptera, Odonata, Plecoptera, and Trichoptera). Of the macroinvertebrates sampled only plecopterans were not collected in all three reaches.

Primary Consumers

The $\delta^{13}C$ values varied among reaches for each species. The $\delta^{13}C$ values of macroinvertebrates ranged from -27.3 (Ephemeroptera) to -20.4 (Chironomids; Fig. 2.2) in the heterogeneous habitat reach, from -25.0 (Megaloptera) to -23.2 (Hemiptera; Fig. 2.2) in the intermediate reach, and from -25.8 (Trichoptera) to -24.2 (Plecoptera; Fig 2.2) in the homogeneous habitat reach. Mean $\delta^{13}C$ values of macroinvertebrates did not differ among reaches (P=0.771), but variance was higher in the heterogeneous habitat reach than the other reaches and had a much wider range of values (Table 2.2; P=0.004). The range of $\delta^{13}C$ in the heterogeneous habitat reach was 3.8 to 4.3 times higher for the intermediate and homogeneous habitat reaches.

The mean $\delta^{15}N$ values for macroinvertebrates were highest in heterogeneous habitat reach for all macroinvertebrate taxa (P=0.014). The $\delta^{15}N$ values were >12.0 in the heterogeneous habitat reach for four of the seven macroinvertebrate taxa, and were <12.0 for all taxa in the intermediate and homogeneous habitat reaches (Fig. 2.2). Macroinvertebrate taxa in homogeneous habitat reach appear to be the least enriched with $\delta^{15}N$ with values ≤11.0 for five of the seven taxa (Fig. 2.2). However, variability of $\delta^{15}N$ did not differ among reaches (P=0.442).

Detritivorous and omnivorous fishes

Similar to primary consumers, the range in $\delta^{13}C$ values for detritivorous and omnivorous fishes varied by reach. The heterogeneous habitat reach had the widest range of $\delta^{13}C$ values with a total range of 2.6‰ (Table 2.2; Fig. 2.2). The intermediate reach $\delta^{13}C$ values had a range of 2.2‰ and showed a wider range in $\delta^{13}C$ values than the homogeneous habitat reach which had a total range of 1.4‰. The overall range of $\delta^{13}C$ values for the detritivorous and omnivorous fishes only ranged from -24.4 to -21.8 (Table 2.2; Fig. 2.2). All reaches showed enrichment in $\delta^{13}C$ from macroinvertebrates to detritivorous and omnivorous fishes except for in the heterogeneous habitat reach where chironomids and hemipterans were more enriched in $\delta^{13}C$ than the fishes (Fig. 2.2). The $\delta^{13}C$ values had the widest range (2.6) in the heterogeneous habitat reach but variability did not differ among reaches (Table 2.2; P=0.409). In contrast, the homogeneous habitat reach has the narrowest range (1.4) and the CV was half the heterogeneous habitat reach CV.

Mean $\delta^{15}N$ values of the detritivorous and omnivorous fishes are more enriched $\delta^{15}N$ compared to natural sources in the heterogeneous habitat reach than in the intermediate and homogeneous habitat reaches (P<0.001) with all species values ranging from 14.0 to 15.8 (Fig. 2.2; Table 2.2). The intermediate reach and the homogeneous habitat reach had similar ranges with $\delta^{15}N$ values ranging from 12.7 to 14.1 and 12.0 to 14.3 respectively (Fig. 2.2; Table 2.2). However variability in $\delta^{15}N$ did not differ among reaches (P=0.976). The heterogeneous habitat reach also showed higher stable isotope TP throughout most of the detritivorous and omnivorous species with 6 of the seven species showing higher TP in the heterogeneous habitat reach compared to the intermediate and homogeneous habitat reaches. The intermediate and homogenous habitat reaches show the detritivorous and omnivorous species consuming prey at a significantly lower TP compared to the heterogeneous habitat reach (P<0.030; Fig. 2.3).

Piscivorous and invertivorous fishes

Piscivorous and invertivorous fishes $\delta^{13}C$ values range from -23.7 to -20.9, -25.0 to -21.8, and -23.7 to -22.3 in the heterogeneous, intermediate, and homogeneous habitat reaches respectively (Table 2.2; Fig. 2.2). The intermediate reach shows the widest range in values, but the heterogeneous habitat reach had the highest enrichment in $\delta^{13}C$ values (Table 2.2, P=0.003). Similar to detritivorous and omnivorous fishes, the homogeneous habitat reach had lower variability of $\delta^{13}C$, about half compared to the heterogeneous and intermediate habitat reaches (Table 2.2, P=0.029).

The heterogeneous habitat reach had significantly higher (P<0.001, Table 2.2) enrichment in $\delta^{15}N$ for piscivorous and invertivorous fishes than in the intermediate and homogeneous habitat reaches, with the heterogeneous habitat reach values >15.8 and in the intermediate and homogeneous habitat reaches all values were <15.7 except for longnose gar (*Lepisosteus osseus*; Table 2.2). Piscivorous and invertivorous species in the heterogeneous habitat reach typically consumed food at higher TPs than in intermediate and homogeneous habitat reaches (Fig. 2.3). Four of the five piscivorous and invertivorous species consumed prey at a higher TP in the heterogeneous habitat reach, with species in the intermediate and homogeneous habitat reaches tending to consume prey at a significantly lower trophic level.

Stomach content and feeding guild analysis

Stomach content analysis revealed that literature-based feeding guilds matched with the stomach contents. Detritivorous fish had greater than 50% of diet as algal/detritus, where piscivorous fish had 95-100% of diet as fish. Omnivorous fishes had a varied diet, but still had

41-64% algae/detritus (Table 2.3). The TP calculated through stable isotope analysis was related to TP calculated by stomach content analysis (P=0.076; Fig. 2.4). However, the slope differed from 1 (P=0.038) because TP calculated by the stable isotope analysis tended to be higher than the stomach content TP for detritivores and omnivores and TP was higher than the stable isotope TP for the piscivorous species (Fig. 2.4).

In general, guilds with high abundance (detritivores and omnivores) had low δ^{15}N and consumed food at lower trophic levels (Fig. 2.5). However, no density dependent patterns were evident within feeding guilds. For example, invertivores in the heterogeneous habitat reach had higher abundance than invertivores in the intermediate and homogeneous habitat reaches, but still had higher TP and δ^{15}N values. For the piscivores, detritivores, and omnivores there is no pattern suggesting that increased abundance was related to lower δ^{15}N enrichment or TP (Fig. 2.5).

DISCUSSION

Land use and instream habitat alterations may cause significant changes in the food web of the Kansas River fish community. Instream and riparian habitat differed throughout the river changing from agriculturally dominated, heterogeneous instream habitat areas to areas dominated by an urban riparian zone with homogeneous instream habitat. This corresponded to urban areas having a deeper and narrower channel with fewer braided channels and islands, which is consistent with Paukert and Makinster (In press) who documented more variable habitat with areas of islands, log jams, rip rap, and more channels in the heterogeneous reach of the Kansas River. The reduction of instream habitat in urban areas of the river suggests homogenization of the habitats, which is consistent with other studies (Lenat and Crawford, 1994; Schueler, 1994; Arnold and Gibbons, 1996; Booth and Jackson, 1997; May et al., 1997; Yoder et al., 1999; Paukert and Makinster, In press).

Agricultural areas typically cause high nitrogen loading into river and stream ecosystems due to the application of industrial fertilizers and animal wastes (Kreitler, 1979; Högberg, 1990; Heaton, 1986; Kendall 1998) and higher enrichment of $\delta^{15}N$ compared to natural sources may occur, which is consistent with our study. Anderson and Cabana (2005) found at 82 different sites in the St. Lawrence lowlands that increased agricultural land use showed increased enrichment of $\delta^{15}N$ values for primary and secondary consumers. This also indicated that primary and secondary consumers are enriched at the same rates with increased agricultural area, suggesting that though $\delta^{15}N$ values are enriched, the calculated TP should not be affected. Our study also indicated an increase in $\delta^{15}N$ values in agricultural areas. However, data collected from the Kansas Department of Health and Environment indicated that nitrate levels at three sites on the Kansas River (one site within 16 km downstream of each of our reaches) from 2006 did not differ throughout the river and total nitrogen was actually highest in the homogeneous habitat reach that contained more urban riparian area (A. Stahl, KDHE unpublished data). Therefore the high $\delta^{15}N$ values in the heterogeneous habitat reach, which contains more agricultural land, may not necessarily be due to high nitrogen loads from agriculture. Species tended to feed at a higher trophic level in the heterogeneous habitat reach suggesting that the loss of instream habitat in the intermediate and homogenous habitat reaches has more of an effect on the food web structure than increased nitrogen values. This is consistent with other studies (Dvorak and Best, 1982; Cyr and Downing, 1988) who showed that habitat complexity is positively correlated with availability of food resources.

Enrichment of $\delta^{15}N$ for fishes and macroinvertebrates typically followed what was expected in the literature. However, two of the fish species appeared to be more enriched in $\delta^{15}N$ than would be expected (e.g. blue sucker and river carpsucker). These two fish were classified as invertivores and detritivores, respectively, but TP indicated blue sucker to be piscivorous and river carpsucker to be omnivorous. A few possible reasons for this are (1) there was an unmeasured $\delta^{15}N$ enriched food source, (2) the species have diet shifts throughout the year, or (3) blue sucker and river carpsucker possibly fractionated $\delta^{15}N$ >3.4‰. The first explanation is less likely for blue sucker because their stomach samples contained mostly trichoptera larvae, but stable isotope analysis indicated a TP similar to piscivores. Although, the trichopteran larvae the blue suckers were consuming may have been occupying the deep, high velocity areas that blue sucker inhabit, which were not sampled. The second reason is possible for both species because the stomach content analysis was only a snap-shot of what these species were consuming at that instant in time. Therefore, it is unknown what the species were consuming weeks or months before the time of collection. The river carpsucker consumed mostly algae (which were not measured) and detritus. The third explanation is possible for both species because of variability in enrichment. Post (2002) indicated that a trophic position enrichment of 3.4‰ of $\delta^{15}N$ is only an observed average over many trophic pathways with enrichment ranging from ~2 to 5‰. Also, Mill et al. (2007) found that $^{15}N/^{14}N$ fractionation was significantly higher than 3.4‰ for herbivores. Therefore, blue sucker and river carpsucker may show higher fractionation of $\delta^{15}N$ than other taxa or were feeding on diet items that were not collected for stable isotope analysis leading to increased and biased TP.

There was lower variation in $\delta^{13}C$ in the homogeneous habitat reach for all feeding levels, which suggests the reduction of habitat affects food web variability. Finlay et al. (1999)

related $\delta^{13}C$ values to flow indicating that habitats with higher flows were more depleted in $\delta^{13}C$, and related this to the increase in the supply rate of CO_2 to benthic algae because discrimination against $\delta^{13}C$ occurs during photosynthesis with increase in CO_2 (Calder and Parker, 1973; Pardue et al., 1976). Although enrichment of $\delta^{13}C$ was similar among reaches, there was higher variability in $\delta^{13}C$ in the heterogeneous habitat reach suggesting higher variability in flows, which is likely due to increase in the habitat complexity (e.g. more channels and islands) in the heterogeneous habitat reach documented in our study. The algal sources in the heterogeneous habitat reach are most likely assimilating the $\delta^{13}C$ at different rates in the different habitats therefore causing the higher variation in the $\delta^{13}C$ values (Finlay, 2001; Finlay, 2004). This is similar to findings by Gido et al. (2006), who found higher enrichment and less variability in $\delta^{13}C$ values in secondary channels and suggested this was due to low velocity and a narrow range of habitats in the secondary channels, causing most of the organisms in the secondary channels to feed on similar items. In contrast, the homogeneous habitat reach had reduced habitat complexity (based on our instream and riparian analysis) and the lowest variability in $\delta^{13}C$ for all taxa suggesting that carbon is from similar basal algal sources and species are converging on the same resources.

Abundance of fish within each feeding guild had less of an effect on TP than habitat. Piscivores, omnivores, and detritivores typically fed at higher trophic levels in the heterogeneous habitat reach regardless of abundance. Therefore, changes in the feeding habits of these feeding guilds may be due other abiotic (anthropogenic effects) factors related to habitat. However, invertivores are eating at an 11 and 7% lower trophic level in the intermediate and homogeneous habitat reaches, respectively, where the invertivore abundances are almost a magnitude lower in those reaches versus the heterogeneous habitat reach. This is consistent with Yoder et al. (1999)

who found relative abundance of invertivores to be negatively correlated with increase in urbanized and channelized streams near Columbus, Ohio, and suggested this was due to a disruption in the food web. Also in the Kansas River, Paukert and Makinster (In press) found flathead catfish growth to be fastest in areas with high agricultural land use and more diverse instream habitat. Therefore, the piscivores eating at a higher trophic level in the heterogeneous habitat reach may be reflecting why growth is faster in that area.

Although many studies have determined the effects of land use and instream habitat on density and diversity of taxa (Yoder et al., 1999; Poulton et al., 2003; Walters et al., 2003; Allan, 2004), relatively few studies have evaluated the effects of land use and instream habitat on the food web. Our study suggests that urbanization and channelization reduce habitat variability in the system and also reduces variability in the food web. Homogenization of habitat reduces diversity of species within a community (Klein, 1979; Jones and Clark, 1987; Steedman, 1988; Limburg and Schmidt, 1990; Horner et al., 1997; Wang et al., 1997; Yoder et al., 1999) and may be linked to the homogenization of the food web. The reduction of instream habitat causes a reduction in variability of carbon resources thereby narrowing the food web and causing species to converge on the same diet items. Habitat diversity is essential for native fluvial fishes in large rivers (Galat and Zweimüller, 2001), and our study indicates that habitat diversity may be related to food web diversity and trophic position of fishes. Therefore, restoring natural habitats (e.g. sand bars, grass islands, secondary channels, etc.) in the Kansas River may increase food web diversity and native species diversity.

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Table 2.1. The species sampled in summer 2006 and the feeding guild they represent based on literature (Pflieger, 1997; Thomas et al., 2005).

Common Name	**Species**	**Species Code**	**Feeding Guild**
Blue sucker	*Cycleptus elongatus*	Cycelo	Invertivorous
Bullhead minnow	*Pimephales vigilax*	Pimvig	Omnivorous
Channel catfish	*Ictalurus punctatus*	Ictpun	Omnivorous
Emerald shiner	*Notropis athernoides*	Notath	Detritivorous/Planktivorous
Flathead catfish	*Pylodictis olivaris*	Pyloli	Piscivorous
Freshwater drum	*Aplodinotus grunniens*	Aplgru	Invertivorous
Longnose gar	*Lepisosteus osseus*	Leposs	Piscivorous
Red shiner	*Cyprinella lutrensis*	Cyplut	Omnivorous
River carpsucker	*Carpiodes carpio*	Carcar	Detritivorous
Sand shiner	*Notropis stramineus*	Notstr	Omnivorous
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	Scapla	Invertivorous
Smallmouth buffalo	*Ictiobus bubalus*	Ictbub	Omnivorous

Table 2.2. The mean, range, and coefficient of variation (CV) of δ^{13}C and δ^{15}N values for the heterogeneous habitat reach (rkm 229 to 235), intermediate reach (rkm 120 to 126), and homogeneous habitat reach (rkm 24 to 30) sampled in the Kansas River in summer 2006. The taxa include piscivores (Pisc), invertivores (Inse), omnivores (Omni), detritivores (Detr), macroinvertebrates (Invert), leaves (Leaf), and woody debris (WD). Species codes are given in Table 2.1. P-values indicate if mean isotopic signature or isotopic signature variance differed among reaches for each taxa group for δ^{13}C and δ^{15}N values.

	Heterogeneous reach			**Intermediate reach**			**Homogenous reach**				
Carbon	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV	P-Value Means	P-Value Variance
Pisc/Inse	-22.31	2.9	5.10	-23.25	3.3	4.84	-23.16	1.2	2.16	**0.003**	**0.0292**
Pyloli	-22.08	1.1	1.96	-23.07	3.2	4.66	-23.04	0.8	1.58		
Leposs	-20.87	1.2	2.14	-22.43	1.3	2.90	-23.17	0.8	1.74		
Scapla	-21.1	--	--	-21.75	0.7	1.12	-22.25	0.1	0.32		
Cycelo	-23.73	1.8	3.24	-25.00	--	--	-23.67	0.5	1.06		
Aplgru	-23.35	3.0	5.71	-23.45	3.5	5.75	-23.5	1.7	2.62		
Omni/Detr	-22.51	2.6	4.52	-23.38	2.19	3.59	-23.81	1.4	2.09	**<0.0001**	0.4092
Pimvig	-21.78	1.3	2.77	-22.75	1.2	2.28	-23.93	0.7	1.38		
Ictpun	-22.63	1.1	2.12	-23.78	3.5	5.18	-23.35	1.3	1.99		
Notath	-23.00	0.4	1.23	-24.31	0.79	1.67	-23.7	--	--		
Cyplut	-24.38	1.9	3.95	-23.73	0.9	1.59	-24.4	1.1	1.90		
Carcar	-22.07	1.0	1.85	-23.25	1	1.67	-23.6	1.0	1.59		
Notstr	-21.90	0.8	1.67	-22.13	1	2.07	-23	1.9	4.53		
Ictbub	-21.93	2.2	4.67	-24.14	3.1	5.14	-24.22	2.3	3.74		
Invertebrate	-24.26	6.9	10.65	-24.43	1.8	2.72	-24.74	1.6	2.74	0.7705	**0.0035**
Nitrogen											
Pisc/Inve	16.72	2.6	4.89	15.23	4.0	6.55	15.34	3.8	6.60	**<0.0001**	0.9984
Pyloli	16.6	1.8	4.57	14.52	1.8	4.10	15.32	0.4	1.07		
Leposs	17.57	1.1	2.35	17.23	0.5	1.46	17.33	0.1	0.33		
Scapla	16.9	--	--	15.05	2.3	5.18	15.45	0.7	3.20		
Cycelo	17.18	2.1	5.41	15.7	--	--	14.73	0.8	3.13		
Aplgru	15.8	0.7	2.00	15.03	0.5	1.50	14.63	1.5	3.88		
Omni/Detr	15.04	4.1	6.43	13.45	5.2	7.85	13.06	3.0	7.14	**<0.0001**	0.9763
Pimvig	14.8	1.0	3.07	13.45	1.6	5.61	12.88	0.4	1.33		
Ictpun	13.95	1.2	4.24	12.78	5.2	14.5	12.52	1.2	3.17		
Notath	14	0.6	3.03	13.68	4.33	14.06	13.4	--	--		
Cyplut	15.58	2.9	8.68	12.68	0.8	3.05	12.02	0.8	2.91		
Carcar	15.55	1.2	8.68	14.07	0.6	1.47	14.36	0.8	2.23		
Notstr	15.85	1.4	3.62	14.08	0.6	1.96	12.45	1.3	4.93		
Ictbub	14.78	2.4	6.91	13.64	2.0	5.60	14.02	0.7	2.10		
Invertebrate	12.03	2.2	7.13	11.4	1.5	5.17	10.79	1.8	5.55	**0.0141**	0.4417

Table 2.3. The mean proportion of diet items consumed by each fish feeding guild in the heterogeneous reach (1, rkm 229 to 235), intermediate reach (2, rkm 120 to 126), and homogeneous reach (3, rkm 24 to 30) sampled in the Kansas River during summer 2006. Values in parenthesis represent 1 standard error.

Reach	Guild	Fish	Aquatic Macro-invertebrates	Terrestrial Macro-invertebrates	Zooplankton	Algae/ Detritus
1	Detritivore	0.0	1.2(0.7)	0.0	24.4(16.0)	74.4(16.3)
2	Detritivore	0.0	44.7(17.6)	5.4(5.4)	0.0	50.0(18.9)
3	Detritivore	0.0	4.9(4.9)	0.0	0.0	95.1(4.9)
1	Omnivore	6.8(5.8)	28.7(9.4)	1.5(1.3)	18.7(9.2)	44.3(10.5)
2	Omnivore	0.3(0.3)	21.6(7.5)	4.5(4.4)	9.9(6.8)	63.7(9.5)
3	Omnivore	11.0(7.5)	21.3(8.9)	5.8(5.1)	20.8(9.5)	41.0(11.3)
1	Invertivore	7.7(7.7)	49.3(10.8)	0.0	0.0	43.0(10.6)
2	Invertivore	4.7(4.7)	65.7(10.4)	0.0	0.0	30.0(9.3)
3	Invertivore	0.0	56.1(12.8)	4.9(4.9)	0.0	39.0(11.6)
1	Piscivore	100.0(0)	0.0	0.0	0.0	0.0
2	Piscivore	95.5(4.5)	4.5(4.5)	0.0	0.0	0.0
3	Piscivore	97.0(3)	3.0(3)	0.0	0.0	0.0

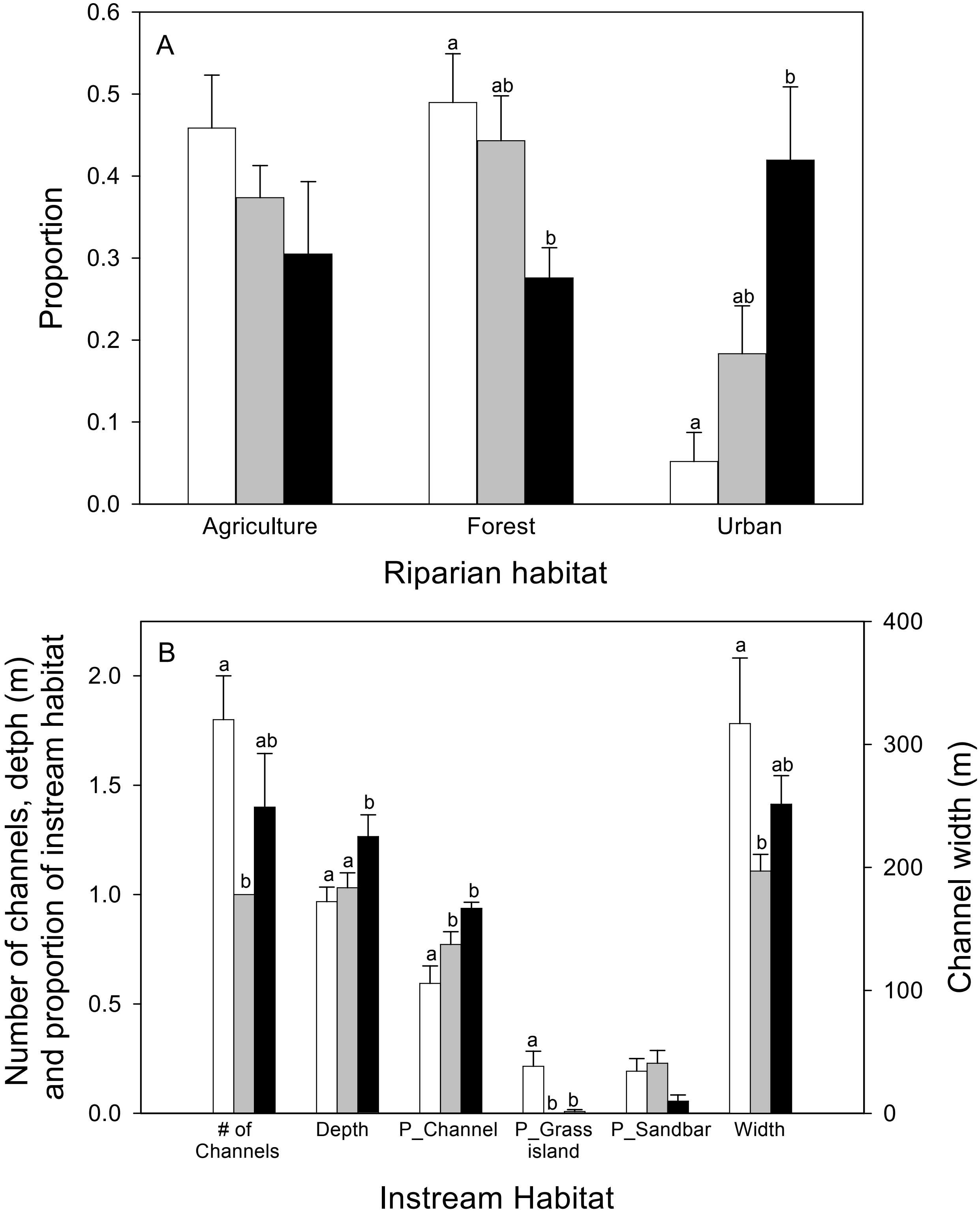

A
Proportion
0.0
0.1
0.2
0.3
0.4
0.5
0.6
a
ab
b
a
ab
b
Agriculture
Forest
Urban
Riparian habitat
B
Number of channels, detph (m) and proportion of instream habitat
Channel width (m)
0.0
0.5
1.0
1.5
2.0
0
100
200
300
400
a
b
ab
a
a
b
a
b
b
a
b
b
a
b
ab
# of Channels
Depth
P_Channel
P_Grass island
P_Sandbar
Width
Instream Habitat

Figure 2.1

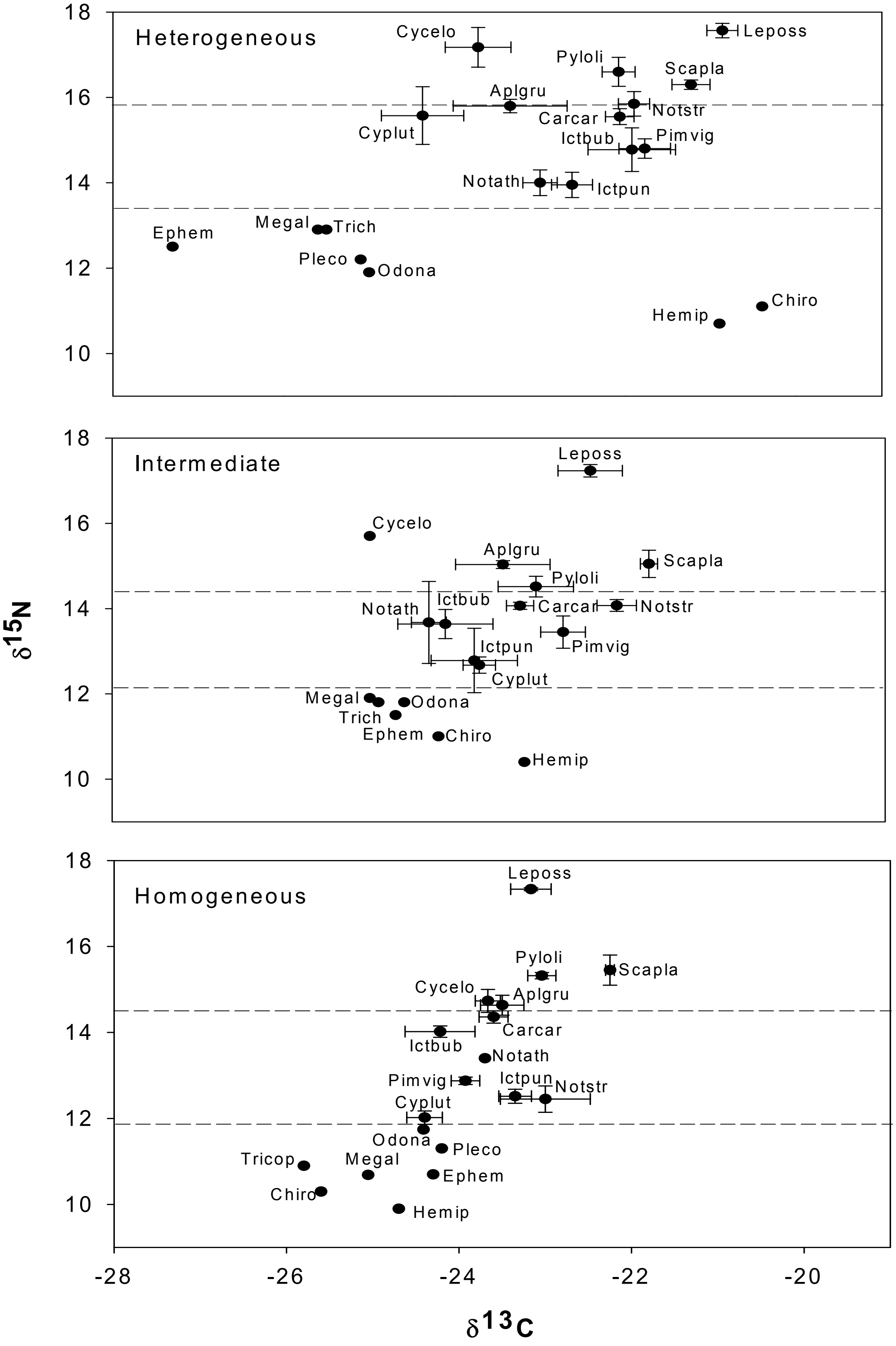
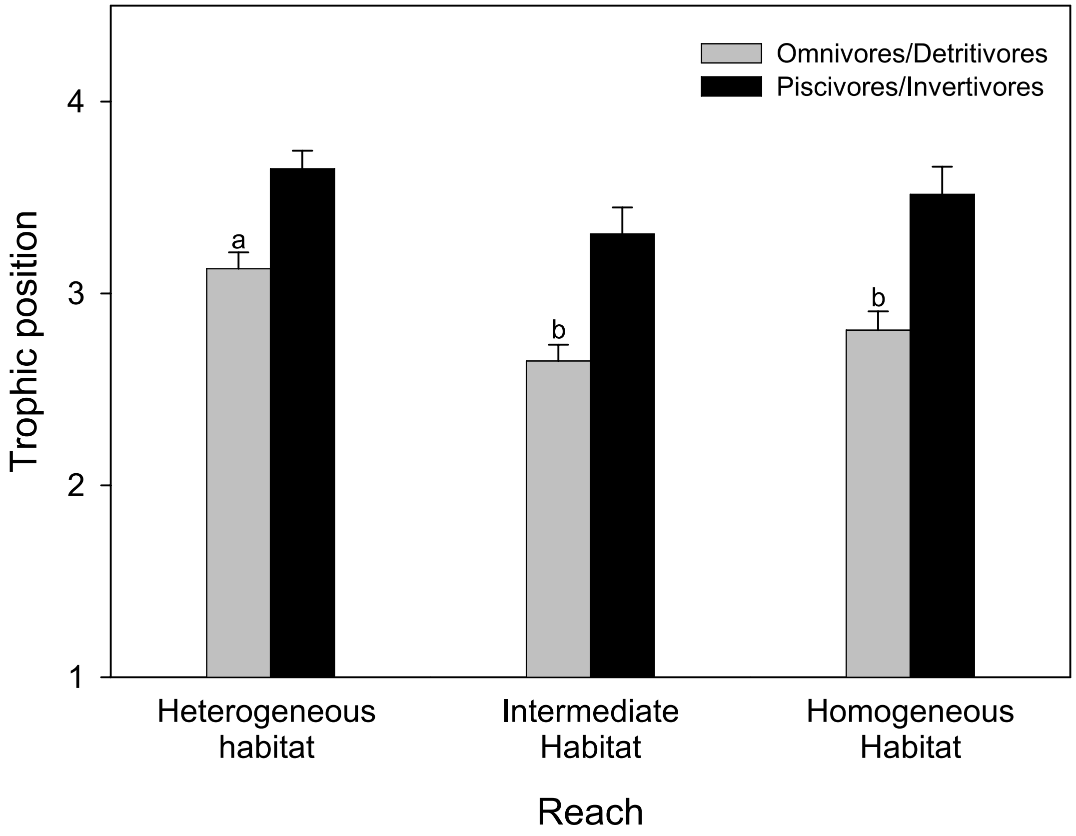
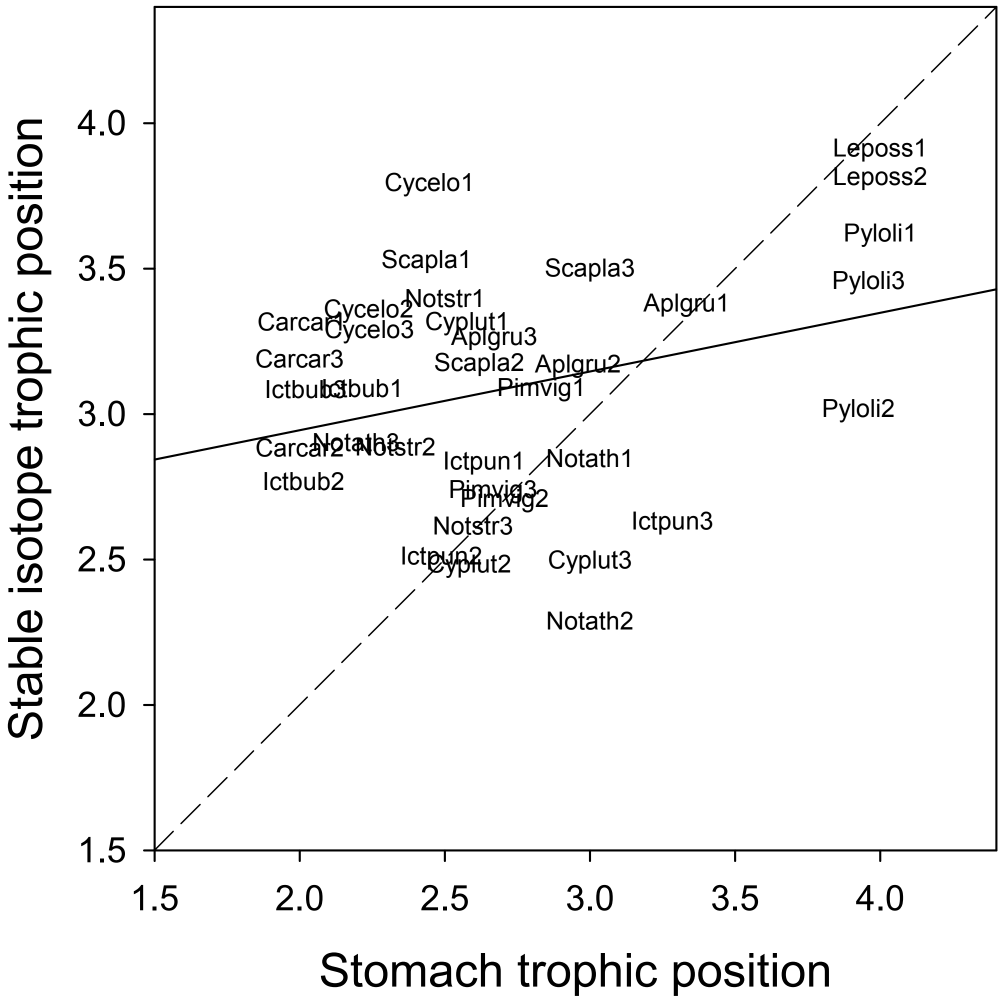

Heterogeneous
Cycelo
Leposs
Pyloli
Scapla
Aplgru
Notstr
Carcar
Cyplut
Ictbub
Pimvig
Notath
Ictpun
Ephem
Megal
Trich
Pleco
Odona
Chiro
Hemip
Intermediate
Leposs
Cycelo
Aplgru
Scapla
Pyloli
Ictbub
Notath
Carcar
Notstr
Pimvig
Ictpun
Cyplut
Megal
Odona
Trich
Ephem
Chiro
Hemip
Homogeneous
Leposs
Pyloli
Scapla
Cycelo
Aplgru
Carcar
Ictbub
Notath
Pimvig
Ictpun
Notstr
Cyplut
Odona
Pleco
Tricop
Megal
Ephem
Chiro
Hemip
18
16
14
12
10
$\delta^{15}N$
-28
-26
-24
-22
-20
$\delta^{13}C$

Figure 2.2



Omnivores/Detritivores
Piscivores/Invertivores
Trophic position
1
2
3
4
a
b
b
Heterogeneous habitat
Intermediate Habitat
Homogeneous Habitat
Reach

Figure 2.3



Stable isotope trophic position
Stomach trophic position
1.5
2.0
2.5
3.0
3.5
4.0
1.5
2.0
2.5
3.0
3.5
4.0
Leposs1
Leposs2
Cycelo1
Pyloli1
Scapla1
Scapla3
Pyloli3
Notstr1
Aplgru1
Cycelo2
Carcar1
Cyplut1
Cycelo3
Aplgru3
Carcar3
Scapla2
Aplgru2
Ictbub3
Ictbub1
Pimvig1
Pyloli2
Notath3
Carcar2
Notstr2
Ictpun1
Notath1
Ictbub2
Pimvig3
Pimvig2
Notstr3
Ictpun3
Ictpun2
Cyplut2
Cyplut3
Notath2

Figure 2.4

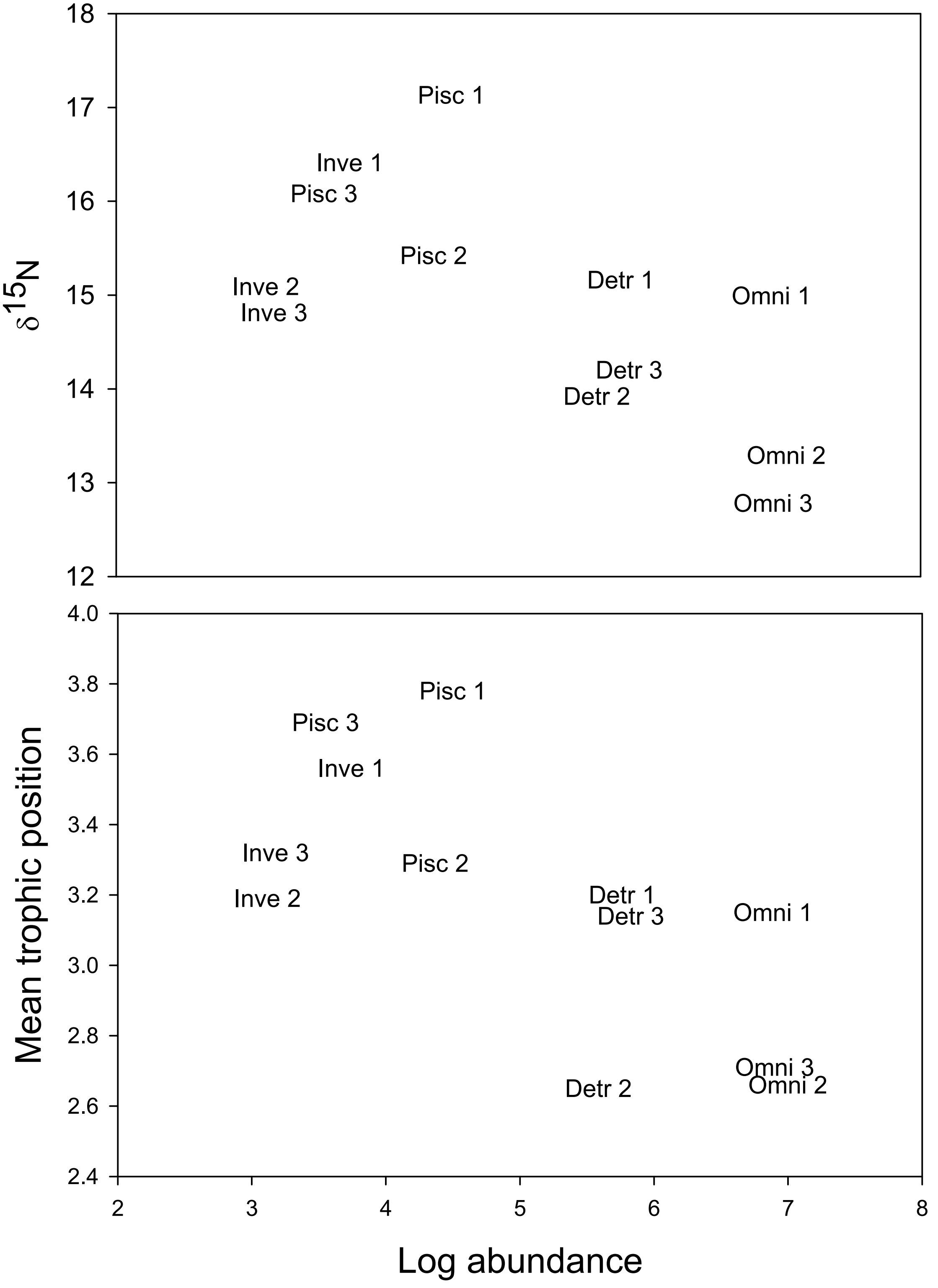

18
17
16
15
14
13
12
δ^{15}N
Pisc 1
Inve 1
Pisc 3
Pisc 2
Inve 2
Inve 3
Detr 1
Omni 1
Detr 3
Detr 2
Omni 2
Omni 3
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
Mean trophic position
Pisc 1
Pisc 3
Inve 1
Inve 3
Pisc 2
Inve 2
Detr 1
Detr 3
Omni 1
Omni 3
Omni 2
Detr 2
2
3
4
5
6
7
8
Log abundance

Figure 2.5

Appendix 1. List of diet items (percent by dry weight) of the 12 species collected for stable isotope analysis in the Kansas River in summer 2006 in the heterogeneous (hetero), intermediate (Inter), and homogeneous (homo) reaches. The values in parenthesis represent 1 standard error.

	Shovelnose sturgeon			Longnose gar			Red shiner			Emerald Shiner		
Reach	**Hetero**	**Inter**	**Homo**	**Hetero**	**Inter**	**Homo**	**Hetero**	**Inter**	**Homo**	**Hetero**	**Inter**	**Homo**
Fish												
Bullhead minnow				35.2(35)								
Channel catfish												
Red shiner												
White crappie												
Fish eggs												
Unidentified fish				64.8(35)	100.0(0)							
TOTAL	0.0	0.0	0.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aquatic Macroinvertebrates												
Chironomidae	41.5(14)	56.9(17)	100.0(0)					6.4(4)				
Corixidae									50.0(50)	2.5(2)	68.5(19)	19.4(0)
Crayfish												
Ephemoptera	0.1(0)											
Mollusc												
Odonata	0.4(0)											
Ostrecoda												
Trichoptera	2.2(1)	5.0(3)						52.0(26)				
Other									12.5(13)		20.7(20)	
TOTAL	44.1	61.9	100.0	0.0	0.0	0.0	0.0	58.4	62.5	2.5	89.2	19.4
Terrestrial Macroinvertebrates												
Coleoptera												
Diptera											10.8(10)	
Isopoda												
Lepidoptera												
Orthoptera												
Other												
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.8	0.0
Zooplankton												
Zooplankton							57.7(42)		37.5(37)	97.5(3)		
Algae/Detritus/Plant Matter												
Algae/Detritus	56.3(15)	38.1(15)					42.3(42)	41.6(25)				80.6(0)
Morus spp. fruit												
TOTAL	56.3	38.1	0.0	0.0	0.0	0.0	42.3	41.6	0.0	0.0	0.0	80.6

Appendix 1 continued.

	Sand shiner			Bullhead minnow			River carpsucker			Blue sucker		
Reach	**Hetero**	**Inter**	**Homo**	**Hetero**	**Inter**	**Homo**	**Hetero**	**Inter**	**Homo**	**Hetero**	**Inter**	**Homo**
Fish												
Bullhead minnow												
Channel catfish												
Red shiner												
White crappie												
Fish eggs												
Unidentified fish												
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aquatic Macroinvertebrates												
Chironomidae		2.0(2)		1.0(1)	1.0(1)		0.7(0)			0.1(0)		
Corixidae		0.1(0)		41.6(25)	0.1(0)	28.1(28)						
Orconectes spp.												
Ephemoptera							0.1(0)			0.3(0)		
Mollusc												
Odonata												
Ostrecoda					3.1(3)							
Trichoptera	8.6(6)	31.1(21)	9.7(9)	40.7(16)	19.8(12)	5.3(5)		0.1(0)		44.5(19)	23.8(0)	24.0(15)
Other												
TOTAL	8.6	33.0	9.7	83.3	23.8	33.3	0.7	0.1	0.0	44.7	23.8	24.0
Terrestrial Macroinvertebrates												
Coleoptera												
Isopoda												
Lepidoptera												
Orthoptera												
Other												
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zooplankton												
Zooplankton	41.4(22)		50.0(29)	0.1(0)	46.9(27)	33.3(33)						
Algae/Detritus/Plant Matter												
Algae/Detritus	50.0(23)	67.0(23)	40.3(25)	16.7(10)	29.3(17)	33.3(33)	99.3(1)	99.9(0)	100.0(0)	55.3(19)	76.2(0)	76.0(15)
Morus spp. fruit												
TOTAL	50.0	67.0	40.3	16.7	29.3	33.3	99.3	99.9	100.0	55.3	76.2	76.0

Appendix 1 continued.

	Smallmouth buffalo			Channel catfish			Flathead catfish			Freshwater drum		
Reach	**Hetero**	**Inter**	**Homo**	**Hetero**	**Inter**	**Homo**	**Hetero**	**Inter**	**Homo**	**Hetero**	**Inter**	**Homo**
Fish												
Bullhead minnow							7.0(7)				10.1(10)	
Channel catfish									33.3(33)			
Red shiner							26.5(26)	25.9(25)		33.3(33)		
White crappie						20.0(20)			29.3(29)			
Fish eggs									33.3(33)			
Unidentified fish				25.5(21)	3.0(3)	19.6(19)	66.7(33)	66.7(33)				
TOTAL	0.0	0.0	0.0	25.5	3	39.6	100	92.5	96	33.3	10.1	0
Aquatic Macroinvertebrates												
Chironomidae		0.4(0)	1.3(1)			0.1(0)				1.3(1)	0.3(0)	2.7(2)
Corixidae										20.2(20)	0.3(0)	30.2(17)
Orconectes spp.								7.5(7)	4.0(4)		25.4(17)	
Ephemoptera				1.2(1)	0.2(0)						7.8(8)	18.0(14)
Mollusc	21.5(0)	0.7(0)								21.6(21)	24.9(17)	9.5(9)
Odonata				3.4(3)						10.1(10)	0.1(0)	
Ostrecoda												
Trichoptera		0.2(0)	1.0(1)	5.8(5)		19.9(19)				13.6(11)	17.7(9)	4.4(2)
Other						2.2(2)						8.2(8)
TOTAL	21.5	1.3	2.1	10.4	0.2	22.2	0.0	7.5	4	66.8	76.5	73.1
Terrestrial Macroinvertebrates												
Coleoptera				0.8(0)	41.7(41)							
Isopoda				4.7(4)								
Lepidoptera					0.8(0)							
Orthoptera						8.2(8)						
Other						12.8(10)						
TOTAL	0.0	0.0	0.0	5.5	42.5	21	0.0	0.0	0.0	0.0	0.0	0.0
Zooplankton												
Zooplankton				0.1(0)	46.9(27)	33.3(33)						
Algae/Detritus/Plant Matter												
Algae/Detritus	78.5(0)	98.7(1)	97.9(1)	36.5(23)	5.2(5)	17.2(17)					13.4(9)	26.9(12)
Morus spp. fruit				22.2(22)	49.0(49)							
TOTAL	78.5	98.7	97.9	58.6	54.3	17.2	0.0	0.0	0.0	0.0	13.4	26.9