Potential for the Kentucky Dam Tailwater of the Tennessee River to Serve as a Mussel Refuge from Invading Zebra Mussels

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Abstract. The lower Tennessee River, especially between the tailwater reach of Kentucky Dam (mile 22.4) and the Ohio River, continues to support a diverse unionid fauna. Although no endangered species have been reported in over 8 years, earlier surveys reported *Plethobasus cooperianus, Lampsilis abrupta, Cyprogenia stegaria,* and *Obovaria retusa.* The recent invasion and rapid colonization of the Ohio River by zebra mussels has threatened its unionids. Few zebra mussels, however, occur in the Tennessee River. Data from European studies and our recent studies suggest that the Ca^{++} concentration in the Tennessee River is below that required for successful zebra mussel reproduction and colonization. The zebra mussels living in the Tennessee River probably have fallen from vessels traveling from the Ohio River and may not be reproducing. If zebra mussels are not successful in the Tennessee River, it could be used as a refugia for endangered or rare unionids from the Ohio River and other rivers colonized by zebra mussels until populations of zebra mussels in those rivers decline and stabilize. To determine if unionids could be relocated and monitored in the Kentucky Dam tailwater and to determine if methods of placement by divers affected survival and recovery, on 12 June 1993 we tagged 71 *Amblema plicata* and relocated them into a 1 x 15–m area marked with iron bars driven into the sediment at river mile 20.8. Thirty-nine were buried in a natural position and 32 were laid on the surface of the riverbed. On 1 October 1995, 45 of the tagged mussels were recovered. Survival was not dependent on burying the unionids. Only one zebra mussel was found in the area. This work indicates that unionids can be relocated and recovered successfully in the Kentucky Dam tailwater, and that the Tennessee River may be an excellent refuge for endangered unionids.

Introduction

The Kentucky Dam tailwater of the lower Tennessee River has the potential to provide unionid mussel a refuge from invading zebra mussels. This section of the lower Tennessee River between Kentucky Dam (river mile 22.4) and the Ohio River maintains a diverse unionid fauna and has few zebra mussels. Miller et al. (1992) reported 23 species. Sickel (1985) reported 36 species, four of which are federally endangered: *Cyprogenia stegaria, Lampsilis abrupta, Obovaria retusa,* and *Plethobasus cooperianus.* The densities of the endangered species are so low, however, that it is unlikely any reproduce successfully at this time (Sickel 1985). Relocation of some or all of these species from the Ohio River into the Tennessee River may help reestablish breeding populations, providing the appropriate fish hosts are present. The diversity and stability of the unionid fauna and the lack of zebra mussels make this area a potentially ideal refuge for endangered species.

Over 20% of the species of unionid mussels in North America are on the endangered species list (Cope and Waller 1995). About 7% of the pre-1900 fauna is extinct. Relocation into refugia may be the best, and possibly the only, action that will prevent many more species from becoming extinct. Not only will relocation salvage individuals that may otherwise be destroyed by zebra mussels, but it may increase the likelihood of reproductive success and the resulting reestablishment of self-sustaining populations in areas where prior pollution, overharvest, or habitat alteration have reduced populations to below viable densities.

Relocation as a means of conservation of unionids was evaluated by Cope and Waller (1995). They showed that recovery success of relocated individuals varied greatly with source and destination habitats and methods of relocation. Also, they suggested that further investigations were needed regarding the variables of aerial exposure, air temperature and relative humidity, methods of collection, handling and transport, depth changes, position in substrate, and methods of tagging. Sheehan et al. (1989) suggested that habitat

characteristics, water quality, and physiological condition of unionids must be considered in any relocation effort. Other relocation studies were reported by Dunn (1993) and Trdan and Hoeh (1993).

The need for a refuge from zebra mussels for unionids living in the Ohio River is critical. Since the invasion of the Ohio River in 1991, zebra mussel populations have increased exponentially (Sickel and Leek 1994; Sickel 1995b). In a recent survey of unionids at Ohio River mile 746.0 near Rockport, Indiana, Sickel (1995b) found zebra mussels attached to every unionid. On a sample of 26 *Fusconaia ebena*, the most abundant unionid at the site, the mean density of zebra mussels was 98.2/unionid (S.E. = 8.5). The dry tissue mass of those unionids was 30% less than that of the same species from the Tennessee River where no zebra mussels had attached. Although excessive mortality of unionids was not evident in the Ohio River, the apparently lowered tissue mass suggests reduced condition, which may interfere with reproduction (Sickel 1995b).

About the time in 1991 that zebra mussels were first discovered in the Ohio River, a commercial clammer pulled up a unionid with an attached zebra mussel in Kentucky Lake, about 8 miles upstream from Kentucky Dam (TVA 1991). As of fall 1995, even though zebra mussels are common in the lock chamber at Kentucky Dam, only about a dozen have been found in the Kentucky Dam tailwater of the Tennessee River. At river mile 16.8, Sickel (1995a) found only four zebra mussels in a quantitative sample of 5.25 m^2 and a qualitative sample area of 320 m^2.

We believe that the calcium ion concentration in the Tennessee River is below that required for successful reproduction and development of zebra mussels. Data from European studies indicate that zebra mussels are absent from lakes with less than 28.3 mg/l Ca^{++} and a pH below 7.3 (Ramcharan et al. 1992). Sprung (1987) reported that egg-rearing success decreased significantly in water with calcium below 40 mg/l, and was nil at 12 mg/l. Leek and Sickel (1995) reported Ca^{++} in Kentucky Lake water ranged from 16 to 24 mg/l, averaging around 18 mg/l, while Ohio River water ranged from 26 to 43 mg/l. If zebra mussels are not successful in the lower Tennessee River, sections of the river may be useful as refugia for translocated unionids.

The purpose of our study was to determine if unionid mussels in the Kentucky Dam tailwater could be relocated successfully and monitored for several years. The study also was designed to determine if method of placement of unionid mussels on or in the sediment by divers had any influence on survival and recovery.

Methods

On 12 June 1993, a site was selected in the Tennessee River downstream from Kentucky Dam. The site was located out of the navigation channel in a known unionid bed (Sickel 1985). The location was set by positioning the boat directly under the second set of power lines downstream from the Interstate 24 bridge, and by sighting upstream aligning the third bridge support from the left between the federal mooring cells (Figure 1). At the site, an area measuring 1 x 15 m was marked with nylon rope tied to four reinforcing bars that had been driven into the riverbed by divers using a slide hammer (Figure 2). Seventy-one threeridge (*Amblema plicata*) were obtained from Tennessee Valley Authority (TVA) divers, tagged with Floy pennant tags, marked with file marks, and placed either in or on the sediment within the marked area. Thirty-nine of the mussels were buried in the sediment in a natural position and 32 were laid on the surface of the riverbed.

Tags consisted of consecutively numbered, laminated, oval pennant tags from Floy Tag & Manufacturing, Inc. They measured 6.8 x 3.3 x 1.0 mm. On each mussel, a flat area on the left valve was filed clean and dabbed with surface prep on an applicator brush (Surehold Surface Prep from Barristo, Ltd.). A drop of super glue (Quicktite High Performance Super Glue, Lot 2KP036, from Loctite Corporation) was placed on the tag, and the tag was immediately pressed onto the shell and held in place for approximately 10 seconds. The surface prep contains trichloroethane which may serve only to evaporate and cool the surface, causing a molecular film of water to condense. This apparently causes the super glue to set more securely (pers. comm., Barristo, Ltd.)

On 1 October 1995, two divers, using SCUBA, searched the 1 x 15-m area collecting all unionids, dead or alive, lying on the sediment surface. Then the divers searched the area for unionids buried in the sediment. All mussels that could be found in approximately 1 hour were collected. The divers dug into the coarse gravel and sand sediment, but mussels deeply buried may have been overlooked. All mussels were identified, counted, and those with tags were noted. Discharge at Kentucky Dam was 20,000 cfs. The depth at the site was 3.5 m.

Results and Discussion

A total of 284 live (untagged) mussels and 144 empty shells (untagged) was found within the 1 x

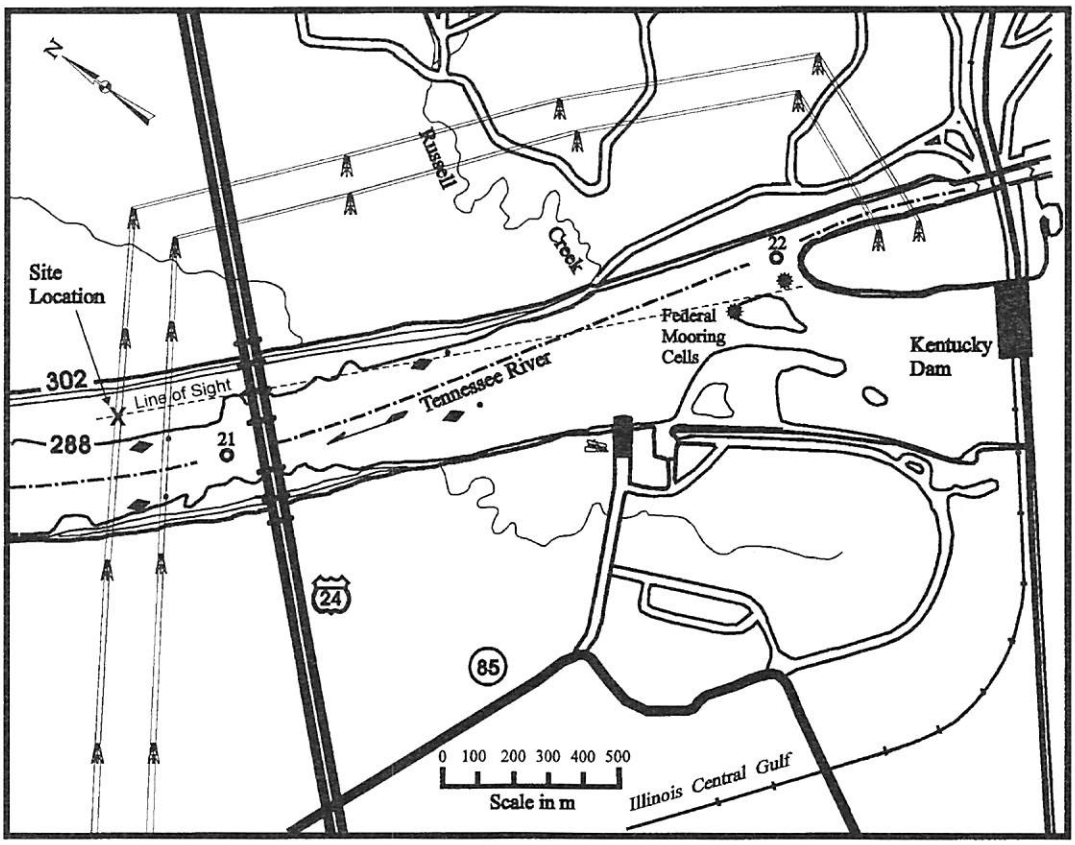

Figure. 1. Map of the Kentucky Dam tailwater section of the Tennessee River showing mussel relocation site (X) at river mile 20.8, under power lines and in line of sight with bridge support and federal mooring cells.

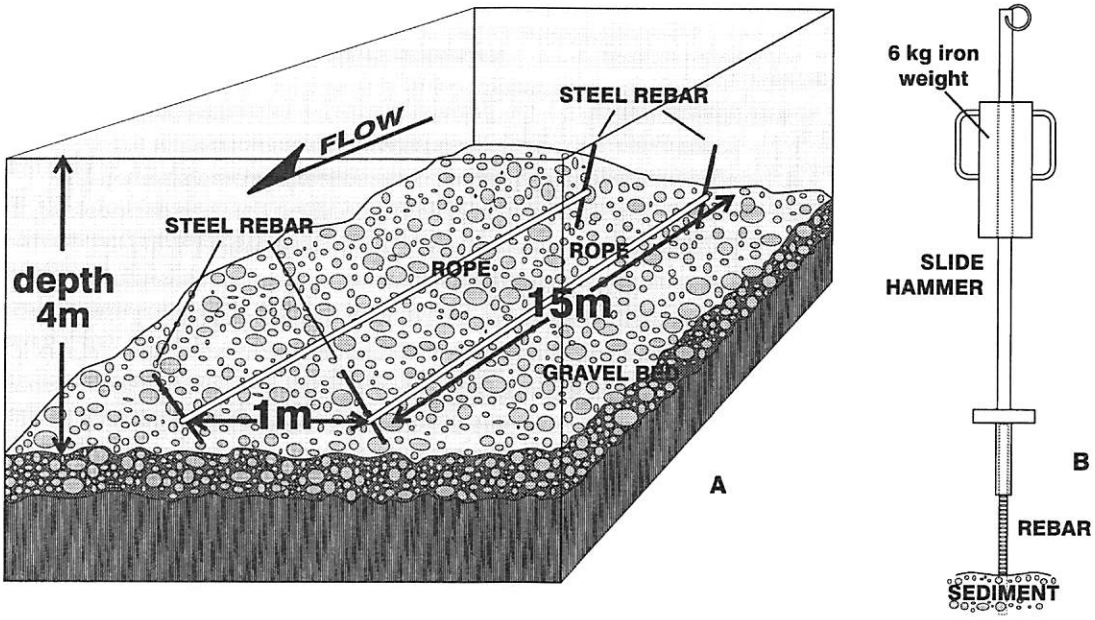

Figure. 2. A. Diagram of riverbed with 15-m^2 relocation site marked by rope attached to steel rebars driven into sediment. **B.** Slide hammer used to drive rebars into riverbed.

15–m area (Table 1) in addition to 45 of the original 71 tagged mussels. Table 1 shows the 15 species found within the 15-m^2 area and indicates whether they were found buried in a natural position in the sediment or not buried and laying on the surface. Of the original 71 tagged mussels, 45 were recovered with 42 being alive. The total of 326 live mussels found in the 15-m^2 area indicates a density of at least 22 mussels/m^2 living in the bed. Undoubtedly, more mussels were in the bed than were recovered. Earlier studies by Sickel (unpublished) indicate that unionid mussels, especially juveniles, in the lower Tennessee River sediments may bury themselves as deep as 0.5 m. We believe that more extensive searching at the site would recover more of the tagged mussels as well as more untagged mussels.

Table 2 shows the number of the original 71 tagged mussels that were recovered either buried in a natural position or lying on the sediment surface and either living or dead (empty shells). Among the tagged mussels that were recovered, a greater proportion was recovered live of those that had been originally laid on the surface (72%) than of those that were buried (49%). Of those originally buried, two (5%) were found dead, while of those not buried only one (3%) was found dead. The lower recovery of those that had been buried may have been possible because they were able to bury themselves deeper in the sediment, making recovery more difficult. We don't believe the difference in survival and mortality between those buried and those not buried is significant, but we did not determine this

Table 1. Native mussels (not tagged) collected in mussel bed within 15-m^2 relocation site on 1 October 1995 in the Kentucky Dam Tailwater.

	Buried in Sediment		Not Buried in Sediment	
SPECIES	Live	Dead	Live	Dead
Amblema plicata	25	0	5	12
Arcidens confragosus	1	0	0	0
Cyclonaias tuberculata	15	0	0	0
Ellipsaria lineolata	4	0	0	1
Elliptio crassidens	1	0	0	0
Elliptio dilatata	3	0	0	1
Fusconaia ebena	181	10	0	101
Leptodea fragilis	1	0	0	0
Megalonaias nervosa	3	0	1	0
Obliquaria reflexa	3	0	1	3
Pleurobema cordatum	5	0	3	1
Potamilus alatus	1	0	0	1
Quadrula pustulosa	21	0	0	12
Quadrula quadrula	10	0	0	1
Truncilla truncata	0	0	0	1
TOTALS	274	10	10	134

Table 2. Record of tagged mussels that had been either buried (B) in a natural position in the sediment or laid on their side on the sediment surface (NB) within a 1 x 15-m area in the tailwater reach of Kentucky Dam on 12 June 1993 and recovered on 1 October 1995.

Original Condition	Number Tagged	Number Recovered	Condition of Recovered Mussels			
			Live B	Live NB	Dead B	Dead NB
Buried (B)	39	21	19	0	1	1
Not Buried (NB)	32	24	22	1	0	1
TOTALS	71	45	41	1	1	2

because we do not know the fate of the unrecovered tagged mussels.

The study area consists of an established mussel bed with a high diversity of mussels. No endangered species were found within the 15-m^2 site, but two individuals of *Plethobasus cooperianus* were observed by Sickel (1985) nearby, and a *Lampsilis abrupta* was observed approximately 800 m upstream (Sickel 1987). Only one zebra mussel, *Dreissena polymorpha*, was found in the 1 x 15–m relocation area. It was attached to a dead, untagged *Amblema plicata*. There is no indication that zebra mussels are reproducing in the lower Tennessee River. This makes the area an excellent site for relocating endangered species to protect them from zebra mussels and to attempt to reestablish reproducing populations of endangered unionids in the lower Tennessee River.

How many individual mussels of a particular species must be present in a community for that species to survive? No one knows for sure. Lynch et al. (1995) suggested that far more than 1,000 breeding adults are required in an animal population to prevent what they call "mutational meltdown," which leads to extinction. If this number is anywhere near accurate for unionid mussels, most endangered species and many rare species are headed for extinction unless efforts are initiated soon to concentrate individuals to increase chances of reproductive success and to build population numbers. We believe that the Kentucky Dam tailwater provides a location of stable substrate, free from zebra mussels and commercial harvest, and capable of being monitored where endangered and rare species can be placed in an attempt to recover reproducing populations provided appropriate fish hosts are present.

Conclusions

Unionid mussels can be relocated successfully with a high survival and recovery rate in the Kentucky Dam tailwater of the Tennessee River. The reach from the dam at river mile 22.4 to mile 17.8 is a state-designated mussel sanctuary that prohibits commercial harvest. Discharge at Kentucky Dam can be regulated to provide low-flow conditions during diving operations. The Interstate 24 bridge provides a barrier that prevents barge traffic over the bed selected for this study. The bed has a high diversity of mussels, indicating a healthy environment. Endangered species are known to occur in the area. Zebra mussels are present in low numbers and do not appear to be reproducing, possibly because of the low calcium concentration. This combination of factors makes the Kentucky Dam tailwater an excellent site for relocation projects aimed at conserving rare and endangered species of unionid mussels.

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