FINAL REPORT

Arkansia wheeleri monitoring in the Kiamichi and Little Rivers

Submitted to:

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PROJECT TITLE: *Arkansia wheeleri* Monitoring in the Kiamichi and Little Rivers.

DATES: July 1, 2003 – September 30, 2005

A. ABSTRACT

During the summers of 2003-2005 we sampled mussels at 10 monitoring sites in the Kiamichi River, identified and sampled previously unmapped sites in the Kiamichi River, and sampled five sites in the Little River. Mussel species richness and mussel densities for the 10 Kiamichi River monitoring sites decreased from 1991 to 2003-2005. Mean mussel density for the entire river decreased 65% from 1991 to 2003-2005. We also observed changes in mussel community composition for the river as a whole and on a site-by-site basis. In our 2003-2005 surveys, we did not find *Arkansia wheeleri* at any of its previously recorded (1991) locations nor did we find any previously marked individuals. In 2003-2005 we identified 26 previously unmapped mussel beds in the Kiamichi River between Whitesboro and Moyers; only one of these new mussel beds contained living *A. wheeleri*. *Arkansia wheeleri*, although rare, was historically widespread in the Kiamichi River. It is evident from our field collections that this species is undergoing a severe decline along with the entire mussel population. We also found three fresh dead *Leptodea leptodon* shells in the Kiamichi River in 2003-2005.

In the summer of 2005, we surveyed five mussel beds in the Little River. We found two individuals of *A. wheeleri* in the Little River approximately 1 km above the confluence of the Mountain Fork River, on the Little River National Wildlife Refuge.

In addition to *A. wheeleri*, we found individuals that we believe are *Quadrula fragosa*. Tissue samples from these specimens have been sent to Dr. Jeanne Serb at Iowa State University for genetic confirmation of species identity. Historically, *A. wheeleri* also has been found in the Little River, but at lower abundance than in the Kiamichi River. This still appears to be the case with live individuals found only at a single site in the Little River.

B. OBJECTIVES

To determine the abundance, density and population size structure of *Arkansia wheeleri* and associated mussel species at ten established monitoring sites in the Kiamichi River, and to search for other potential mussel beds which support *A. wheeleri*.

C. NEED

Arkansia (syn. *Arcidens*) *wheeleri*, the Ouachita Rock Pocketbook mussel, is a federally endangered species whose only known remaining viable population occurs within a 123 km stretch of the Kiamichi River in Pushmataha County, Oklahoma. In 1990, Dr. Caryn Vaughn and her students conducted qualitative and semi-qualitative (timed searches) surveys at over 30 sites in this river (Vaughn et al. 1993). In 1991 and 1992, quantitative (excavated quadrats) and semi-quantitative sampling was completed. In 1992, 10 proposed long-term population monitoring sites for *Arkansia wheeleri* were established (Figure 1 and Table 1). These sites were chosen to be as evenly distributed as possible along the Kiamichi River above Hugo Reservoir while still being reasonably accessible, and were located such that four sites were above and six sites were below the inflow of Jackfork Creek, which was impounded in the 1980s to construct Sardis Reservoir. All *A. wheeleri* that were found at these sites were measured using digital calipers (height, width, length), and individually marked using numbered, laminated plastic fish tags. All specimens were returned to the same location from which they were captured. Additionally, relative abundance and densities of associated mussel populations were recorded at these sites. For all mussels of all species, size distributions (which correlate to age) were calculated.

Along with *A. wheeleri*, the Kiamichi contains other rare mussel species including the recently listed Scaleshell (*Leptodea leptodon*). Observations by researchers in the early 1990's suggest that recruitment of mussels is decreasing in that portion of the Kiamichi River below the inflow from Sardis Reservoir (Vaughn and Pyron 1995). Monitoring these trends in a timely manner could prevent the need for listing of other mussel species in the Kiamichi River system.

D. APPROACH

Between June 2003 and August 2005, we surveyed the Kiamichi and Little rivers for all mussel species including *Arkansia wheeleri* and *Leptodea leptodon*. We re-sampled ten known mussel beds in the Kiamichi River that were previously sampled by Vaughn in the early 1990's. We also canoed the river between Whitesboro and Moyers to identify new mussel beds as potential monitoring sites and for the presence of *A. wheeleri* (Figure 1). "New" mussel beds refer to beds unmapped in Vaughn's 1990-1992 survey, not necessarily to beds that may have formed since the last survey. We located new beds by conducting visual searches in shallow water and looking for dead shells on the shore. We also surveyed five known mussel beds in the Little River to determine if *A. wheeleri* is still present in this river.

Mussel Sampling

At each of the ten Kiamichi River monitoring sites and the five Little River sites we quantitatively (quadrats) and semi-quantitatively (timed searches) sampled mussels. We excavated fifteen $0.25m^2$ quadrats and conducted timed searches at each site. Timed searches consisted of at least 2 hours of searching for mussels by hand, snorkel, or SCUBA in deeper areas (>0.75m). All mussels were identified to species and their total lengths measured before returning them to the mussel bed. In beds that were known to have contained *A. wheeleri* in past surveys, we spent additional time searching habitat appropriate for this species (Vaughn and Pyron 1995) and looking for individuals of *A. wheeleri* that were marked in the early 1990s.

For most of the newly identified sites, we performed a short timed search (usually 30 minutes) to obtain a rough estimate of mussel richness. We also searched each new site for potential *A. wheeleri* habitat so that we might more thoroughly search these sites in the future (Table 1).

Habitat Characterization

At each of the fifteen known mussel beds, we recorded notes on riparian condition, surrounding land use, and existing and potential threats to *A. wheeleri* and other mussel species.

Data Analysis

We used analysis of variance (ANOVA) to determine differences in overall species richness and mussel density between 1991 and 2003-2005. To determine if there were differences in mussel density among years within sites, we used a nested ANOVA with year nested within site. We graphically analyzed changes in relative abundance and size structure from 1991 to the present.

E. RESULTS AND DISCUSSION

(1) Kiamichi River

Between the summer of 2003 and the summer of 2005, we identified 26 previously unmapped mussel beds in the Kiamichi River between Whitesboro and Moyers (Figure 1). Only one of these new mussel beds contained living *A. wheeleri* (see below); however, we did locate a dead *A. wheeleri* shell at another of the new mussel beds. We found a total of 21 species of living mussels in the Kiamichi River (including both monitoring sites and newly discovered mussel beds) (Table 2).

Unionids: Comparison of 1990's to 2000's

We found a marginally significant decrease in combined species richness across all ten sites from 1991 to the present ($F=3.96$, $p=0.062$; Figure 2). Each of the 10 sites decreased in species richness with the exception of site 10 (Figure 3), with the largest decreases occurring at site 9 (loss of 5 species) and site 6 (loss of 4 species). We also observed changes in community composition as indicated by relative abundance of both abundant and rare species in the entire river (Figure 4) and at each site (Figures 5-14).

Mean mussel density for the entire river was found to significantly decrease by almost 65% from 1991 ($F=25.579$, $p<0.001$) with mean densities in 1991 at 23.2 (± 6.6) and in 2003-2005 approximately 7.9 (± 6.9). Density also decreased at each site from 1991 to the present ($F=9.506$, $p<0.001$; Figure 15). This can be seen by the dramatic decreases in even the three most abundant species in the Kiamichi (*Actinonaias ligamentina, Amblema plicata,* and *Quadrula pustulosa*). *Actinonaias ligamentina* decreased in density at all sites except site 7, and was not found at all at site 1, where it was historically abundant (Figure 16). *Amblema plicata* density also decreased at all of the sites except for site 10 (Figure 17) and *Q. pustulosa* densities decreased at all 10 sites (Figure 18).

There appeared to be no major shifts in mussel size distribution over the last decade as evidenced by these same three species. The frequency of mussels found in each size class from 2003-2005 closely match the frequency distribution of size classes in 1991 (Figures 19-21). The apparent lack of juvenile mussels in these distributions is likely an artifact of our sampling methods which are not designed to target the collection of small individuals (Vaughn et al. 1997).

Arkansia wheeleri***: Comparison of 1990's to 2000's***

Historically, *Arkansia wheeleri* was found at six of the ten monitoring sites in the Kiamichi River (Figure 22). Vaughn also found *A. wheeleri* in 1993 in a mussel bed approximately 5 km upstream of the Rattan boat launch; however, we were unable to re-sample this bed for this study. In our 2003-2005 surveys, we did not find *A. wheeleri* at any of its previously recorded locations nor did we find any previously marked individuals. We did find three individuals at one of our new mussel bed locations at the K-River Campground in Moyers, Oklahoma (Figure 23). The individuals found between 2003 and 2005 are within the size distribution of those found in the past (Figure 24), however, we did not find the range of sizes historically seen in the Kiamichi River. We also found a relict *A. wheeleri* shell at another new mussel bed located between sites 5 and 6 (Figure 23).

In addition to *A. wheeleri*, we also found 3 fresh dead *Leptodea leptodon* shells over the period of our study. One of these shells was found at site 2 near Albion and the other two shells at the K-River Campground location where the *A. wheeleri* population was discovered. One of the *L. leptodon* shells from the campground site was a juvenile.

Habitat Characterization

At several of the mussel beds in the Kiamichi we found what we feel are significant threats to the health of the freshwater mussel community. Site 4 (Clayton County Park) has been impacted by logging and construction in the riparian region along with people "off-roading" in the river and driving over parts of the mussel bed. The site 5 mussel bed has been silted in presumably due to gravel mining just upstream of this bed. The campground site containing *A. wheeleri* and potentially *L. leptodon* is severely impacted by human disturbance. This mussel bed has been bulldozed to create a fishing hole for campers at the K-River campground and to build a low-water crossing at the top of the mussel bed. The riparian forest has been completely stripped and replaced with campsites and the mussel bed has been silted in during the past 2 years that we have been surveying at this site.

Other beds in the Kiamichi River appear to be susceptible to low water conditions, particularly during drought years. Sites 3 and 8 (and Site 7 to a lesser extent) were devastated during the 2005 drought during which time mussel beds were completely exposed and thousands of mussels were found to be dead. These conditions do not appear to be improving as water levels in the Kiamichi River are still very low (USGS 2005).

(2) Little River

Unionid Distribution and Abundance

In the summer of 2005, we surveyed five mussel beds in the Little River, some of which had not historically been surveyed for *A. wheeleri* (Figure 25) (Vaughn et al. 1995). Among these five sites, we found a total species richness of 24 mussels (Table 3) with an average of 18.4 (± 1.5) species per site (Figure 26). Relative abundance of individual species varied among sites

(Figures 27-31). Overall, four species were dominant: *A. ligamentina*, *A. plicata*, *Q. pustulosa*, and *Plectomerus dombeyanus* (Figure 32).

Mean mussel density was 47.3 mussels/m^2 (± 30.5), with densities ranging from 15.5 at site 5 to 97.9 at site 4 (Figure 33). Individual species varied in their density (Figures 34-37), with *Q. pustulosa* most dense among the five sites (13.8 ± 6.0), followed by *A. ligamentina* (12.0 ± 20.6), *A. plicata* (4.2 ± 2.9), and *P. dombeyanus* (3.4 ± 2.0). Each of these four species encompassed a range of size classes (Figures 38-41). Once again, our sampling methods were not adequate for detecting small individuals which might explain the apparent lack of mussels smaller than 30mm.

Arkansia wheeleri *Distribution and Abundance*

We found two individuals of *A. wheeleri* in the Little River at site 4, less than 1 km above the confluence of the Mountain Fork River (Figure 25) on the Little River National Wildlife Refuge. Both individuals were large (92 and 121 mm) and both were stranded out of water; they were replaced in a deeper portion of the mussel bed that was still under water. The water levels over this mussel bed were extremely low at the time we were sampling (August 8, 2005), and many other mussels were stranded and/or dead.

In addition to *A. wheeleri*, we found individuals that we believe are *Quadrula fragosa* at sites 1, 2, 3, and 4 in the Little River. As Vaughn has a permit to collect *Q. fragosa*, we collected mantle clippings (Berg et al. 1995) from several individuals as well as a voucher specimen to be sent away for genetic analysis. These samples recently were sent to Dr. Jeanne Serb at Iowa State University for genetic confirmation on species identity.

Habitat Characterization

We believe that all five of the mussel beds we surveyed in the Little River are at risk. Site 1 is a fishing location and receives heavy human traffic. We found this site to be littered with trash; low water does not appear to be a threat here. Sites 2, 3, and 4, however, were all impacted by low water conditions. At site 4, hundreds of mussels (including *A. wheeleri*) were found stranded out of the water and many of these mussels were dead or near dead, likely as a result of heat and desiccation. Site 3 also experienced low water. Although fewer mussels were stranded completely out of the water, we believe an algal bloom caused a massive die-off in this bed in both rare (ex. *Quadrula cylindrica*) and abundant (ex. *A. ligamentina*) species. Low water and associated algal blooms were also problematic at site 2, but to a lesser extent as mussel densities are significantly lower at site 2 than site 3. We also feel that the site 5 mussel bed is at risk particularly from human disturbance; this site is, again, a popular fishing and swimming location. Additionally, several locals apparently witnessed mussel harvesters removing huge numbers of mussels from this bed within the last 2 years.

CONCLUSIONS AND RECOMMENDATIONS

Arkansia wheeleri, although rare, was historically widespread in the Kiamichi River (Figure 20). It is evident from our field collections that this species is undergoing a severe decline along with the entire mussel population (Figures 3 and 15). Since 1991, there has been a loss of both species richness and mussel density along with a change in community composition as indicated by a change in relative abundance of mussel species (Figure 4-14). We found no difference in the size class distribution of mussels in the Kiamichi River between the two years (Figures 19-21), but we did find significant decreases in mussel density (Figure 15). This indicates that mussels in general are declining, and the effects are not limited to one or a few size classes.

The decline of *A. wheeleri* is probably due to the same factors responsible for the decline of freshwater mussels in general in this river. These factors include siltation (Ellis 1936, Simmons and Reed 1973) and physical disturbance due to human activity (ex. bull-dozing), along with low water flow and volume during hot summer months in recent drought years. Low water conditions can lead to mussel mortality through stranding, where mussels can be killed by desiccation, thermal shock, or a combination of two, and indirectly by oxygen deprivation as a result of algal blooms (Spooner et al. 2005). In recent years, water levels in both the Kiamichi and Little rivers have been quite low from mid-summer on through fall. These low flow, low water volume conditions lead to the formation of isolated pools separated by stretches of river that are completely dry. In the summer when air temperatures are high, the water temperatures in these pools can become quite high, exceeding 40ºC. Such high water temperatures can directly cause mussel mortality or impair mussel physiological condition (Spooner et al. 2005). The lack of flow in these pools combined with warm temperatures leads to high algal growth (algal blooms). The algae deplete the oxygen, leading to low oxygen levels and mussel mortality. In addition, when mussels die, their decaying flesh contributes additional nutrients to the water in the isolated pools, causing further algal growth, further de-oxygenation and further mussel mortality (Galbraith and Spooner, unpublished data; Spooner et al. 2005). This was witnessed in both the Kiamichi and the Little Rivers during the summer of 2005 (Galbraith and Spooner, unpublished data).

Historically, *A. wheeleri* also has been found in the Little River, but at lower abundance than in the Kiamichi River. This still appears to be the case with live individuals found only at a single site in the Little River. How the mussel fauna has changed in the Little River is beyond the scope of this project. It appears to have higher species richness and higher mussel densities than the Kiamichi River; however, we witnessed large mussel die-offs in this which we believed may be due to low water conditions in the summer months leading to high water temperatures and algal blooms in isolated pools

Freshwater mussels are known to provide important services to the aquatic community (Vaughn and Hakenkamp 2001, Vaughn et al. 2004, Spooner and Vaughn 2006). Southeastern Oklahoma provides habitat to over 41 mussel species of North America's 300 species. It has some of the last remaining populations of *A. wheeleri*, *L. leptodon*, *Q. cylindrica* and possibly *Q. fragosa*. Therefore, we recommend that measures be taken to protect the health of mussel beds in both the Kiamichi and the Little Rivers. This includes taking measures to protect riparian habitat around and upstream of mussel beds, along with regulating human activity that could be detrimental to the health of the beds. We also suggest that measures be taken to maintain water levels over mussel beds during periods of low flow and high temperature when mussel beds are most vulnerable. Finally, we recommend regular monitoring of the 15 sites included in this study as well as thorough surveys of the new mussel beds discovered in the Kiamichi River.

F. SIGNIFICANT DEVIATIONS

We received a supplement to the original project to survey five sites in the Little River, in addition to the work described in the objectives for the Kiamichi River. Thus, results for both the Little and Kiamichi Rivers are presented in this report.

Table 1. Description of sampling locations.

River	SITE #	DATE SAMPLED	*A. wheeleri* present 1990-1992	*A. wheeleri* found 2003-2005	OTHER INFORMATION
Kiamichi	**1**	8-Jul-03	yes	no	
Kiamichi	**2**	22-Jul-03	yes	no	Fresh dead scaleshell (*Leptodea leptodon*) found at this site in July 2005
Kiamichi	**3**	23-Jul-03	yes	no	Site experiencing major disturbance from low water
Kiamichi	**4**	21-Jul-03	no	no	Site experiencing major disturbance from construction activities
Kiamichi	**5**	14-Aug-04	yes	no	Site experiencing major disturbance from gravel mining activities
Kiamichi	**6**	7-Aug-03	yes	no	
Kiamichi	**7**	5-Aug-03	yes	no	Site currently experiencing low water
Kiamichi	**8**	6-Aug-03	no	no	Site currently experiencing low water
Kiamichi	**9**	21-Aug-04	no	no	
Kiamichi	**10**	15-Aug-04	no	no	Fresh dead scaleshell (*Leptodea leptodon)* found at this site in August 2004
Kiamichi		7-Jul-03	unknown	yes	New monitoring site established in 2000 Fresh dead scaleshell (*Leptodea leptodon)* found here in July 2000 and July 2005 Site experiencing major disturbance from land-clearing and construction activities
Kiamichi			yes*	not resampled	New monitoring site established in 1993 **A. wheeleri* found at this site in 1993
Kiamichi		9-Jul-03	unknown	no	New site located in river stretch between sites 1 and 2
Kiamichi		9-Jul-03	unknown	no	New site located in river stretch between sites 1 and 2
Kiamichi		9-Jul-03	unknown	no	New site located in river stretch between sites 1 and 2

Table 1 (continued). Description of sampling locations.

River	SITE #	DATE SAMPLED	*A. wheeleri* present 1990-1992	*A. wheeleri* found 2003-2005	OTHER INFORMATION
Kiamichi		9-Jul-03	unknown	no	New site located in river stretch between sites 1 and 2
Kiamichi		9-Jul-03	unknown	no	New site located in river stretch between sites 1 and 2
Kiamichi		22-Jul-03	unknown	no	New site located in river stretch between sites 1 and 2
Kiamichi		19-Aug-03	unknown	no	New site located in river stretch upstream of site 3 to site 4
Kiamichi		19-Aug-03	unknown	no	New site located in river stretch upstream of site 3 to site 4
Kiamichi		19-Aug-03	unknown	no	New site located in river stretch upstream of site 3 to site 4
Kiamichi		17-Jul-05	unknown		New site located in river stretch between sites 5 and 6
Kiamichi		17-Jul-05	unknown		New site located in river stretch between sites 5 and 6 *A. wheeleri* shell found on shore of this site
Kiamichi		17-Jul-05	unknown		New site located in river stretch between sites 5 and 6
Kiamichi		17-Jul-05	unknown		New site located in river stretch between sites 5 and 6
Kiamichi		17-Jul-05	unknown		New site located in river stretch between sites 5 and 6
Kiamichi		17-Jul-05	unknown		New site located in river stretch between sites 5 and 6
Kiamichi		17-Jul-05	unknown		New site located in river stretch between sites 5 and 6
Kiamichi		17-Jul-05	unknown		New site located in river stretch between sites 5 and 6
Kiamichi		18-Jul-05	unknown		New site located in river stretch downstream of site 8 to new campground site
Kiamichi		18-Jul-05	unknown		New site located in river stretch downstream of site 8 to new campground site
Kiamichi		18-Jul-05	unknown		New site located in river stretch downstream of site 8 to new campground site

Table 1 (continued). Description of sampling locations.

River	SITE #	DATE SAMPLED	*A. wheeleri* present 1990-1992	*A. wheeleri* found 2003-2005	OTHER INFORMATION
Kiamichi		18-Jul-05	unknown		New site located in river stretch downstream of site 8 to new campground site
Kiamichi		18-Jul-05	unknown		New site located in river stretch downstream of site 8 to new campground site
Kiamichi		18-Jul-05	unknown		New site located in river stretch downstream of site 8 to new campground site
Kiamichi		18-Jul-05	unknown		New site located in river stretch downstream of site 8 to new campground site
Kiamichi		18-Jul-05	unknown		New site located in river stretch downstream of site 8 to new campground site
Little	**1**		unknown		Site experiencing human disturbance *Q. fragosa* (?) found here
Little	**2**		unknown		Site experiencing low water and algal blooms *Q. fragosa* (?) found here
Little	**3**		yes*		Site experiencing low water and algal blooms **A. wheeleri* found here in 1994 *Q. fragosa* (?) found here
Little	**4**		yes*		Site experiencing low water **A. wheeleri* found here in 1994 *Q. fragosa* (?) found here
Little	**5**		unknown		Site potentially influenced by mussel harvesting

Table 2. Species found alive in the Kiamichi River between 2003-2005.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	New Sites
Actinonaias ligamentina	X	X	X	X	X	X	X	X	X	X	
Amblema plicata	X	X	X	X	X	X	X	X	X	X	
Arkansia wheeleri											X
Ellipsaria lineolata			X	X		X	X			X	
Fusconaia flava	X	X			X	X	X	X	X	X	
Lampsilis cardium	X	X	X	X	X	X	X	X	X	X	
Lampsilis siliquoidea	X	X	X					X			
Lampsilis teres	X					X		X			
Leptodea fragilis			X		X	X	X	X		X	
Megalonaias nervosa						X	X				
Obliquaria reflexa			X	X	X	X	X	X	X	X	
Obovaria jacksoniana						X					
Pleurobema sintoxia											X
Potamilus purpuratus	X	X	X	X	X	X	X	X		X	
Ptychobranchus occidentalis	X	X	X	X			X	X			
Quadrula pustulosa	X	X	X	X	X	X	X	X	X	X	
Quadrula quadrula		X				X				X	
Strophitus undulatus											X
Tritogonia verrucosa	X	X	X				X	X	X	X	
Truncilla donaciformis			X				X				
Truncilla truncata		X	X	X	X	X	X	X		X	

Table 3. Species found alive in the Little River in 2005.

	Site 1	Site 2	Site 3	Site 4	Site 5
Actinonaias ligamentina	X	X	X	X	X
Amblema plicata	X	X	X	X	X
Arkansia wheeleri				X	
Ellipsaria lineolata	X	X	X		X
Fusconaia flava	X	X	X	X	X
Lampsilis cardium	X	X	X	X	X
Lampsilis siliquoidea	X				
Lampsilis teres		X	X	X	
Lasmigona costata		X	X	X	X
Leptodea fragilis	X		X	X	
Megalonaias nervosa	X	X	X	X	X
Obliquaria reflexa	X	X	X	X	X
Plectomerus dombeyanus	X	X	X	X	X
Pleurobema sintoxia	X	X			
Potamilus purpuratus	X		X	X	X
Ptychobranchus occidentalis		X	X		
Quadrula cylindrica	X	X	X		X
Quadrula fragosa (?)	X	X	X	X	
Quadrula pustulosa	X	X	X	X	X
Quadrula quadrula	X	X	X	X	X
Strophitus undulatus			X		X
Tritogonia verrucosa	X	X	X	X	X
Truncilla donaciformis			X	X	X
Truncilla truncata	X	X	X	X	X

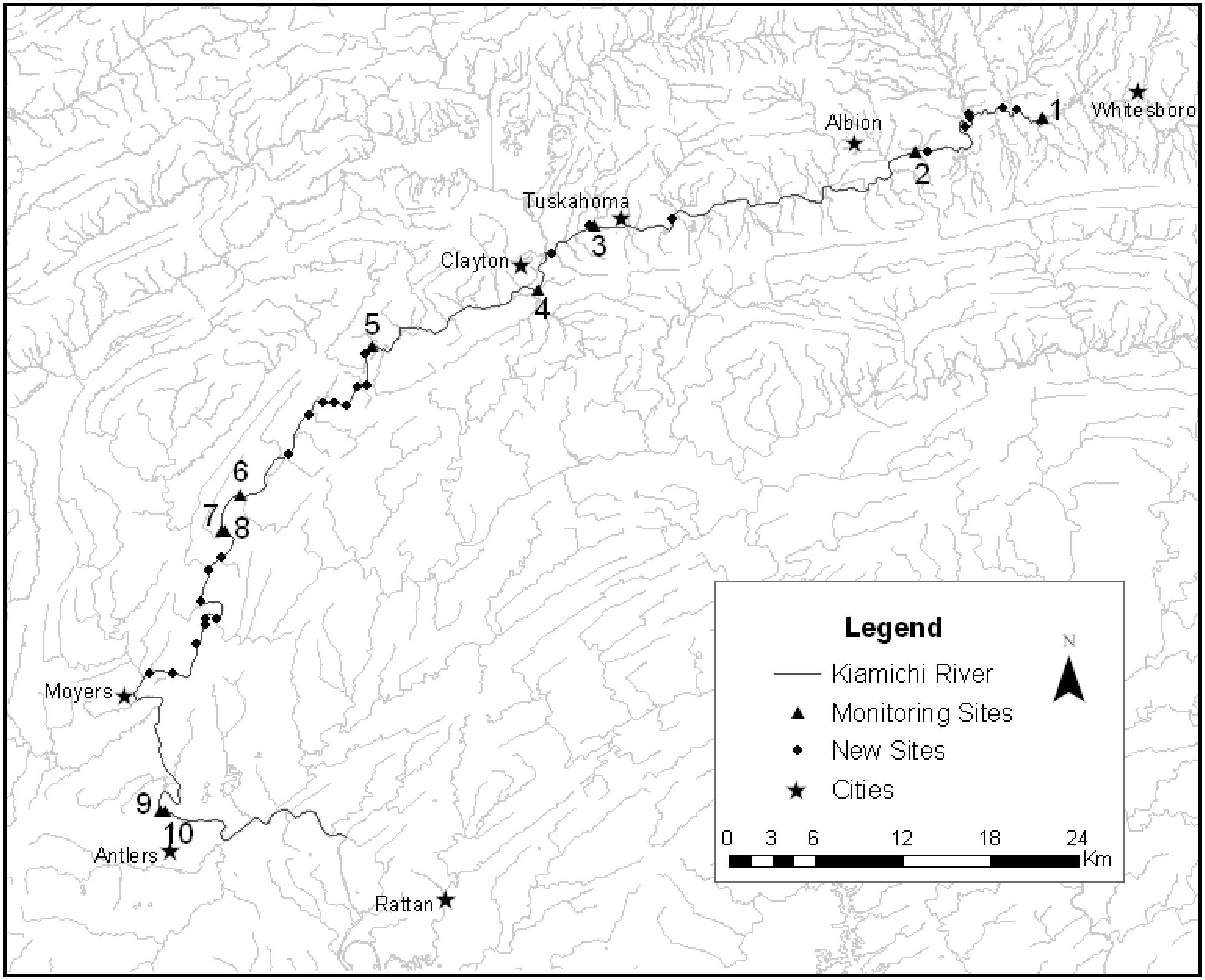


Figure 1. Monitoring sites and previously unrecorded mussel beds in the Kiamichi River.

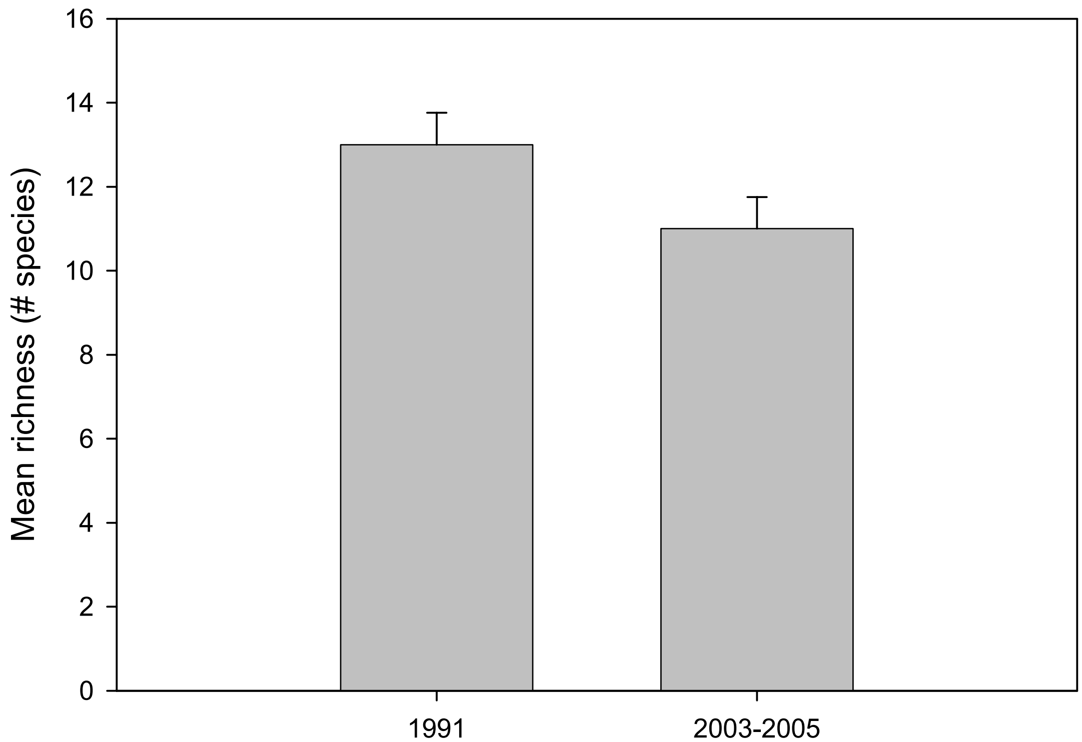


Figure 2. Comparison of mean mussel species richness in the Kiamichi River from 1991 to 2003-2005.

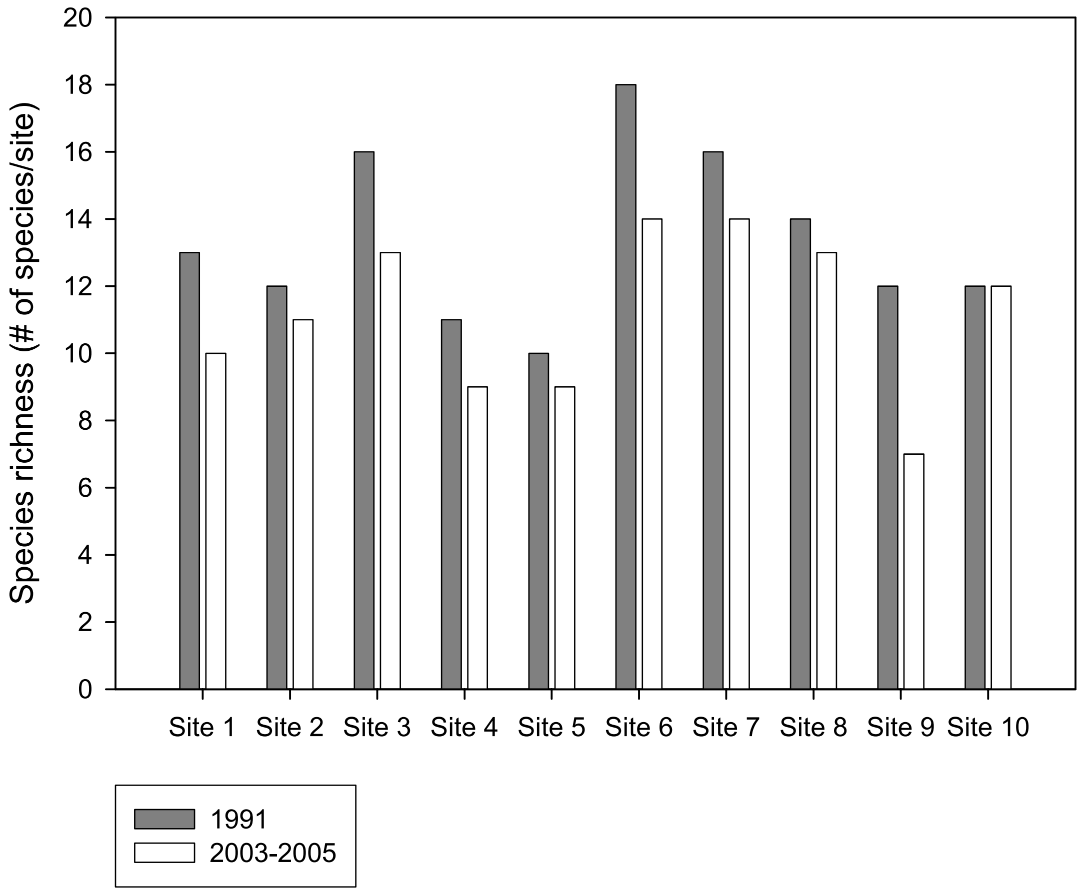
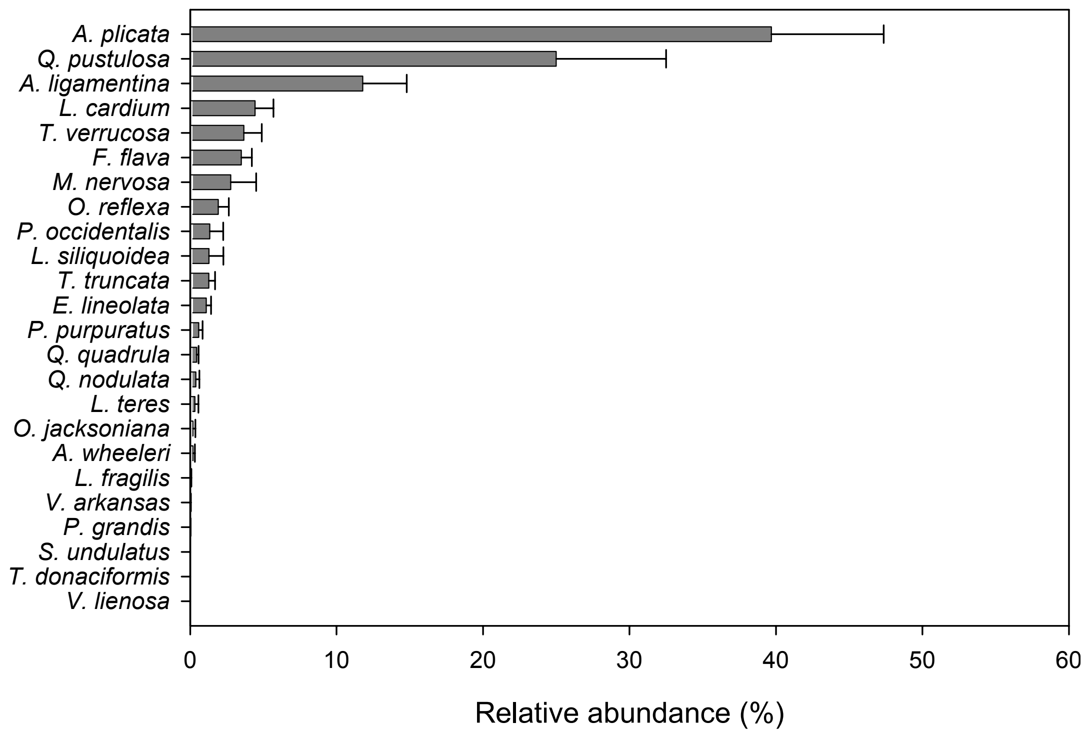


Figure 3. Site-specific comparison of species richness in the Kiamichi River between 1991 and 2003-2005.



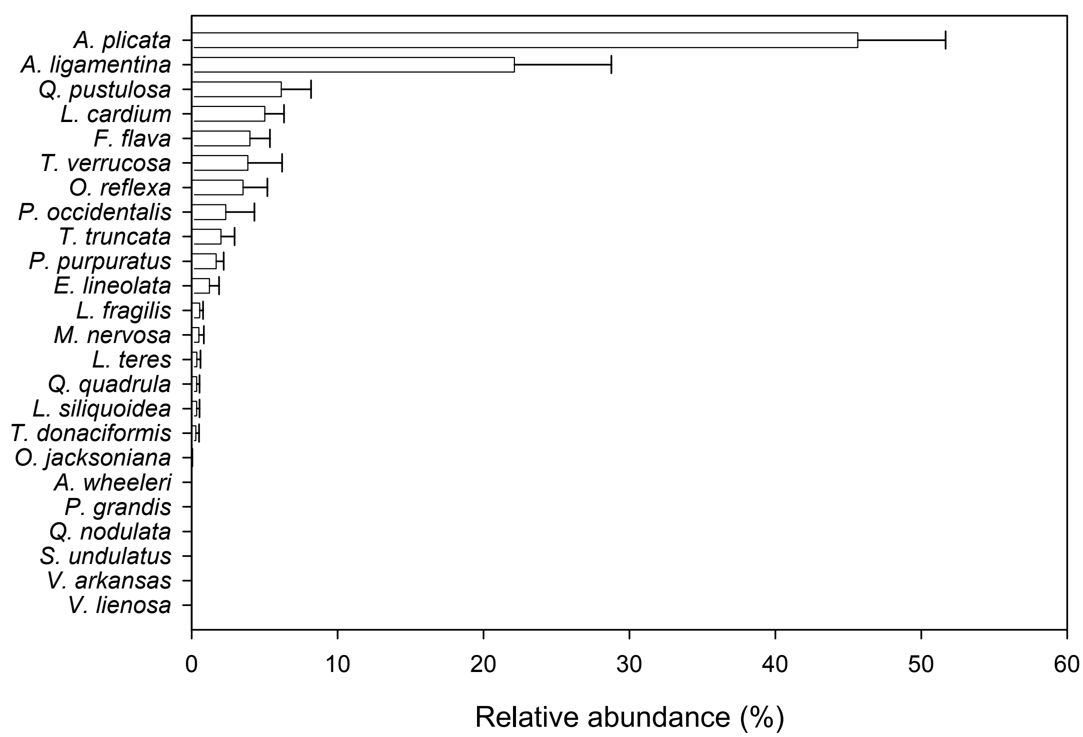


Figure 4. Mean relative abundance and standard error for the Kiamichi River in 1991 (top) and 2003-2005 (bottom).

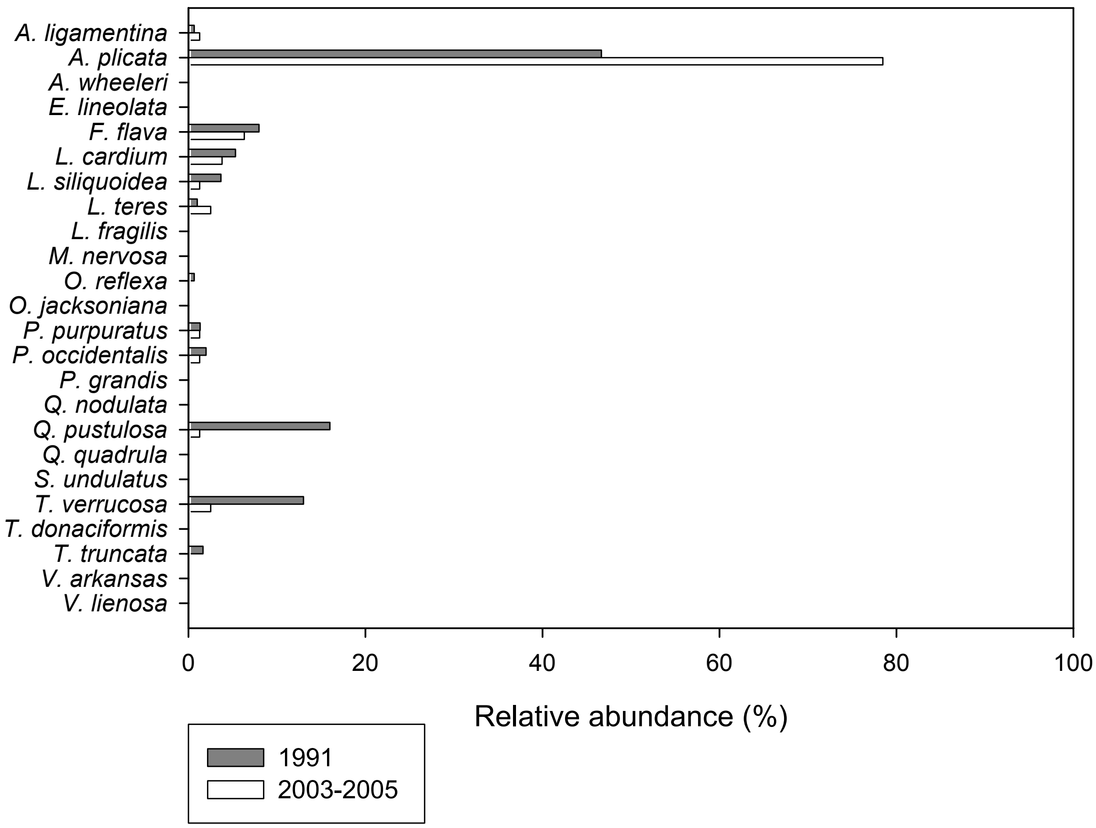


Figure 5. Relative abundance for monitoring site 1 in the Kiamichi River.

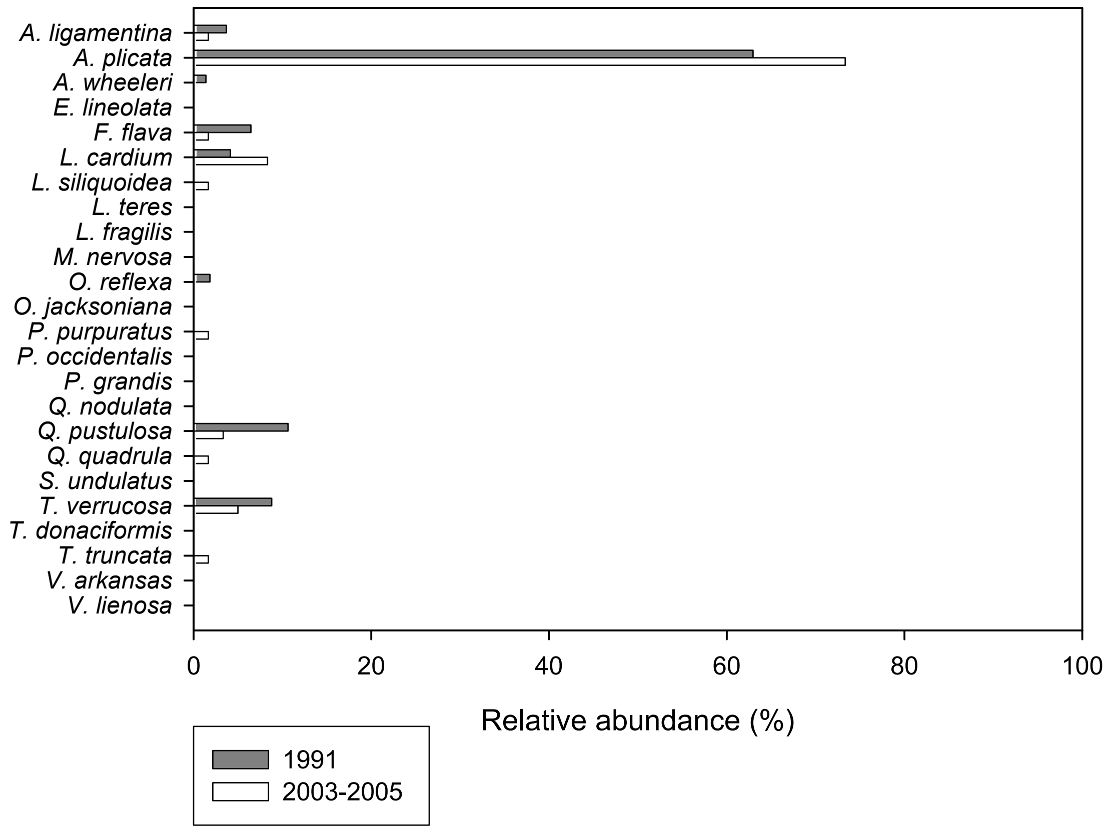


Figure 6. Relative abundance for monitoring site 2 in the Kiamichi River.

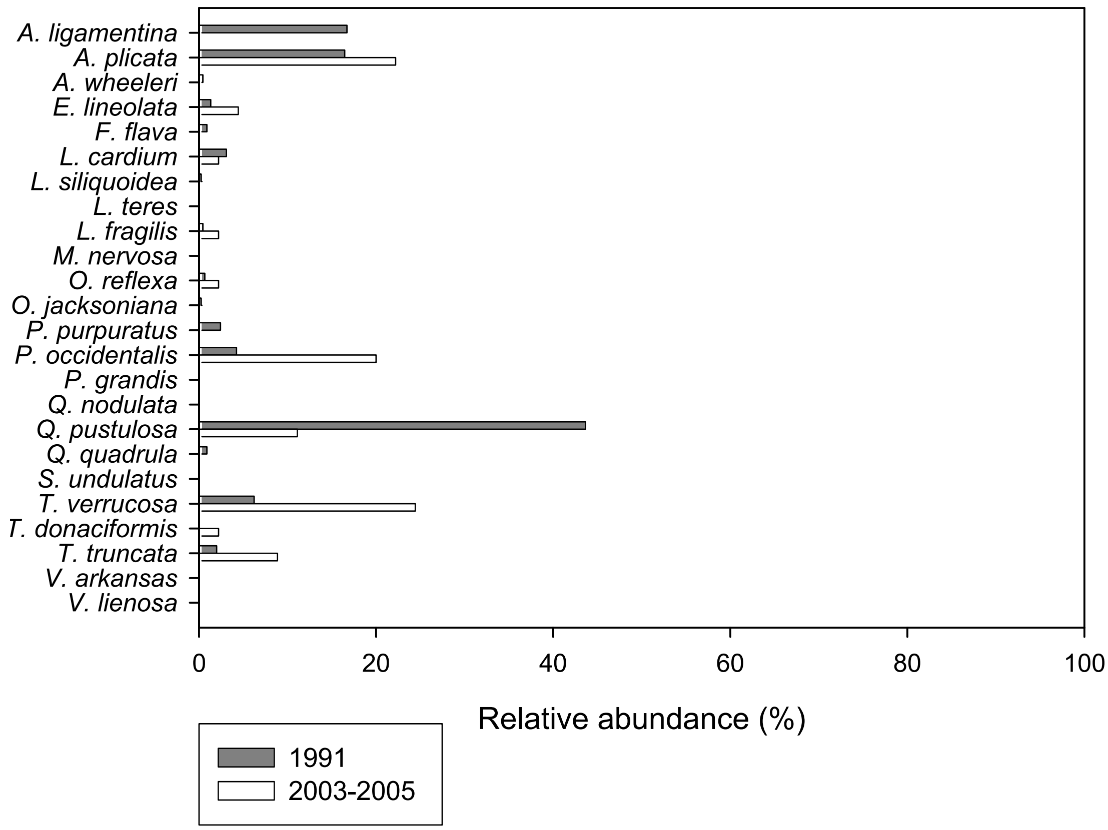


Figure 7. Relative abundance for monitoring site 3 in the Kiamichi River.

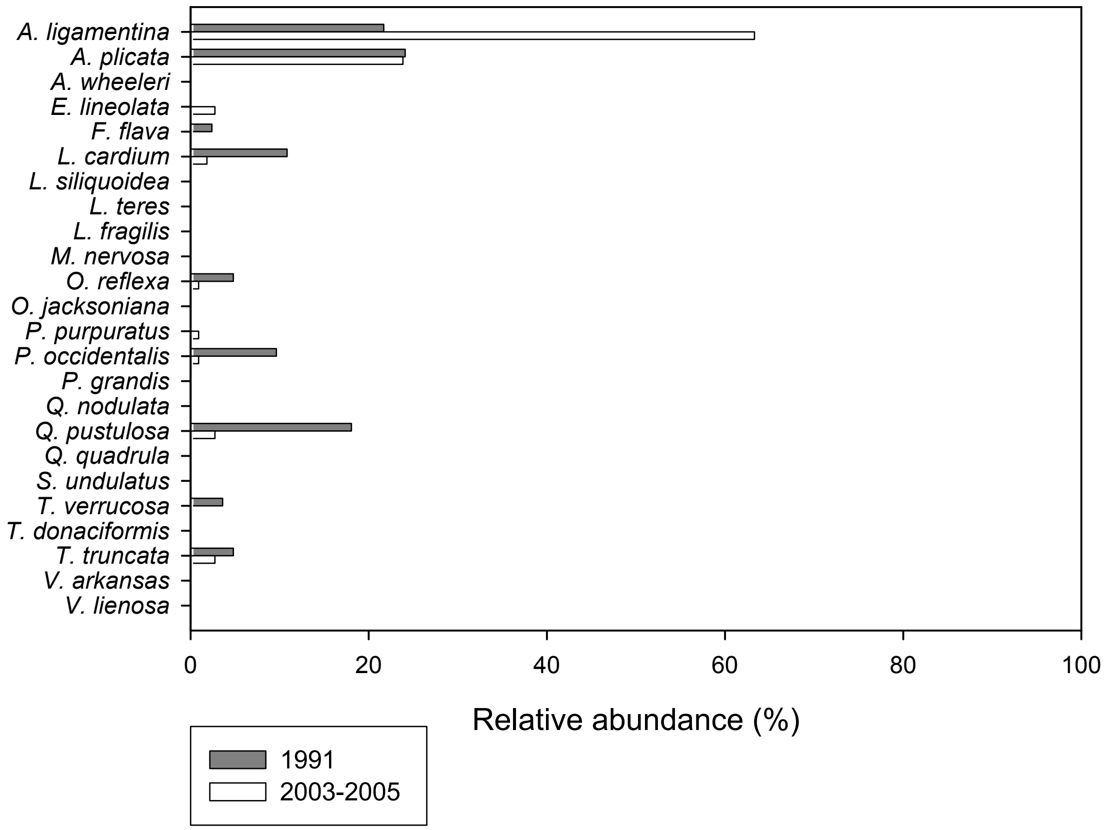


Figure 8. Relative abundance for monitoring site 4 in the Kiamichi River.

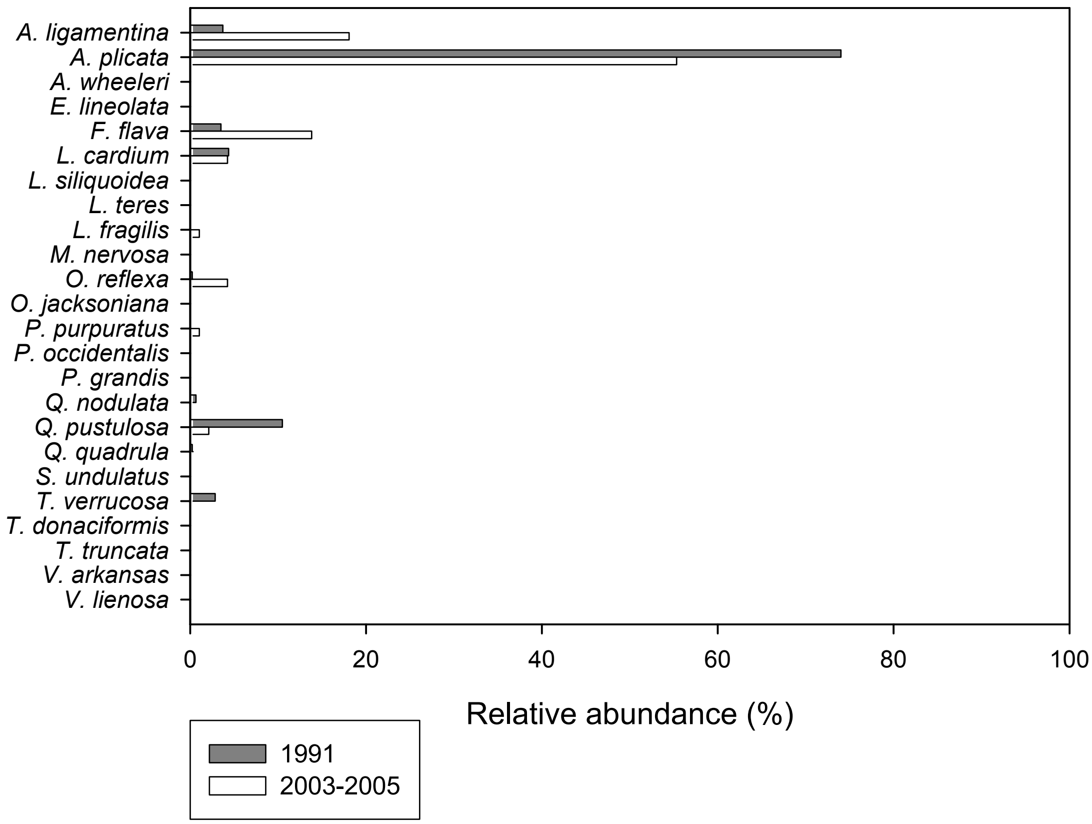


Figure 9. Relative abundance for monitoring site 5 in the Kiamichi River.

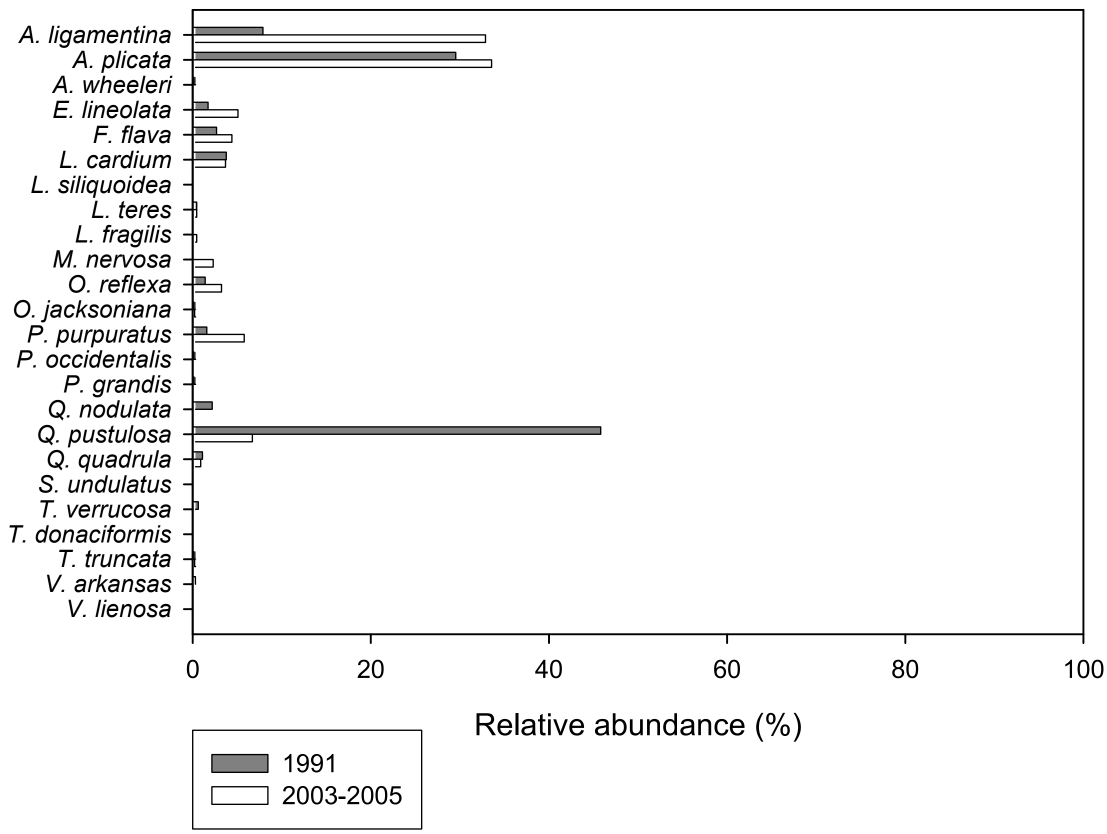


Figure 10. Relative abundance for monitoring site 6 in the Kiamichi River.

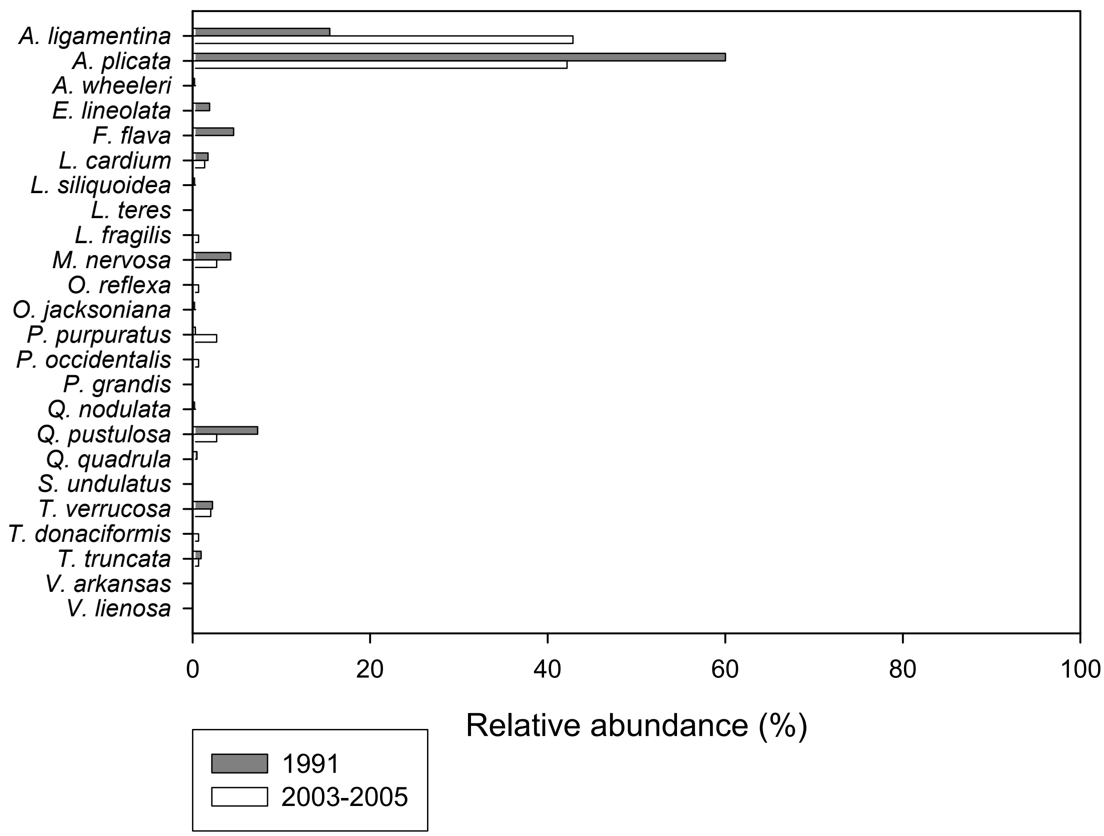


Figure 11. Relative abundance for monitoring site 7 in the Kiamichi River.

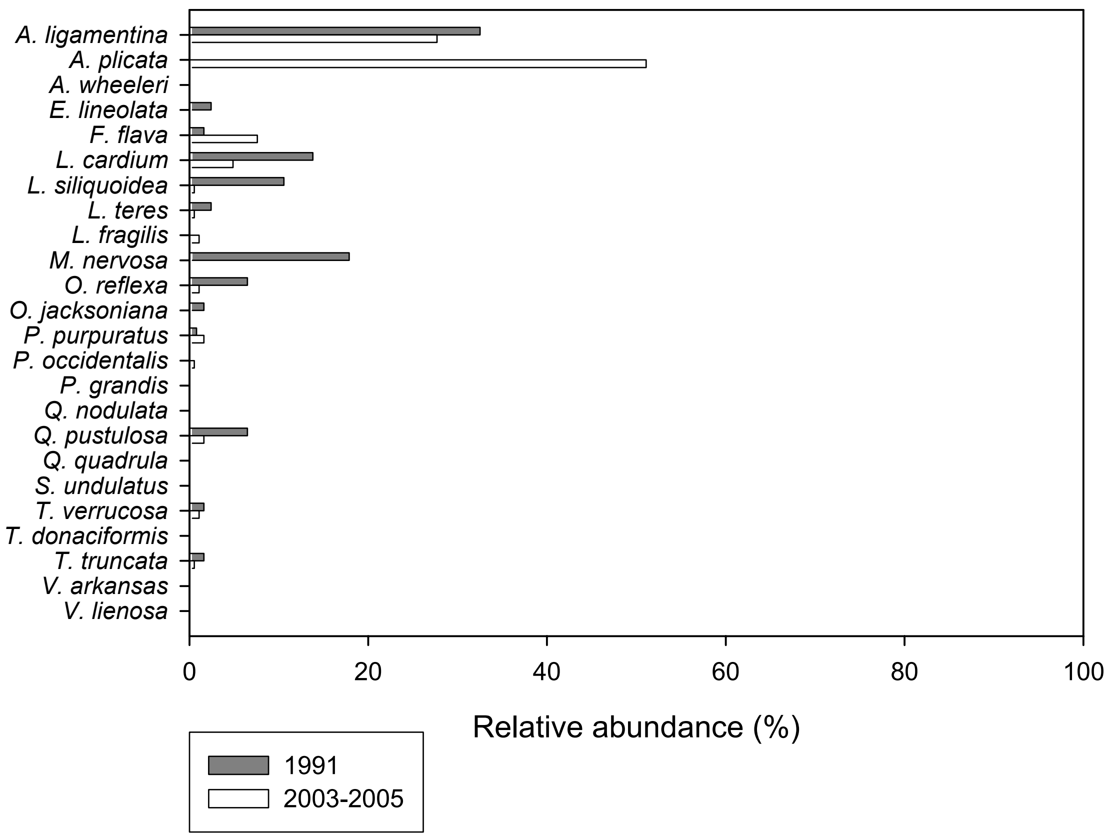


Figure 12. Relative abundance for monitoring site 8 in the Kiamichi River.

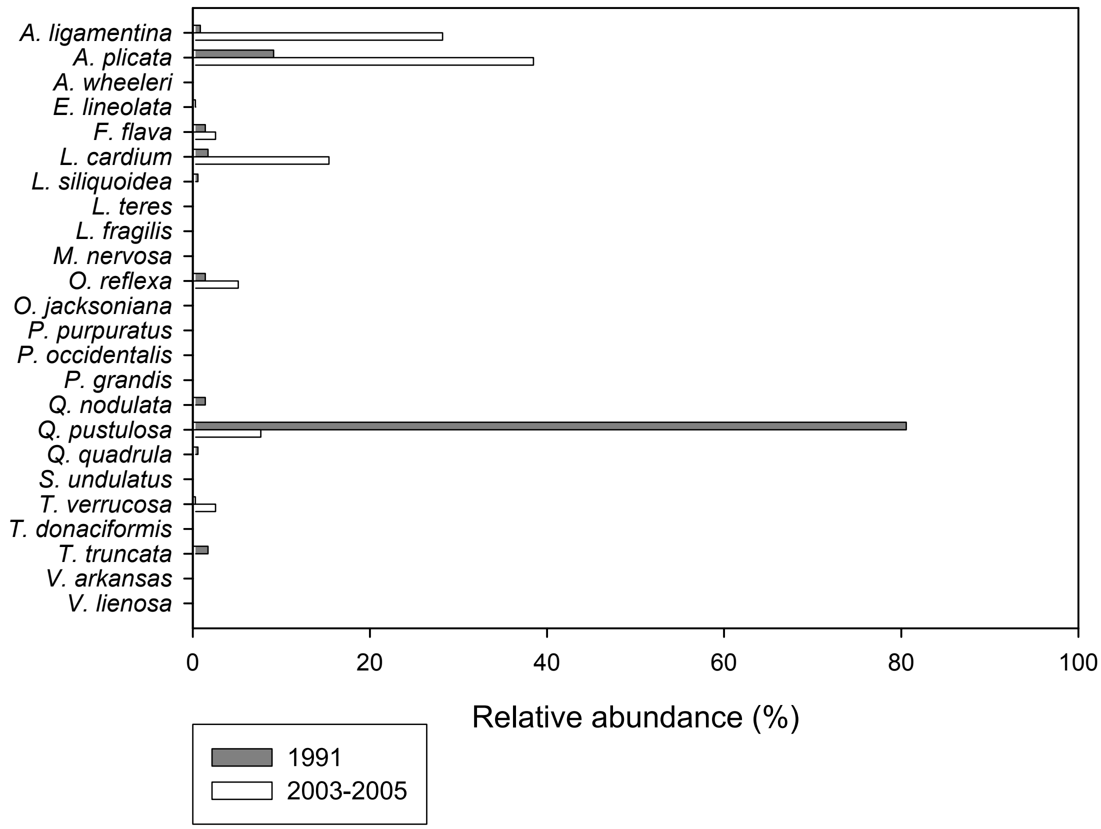


Figure 13. Relative abundance for monitoring site 9 in the Kiamichi River.

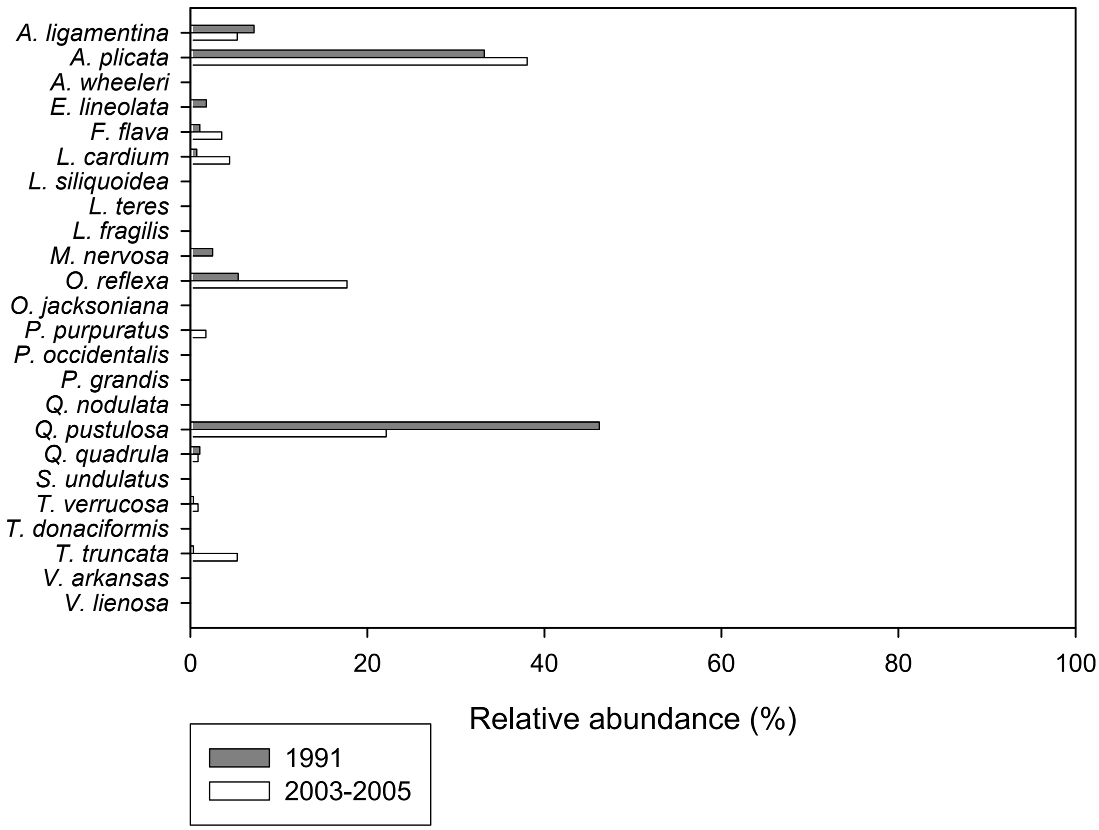


Figure 14. Relative abundance for monitoring site 10 in the Kiamichi River.

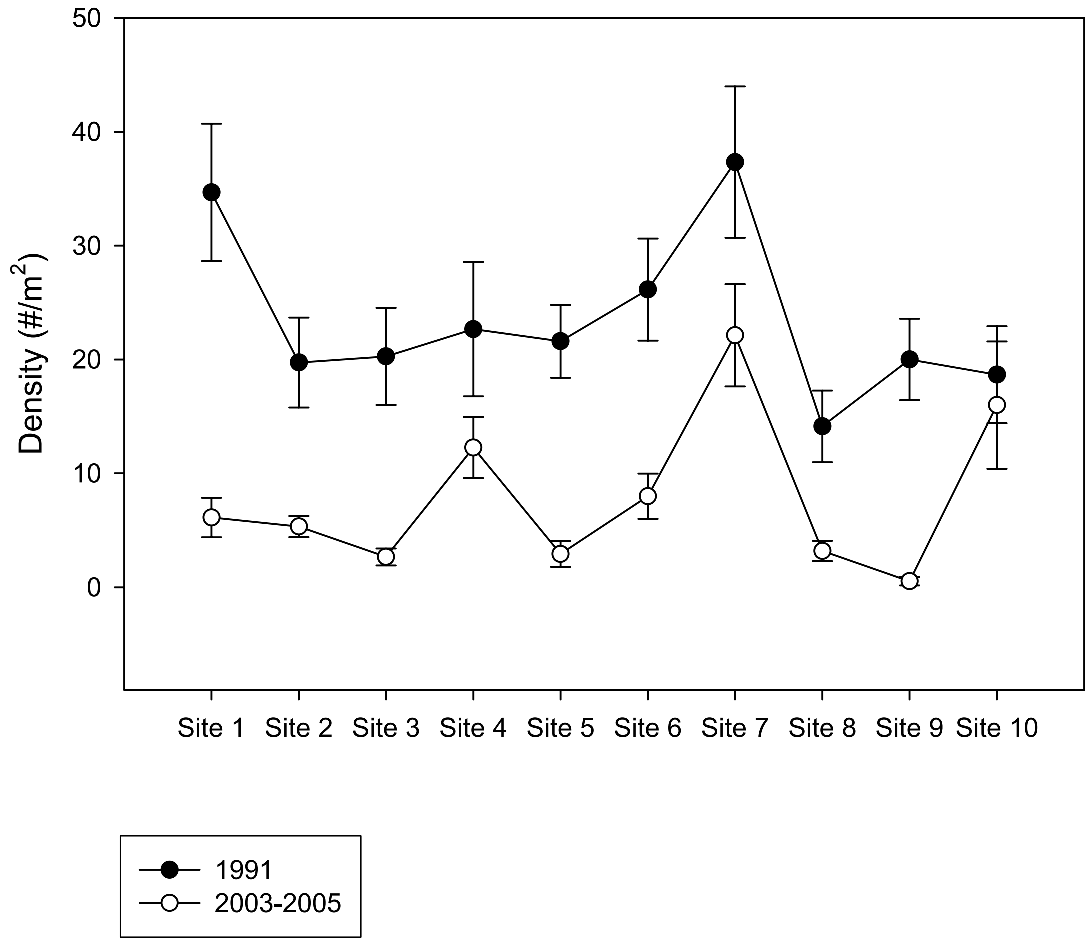


Figure 15. Mean mussel density and standard error at each monitoring site in the Kiamichi River in 1991 and 2003-2005.

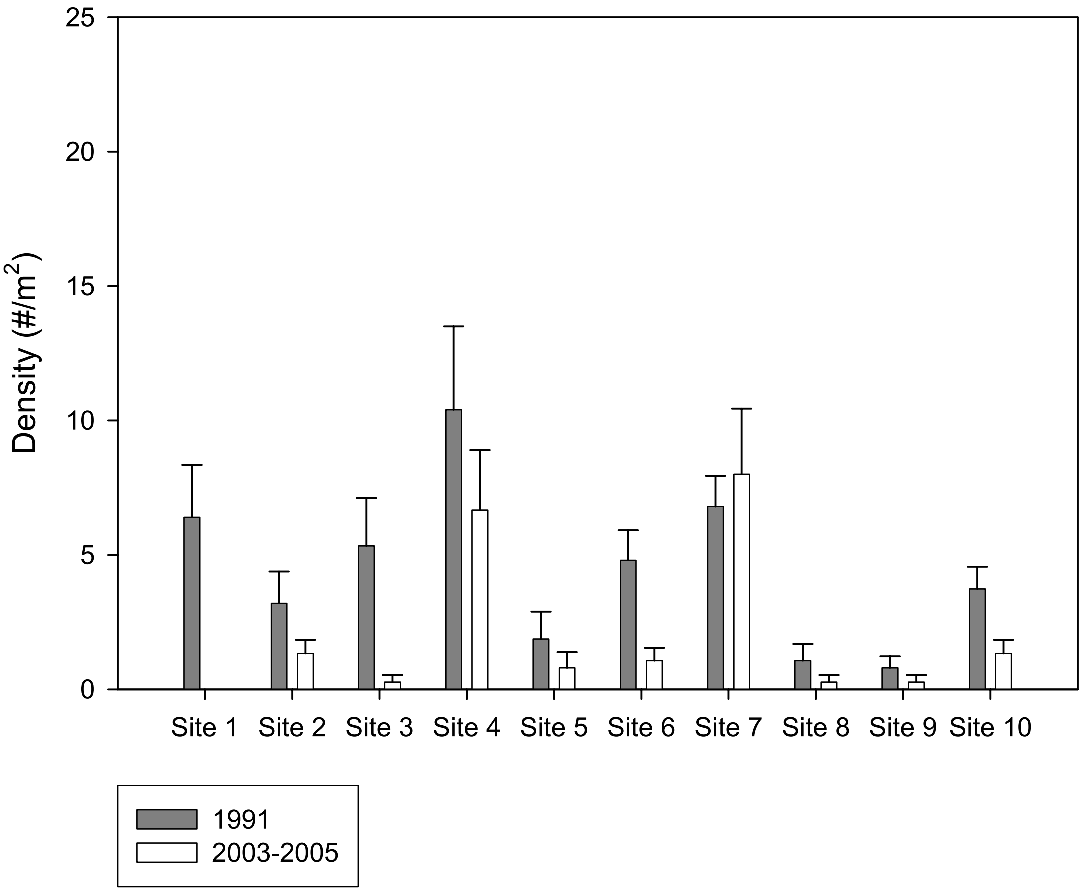


Figure 16. Mean *Actinonaias ligamentina* density and standard error at each monitoring site in the Kiamichi River in 1991 and 2003-2005.

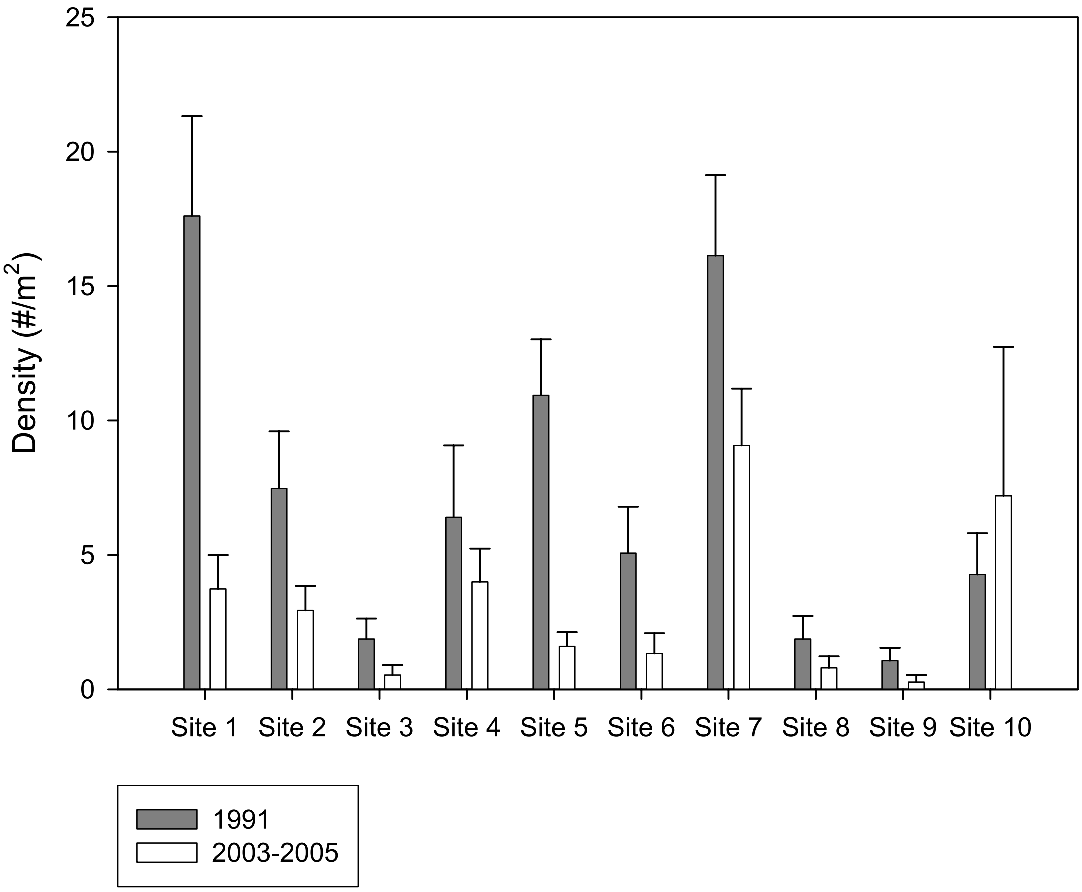


Figure 17. Mean *Amblema plicata* density and standard error at each monitoring site in the Kiamichi River in 1991 and 2003-2005.

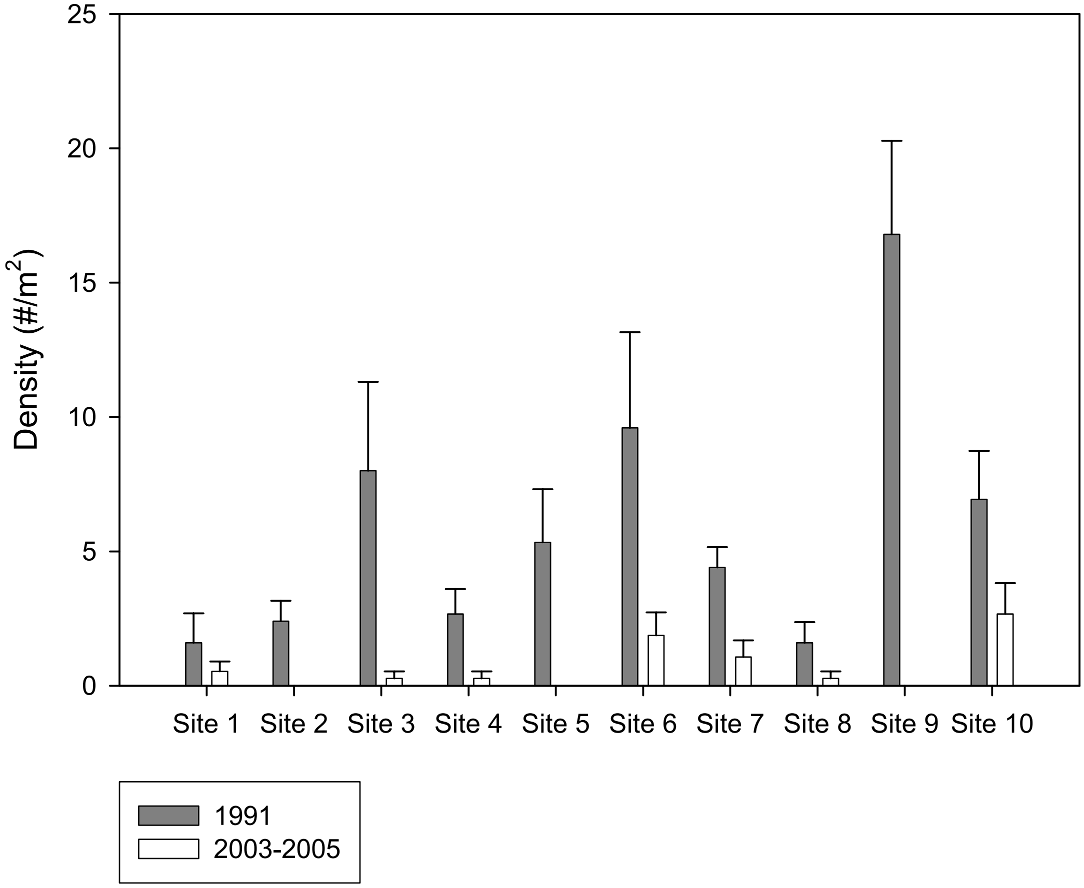


Figure 18. Mean *Quadrula pustulosa* density and standard error at each monitoring site in the Kiamichi River in 1991 and 2003-2005.

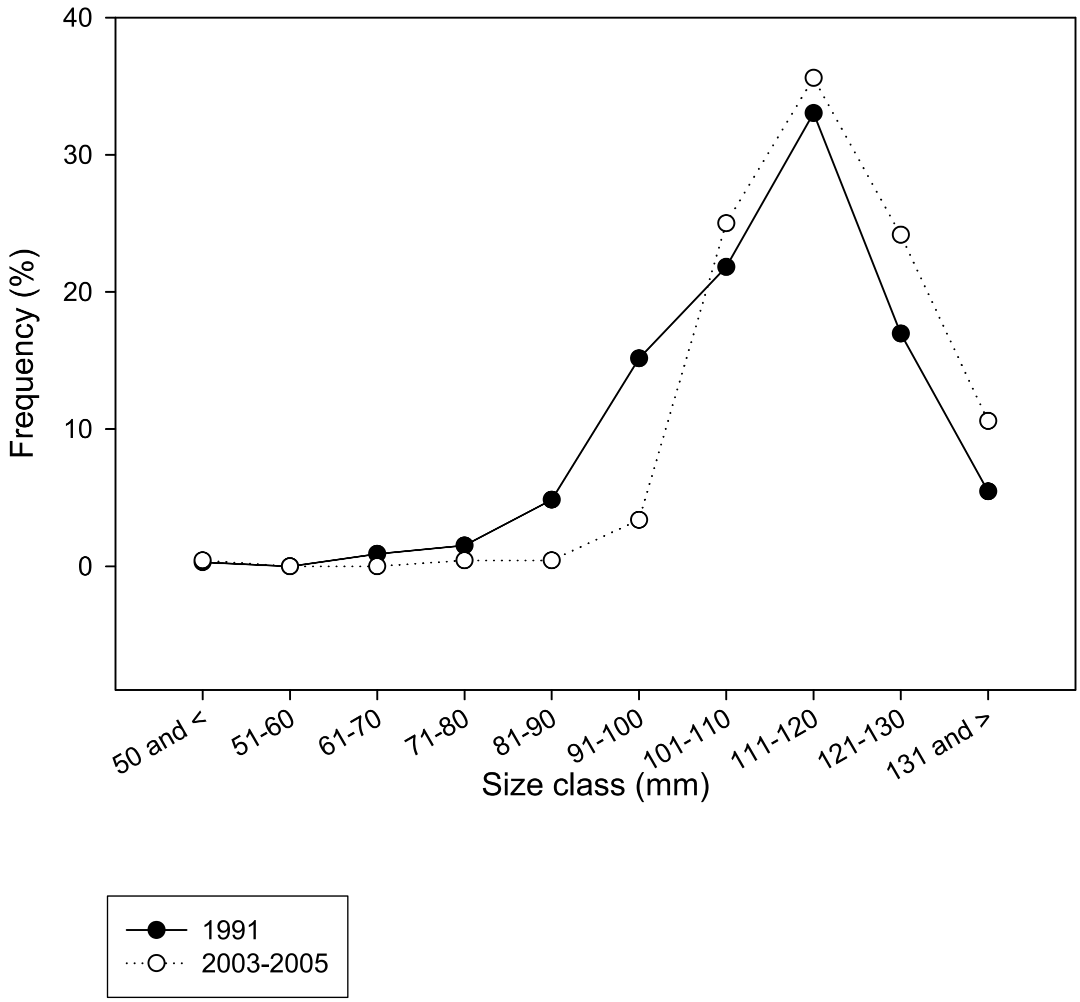


Figure 19. Size class distribution for *Actinonaias ligamentina* for the Kiamichi River in 1991 and 2003-2005.

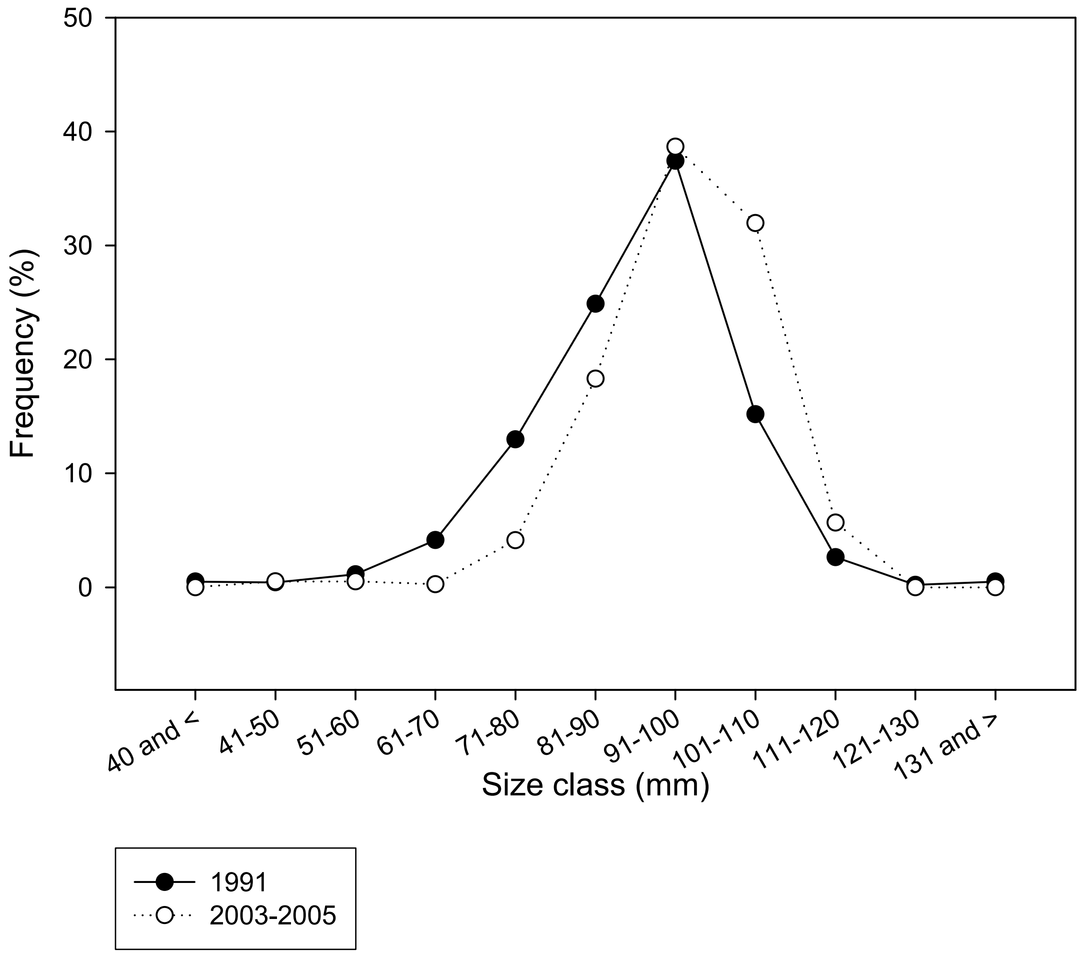


Figure 20. Size class distribution for *Amblema plicata* for the Kiamichi River in 1991 and 2003-2005.

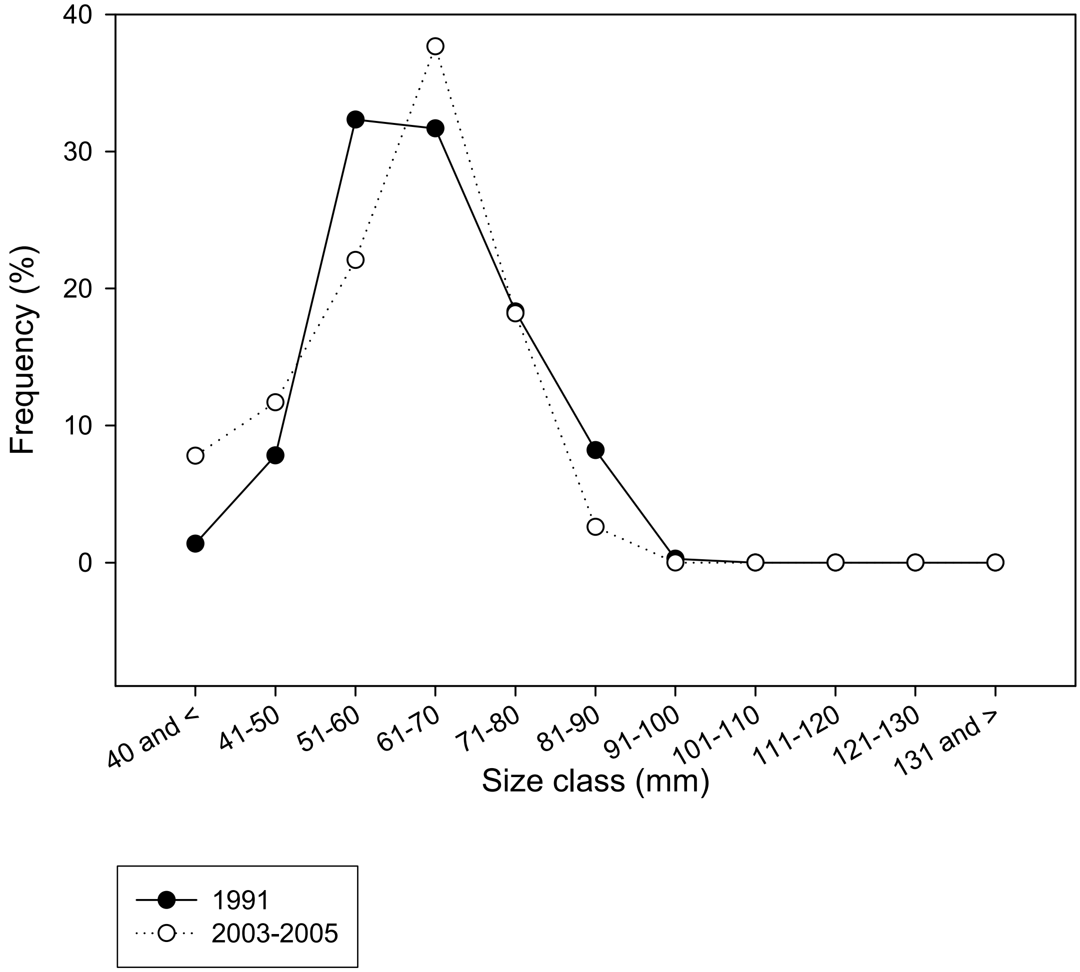


Figure 21. Size class distribution for *Quadrula pustulosa* for the Kiamichi River in 1991 and 2003-2005.

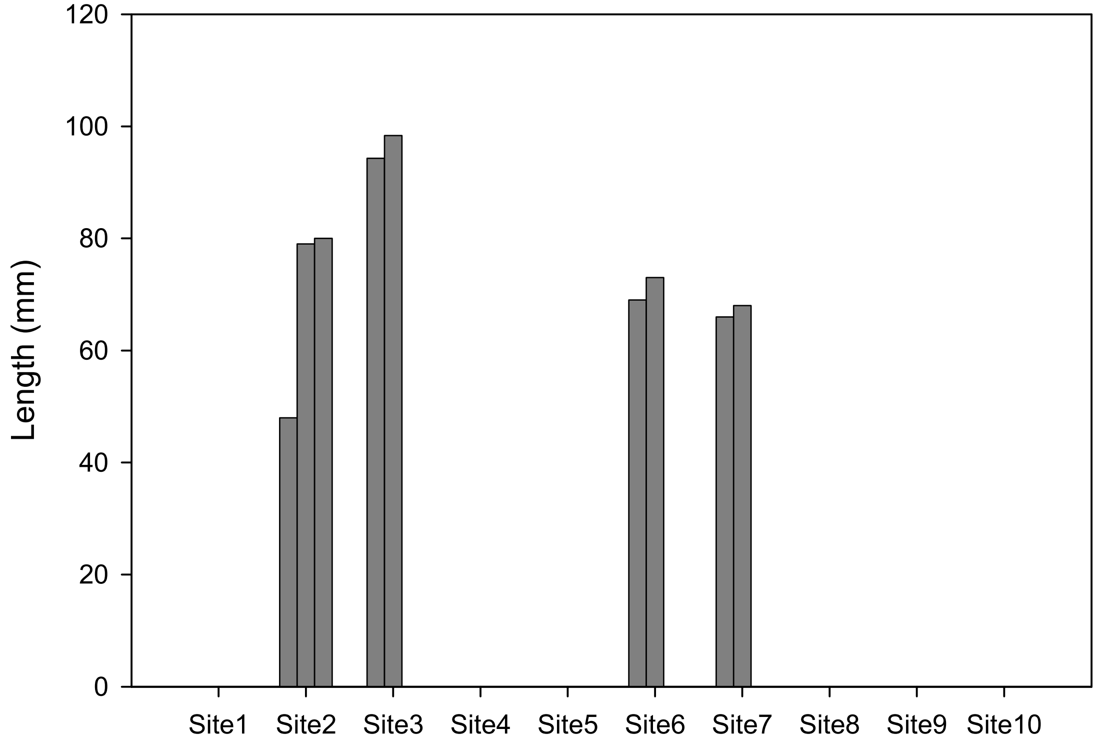


Figure 22. Lengths of individual *Arkansia wheeleri* from Vaughn's 1991 surveys of the Kiamichi River.

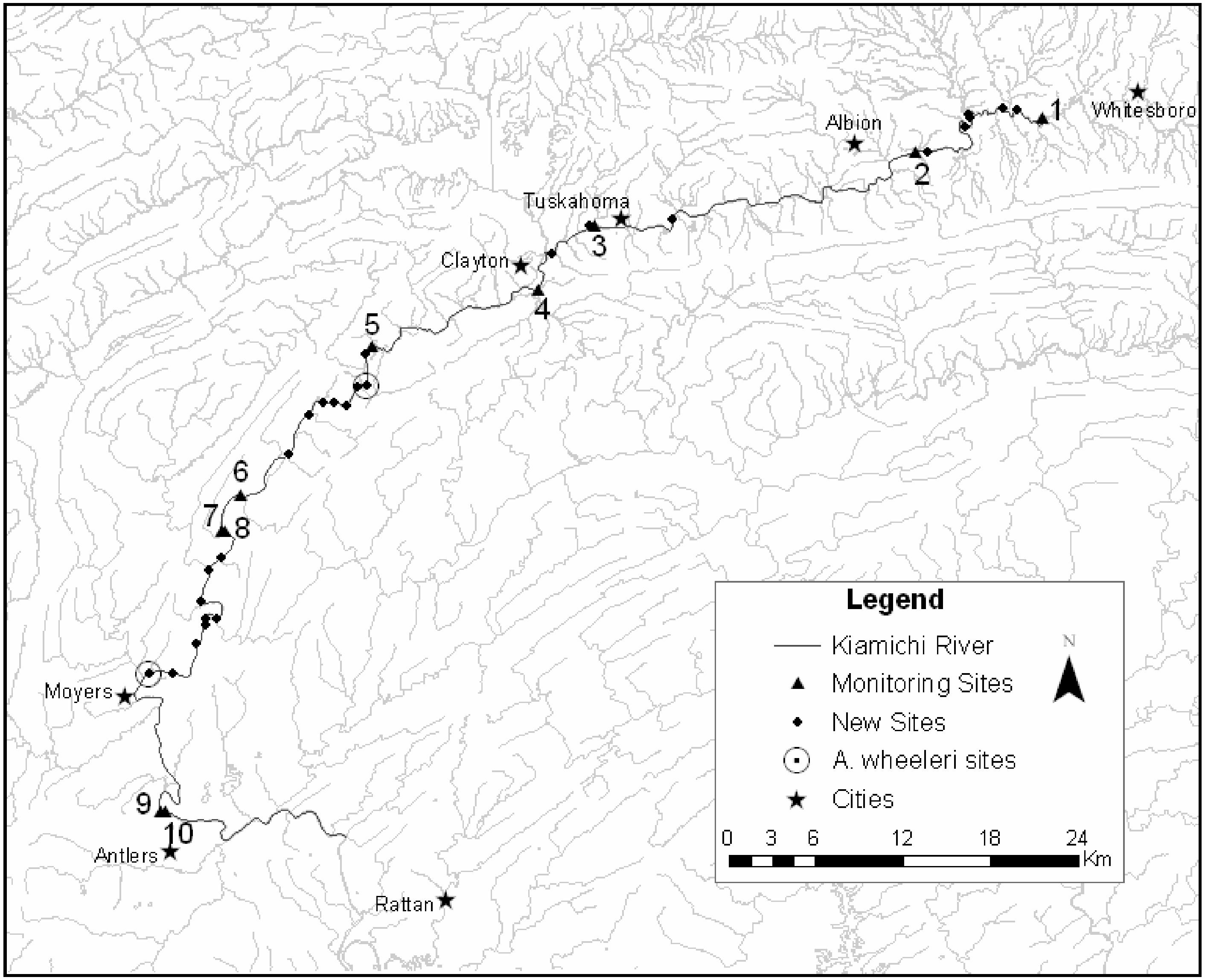


Figure 23. Sampling sites on the Kiamichi River with new *Arkansia wheeleri* sites circled.

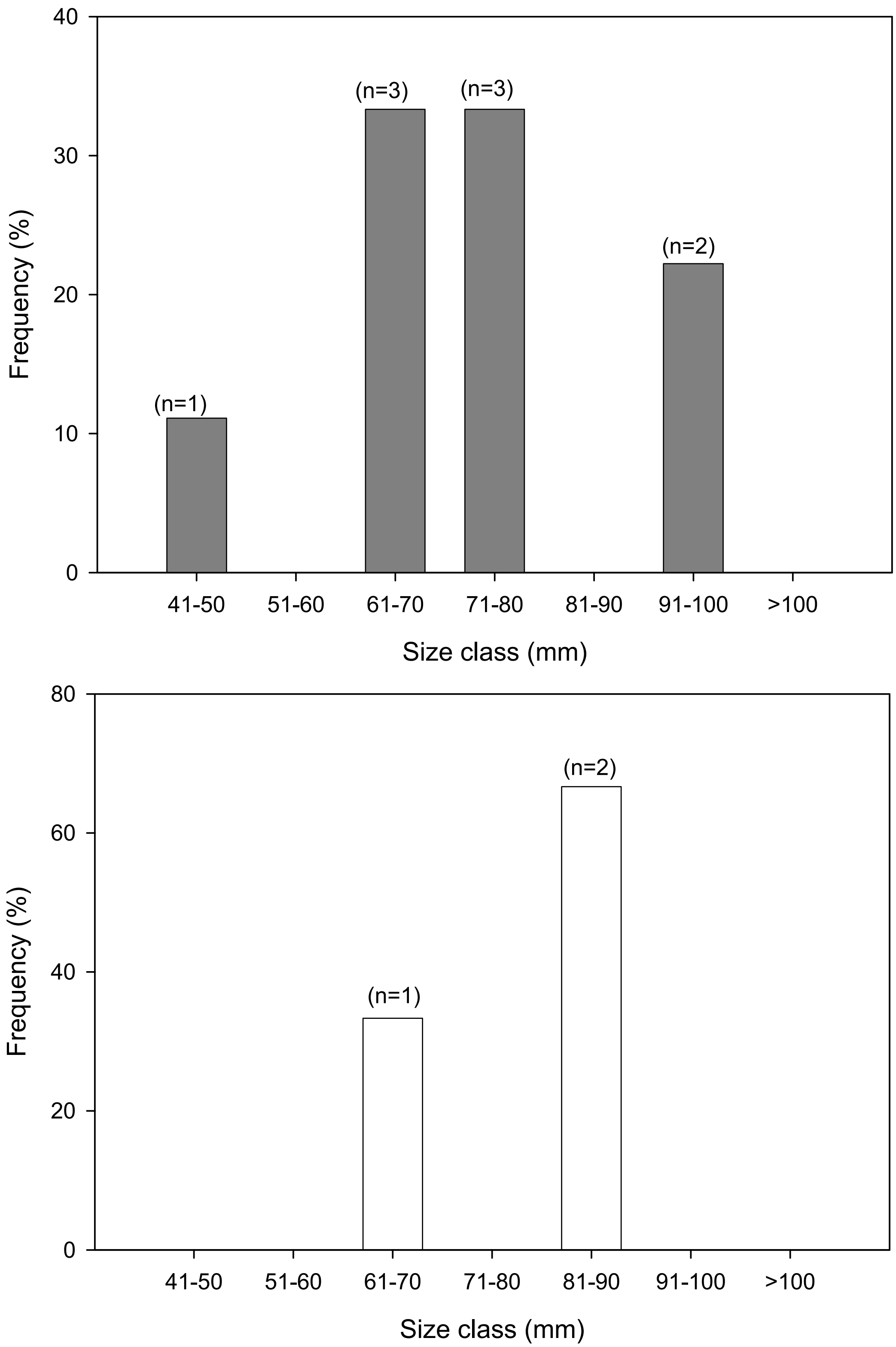


Figure 24. Size class distribution for Arkansia wheeleri in the Kiamichi River in 1991 (top) and 2003-2005 (bottom).

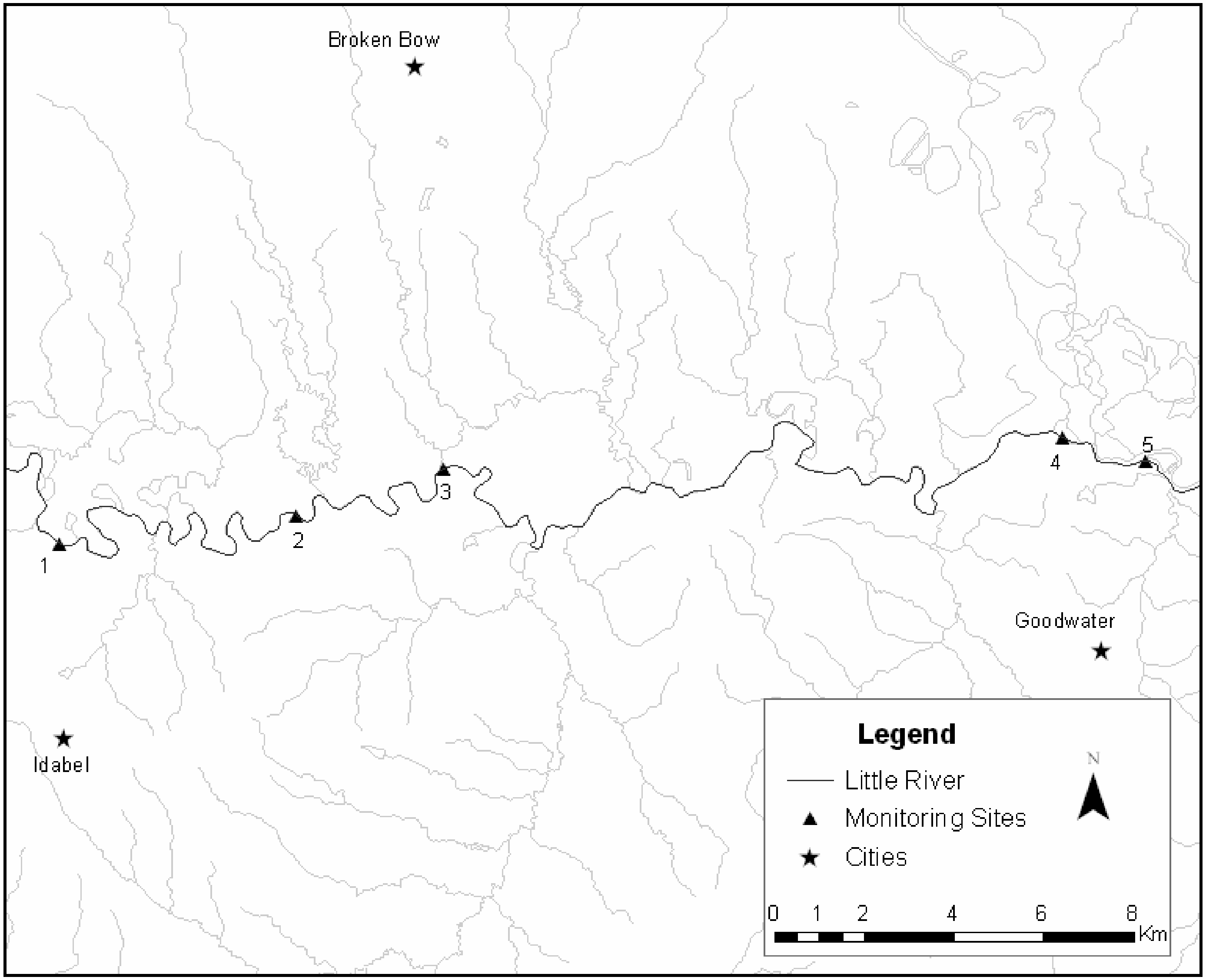


Figure 25. Map showing the 5 monitoring sites in the Little River, Oklahoma.

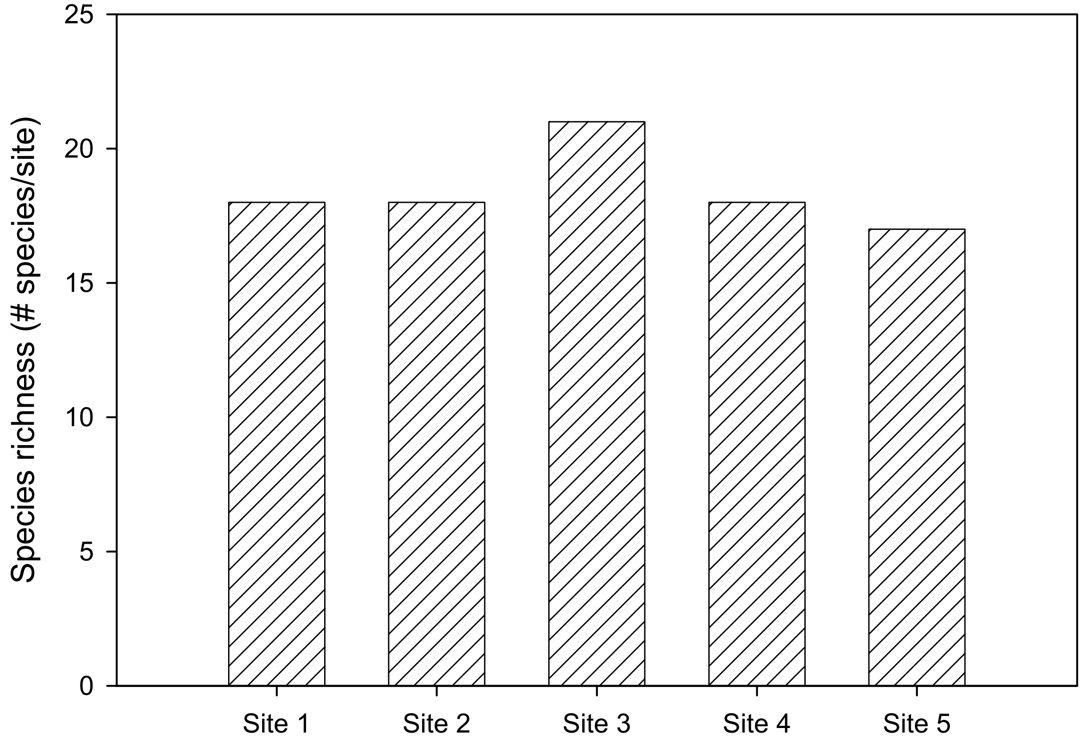


Figure 26. Site-specific species richness of the Little River in 2005.

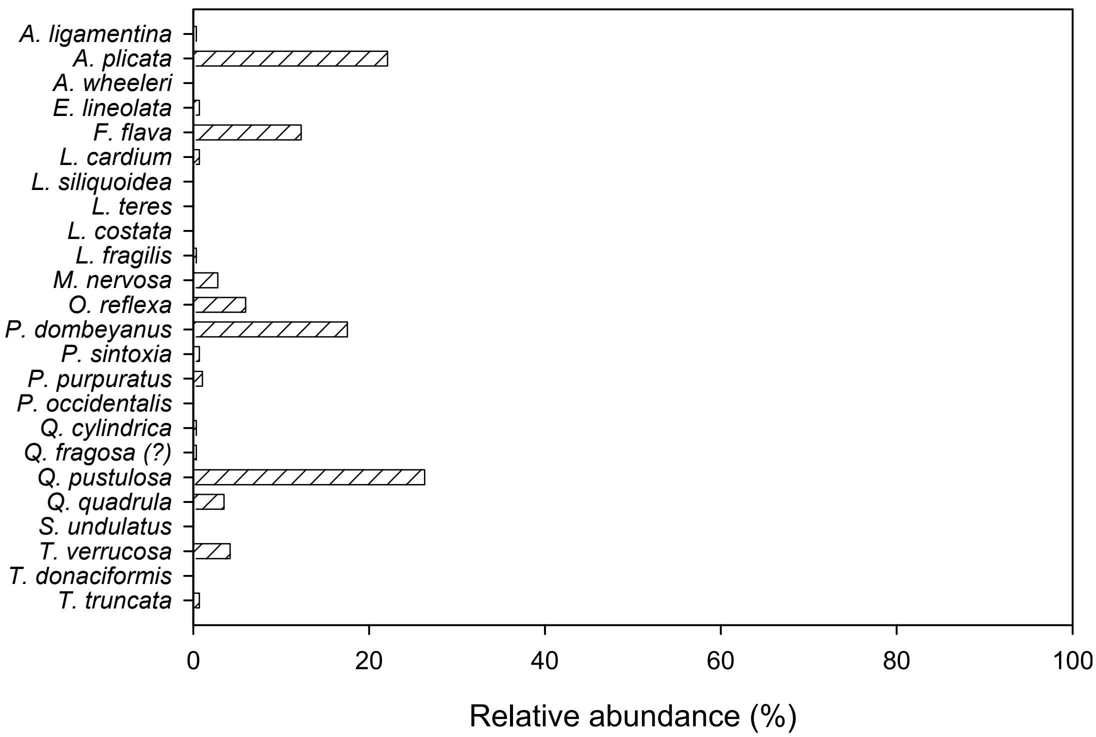


Figure 27. Relative abundance for monitoring site 1 in the Little River in 2005.

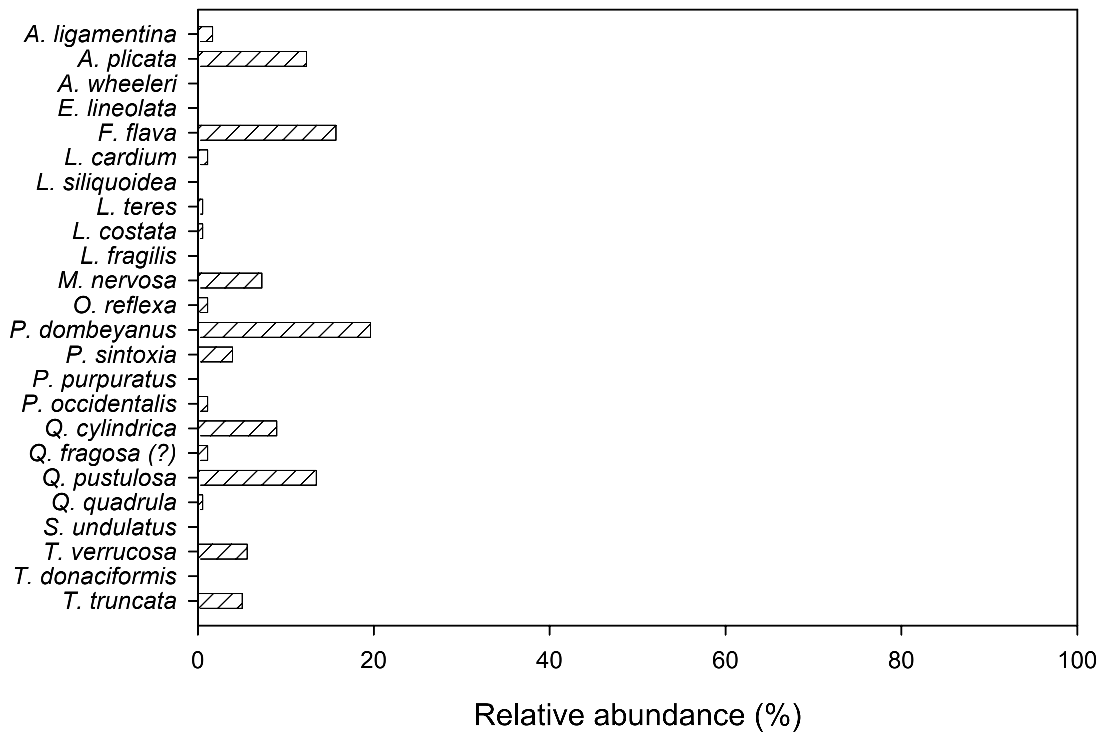


Figure 28. Relative abundance for monitoring site 2 in the Little River in 2005.

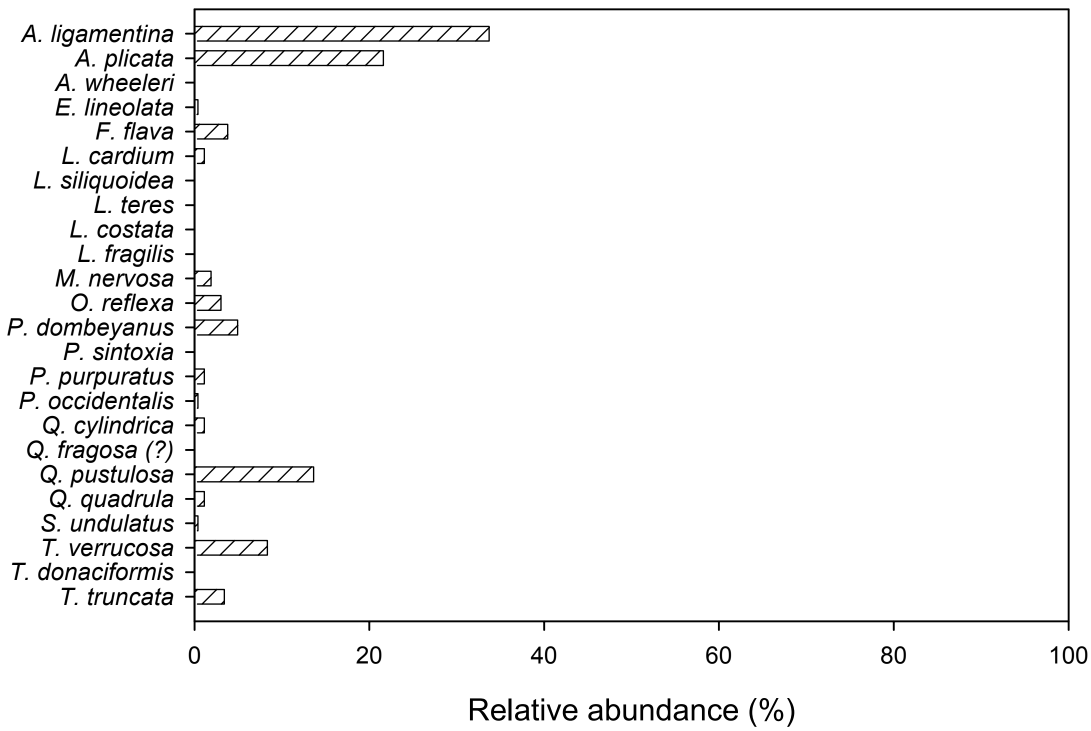


Figure 29. Relative abundance for monitoring site 3 in the Little River in 2005.

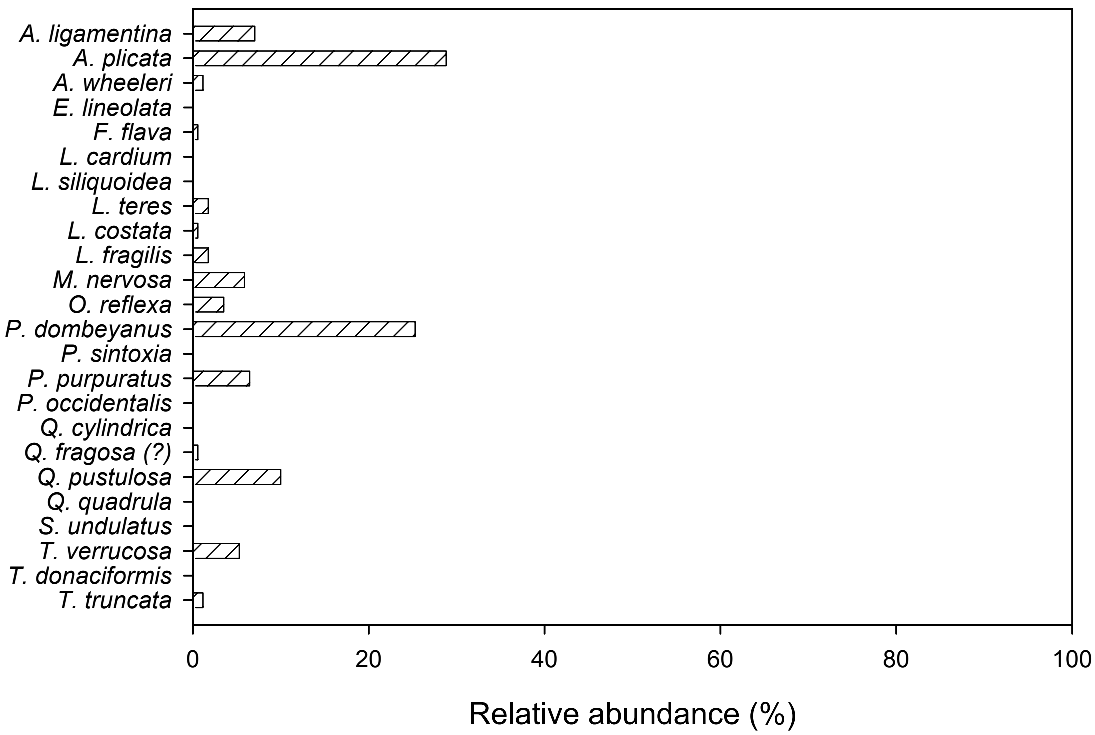


Figure 30. Relative abundance for monitoring site 4 in the Little River in 2005.

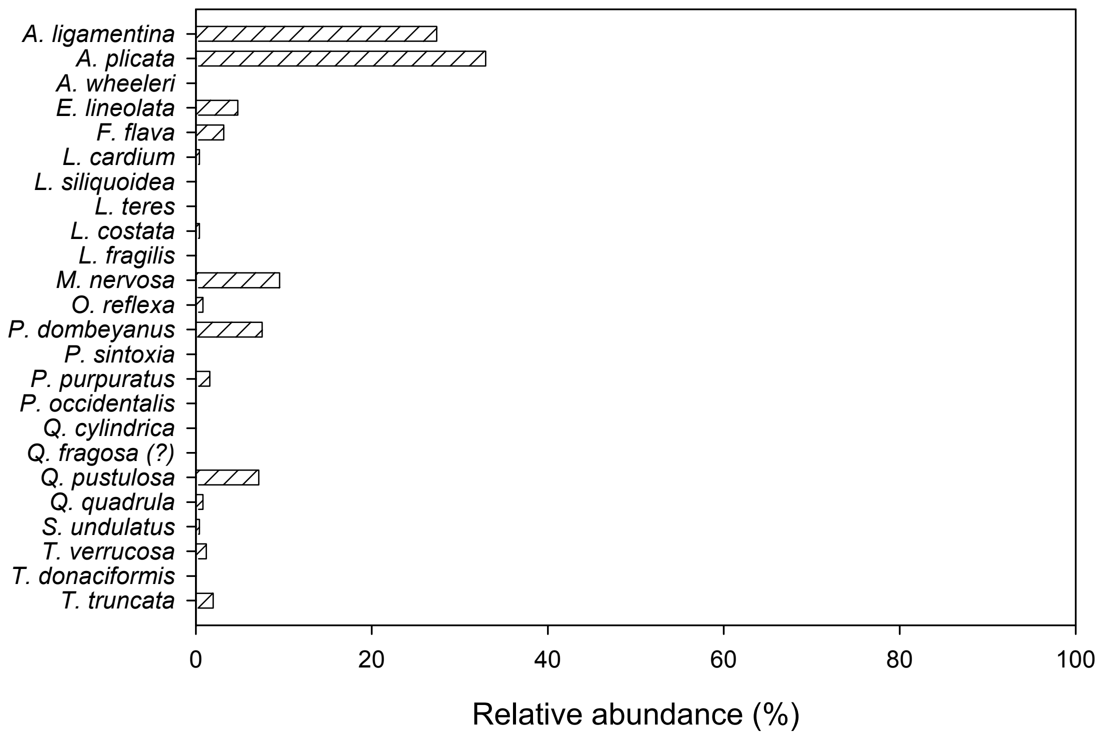


Figure 31. Relative abundance for monitoring site 5 in the Little River in 2005.

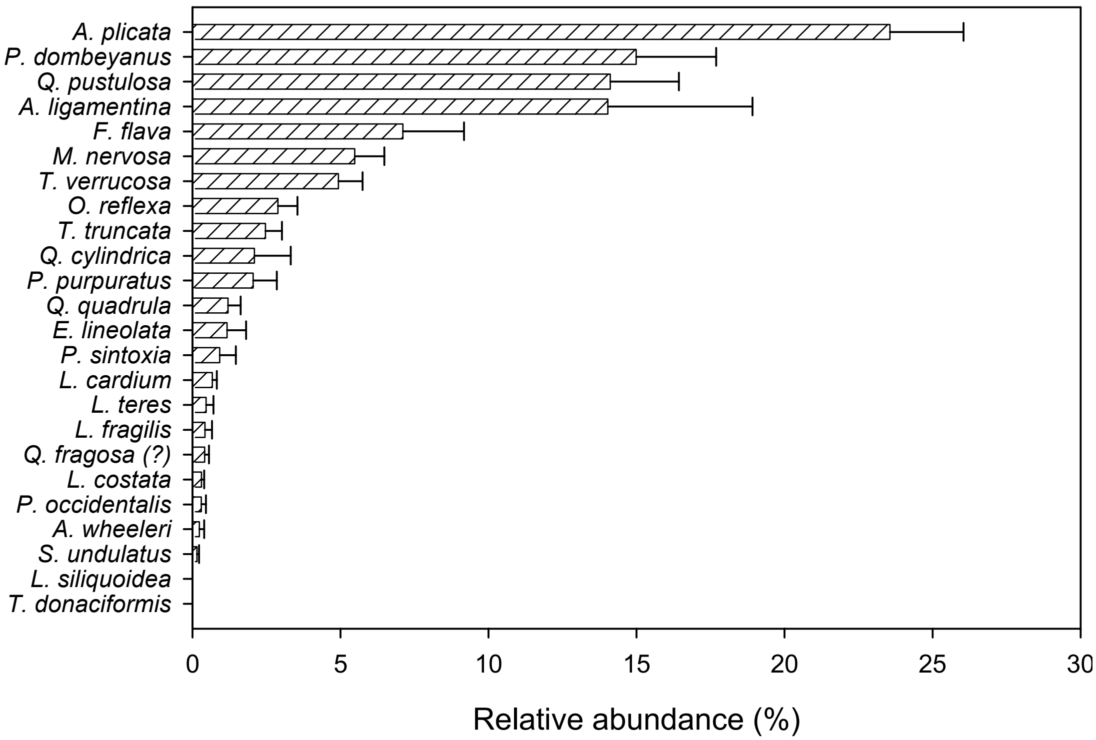


Figure 32. Mean relative abundance and standard error for the Little River in 2005.

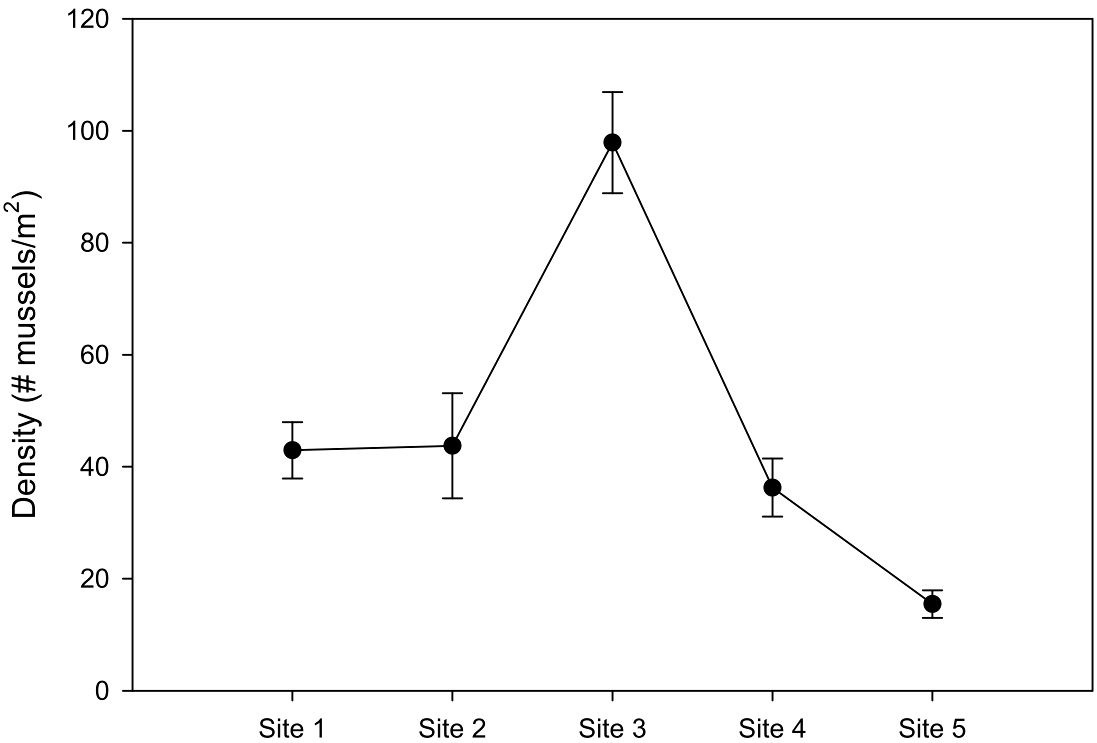


Figure 33. Mean mussel density and standard error at each monitoring site in the Little River in 2005.

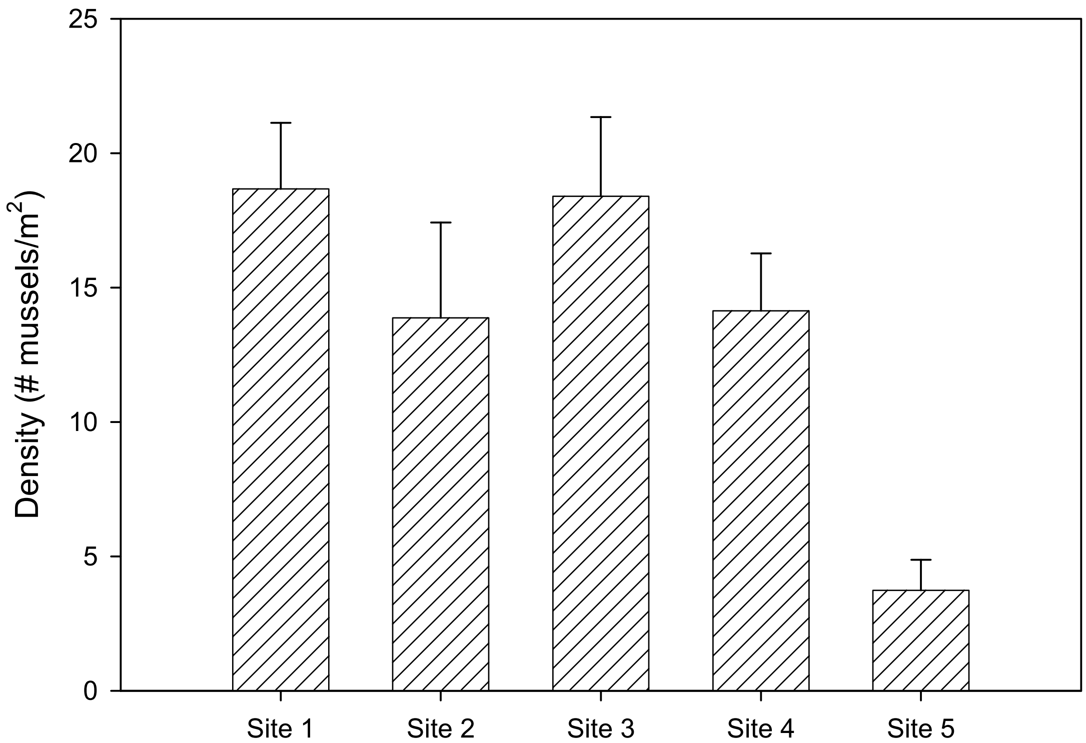


Figure 34. Mean *Quadrula pustulosa* density and standard error at each monitoring site in the Little River in 2005.

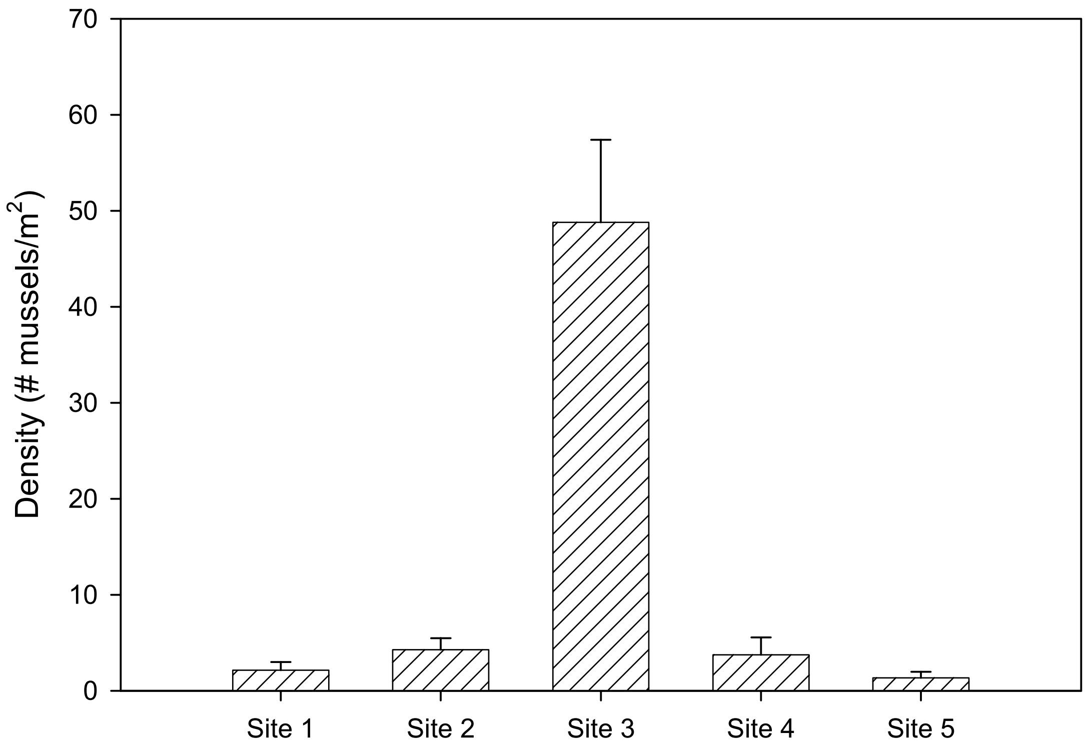


Figure 35. Mean *Actinonaias ligamentina* density and standard error at each monitoring site in the Little River in 2005.

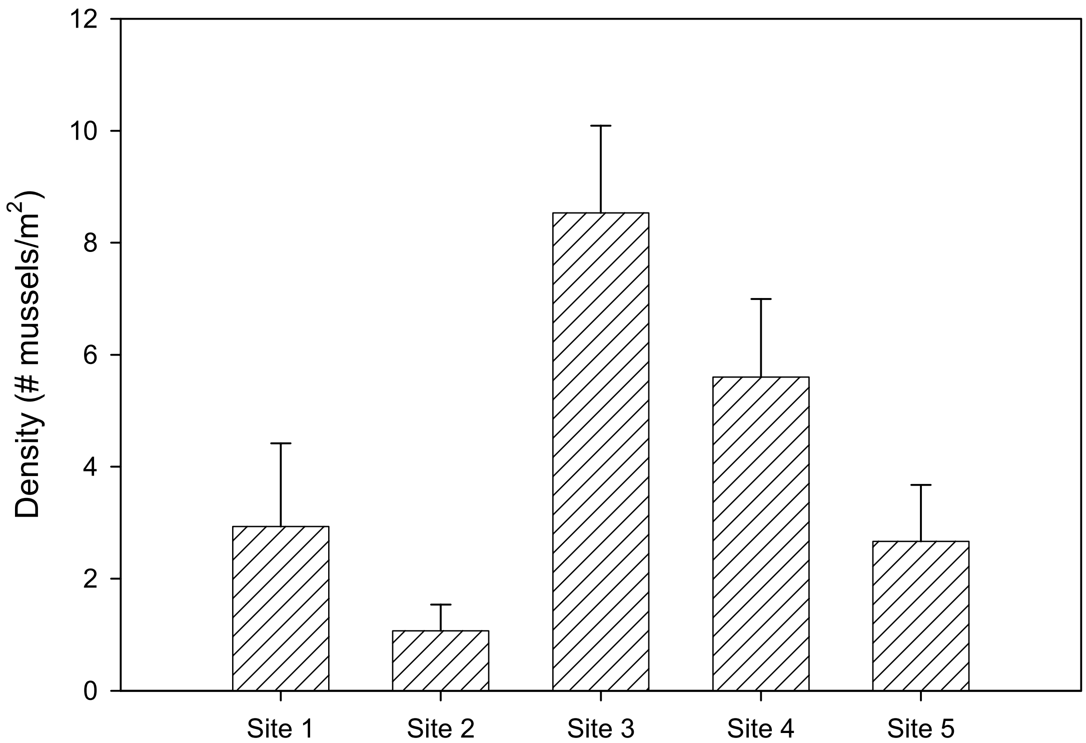


Figure 36. Mean *Amblema plicata* density and standard error at each monitoring site in the Little River in 2005.

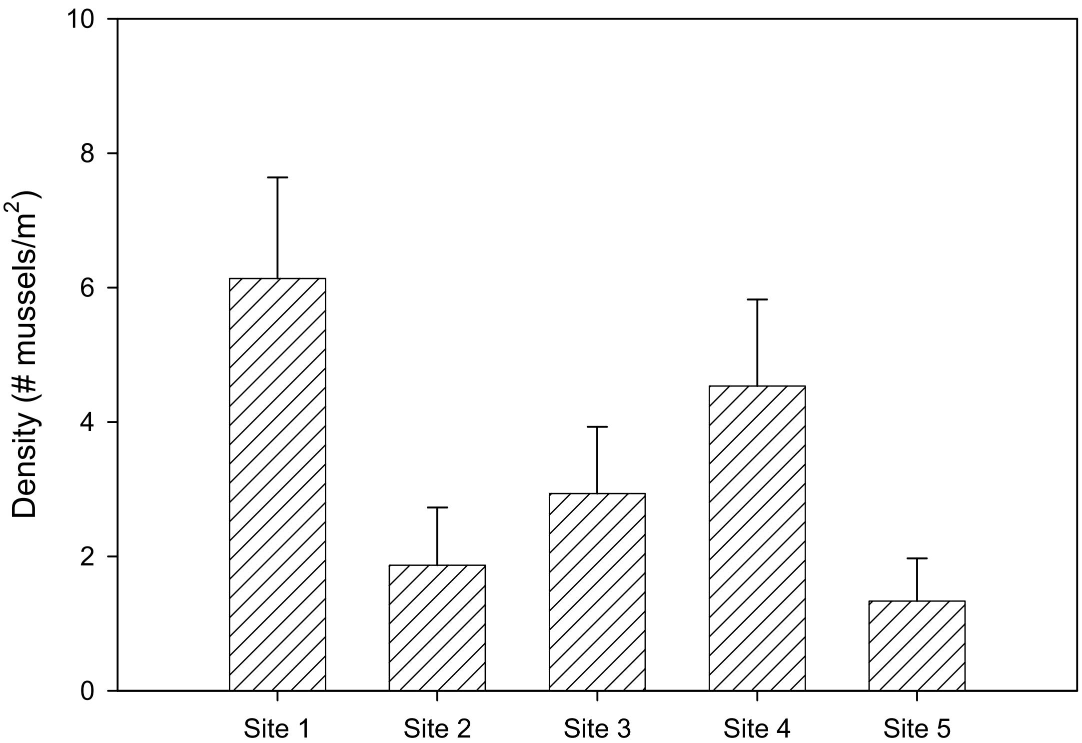


Figure 37. Mean *Plectomerus dombeyanus* density and standard error at each monitoring site in the Little River in 2005.

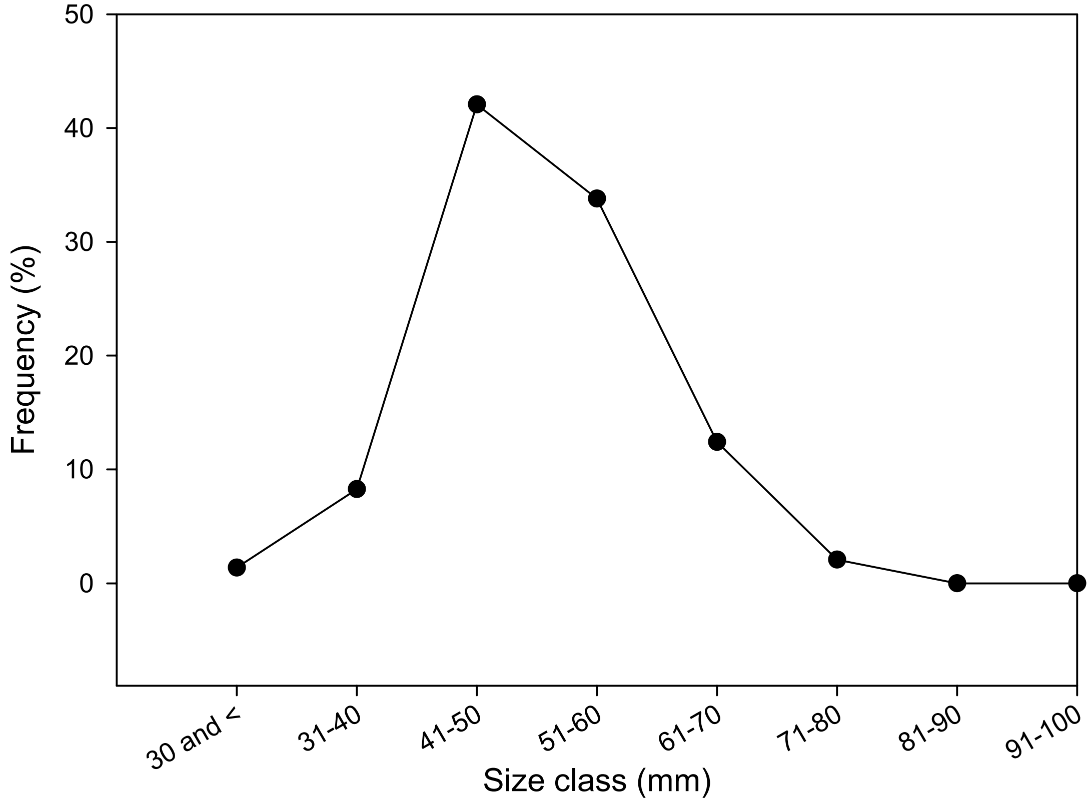


Figure 38. Size class distribution for *Quadrula pustulosa* for the Little River in 2005.

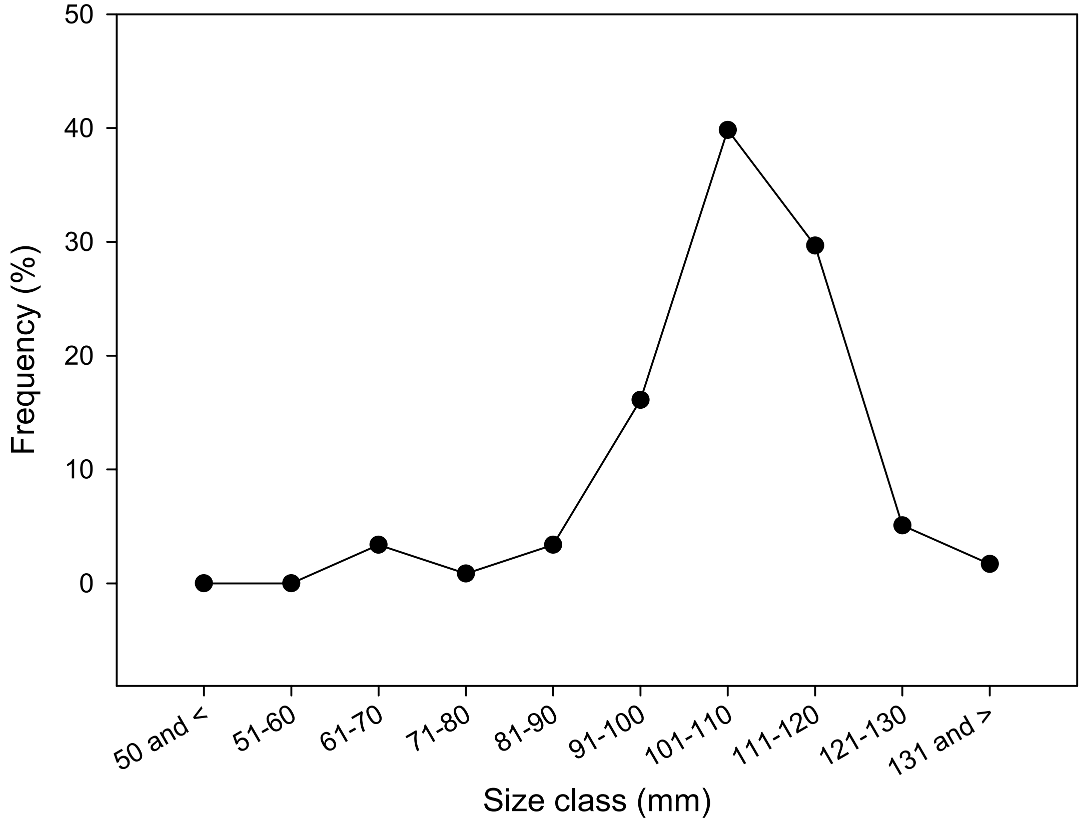


Figure 39. Size class distribution for *Actinonaias ligamentina* for the Little River in 2005.

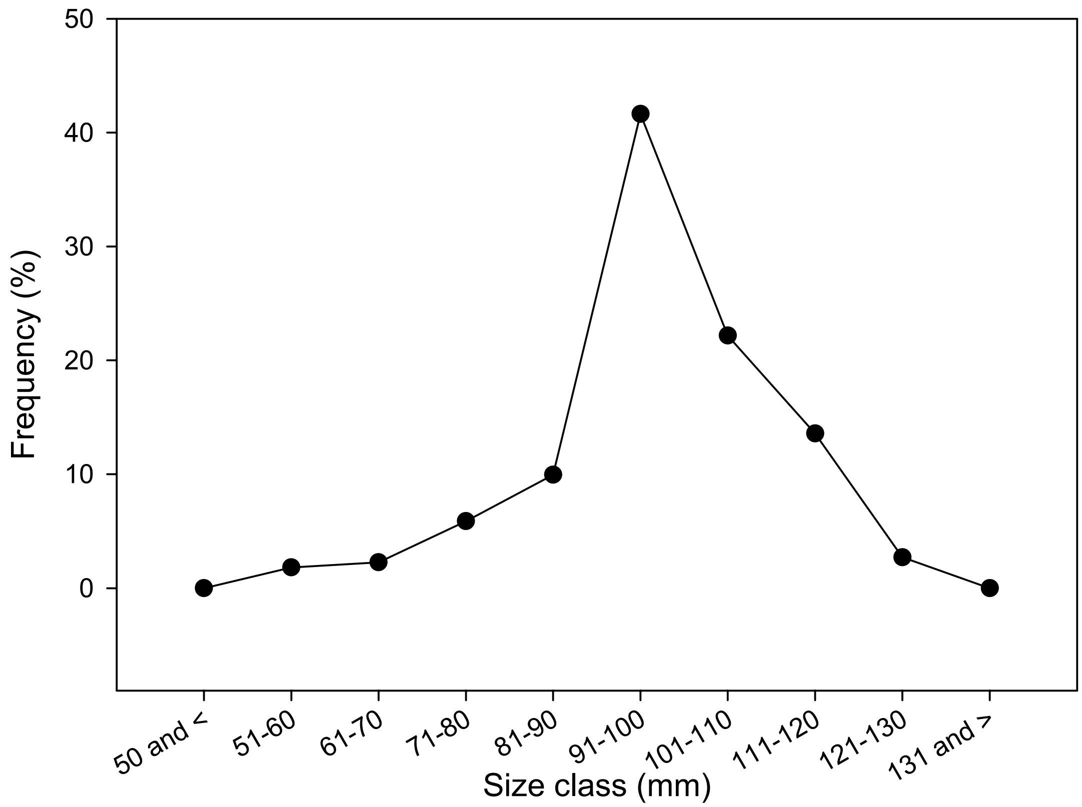


Figure 40. Size class distribution for *Amblema plicata* for the Little River in 2005.

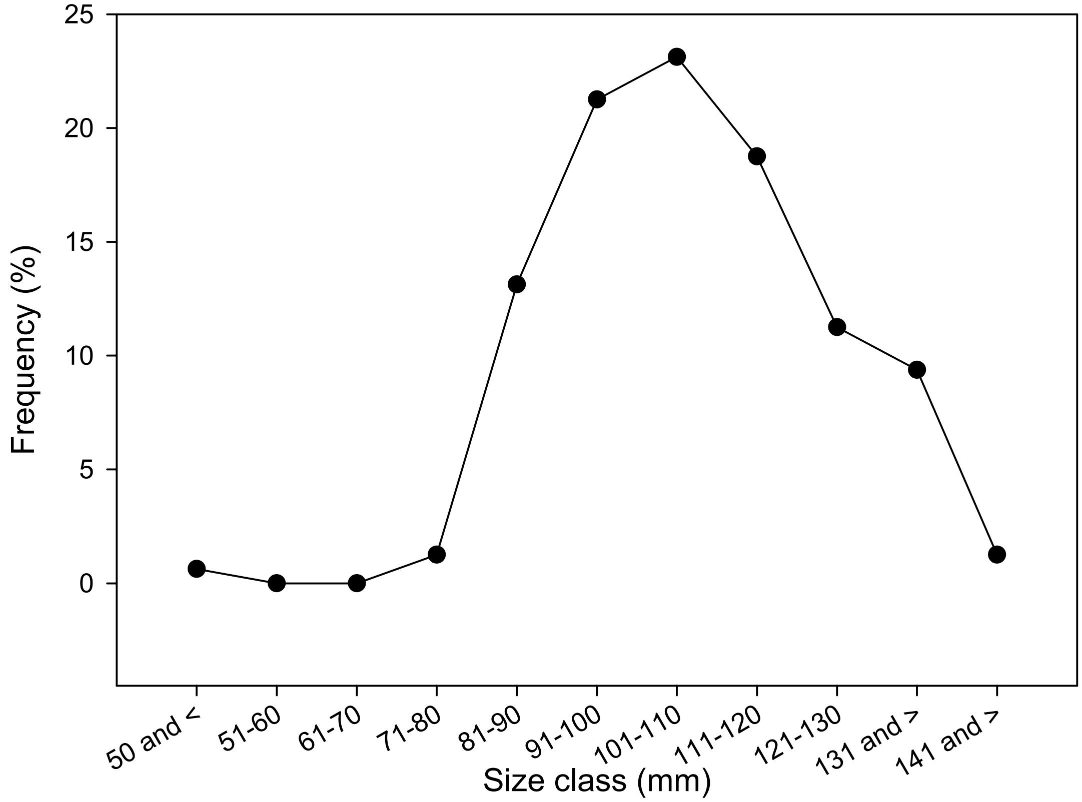


Figure 41. Size class distribution for *Plectomerus dombeyanus* for the Little River in 2005.

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