Nichols 1998

USGS
Biological Resources

Biological Information & Technology Notes

No. 98-010
March 1998

Coexistence of Zebra Mussels and Native Clams in Lake Erie Wetlands

A version of this BIT Note originally appeared in the October 1997 issue of *Nature* 389:6654.

One of the most devastating ecological problems resulting from the recent invasion of North America by zebra mussels *(Dreissena polymorpha)* has been the virtual elimination of native clams or unionids from infested waters. Zebra mussels readily colonize clam shells, disrupting feeding, movement, and reproduction;[1] clams generally die within 1 to 2 years after infestation. This die-off has been well documented in the Great Lakes,[2,3] with near total mortality reported throughout most of western Lake Erie.[4]

Introduction

In 1996, we discovered a large population of native clams in a western Lake Erie wetland that showed little sign of infestation despite zebra mussel colonization of the site since about 1990. We then combined field observations with laboratory experiments to show that warm summer water temperatures and soft silt-clay sediments common to wetlands trigger complete burrowing of clams—providing spatial separation that discourages infestation and also serving as a physical cleansing mechanism to remove encrusted zebra mussels. Subsequent discovery of live clams in other wetlands further indicates that wetlands may provide refugia for maintaining native clam stocks in waters colonized by zebra mussels.

Study Site

Metzger Marsh is a lake-connected wetland located 48 km east of Toledo, Ohio. Prior to 1940, portions of this 360-ha site were diked, actively farmed, and then abandoned and allowed to revert back to wetland. The wetland embayment was protected from storm activity by a barrier beach, which gradually eroded as sediment supply decreased due to progressive armoring of the shoreline of the lake. By 1990, much of the original wetland had eroded also. In 1994, a consortium of Federal, State, and private organizations joined forces to restore the wetland and provide improved habitat for fish and wildlife. A dike was constructed across the opening of the embayment to mimic the protective function of the lost barrier beach, with plans to dewater the wetland to promote seed germination and growth of emergent plants. Following 2 years of drawdown, a water-control structure placed in the dike to mimic the natural barrier opening would be opened to restore hydrologic connection with the lake.

Large Population of Zebra Mussels Found At Study Site

Surveys of the biota before construction of the dike identified a large population of zebra mussels in the lakeward half of the site (Fig. 1). Two types of zebra mussel colonization occurred: (1) extensive layers, several centimeters thick, totally covering the substrate; and (2) individual clusters of mussels limited to hard structures such as logs, rocks, or vegetation. The area totally covered by zebra mussels extended about 150 m × 300 m (Fig. 1). Five live native unionids representing two species—mapleleaf (*Quadrula quadrula)* and fragile papershell *(Leptodea fragilis)*—were also found in the surveys. Since so few unionids were collected and the entire area was colonized by zebra mussels, it seemed likely that only a small remnant clam population was present. However, the dewatering process later exposed a clam population far more extensive than expected.

Native Unionids Thriving

A total of about 6,000 unionids of 21 species, representing a small fraction of those present, were collected and relocated during dewatering. Included were three State of Ohio threatened species (Table). The unionid species assemblage was similar to that found in the open waters of Lake Erie before the zebra mussel invasion.[4] However, most of the species collected in Metzger Marsh have never been reported as occurring in wetlands. The age structure of the population indicates that this wetland habitat has successfully supported clams for years. Most species were represented by animals ranging in size from less than 10 mm to more than 240 mm. Estimates based on shell sections indicate that clams ranged in age from 1 year to more than 40 years. Further evidence of habitat suitability comes from observations on reproductive status. Every adult female clam examined, regardless of species, was in reproductive condition when collected, containing either glochidia or gametes.

Although the presence of native unionids in a freshwater wetland is of interest, the larger question concerning this population is determining 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 40 mm, indicating an established population that was overwintering and successfully reproducing. 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).

Unionid Distribution Varied

The unionids found at Metzger Marsh were not randomly distributed in the wetland. Most of the thick-shelled, less motile clams such as threeridge (*Amblema plicata*) and *Quadrula* spp. were found in just five locations (Fig. 1). Distribution of the thin-shelled, very motile clams before dewatering could not be determined because thin-shelled clams such as fragile papershell and giant floater (*Pyganodon grandis*) followed the water during drawdown. The five sites where the thick-shelled clams occurred had similar water depth (1 m) and substrate (soft silt-clay). The sediment had a soft, pudding-like consistency with an average organic content of 10% (range 9.63% to 11.65%); 55% of the sediment had a grain size less than 500 microns. Two of the sites contained sparse submersed vegetation. Site A (Fig. 1) contained the greatest diversity of unionid species and the oldest clams of any site in the marsh.

Live unionids were not found in all of the areas that contained zebra mussels. No live 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 clams were collected, but the underlying substrate consisted of coarse sand-gravel. The area containing individual clusters of zebra mussels did overlap four of the five sites where live native clams of all ages were collected (Fig. 1). The substrate there consisted of soft silt-clay interspersed with a few sand bars.

Two basic methods 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 is through direct transfer or translocation of juvenile mussels, either by attachment to drifting material or by actual movement onto a new substrate.[5] We believe that the surviving native clams at Metzger Marsh were not susceptible to infestation by translocation of juvenile mussels because these clams did not occur in areas of high juvenile density. However, clams 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 clams 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 to 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 clams from zebra mussel infestation.

Laboratory Testing Confirms Burrowing Hypothesis

Laboratory tests of this hypothesis involved placing clams 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 clam burrowing over a 24-h period. Fifty thick-shelled threeridge and thin-shelled fragile papershell collected from Metzger Marsh were randomly selected. Two size classes of each were used: 25 clams with a shell length less than 60 mm and 25 clams greater than 120 mm. Initial tests were conducted at ambient laboratory temperatures (22 °C). There was no difference in burrowing behavior of clams in the two types of substrate, but there was a difference in behavior between size classes of clams. Small clams of both species burrowed completely within 4 h of being placed in either type of substrate, with only a slim edge of the posterior shell remaining visible. Large clams of both species (greater than 120 mm) burrowed less than 10 mm in either type of sediment—even after 24 h the posterior half of the clam shell remained exposed. When water temperatures were raised to 27 °C, large clams of both species burrowed as rapidly and as deeply in either type of substrate as did small clams. This warmer temperature is consistent with summer water temperatures recorded on a continuous thermograph set in Metzger Marsh.

Because clams were capable of burrowing in either type of sediment but live clams 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 clams collected from Lake Michigan in Green Bay, Wisconsin. One size (greater than 120 mm) of one species (threeridge) 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 clams was different than the behavior of the non-encrusted clams collected from Metzger Marsh. On the coarse sand–gravel, the zebra mussel-encrusted clams were unable to burrow successfully in the sediment (Figs. 2a, b). Burrowing started and continued until the first layer of zebra mussels came in contact with the sand; the clams could burrow no further. However, these same clams burrowed completely when placed in the soft sediment, carrying zebra mussels under the sediment with them (Fig. 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.[6] The mortality rate dropped dramatically when the sediments in the aquaria were aerated. The movement of the native clams in and out of the soft sediment also frequently dislodged small clusters of zebra mussels attached to shells.

 http://biology.usgs.gov/news/98-010.htm

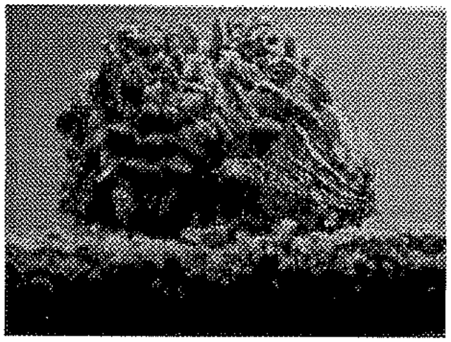

Figure 2a

Figure 2b

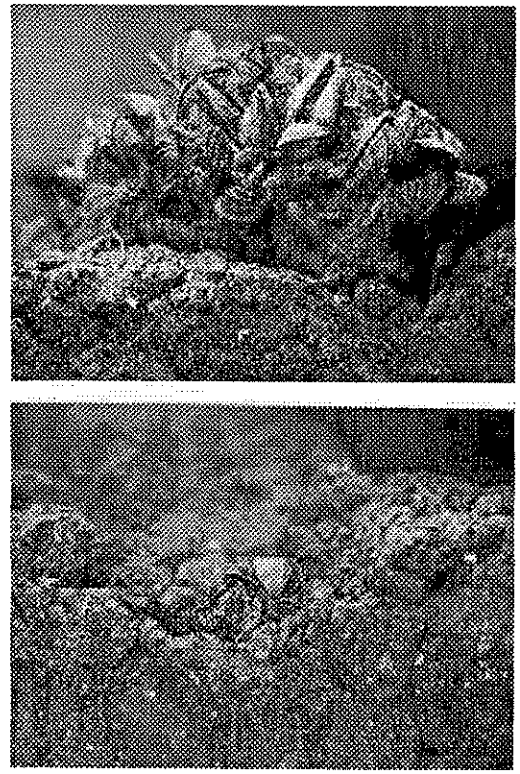

Figure 2c, 2d

Figure 2. Clams encrusted with zebra mussels were placed on sediments collected from Metzger Marsh (2a, c). After 24 hours on coarse sand-gravel, clams burrowed only to the sediment contact with the zebra mussels (2b). On the soft silt-clay, clams burrowed completely, also burying the zebra mussels (2d).

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 (greater than 27 °C) encourage complete burrowing by unionids during summer months. This behavior 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.

Wetlands Critical to Future of Great Lakes Unionids

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, we searched for and found live unionids or fresh shells at three other wetlands. 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

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Common name	Scientific name
Threeridge	*Amblema plicata*
Spike	*Elliptio dilatata*
Wabash pigtoe	*Fusconia flava*
Plain pocketbook	*Lampsilis cardium*
Lake Pepin mucket	*Lampsilis r. luteola*
White heelsplitter	*Lasmigona complanata*
Fragile papershell	*Leptodea fragilis*
Three-horn wartyback	*Obliquaria reflexa*
Hickorynut	*Obovaria olivaria*
Ohio river pigtoe	*Pleurobema sintoxia*
Pink heelsplitter	*Potamilus alatus*
Giant floater	*Pyganadon grandis*
Pimpleback	*Quadrula pustulosa*
Mapleleaf	*Quadrula quadrula*
Squawfoot	*Strophitus undulatus*
Lilliput	*Toxolasma parvus*
Fawnsfoot	*Truncilla donaciformis*
Deertoe	*Truncilla truncata*
Pondhorn	*Uniomerus tetralasmus*
Paper pondshell	*Utterbackia imbecilis*

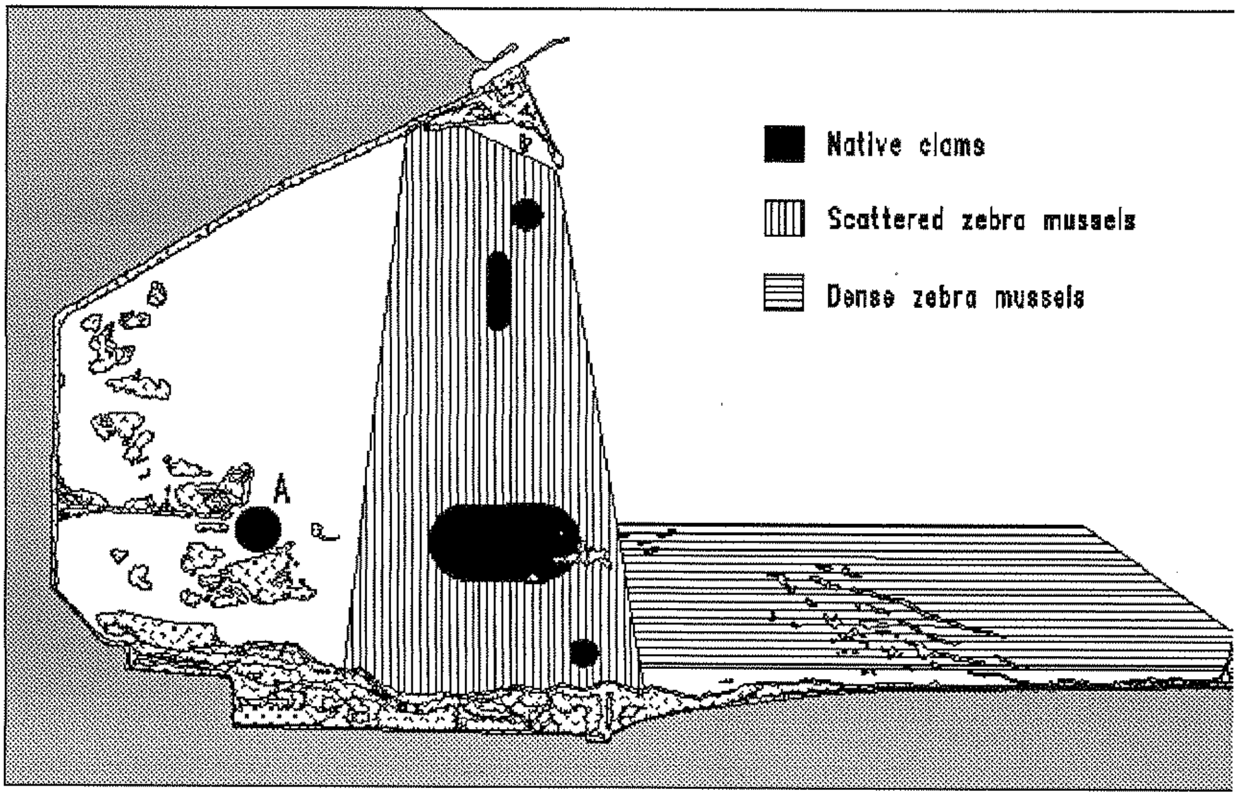

Figure 1. Distribution of native clams and zebra mussels in Metzgar Marsh, 1996.

tool for intensive management of native clam stocks, ensuring survival of these animals in the Great Lakes and other regions invaded by zebra mussels.

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Table. Species of live native clams collected at Metzger Marsh, Lake Erie, in 1996.

X-Sender: croftja@mail.vt.edu
Date: Thu, 09 Apr 1998 15:33:42 -0400
To: mussel, biota, mvaughan@vtvm1
From: Jill Croft <croftja@mail.vt.edu>
Subject: New BIT Note

>Date: Thu, 9 Apr 1998 13:11:20 -0600
>From: Terry_Derchia@usgs.gov (Terry Derchia)
>Subject: New BIT Note
>To: nbs-news-internal@cbi.cr.usgs.gov
>Sender: owner-nbs-news@cbi.cr.usgs.gov
>
> BIT Note No. 98-010, "Coexistence of Zebra Mussels and Native Clams in
> Lake Erie Wetlands," is now available on the BRD Web site at
> <http://biology.usgs.gov/news/98-010.htm>.
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Psalm 37:4--Delight yourself in the Lord and He will give you the desires
of your heart.