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Variation in Unionid Assemblages between Streams and a Reservoir within the Kansas River Basin

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Abstract.—North American freshwater mussels of the Order Unionoida are critically imperiled, primarily due to stream habitat modifications and fragmentation by reservoirs. Whereas many species respond negatively to impoundments, some species benefit by increases in lentic habitat. During winter drawdown of Tuttle Creek Reservoir, KS in 2006–2007, we collected freshwater mussel shells to characterize spatial variation in assemblage structure within the reservoir and compare reservoir assemblages to stream assemblages within the surrounding drainage basin. Of the 22 unionid species that occurred in the basin, six were found in Tuttle Creek Reservoir. Species richness in the reservoir did not differ from that found in both small and large streams. Species composition in streams varied along a gradient from small to large (1st-7th) order streams, and mussel assemblages in the reservoir were most similar to that of large order streams. This study identified the subset of stream-dwelling unionid species that are habitat generalists and capable of persisting in reservoirs.

Introduction

The decimation of the North American freshwater mussel fauna (Order Unionoida) has been primarily attributed to fragmentation of rivers by reservoirs over the last half century (Bogan, 1993; Williams et al., 1993). Nearly 80% of all major rivers in the northern hemisphere are dammed or diverted (Dynesius and Nilsson, 1994) and almost all major rivers in the United States are regulated (Benke, 1990). Reservoirs significantly alter the physical habitat of streams through increased water depth and decreased water velocity thus affecting sedimentation, dissolved oxygen, or biogeochemical cycling (Baxter, 1977). Subsequent habitat modifications can have negative consequences for unionid species not adapted to such conditions (Blalock and Sickel, 1996). Fragmentation caused by reservoirs can disrupt sink-source dynamics of unionid species by limiting the dispersal potential of their obligate parasitic larvae (Watters, 1996; Tiemann et al., 2007) via changes in spatial distribution of host fishes (Gillette et al., 2005) or by altering fish assemblage structure (Taylor et al., 2001). Even if host species are present within a reservoir, altered environmental conditions might not be suitable for juvenile survival after release from hosts (Fuller, 1974).

Although impoundments are a major threat to native unionid species, the littoral habitats of reservoirs are used by some mussel species. Changes in mussel assemblages pre- and post-impoundment are typically quantified by decreased richness or diversity and often characterized by the loss of species with habitat requirements and life history characteristics specialized for stream environments (e.g., Baxter, 1977; Blalock and Sickel, 1996). However, not all studies have reported reduced mussel assemblages following impoundment; not when the pre-impoundment assemblage was comprised of generalist species (Neck, 1989) or when environmental conditions for the native assemblage were optimized after impoundment (White and White, 1977).

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Our primary objective was to characterize native mussel assemblages in Tuttle Creek Reservoir, a major impoundment in the Lower Kansas River basin. We also compared mussel assemblages of the reservoir to stream assemblages within the surrounding drainage basin to evaluate the suite of species and their life history characteristics that might benefit from reservoir environments in this region. We predicted mussel assemblages in reservoirs should be dominated by substrate generalists and species whose host fishes occur in reservoirs will establish populations in reservoirs. Thus, mussel assemblages in Tuttle Creek Reservoir should be more similar to assemblages in larger streams of the Lower Kansas River basin because they are more likely to be tolerant of silt and fine substrata and greater water depths. Because reservoirs are major components of modified stream networks, understanding the structure of mussel assemblages in both reservoirs and streams is critically needed for conservation of native species and will be important in managing assemblages at the scale of entire river basins (e.g., Newton et al., 2008).

METHODS

Tuttle Creek Reservoir is on the Big Blue River and has a surface area of approximately 50 km$^2$ and maximum depth of approximately 15 m. The bottom-draw dam is approximately 14.5 km upstream of the Big Blue River confluence with the Kansas River (Fig. 1), where the
Big Blue River is a 7th order stream (Strahler order). During the winter of 2006–2007, we collected the remnants of stranded mussels from six locations (based on accessibility) in Tuttle Creek Reservoir to represent the native mussel assemblage within the reservoir. During our sampling, the water level rapidly declined to 2.1 m below multipurpose pool elevation (United States Army Corps of Engineers, unpubl. data), and at our sites the entire mussel assemblage appeared to be stranded above the waterline. It is possible some species occupied deeper habitats, but most stranded mussels were >30 m from the waterline, indicating the majority of mussels occurred in the littoral zone. At each site, we conducted a 100–200 m walking transect and collected all whole and half shells from recently dead individuals visible on or in the substrate. Individuals were classified as being recently dead if tissue was still present inside the shells or by a lack of weathering inside and outside of the shell if no tissue was present. Shells were then cleaned of mud and debris and identified to species.

Mussel species data collected by Kansas Department of Wildlife and Parks (KDWP) from streams in the Lower Kansas River basin were used to represent native mussel assemblages in the surrounding drainage basin. The KDWP dataset represents a standardized survey of mussel assemblages from 1994 to present. Timed surveys were performed in which the survey area was searched for live and dead mussel species for one man-hour. Because of different sampling methods between KDWP and our survey of Tuttle Creek Reservoir we only used presence/absence data and we assumed it represented spatial variation in stream assemblages of the Lower Kansas River basin. Locations that were sampled by KDWP multiple times during this period were combined to represent one sample. Sample sites from 1st and 2nd order streams were combined for analyses as only two KDWP sample sites represented 1st order streams. Similarly, 5th and 7th order KDWP sites were combined to increase sample size and because data from 6th order streams was not available. After consolidation, the dataset consisted of 68 basin-wide locations in 1st to 7th order streams that were compared with the reservoir mussel assemblage.

Species richness and composition were used to compare the unionid assemblages in the reservoir and streams of different orders within the drainage basin. A Kruskal-Wallis nonparametric analysis of variance performed in SPSS (Version 11.0, IBM Corporation, Somers, New York) was used to test for differences in mean species richness among stream locations of the same order and Tuttle Creek Reservoir. Tamhane’s post hoc multiple comparisons test was used for pair-wise comparisons between the reservoir and different stream orders. Next, we used non-metric multidimensional scaling (NMDS) to visualize variation among stream and reservoir localities in species composition based on Jaccard’s index of similarity. Similarity calculations and NMDS were performed in NTSYS (Version 2.1., Exeter Publishing Ltd., Setauket, New York) and Primer 5 (Version 5.2.9, Primer-E Ltd., Plymouth, United Kingdom), respectively. Species present at two or fewer locations were excluded from analyses to prevent these species from disproportionately affecting species composition.

We used mussel habitat descriptions reported in Cummings and Mayer (1992) for species that occurred in our study area to evaluate if reservoir species have similar habitat preferences compared to species occurring in streams. Tabulated habitat descriptions consisted of stream size, ponds, lakes, and substrate type (shown in Table 1). A Principal Components Analysis (PCA) was performed on habitat data, converted to binary for analysis, in R (R Development Core Team, 2010).

**Results**

Twenty-four bivalve species (22 unionid species; Table 1) occurred in the Lower Kansas River basin (Table 1). *Corbicula fluminea*, a nonnative Asian clam, occurred at one site in the
Table 1.—Freshwater mussel species present within Tuttle Creek Reservoir (sampled during the winter of 2006–2007) and the Lower Kansas River Basin (sampled by KDWP from 1994 to present). Species codes are used in Figure 4. N is the number of sites in which a species occurred. Occurrence is denoted by the Strahler stream order in which a species was present and R designates presence in the reservoir. Mussel assemblages in streams were sampled by Kansas Department of Wildlife and Parks. No sixth order streams were sampled. Species habitat information (Stream Size and Substrate Type) reported for each species from Cummings and Mayer (1992).

<table>
<thead>
<tr>
<th>Scientific name (Species code)</th>
<th>n</th>
<th>Occurrence Stream order</th>
<th>Stream size</th>
<th>Substrate type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amblema plicata (Ap)</td>
<td>28</td>
<td>1, 2, 3, 4, 7</td>
<td>X</td>
<td>Silt</td>
</tr>
<tr>
<td>Fusconaia flava (Ff)</td>
<td>30</td>
<td>1, 2, 3, 4, 5</td>
<td>X</td>
<td>Sand</td>
</tr>
<tr>
<td>Quadrula quadrula (Qq)</td>
<td>36</td>
<td>1, 2, 3, 4, 5, 7, R</td>
<td>X</td>
<td>Gravel</td>
</tr>
<tr>
<td>Quadrula pustulosa (Qp)</td>
<td>9</td>
<td>3, 4, 5, 7</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Tritogonia verrucosa (Tv)</td>
<td>4</td>
<td>4, 5, 7</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Utterbackia imbecillis (Ui)</td>
<td>2</td>
<td>2, 4</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Leptodea fragilis (Lf)</td>
<td>28</td>
<td>3, 4, 5, 7, R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lampsilis cardium (Lca)</td>
<td>7</td>
<td>2, 4, 5, 7</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lampsilis teres (Lt)</td>
<td>9</td>
<td>1, 4, 5</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lampsilis siliquoidea (Lsi)</td>
<td>11</td>
<td>1, 2, 4, 7</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ligumia recta (Lr)</td>
<td>3</td>
<td>1, 4, 7</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ligumia subrostrata (Lsu)</td>
<td>47</td>
<td>1, 2, 3, 4, 5, 7</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Potamilus ohiensis (Po)</td>
<td>21</td>
<td>3, 4, 5, 7</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Potamilus alatus (Pa)</td>
<td>11</td>
<td>3, 4, 5, R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Potamilus purpuratus (Pp)</td>
<td>1</td>
<td>4</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Toxolasma parvus (Tp)</td>
<td>16</td>
<td>1, 2, 3, 4, 5, 7</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Truncilla donaciformis (Td)</td>
<td>2</td>
<td>5</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
reservoir and four stream sites of 2nd, 3rd, and 4th order. A nonnative species of Sphaeriidae was found in five stream sites of 3rd, 4th, and 7th order. Six native unionid species were found in the reservoir. Three species, giant floater (*Pyganodon grandis*), mapleleaf (*Quadrula quadrula*), and white heelsplitter (*Lasmigona complanata*), were present in the reservoir and at sites from all stream orders. Four species, creeper (*Ligumia recta*), lilliput (*Toxolasma parvus*), pondmussel (*Ligumia subrostrata*), and threeridge (*Amblema*

![Graphs showing frequency of occurrence of freshwater mussel species.](image)

**Fig. 2.**—Frequency of occurrence of freshwater mussel species within Tuttle Creek Reservoir, KS and their frequency of occurrence in streams of different order in the Lower Kansas River basin. No sixth order streams were sampled.

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Plicata) were found in streams of all orders but were absent from the reservoir. Fragile papershell (Leptodea fragilis), mapleleaf, pink heal-splitter (Potamilus alatus), and pink papershell (Potamilus ohiensis) tended to occur more frequently in large streams than small streams and were consistently present at the six reservoir sites (Fig. 2). Pyganodon grandis and L. complanata occurred equally in streams of all sizes, yet in the reservoir, L. complanata occurred at all sites, whereas P. grandis was only present at two sites.

Mean species richness of mussel assemblages varied across streams of different orders (P = 0.009, Table 1) but not between streams and the reservoir (P-values for all pairwise comparisons with the reservoir were >0.05). Average species richness of the reservoir mussel assemblages was six species, which was similar to that of intermediate streams (4th, 5th, and 7th orders) in the region (Fig. 3A).

Three species, bluefer (Potamilus purpuratus), fawnsfoot (Truncilla donaciformis), and paper pondshell (Utterbackia imbecillis), were present at two or fewer locations and were excluded from the NMDS analysis. Mussel assemblages varied along a gradient of stream order, as indicated with the NMDS ordination bi-plot (Fig. 3B). In addition, species composition of local mussel assemblages was more variable across stream sites than within the reservoir. In particular, local assemblages in 1st to 4th order streams were highly variable in species composition, but this variability masked major differences among stream size, as evidenced by large overlapping polygons for 1st through 4th orders in ordination space.

Analysis of habitat associations showed no consistent patterns between reservoir species and habitat preferences (Fig. 4). Pyganodon grandis and Potamilus ohiensis were the reservoir species that associated with lakes and silt, whereas literature descriptions of Lasmigona complanata suggest it was associated with small streams and Leptodea fragilis and P. alatus were associated with medium streams and sand and gravel substrate. Based on the analysis of habitat associations we might expect P. purpuratus and Utterbackia imbecillis to occur in the reservoir as they are strongly associated with lakes and silt similar to P. grandis and P. ohiensis; however, these species were not found within Tuttle Creek Reservoir.

**Discussion**

Sections of the Big Blue River and its tributaries inundated by Tuttle Creek Reservoir have lost a fraction of their historic assemblages, as evidenced by lower cumulative species richness and changes in species composition compared to streams of the Lower Kansas drainage basin. As there have been no apparent changes in water chemistry or invasive species, decreased flow variability and habitat heterogeneity within the reservoir compared to streams are the most likely explanations for reduced mussel diversity in the reservoir. The six unionid species that persisted in Tuttle Creek Reservoir are also common in other impounded rivers (e.g., Cvancara and Freeman, 1978; Neck, 1989), suggesting these species are not constrained by lentic habitats imposed by reservoirs. Analysis of literature based habitat descriptions showed high variability in habitat associations across species in Tuttle Creek Reservoir (Table 1 and Fig. 4) based on the habitat descriptions provided by Cummings and Mayer (1992). Only two of the reservoir species were associated with ponds, lakes, and silt-mud substrate. However, Cummings and Mayer (1992) reported habitat descriptions for these species from accounts in the Upper Midwest (Illinois, Indiana, Ohio, Michigan, Missouri, and Wisconsin) which might not reflect habitat associations of species that occur in Kansas. Whereas the plasticity of mussel habitat preferences are not well known, our analysis of mussel habitat association suggested that habitat might not be the only factor constraining reservoir mussel assemblages.
Fig. 4.—Principal Components Analysis of literature based habitat associations of freshwater mussels in the Lower Kansas River basin, KS. Habitat variables used in the analysis are plotted as lines and variable names are underlined and bolded. Species codes are italicized and bolded for species occurring in Tuttle Creek Reservoir (see Table 1 for species codes).

Fig. 3.—Mean species richness of freshwater mussels (A) at sites of different stream order upstream and downstream and within Tuttle Creek Reservoir, KS (R). Numbers in parentheses indicate the number of sample locations for each stream order and the reservoir. Mean species richness is shown with standard error bars. Non-metric multidimensional scaling (B) based on Jaccard’s similarity coefficients among sites of differing stream order in the Lower Kansas River basin and within the reservoir. Sites (not plotted for clarity) were outlined by polygons to represent the area of different stream orders in 2-dimensional ordination space. First and second order sites were combined and the same was done for fifth and seventh order sites. No sixth order streams were sampled.
The persistence of six unionid species in Tuttle Creek Reservoir also might be contingent on the presence of host fishes in the reservoir. Fish assemblages in Midwestern reservoirs are dominated by facultative reservoir species such as clupeids, large catostomids, and centrarchids capable of moving upstream into tributaries (Taylor et al., 2001; Gido et al., 2009). The six species in Tuttle Creek Reservoir have documented host fishes that include these reservoir species. For example, largemouth bass (Micropterus salmoides) is a known host species for Pyganodon grandis and Lasmigona complanata, and freshwater drum (Aplodinotus grunniens) are a known host for Leptodea fragilis, Potamilus alatus, and P. ohiensis (Fuller, 1974).

Species composition changed along a gradient from small, low order streams to rivers and the reservoir and is likely a function of changes in abiotic factors such as flow stability, substrate composition, and habitat quality (e.g., Mcrae et al., 2004). Littoral zones of reservoirs have little flow variability and homogeneous substrate, whereas streams have greater variability in habitat types (e.g., backwaters, riffles, and pools). Changes in mussel diversity and species composition are also likely a result of changes in fish assemblages along the same gradient. Both Watters (1992) and Vaughn and Taylor (2000) have found fish species richness and abundance to be strong predictors of mussel assemblage structure at both local and regional scales. Midwestern reservoir fish assemblages are composed of species with similar ecological traits and are a subset of the more diverse regional species pool which includes many obligate stream fish species (Gido et al., 2009). Although species richness in the reservoir did not significantly differ from richness in streams and rivers, the mussel species composition in reservoirs may be constrained by available habitat and dominant fish species occurring in the reservoir.

Reservoirs clearly threaten the persistence of many unionid species, but our results and those of others (e.g., Blalock and Sickel, 1996) show that a particular subset of lentic tolerant species can persist in reservoirs; albeit, in our study, they were heavily affected by rapidly receding water levels. Differences in geomorphology and water chemistry among reservoirs could play an important role in mussel persistence in other reservoirs, and because reservoir mussel assemblages are a subset of species occurring in the drainage basin, lentic tolerant species must be present in the regional species pool. To be successful in a reservoir, colonizing mussel species have to contend with different environmental and biotic conditions than mussels in lotic systems. It is also possible that reservoir and stream assemblages interact. In particular, we cannot discard the possibility that reservoir assemblages might be dependent on river assemblages as source populations. Given the often variable fluctuations in reservoir water levels, reservoirs may be too unstable to sustain viable mussel populations because individuals can become stranded on shorelines and susceptible to predation (Burlakova and Karatayev, 2007). Alternatively, reservoir fish infected with unionid glochidia might move out of reservoirs and translocate species into tributary streams. The addition of reservoirs to river networks has clearly changed the environmental template in which mussel assemblages persist. Understanding the role of reservoirs as source or sink habitats for freshwater mussels within river basins will aid conservation efforts to maintain diversity of this highly imperiled group.

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LITERATURE CITED


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