# APPENDIX 2

## FACTORS PROTECTING UNIONIDS FROM ZEBRA-MUSSEL INDUCED MORTALITY AT METZGER MARSH, LAKE ERIE

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Although the presence of native unionids in a freshwater wetland is of interest, the larger question concerning this population is what mechanisms prevented zebra mussels from infesting and eliminating these animals. Zebra mussels are believed to have initially invaded this area around 1990. Those collected at Metzger Marsh ranged in size from 1 to 40mm indicating an established population that was overwintering and successfully reproducing. However, less than 1% of the unionids removed from this site during dewatering were encrusted by zebra mussels or showed any signs of previous infestation (i.e., byssus threads).

The unionids found at Metzger Marsh were not randomly distributed in the wetland. Most of the thick-shelled, less-motile native mussels, such as *Amblema plicata* and *Quadrula spp.*, were found in just 5 locations (Figure 1). The distribution of the thin-shelled, very motile native mussels before dewatering could not be determined because thin-shelled species such as *Leptodea ftagilis* and *Pyganadon grandis* followed the water during drawdown. The five sites where the thick-shelled species occurred had shallow water depth (<0.5 m) and substrate (soft silt-clay). The sediment had a soft, pudding-like consistency with an average organic content of 100/o (range 9.63-11.65%); 55% of the sediment had a grain size <500 microns. Two of the sites contained sparse submersed vegetation. Site "A" (see Figure 1) contained the greatest diversity of unionid species and the oldest unionids of any site in the marsh.

Live unionids were not found in all of the areas that contained zebra mussels. No five unionids were collected in the area covered by a solid layer of zebra mussels. Water depth in this area was the same as found in sites where live unionids were collected, but the underlying substrate consisted of coarse sand-gravel. The area containing individual clusters of zebra mussels did overlap four out of the five sites where live native mussels of all ages were collected Figure 1). The substrate there consisted of soft silt-clay interspersed with a few sand bars.

There are two basic methods that disperse zebra mussels throughout a habitat. The first is through the planktonic drifting of mussel larvae, allowing contact with suitable colonization substrates some distance from the adult population. The second method is through direct transfer or translocation of juvenile mussels, either by attachment to drifting material or by actual movement onto a new substrate'. We believe that the surviving native mussels at Metzger Marsh were not susceptible to infestation by translocation of juvenile mussels because these unionids did not occur in areas of high juvenile density. However, unionids should be susceptible to infestation by planktonic larvae, since all other types of hard substrate in the same area were colonized. The lack of zebra mussel infestation indicates some type of behavioral mechanism by which the unionids remained separate from drifting zebra mussel larvae or were able to remove attached zebra mussels. Field observations indicated that unionids at Metzger Marsh burrowed 2-40 cm into the sediment for at least part of the day. Our initial hypothesis was that the soft, silt-clay sediments encouraged burrowing behavior and thus protected the unionids from zebra mussel infestation.

Laboratory tests of this hypothesis involved placing unionids in aquaria containing 20 cm of soft sediment collected from site *"A"* in Metzger Marsh (live unionid site) and coarse sand from the site of extensive zebra mussel colonization (no live unionids). We then determined the rate and depth of burrowing over a 24-hour period. Fitly thick-shelled *Amblema plicata* and thin-shelled *Leptodea fragilis* collected from Metzger Marsh were randomly selected. Two size classes of each were used, 25 unionids with a shell length <60 mm and 25 individuals >120 mm. Tests were conducted initially at ambient laboratory temperatures (22°C). There was no difference in burrowing behavior of these bivalves in the two types of substrate, but there was a difference in behavior between size classes of unionids. Small individuals of both species burrowed completely within 4 hours of being placed in either type of substrate, with only a thin edge of the posterior shell remaining visible. Large individuals of both species (> 120 mm) burrowed less than 10 mm in either type of sediment even after 24 hours; the posterior half of the clan shell remained exposed. However, when water temperatures were raised to 27°C, large individuals of both species burrowed as rapidly and as deeply in either type of substrate as small ones. This warmer temperature is consistent with water temperatures recorded on a continuous thermograph set in Metzger Marsh.

Since unionids were capable of burrowing in either type of sediment but live individuals were collected only from the soft sediments in the wetland, a second test was performed to explore potential limitations of burrowing caused by zebra mussel infestation. The same substrates and physical conditions described above were used to test zebra mussel-encrusted unionids collected from Lake Michigan in Green Bay, Wisconsin. One size (>120 mm) of one species *(Amblema plicata)* was tested at 27°C. The number of zebra mussels on each of 15 animals ranged from 20 to 150.

Burrowing behavior of these encrusted unionids was different than the behavior of the non-encrusted unionids collected from Metzger Marsh. On the coarse sand-gravel, the zebra mussel-encrusted unionids were unable to burrow successfully in the sediment (Figure 2a & b). Burrowing started and continued until the first layer of zebra mussels cane in contact with the sand; the unionids could burrow no further. However, these same unionids burrowed completely when placed in the soft sediments, carrying zebra mussels under the sediment with them (Figure 2c & d). The fate of these buried zebra mussels varied. Initially, most died after 24 hours in the sediment, likely as a result of their inability to tolerate low levels of oxygen. The mortality rate dropped dramatically when the sediments in the aquaria were aerated. The movement of the native mussels in and out of the soft sediment also frequently dislodged small clusters of zebra mussels attached to shells.

We used a combination of field observations with laboratory experiments to show that warm water temperatures and the soft, silt/clay sediments common to wetlands trigger complete burrowing of unionids. This provided a spatial separation that discourages infestation by zebra mussels and also served as a physical cleansing mechanism to remove any encrusted mussels.

Based on these laboratory experiments, we now believe that native clams have been protected from zebra mussel infestation at Metzger Marsh by the interaction between temperature and sediment type. The warm water temperatures at this shallow wetland (>27°C) encourage complete burrowing by the unionids during summer months. This provides spatial separation that would discourage some zebra mussel infestation. However, warm water alone is not sufficient to discourage infestation. Otherwise, live unionids would have been found in all types of substrate. The key factor in unionid survival is the soft sediment. If the native clams do become colonized by zebra mussels, burrowing can still occur in the soft sediments but not in the coarser sand. The ability to burrow not only protects the clams from adverse environmental conditions such as warm summer temperatures and winter freezing, it also serves as a cleansing mechanism to remove encrusted zebra mussels.

A number of lake-connected wetlands along the coast of Lake Erie have physical conditions similar to those found in Metzger Marsh. Following discovery of clams at Metzger Marsh, surveys were conducted at similar areas in the Great Lakes. Live unionids were found at five other locations, including one in Lake St. Clair, one in Crane Creek estuary adjacent to Metzger Marsh, one at Stone Laboratory in western Lake Erie, and the other tow in eastern Lake Erie. These discoveries of coexisting zebra mussels and clams do not lessen the crisis faced by unionids in the wake of the zebra mussel invasion of North America. However, they do give promise that at least some brood stock remains available that could recolonize Lake Erie if zebra mussel populations ultimately decline. Wetlands may provide an additional tool for intensive management of native clam stocks, ensuring survival of these animal in the Great Lakes and other regions invaded by zebra mussels.

For Further Information:

1. Nichols S. J. and Wilcox D.A. 1997. Coexistence of zebra mussels and native clams in Lake Erie wetlands. Nature. 389:921.
2. Nichols S. J. and Amberg J. 1999. Co-existence of zebra mussels and freshwater unionids: population dynamics of Leptodea fragilis in a coastal wetland infested with zebra mussels. Canadian Journal Zoology. 77:423-432.

**Figure 1**.
Distribution of zebra mussels and thick-shelled unionids collected from Metzger Marsh, western Lake Erie, 1996. "Dense zebra mussels" refers to areas where extensive colony mats covered the substrates and "scattered zebra mussels" to areas where minimal substrate colonization occurred by all other objects (vegetation, rocks, logs, etc.) were colonized with the exception of the unionids. "A" marks the site where the oldest and largest individuals of all species were collected.

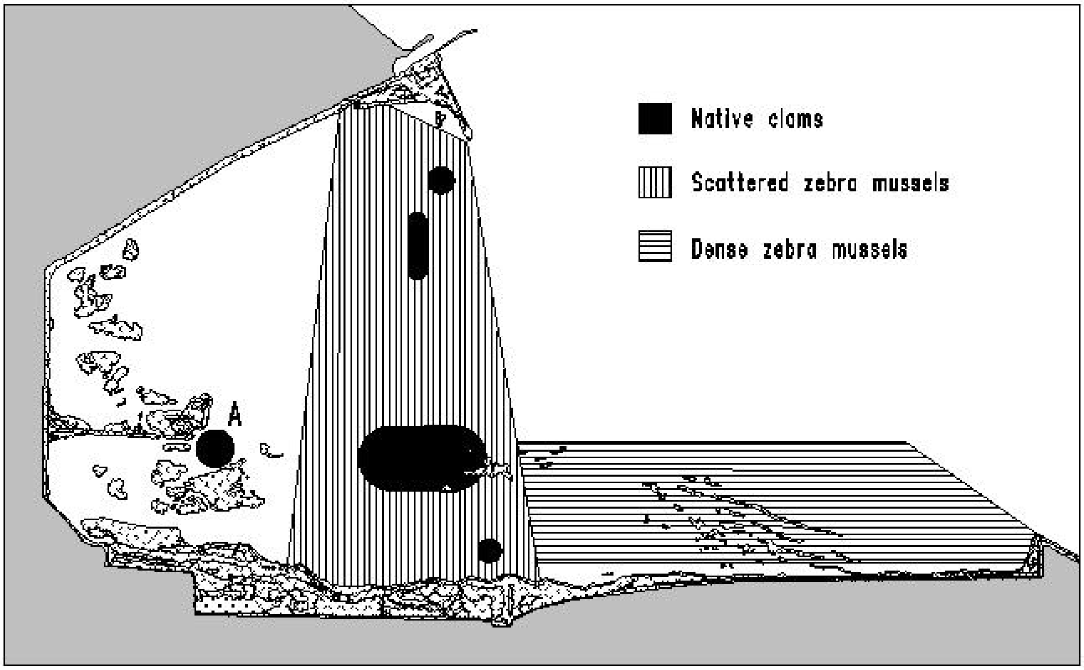

**Figure 2**.
Unionids encrusted with zebra mussels were placed on sediments collected from Metzger Marsh (A, B). (C) After 24 hours, unionids on coarse sand-gravel had burrowed only to point where the sediment was in contact with the zebra mussels. (D). After 24 hours on the soft silt-clay, the unionid burrowed completely, also burying the zebra mussels.