2006 SOUTHEASTERN NATURALIST 5(3):383–392

Increase of Unionid Mussel Populations in the Verdigris River, Kansas, from 1991 to 2003

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Abstract - Periodic quantitative surveys to monitor populations of freshwater mussels (Unionidae) were conducted at eight sites in the Verdigris River, KS during 1991, 1997, and 2003. Twenty-two species were collected including several on the Kansas rare-species list. Overall mussel abundance increased from 1991–2003. Abundance of 10 species (*Cyprogenia aberti, Fusconaia flava, Lasmigona complanata, Pleurobema sintoxia, Ptychobranchus occidentalis, Quadrula metanevra, Quadrula nodulata, Quadrula pustulosa, Tritogonia verrucosa, and Truncilla donaciformis*) increased significantly while only *Lampsilis teres* decreased. This positive trend in unionid abundance could be due to various factors that have improved habitat quality of this reach of river.

Introduction

The Verdigris River in southeast Kansas has a high diversity and density of freshwater mussels (Family Unionidae) including 24 extant species (Obermeyer et al. 1997). The existence of this mussel assemblage in the region is attributable to local geology, land use, rainfall, and sufficient habitat quality. The operation of two federal reservoirs affects the flow rate of the Verdigris River at the survey sites. The watershed above these reservoirs is nearly 90% native grassland (United States Geological Survey 2000). Below the reservoirs, land use is about one-third cropland with the majority of cover in grassland. The chert and limestone gravel that forms favorable substrate for unionid mussels inhabiting this river has been eroded from limestone bedrock and streambank deposits of the Flint Hills and Osage Questas physiographic regions.

This survey was initiated in 1991 to determine the effect of commercial mussel harvest in the Verdigris River and gather baseline data to monitor mussel populations. Because mussels are long-lived, relatively sedentary suspension feeders that use fish as hosts to complete their life cycle, their trends are suitable long-term indicators of a watershed's ecological condition (Bogan 1993, Goudreau et al. 1993, Prophet and Edwards 1973, Sparks and Strayer 1998). Moreover, monitoring of population trends is essential in the regulation and management of commercially harvested and imperiled unionid species.

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Methods

Mussel surveys were conducted along a 13.2-km reach of the Verdigris River in Montgomery and Wilson Counties in Kansas during 1991, 1997, and 2003. The upper-most site is located just below the confluence of the Verdigris and Fall Rivers (Fig. 1) and downstream from two federal reservoirs. This portion of the Verdigris River includes a 10.7-km reach designated as a refuge from commercial mussel harvest since 1988. Eight sites were sampled (Fig. 1): four within the protected reach, two

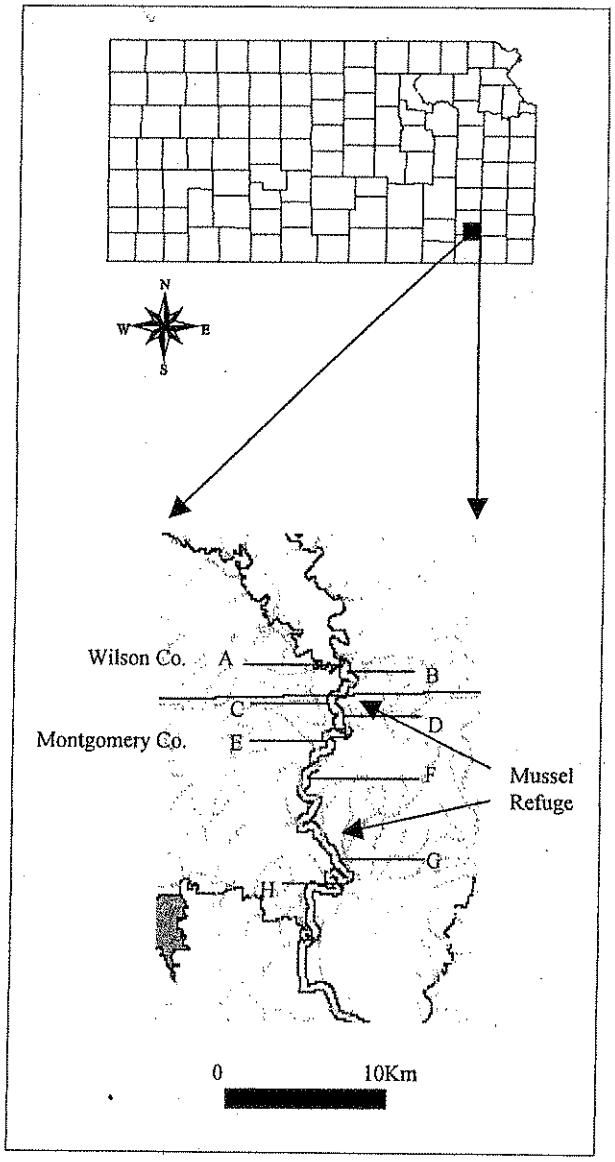


Figure 1. Map showing a portion of the Verdigris River in Kansas and the location of the eight sample sites (A–H).

upstream, and two downstream of the refuge boundaries. We selected these sites because they had been sampled previously (Cope 1983), were identified as sites of high commercial harvest, or had stable gravel substrates due to upstream bedrock exposures.

Sampling was conducted during summer low flows (< 150 cfs). All sample sites measured 100 m in length by 10 m in width, beginning from the shallow (gravel bar) side of the river and 1 m from the shore. At each site, 40 one-m^2 quadrats were chosen from coordinates drawn from a random number table. This sample size was based on results from a previous survey (Cope 1983) and our pilot study that showed 95% of the species present were encountered by sampling 4% of the site area. Each quadrat was sampled by hand excavating the substrate to about 15–20 cm depth or until bedrock or a compacted layer of gravel was reached. Collected mussels were identified and measured before we returned them to the substrate.

Total abundance of mussels (all species, mean number/m^2) was calculated for each site and each sample year. Mean reach-wide abundance of total unionids and individual species was calculated across all eight sites for each sample year. We tested for reach-wide differences in mussel abundance between 1991/1997 and between 1997/2003 using a Wilcoxon rank-sum test for paired samples.

Mean overall shell length was compared between sample years for species that showed significant density increases between 1997/2003 using the Kruskal-Wallis test. We constructed length-frequency histograms using 20-mm length classes for each year on species that comprised > 4% of total relative abundance.

Results

We collected a total of 22 mussel species and 9775 individuals during the course of the study. Mussel abundance varied widely among sites, ranging from 1.88-56.38 mussels/m^2 (Table 1). Number of mussels in individual 1-m^2 quadrats ranged from 0–149. Twelve species found in the study have conservation status in Kansas, and four have a history of recent commercial harvest in the river (Table 2).

Table 1. Total mussel abundance at eight sites in the Verdigris River from 1991, 1997, and 2003.

	Number of mussels/m^2 (1SE)		
Site	1991	1997	2003
A	5.23 (0.50)	3.88 (0.80)	5.10 (1.20)
B	3.05 (0.39)	4.53 (0.56)	8.78 (0.89)
C	7.60 (0.92)	7.17 (0.92)	16.25 (1.6)
D	10.05 (1.13)	24.88 (1.95)	56.38 (3.51)
E	6.05 (1.05)	8.28 (1.00)	10.78 (1.73)
F	4.45 (0.54)	1.88 (0.42)	4.60 (0.82)
G	5.18 (0.46)	5.53 (0.52)	10.05 (1.07)
H	5.63 (0.66)	12.03 (1.04)	17.08 (1.57)

Between 1991/2003, unionid abundance increased markedly at six of eight sites, both within and outside of the mussel refuge (Table 1). Only three species increased significantly between 1991/1997: *Cyprogenia aberti* (Conrad) (western fanshell), *Quadrula metanevra* (Rafinesque) (monkeyface), and *Quadrula nodulata* (Rafinesque) (wartyback) (Table 2). However, 10 species increased significantly between 1997/2003: *C. aberti*, *Fusconaia flava* (Rafinesque) (Wabash pigtoe), *Lasmigona complanata* (Barnes) (white heelsplitter), *Pleurobema sintoxia* (Rafinesque) (round pigtoe), *Ptychobranchus occidentalis* (Conrad) (Ouachita kidneyshell), *Q. metanevra*, *Q. nodulata*, *Quadrula pustulosa* (Lea) (pimpleback), *Tritogonia verrucosa* (Rafinesque) (pistolgrip), and *Truncilla donaciformis* (Lea) (fawnsfoot) (Table 2). Shell length-frequency histograms are shown for these species that make up > 4% of the total relative abundance (Fig. 2). Only one species, *Lampsilis teres* (Rafinesque) (yellow sandshell), decreased during the study. Abundance of six species that constituted > 1% of

Table 2. Mean mussel abundance across eight sites in the Verdigris River from 1991, 1997, and 2003. Estimates with different superscripted numbers were significantly different at $P \leq 0.05$ (Wilcoxon paired-sample test). Kansas status is indicated by superscripted letter following name (Kansas Department of Wildlife and Parks 2000).

	Mean number of mussels/m^2 (% relative abundance)		
Species	1991	1997	2003
Amblema plicata^C	0.86^1 (14.6)	0.54^1 (6.4)	0.63^1 (3.9)
Cyprogenia aberti^E	0.01^1 (0.2)	0.05^2 (0.6)	0.34^3 (2.1)
Ellipsaria lineolata^T	0.02^1 (0.3)	0.04^1 (0.4)	0.05^1 (0.3)
Fusconaia flava^S	0.58^1 (9.7)	1.29^1 (15.2)	3.25^2 (20.2)
Lampsilis cardium	0.15^1 (2.6)	0.10^1 (1.2)	0.18^1 (1.1)
Lampsilis rafinesqueana^E	0.02^1 (0.3)	0.01^1 (0.1)	0.02^1 (0.1)
Lampsilis teres^S	0.04^1 (0.7)	0.00^2 (0.0)	0.01^2 (< 0.1)
Lasmigona complanata	0.02^1 (0.3)	0.02^1 (0.2)	0.07^2 (0.4)
Leptodea fragilis	0.20^1 (3.4)	0.22^1 (2.5)	0.20^1 (1.2)
Megalonaias nervosa^S	0.02^1 (0.4)	0.01^1 (0.1)	0.04^1 (0.3)
Obliquaria reflexa	0.32^1 (5.4)	0.49^1 (5.7)	0.82^1 (5.1)
Pleurobema sintoxia^S	0.13^1 (2.2)	0.23^1 (2.7)	0.68^2 (4.2)
Potamilus purpuratus^C	0.08^1 (1.4)	0.04^1 (0.4)	0.08^1 (0.5)
Ptychobranchus occidentalis^T	0.02^1 (0.4)	0.07^1 (0.8)	0.42^2 (2.6)
Quadrula metanevra^C	1.58^1 (26.6)	3.03^2 (35.6)	4.73^3 (29.4)
Quadrula nodulata^S	0.03^1 (0.6)	0.06^2 (0.7)	0.26^3 (1.6)
Quadrula pustulosa	1.03^1 (17.5)	1.46^1 (17.1)	2.32^2 (14.4)
Quadrula quadrula^C	0.27^1 (4.5)	0.37^1 (4.3)	0.48^1 (3.0)
Strophitus undulatus^S	0.12^1 (2.0)	0.08^1 (0.9)	0.15^1 (0.9)
Tritogonia verrucosa	0.26^1 (4.4)	0.36^1 (4.3)	0.81^2 (5.0)
Truncilla donaciformis^S	0.14^1 (2.4)	0.07^1 (0.9)	0.59^2 (3.7)
Truncilla truncata^S	0.00^1 (0.0)	0.00^1 (0.0)	$< 0.01^1$ (< 0.1)
Total abundance (no/m^2)	5.9^1	8.5^1	16.1^2
Area sampled (m^2)	320	320	320
Total number of mussels	1889	2726	5160

^{C}Commercially harvestable from 1992-2003.
^{E}Listed as endangered in Kansas.
^{T}Listed as threatened in Kansas.
^{S}Listed as "species in need of conservation" in Kansas.

total unionids did not change during the study: *Amblema plicata* (Say) (threeridge), *Lampsilis cardium* Rafinesque (plain pocketbook), *Leptodea fragilis* (Rafinesque) (fragile papershell), *Obliquaria reflexa* Rafinesque (threehorn wartyback), *Quadrula quadrula* (Rafinesque) (mapleleaf), and *Strophitus undulatus* (Say) (creeper) (Table 2).

Overall, community composition remained relatively similar during the study period. *Fusconaia flava*, *O. reflexa*, *Q. metanevra*, and *Q. pustulosa* were among the five most abundant species in all three years. However, *C. aberti*, and *P. occidentalis* increased at a disproportionately high rate; abundance increased 34- and 21-fold, respectively, with the highest rate of increase occurring between 1997/2003 for both species (Table 2).

Of the 10 species that showed a significant increase in abundance between 1997/2003, the mean shell length decreased significantly for *P. sintoxia*, *P. occidentalis*, *T. verrucosa*, and *T. donaciformis* (Table 3).

Discussion

Past surveys that documented both diversity and density of unionid mussels in the Verdigris River are sparse (Cope 1983, Isely 1925) but valuable benchmarks for comparison to our survey results. Our 1991 overall density estimate (5.9 mussels/m^2) was similar to densities at three Verdigris River sites surveyed in 1981 and 1982 (5.7, 4.1, and 3.9 mussels/m^2; Cope 1983). By 2003, the overall density of unionids (16.5 mussels/m^2) were comparable to densities reported in 1912 at two Verdigris River sites in northern Oklahoma (41.2 and 26.6 mussels/m^2; Isely 1925).

The increase in mussel density and the number of juvenile mussels sampled suggests the general habitat condition is improving. Mussel species responded at different times to the improved conditions over the survey period. *Quadrula metanevra* began to respond in the early 1980s, when the 2–4 year age class comprised the greatest percentage of individuals (Cope 1983). Previously, *Q. metanevra* was considered to be uncommon to rare in the Verdigris River (Cope 1979, Murray and Leonard 1962, Schuster 1979). In

Table 3. Mean length of mussels that increased in abundance in the Verdigris River from 1997–2003. Means with different superscripted numbers were significantly different at $P \leq 0.05$.

Species	Mean length (mm) ± 1SE	
	1997	2003
Cyprogenia aberti	67.2^1 (3.47)	58.3^1 (1.76)
Fusconaia flava	68.1^1 (0.85)	64.7^1 (0.74)
Lasmigona complanata	129.0^1 (5.40)	126.6^1 (4.00)
Pleurobema sintoxia	67.9^1 (2.03)	59.5^2 (1.45)
Ptychobranchus occidentalis	87.6^1 (3.30)	56.3^2 (2.64)
Quadrula metanevra	74.3^1 (0.54)	75.3^1 (0.51
Quadrula nodulata	46.9^1 (2.19)	45.5^1 (1.19)
Quadrula pustulosa	51.7^1(0.56)	50.0^1 (0.62)
Tritogonia verrucosa	108.4^1 (2.32)	95.0^2 (2.43)
Truncilla donaciformis	20.1^1 (1.46)	24.7^2 (0.45)

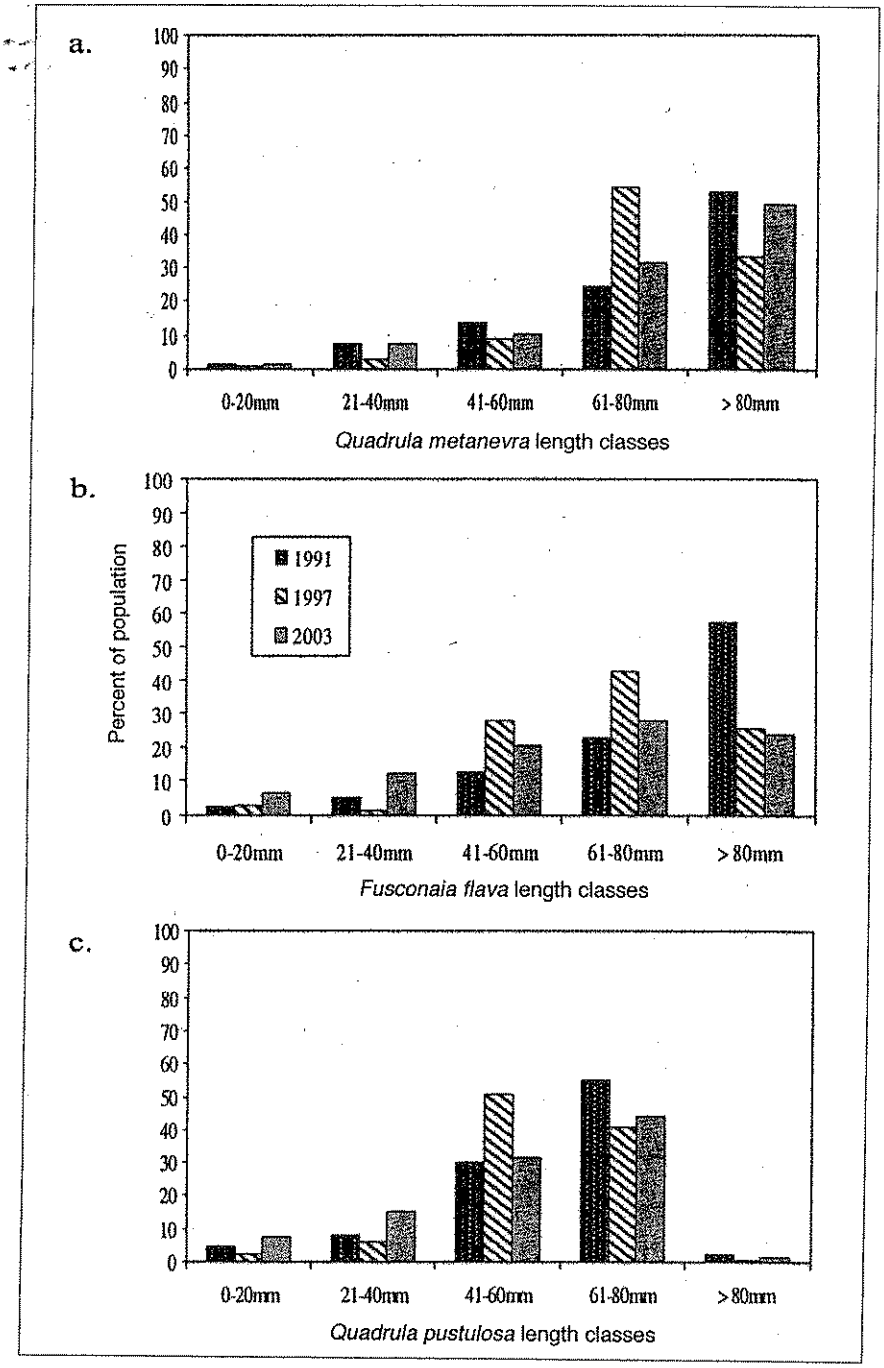
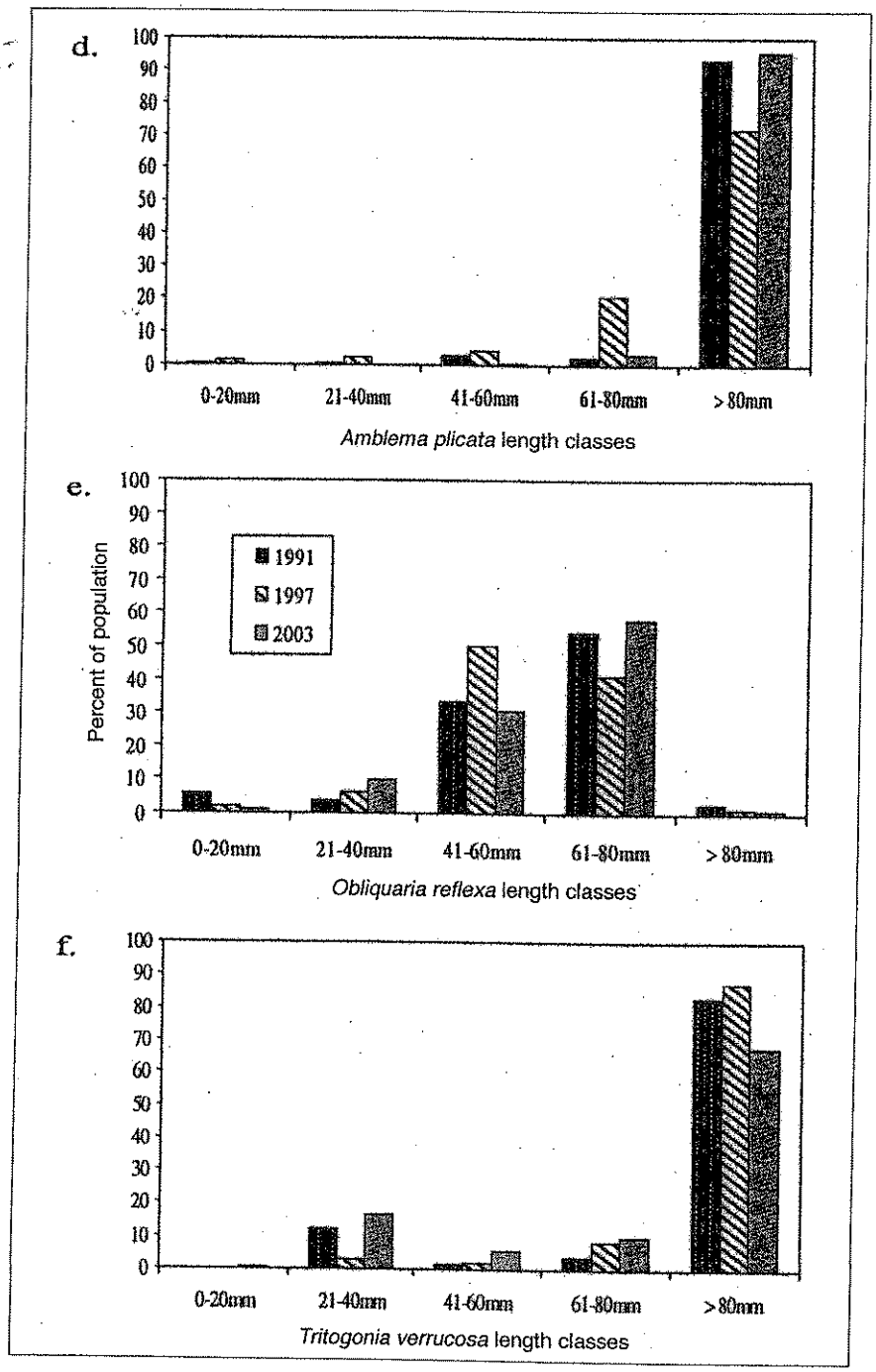


Figure 2a–f. Length-frequency histograms comparing the six most common mussels (from most to least common) found in the Verdigris River, KS, in 1991, 1997, and 2003. *Quadrula metanevra* increased significantly in abundance between 1991/1997 and



1997/2003. *Fusconaia flava*, *Quadrula pustulosa*, and *Tritogonia verrucosa* increased significantly in abundance between 1997/2003. *Obliquaria reflexa* and *Amblema plicata* sample data showed no significant change in abundance.

our study, *Q. metanevra* continued to increase from 1991 to 2003 (Fig. 2a). *Fusconaia flava* responded later than *Q. metanevra*, but showed a strong increase in most shell-length classes by 2003 (Fig. 2b). Three species that appear to have more recently responded to improved conditions are *P. occidentalis, P. sintoxia*, and *T. verrucosa*, as exhibited by their significantly smaller shell sizes in 2003 than 1997 (Table 3). These three species may have achieved adequate population densities for more optimal reproduction and recruitment. This would indicate that the improvement of habitat conditions for mussels in the Verdigris River is continuing.

We have no fish-density trends to show that mussels may be responding to an increased abundance of their host fishes. However, fish-host abundance does not appear to be a limiting factor for nearly half of the mussel species in the Verdigris River. Mussel species showing significant increases in density use hosts representing five fish families. Those that share a common fish host were inconsistent in their density response. For instance, *Aplodinotus grunniens* Rafinesque (freshwater drum) is the known host for *T. donaciformis*, *Ellipsaria lineolata* (Rafinesque) (butterfly), and *Potamilus purpuratus* (Lamarck) (bleufer) (Oesch 1984), and is a common fish in the Verdigris River, but only *T. donaciformis* showed a significant increase in density between 1997/2003.

Formerly, *A. plicata* was the most common species in this reach of the Verdigris River (Cope 1983, Schuster 1979). Although *A. plicata* did not show significant declines during our survey period, it comprised only 3.9% of the mussel abundance by 2003 (Table 2). It is possible that this species was greatly reduced by commercial harvest occurring as late as 1995 and 1996 (Mosher 1996, 1997). This population may have been reduced to such low numbers that it has as yet been unable to rebound. In 2003, a 10-year moratorium was implemented on commercial harvest of mussels from Kansas waters, and additional surveys during this time span will determine future regulation of commercial shell harvest.

Several factors could be responsible for the apparently favorable habitat conditions for mussels in the Verdigris River. Minimum-flow releases from the two upstream reservoirs to satisfy municipal needs downstream of the sampling sites may have alleviated summer no-flow conditions that could have otherwise occurred over the last 20 years, but no long-term droughts have occurred on the Verdigris River since 1955 (Miller and Obermeyer 1997). Conversely, the occasional dry March–April, such as was evident in 2002, may enhance reproductive success by precluding extended high-flow reservoir discharges. The resulting lower flow rates improve water clarity and concentrate fish, thus increasing the probability of glochidia and fish host making contact. There were no policy changes in reservoir management (T. Lyons, US Army Corps of Engineers, Fall River, KS, pers. comm., 2004) that altered water releases in a way that might enhance mussel populations. By the late 1970s, an oil refinery was closed at Neodesha, KS, 8 km upstream from site A, and wastewater from local industry was incorporated into the city's wastewater

treatment system rather then being treated on site. Although no formal studies were conducted to monitor the effects of these factors on downstream water quality (R. Angelo, Kansas Department of Health and Environment, Topeka, KS, pers. comm., 2004), either of these changes could have removed a limiting factor affecting mussel populations.

Finally, total suspended solids have decreased in Kansas streams statewide in the last two decades (Angelo et al. 2004). This reduction in turbidity may have enhanced recruitment of mussel species that use sight lures (e.g., *P. occidentalis, C. aberti*) to attract darters (family Percidae) as host fish (Barnhart and Roberts 1997).

If nonpoint-source pollution reduction is largely responsible for improved conditions in the Verdigris River, then we should see similar improvements in nearby river systems given statewide changes in agricultural land-use practices. On the other hand, if abatement of point-source pollution is responsible for improved conditions for mussels, the increase will probably be noted only in the Verdigris River below the former input sites. Ongoing mussel survey work currently funded by a federally cost-shared State Wildlife Grant on the upper Verdigris, Fall, Neosho, Spring, Marais des Cygnes, Walnut, and Marmaton Rivers will help answer this question. A follow-up paper comparing commercially harvested mussel populations between refuge and nonrefuge sites is being prepared.

Acknowledgments

We would first like to acknowledge the Kansas Department of Wildlife and Parks for allowing field personnel to spend time monitoring mussel populations. We would also like to thank the cooperation we received from landowners, especially the Small family, who allowed us access to the river for research and aquatic education. We would like to thank the following for advice or for the physical labor of hand-digging the substrate for mussels: Bob Andrews, Bob Angelo, Chris Barnhart, Aaron Baugh, Doug Blex, Katelyn Brunson, Ken Brunson, Bill Busby, Colin Busby, Charlie Cope, Philip Dickerson, Chris Duermyer, Tim Eaton, Nathan Eckert, Brian Foreman, Lloyd Fox, Luke Freeman, Hank Guarisco, Jason Goeckler, Bob Hartmann, Jerry Horak, Joe Hutto, Dennis Knuth, Tim Leakey, Chris Mammoliti, Kirsten Miller, Lina Miller, Jim Minnerath, Tom Mosher, Ben Mulhern, Dan Mulhern, Keith Rather, Daren Riedle, Marvin Schwilling, Rick Tush, and Karen Yates. Finally, we would like to thank guest editor Robert Butler of the US Fish and Wildlife Service and two anonymous reviewers whose diligence greatly improved this manuscript. Partial funding for this project was received through a State Wildlife Grant from the US Fish and Wildlife Service.

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