

**Final Report: EFFECTS OF HYDROLOGY ON ZEBRA MUSSELS AND UNIONIDS IN  
A LAKE ERIE COASTAL WETLAND**

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**Introduction**

North America has the highest number of unionid species in the world with about 300 species (Bogan 1993, Parmalee and Bogan 1998, Nedeau et al. 2000, Cummings and Mayer 1992). Seventy-eight species occur in Ohio, and Herdendorf (1987) lists 35 species in western Lake Erie coastal wetlands and nearshore areas. Unfortunately, about 75% of unionid species are threatened (Williams et al. 1993). Although greatest declines have occurred in the southeastern United States (Bogan 1993), 49 of Ohio species are at risk of extinction (Bogan and Cummings 2001).

Unionid populations have declined in the United States because of the effects of impoundments, commercial exploitation, pollution, and siltation (Waller et al. 1999, Bogan 1993, Brim-Box and Mossa 1999). Furthermore, non-native species such as the zebra mussels, *Dreissena polymorpha*, have also caused drastic declines in unionid populations (Schlosser and Nalepa 1994, Ricciardi et al. 1996, Brim-Box and Mossa 1999, Strayer 1999, Strayer and Smith 1996, Ricciardi et al. 1998). Zebra mussels were introduced into the Great Lakes in 1986 and have spread throughout North America (Schlosser and Nalepa 1994, Ricciardi et al. 1996). Both unionids and zebra mussels filter feed on diatoms and detritus (Thorp and Covich 1991). Zebra mussels affect

unionids by biofouling (Ricciardi et al. 1996), and they can out-compete unionids for food (Strayer and Smith 1996). Zebra mussels have been implicated as one of the primary causes for recent dramatic decreases in unionids throughout the Great Lakes (Ricciardi et al. 1996).

Zebra mussels are endemic to Eurasia in the Black, Caspian, and Aral seas where they can be one of the most abundant benthic organisms (Strayer 1999). They have a 3-5 year lifespan and reproduce after 1-2 years (Marsden 1992). Zebra mussels reproduce when water temperatures are  $>10^{\circ}\text{C}$ , and they spawn in Lake Erie in late July and late August (Garton and Haag 1990). Females release 30,000 to 40,000 eggs that are fertilized in the water column and form planktonic larvae called veligers (Marsden 1992). When veligers reach a size of 180-250  $\mu\text{m}$  they attach to solid substrates with protein threads called byssal threads. Although veligers can settle on soft substrates, they usually only survive when they attach to hard surfaces (Strayer 1999) because zebra mussels are susceptible to being buried or dislodged (Toczowski 1999, Karatayev 1998, MacIsaac 1996).

We conducted a study in Crane Creek Marsh, which is a coastal wetland in western Lake Erie. Empty shells of 17 unionid species were collected on the shoreline of this marsh in summer 2000 (F. de Szalay, pers. observ.), but it was not known how many species still inhabited this wetland. Because unionid numbers in the Great Lakes are declining, determining the characteristics of habitats that still have unionids is important for the preservation and management of these animals. We examined factors that affect unionids and zebra mussels in Crane Creek Marsh. In summer 2001, we examined the following questions: 1. what are the distributions of unionid mussels; 2. how does water

depth affect unionid and zebra mussel distributions, and; 3. what are the densities of zebra mussels on unionids?

## Methods

### Site Description

Lake Erie has 268 km<sup>2</sup> of coastal wetlands, which is the least amount of coastal wetlands of all the Great Lakes (Herdendorf 1987). Crane Creek Marsh is found in Ottawa National Wildlife Refuge about 27 km east of Toledo and is managed by the U.S. Fish and Wildlife Service. Ottawa National Wildlife Refuge is managed to optimize wildlife habitats using internal dikes and water pumping systems. A partial dike protects Crane Creek marsh from storm and wave activity in Lake Erie, but a permanent opening allows Lake Erie water fluctuations to affect marsh water levels.

### Unionid Survey

We created a map of Crane Creek Marsh with GIS software (ARCVIEW, ESRI, Redlands, CA) and a satellite image of the marsh (<http://terraserver.homeadvisor.msn.com>). Lake Erie water levels decrease in late summer, which exposed many mudflats in Crane Creek Marsh. On 15 September 2001, we used a GPS unit (Trimble Geoexplorer3, Sunnyvale, CA), to map the perimeter of all mudflats and incorporated this into the map.

Water levels in Crane Creek Marsh were measured every 30 minutes from late May to the end of July using a water level data logger (Global Water, Model WL 14X). Although mussel sampling (see below) continued until August 2001 the logger malfunctioned on 29 July 2001, and no water level data was collected after that date.

We determined our unionid mussel sampling locations by first overlaying a grid onto the map using AutoCAD software (Autodesk, San Rafael, CA). Each square in the grid was one 50 m x 50 m area of the marsh. Next, we subdivided the entire grid into subregions that each comprised 9 squares in a 3 x 3 arrangement. We randomly selected one square from each of the subregions as a sample plot (77 plots total). We uploaded the coordinates of all sample plots into a GPS unit and used this to find their locations in the field (Figure 1).

Teams of 3-6 people searched for mussels within each sample plot (i.e. a 50 m x 50 m area). Wooden stakes were used to mark the corners of the plot, and teams conducted tactile searches for a total of four person hours per plot. We manually probed the substrate to locate live mussels and collected them in a mesh bag. Although this method did not give us an exact measure of density (i.e. we probably did not find all mussels per plot), more accurate methods (e.g., Quadrat and Transect line studies; Smith et al. 2001, Metcalf-Smith and Di Maio 2000) are much more labor intensive and were not feasible due the size of the marsh.

We identified all mussels in the field, measured shell length, counted attached zebra mussels, and visually estimated the percent cover of byssal threads. We used Cummings and Mayer (1992), Parmalee and Bogan (1998), Watters (1993) and a reference collection from the Cleveland Museum of Natural History to identify the mussels to species. We also estimated mussel age by counting annuli, which are the visible growth lines on their shell (Day 1983, Metcalf-Smith & Green 1992, Veinott & Cornett 1995, McCuaig & Green 1982). Shells from recently dead animals were also collected to document additional species that were not found in the sampling plots. We also classified species as thick-shelled or thin-shelled to examine if this affected their

distribution. We based this on information in the species descriptions in Cummings and Mayer (1992).

Water levels were measured in the corners of each sampling plot to determine the average depth. We also measured the deepest depth in each sample plot. These depths will be standardized using the data from the water level logger for samples collected before July.

### **Zebra mussel colonization**

We measured the colonization rates of zebra mussel veligers using PVC plates (15 cm x 15 cm) as an artificial substrate. The surfaces of the colonization plates were roughened with sandpaper to create a suitable attachment surface (Marsden 1992). Because veligers prefer to settle on surfaces with biofilm (i.e. a matrix of bacteria and algae), we conditioned the colonization plates for 14 days in 36.8 L plastic containers in filtered marsh water to allow the biofilm to develop. The containers were held on the shore in a shaded area near the outlet to the marsh, and they were covered to prevent rainwater from overflowing the tubs.

On 22 June, we placed colonization plates in Crane Creek Marsh at four locations: 1. in the creek above the marsh; 2. in the creek channel where it enters the marsh; 3. in the creek channel midway towards the mouth of the marsh at Lake Erie; and, 4. at the opening of the dike where the marsh was connected to Lake Erie. At each location, we placed 12 upright wooden stakes spaced one meter apart along a 12-m transect. On each stake, we attached one colonization plate at each of three water depths (3 plates/stake). Water depths were 1 cm, 17 cm, and 34 cm depth below the surface. After two weeks, the plates were removed and preserved with ethanol in a sealed plastic bag. Zebra

mussels were counted in the laboratory under a dissecting scope using 20X magnification.

We used a cage experiment to determine survivorship of zebra mussels in different water depths. We built cages (312 cm<sup>3</sup>) with galvanized metal screening (mesh size 0.5 cm). We placed 12 upright wooden stakes one meter apart along a 12-m transect near the opening of the marsh at location 4 of the colonization plate experiment (see above). Adult zebra mussels (2.5-3.5 cm) were collected on 15 September 2001 from riprap along the creek channel in Crane Creek Marsh and were held overnight in an aerated plastic container. On 16 September we put 10 zebra mussels in each cage and attached three cages to each stake at 1cm, 17 cm, and 34 cm below the water surface. Cages remained in the marsh from 16 September to 13 October 2001, and living and dead zebra mussels were counted every week.

## **Results**

### **Unionid survey**

We found 14 species of mussels in Crane Creek Marsh (Table 1). One additional species, *Utterbackia imbecillis*, was not collected during the survey but two live animals were later observed in the marsh. *Quadrula quadrula* was the most abundant species (comprising 42% of the population) and *Leptodea fragilis* and *Amblema plicata* made up 24% and 18% respectively of the population. Four other species were listed by Ohio as threatened species or species of special concern.

Mussels were dispersed throughout Crane Creek Marsh and had the highest abundance in the creek channel (Figure 2). Few were found in shallow areas that became

mudflats in late summer. Thin-shelled species were widely dispersed across the entire marsh (Figure 3), but thick-shelled species were restricted to the creek channel (Figure 4). Unionids were most abundant in deeper depths. For example, mean total density was 55 unionids/plot in >34 cm water depths, but mean densities were only 5 and 11 unionids/plot in water depths of 1-17 cm and 18-34 cm, respectively (Figure 5). Almost all thick shelled species were found at the deepest water depths. The age structure of the unionids indicated that active recruitment occurred in the marsh (Figure 6). For example, 30% of the population was only 1-5 years in age. Ages ranged from 1 to 28 years old.

### **Zebra mussel colonization and survivorship**

The highest numbers of zebra mussel veligers colonized plates at the deepest water depths (Figure 7a-d). For example, at site 4 no zebra mussels were found on plates at 1-17 cm depth, 10 zebra mussels/plate occurred at 18-34 cm depth, and 195 zebra mussels/plate occurred at >35 cm depth (Figure 7). Adult zebra mussels also had the highest survival rate in the deepest water depths. For example, all zebra mussels died within one week in cages held at 1-17cm depths, but 27% of zebra mussels survived at 18-34 cm, and 95% of zebra mussels survived the deepest depths (Figure 8).

Although zebra mussels are colonizing the marsh, unionids in Crane Creek Marsh had low numbers of live zebra mussels attached on their shells. Seventy-seven percent of the population had no attached live zebra mussels, and 92% had <10 zebra mussels on their shell (Figure 9). In contrast, percent byssal thread cover showed that >60% of the population had attached zebra mussel in the past (Figure 10).

## **Discussion**

The evenly dispersed age structure and abundant juvenile unionids indicates that active recruitment is occurring and adult survival is high (Nedea et al. 2000). Furthermore, Bertram and Stadler-Salt (2000) considered coastal marshes with >12 species of unionids, low numbers of dreissenid mussels, and young unionids to be good quality ecosystems. Crane Creek Marsh meets all these criteria and by these standards is a relatively good quality unionid habitat. This suggests that this marsh is an important refugia for unionids that have been eliminated from Lake Erie by zebra mussels.

Studies show that zebra mussels will often eliminate unionids when they are found in the same habitat (Strayer and Smith 1996, Schlosser and Nalepa 1994). In Crane Creek Marsh, unionid densities and numbers of zebra mussels on colonization plates are both highest at water depths >35 cm. Byssal threads are found on most unionids but relatively few live zebra mussels were found infesting unionids. Apparently zebra mussels are colonizing unionids but do not survive to build up to high numbers on the unionid shells. We found many older mussels that have lived in the marsh since before zebra mussels were introduced to Lake Erie. This indicates that the potential habitat overlap between unionids and dreissenids may not be having a direct impact on the unionid community. Future studies would be valuable to determine if unionid populations are stable or changing.

The reasons why zebra mussels do not survive after attaching to unionids in coastal wetlands are not fully understood, but may be related to water depth and unionid burrowing. We found that zebra mussels have low survivorship in shallower water depths where they are intermittently dewatered by seiches. Dewatering by seiche activity is a hydrological stressor that may limit the possible suitable habitats for zebra mussels in Great Lakes coastal marshes.

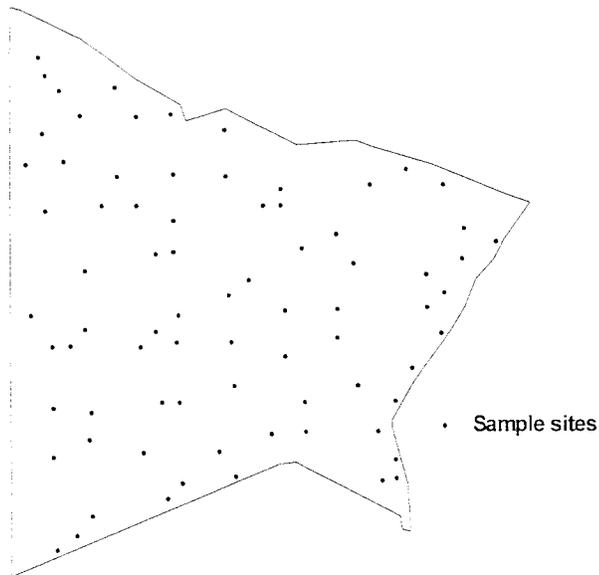
Burrowing by unionids may be another reason why zebra mussels die after attaching to unionids. Previous research suggests that unionids smother attached zebra mussels when they burrow down into the soft mud (Nichols and Wilcox 1997). We feel that sediment depth might affect these interactions because we observed that unionids in areas with shallow sediments generally had more zebra mussels on their shell than unionids in areas with deep sediment (R. Bowers, pers. observ.). Future research should examine the effect of unionid burrowing on zebra mussel colonization and survival in coastal wetlands to determine the role of these as unionid habitats.

### **References Cited:**

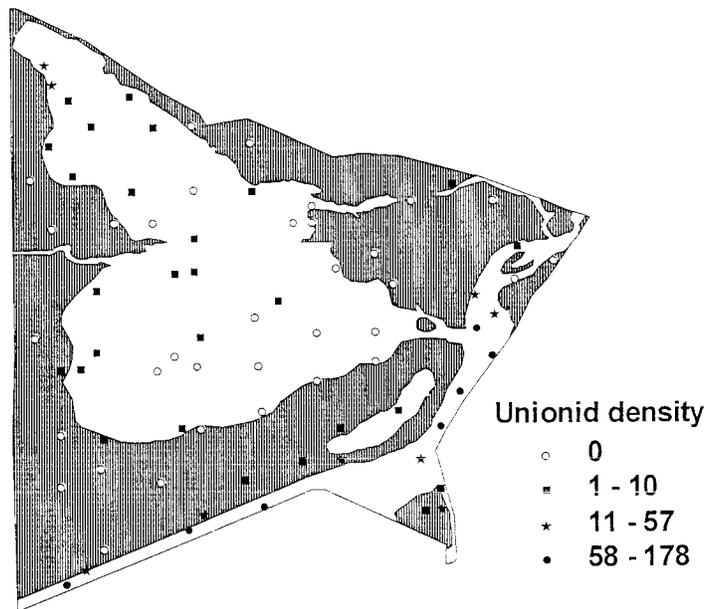
- Bertram, P. & N. Stadler-Salt. 2000. Selection of indicators for Great Lakes basin ecosystem health. State of the Lakes Ecosystem Conference. Indicator ID:68 pp. 1-13, 1-14.
- Bogan, A.E. 1993. Freshwater bivalve extinctions (Mollusca: Unionidae) a search for causes. *American Zoologist* 33:599-609.
- Bogan, A.E. & K.S. Cummings. 2001. An introduction to the freshwater mollusks of North America: taxonomy and information sources. pp. 1-36 *In* A.E. Bogan (editor). Taxonomy and systematics of the freshwater mollusks of North America: an introduction. North American Benthological Society Technical Information Workshop, 49<sup>th</sup> Annual Meeting, La Crosse, Wisconsin. 76 pp.
- Box, J. Brim, & J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. *Journal of the North American Benthological Society* 18:99-117
- Cummings, K.S. & C.A. Mayer. 1992. Field guide to freshwater mussels of the Midwest. Illinois Natural History Survey, Manual 5. 194 pp.
- Day, M.E. 1983. The shell as a recording device: growth record and shell ultrastructure of *Lampsilis radiata radiata* (Pelecypoda: Unionidae). *Canadian Journal of Zoology* 62:2495-2504
- Garton, D.W., & W.R. Haag. 1990. Seasonal patterns of reproduction and larval abundance of *Dreissena* in western Lake Erie: what a difference a year makes. P. 7 *In* Proceedings of the International Zebra mussel Research Conference. Columbus, Ohio, December 1990. Ohio Sea Grant College Program. Columbus
- Herdendorf, C.E. 1987. The ecology of the coastal marshes of western Lake Erie: a community profile. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.9). 171 pp.
- Karatayev, A.Y., L.E. Burklakova, & D.K. Padilla. 1998. Physical factors that limit the distribution and abundance of *Dreissena polymorpha* (Pall.). *Journal of Shellfish Research* 17(4):1219-1235.
- MacIsaac, H.J. 1996. Population structure of an introduced species (*Dreissena*

- polymorpha*) along a wave-swept disturbance gradient. *Oecologia* 105:484-492.
- Marsden, J.E. 1992. Standard protocols for monitoring and sampling zebra mussels. Illinois Natural History Survey Biological Notes 138. 40pp.
- McCuaig, J.M. & R.H. Green. 1982. Unionid growth curves derived from annual rings: a baseline model for Long Point Bay, Lake Erie. *Canadian Journal of Fisheries and Aquatic Sciences* 40:436-442.
- Metcalf-Smith, J.L. & R.H. Green. 1992. Ageing studies on three species of freshwater mussels from a metal-polluted watershed in Nova Scotia, Canada. *Canadian Journal of Zoology* 70:1284-1291.
- Metcalf-Smith, J.L., J. Di Maio, S.K. Staton, & G.L. Mackie. 2000. Effect of sampling effort on the efficiency of the timed search method for sampling freshwater mussel communities. *Journal of the North American Benthological Society* 19:725-732.
- Nedeau, E.J., M.A. McCollough, B.I. Swartz. 2000. The freshwater mussels of Maine. pp.118
- Nichols, J.S. & D.A. Wilcox. 1997. Burrowing saves Lake Erie clams. *Nature*. 389:921
- Parmalee, P.W. & A.E. Bogan. 1998. *The Freshwater Mussels of Tennessee*. The University of Tennessee Press, Knoxville 328 pp.
- Ricciardi, A., F.G. Whoriskey, & J.B. Rasmussen. 1996. Impact of *Dreissena* invasion on native bivalves in the upper St. Lawrence River. *Canadian Journal of Fisheries and Aquatic Sciences* 53:1434-1444.
- Ricciardi, A., R.J. Neves, & J.B. Rasmussen. 1998. Impending extinctions of North American freshwater mussels (Unionidae) following the zebra mussel (*Dreissena polymorpha*) invasion. *Journal of Animal Ecology* 67:613-619.
- Schlosser, D.W. & T.F. Nalepa. 1994. Dramatic decline of unionid bivalves in offshore waters of western Lake Erie after infestation by the zebra mussel, *Dreissena polymorpha*. *Canadian Journal of Fisheries and Aquatic Sciences* 51:2234-2242.
- Smith D.R., R.F. Vilella, & D.P. Lemarie. 2001. Survey protocol for assessment of endangered freshwater mussels in the Allegheny River, Pennsylvania. *Journal of the North American Benthological Society* 20:118-132.
- Strayer, D.L., L.C. Smith. 1996. Relationships between zebra mussels (*Dreissena polymorpha*) and unionid clams during the early stages of the zebra mussel invasion of the Hudson River. 36:771-779.
- Strayer, D.L. 1999. Effects of alien species on freshwater mollusks in North America. *Journal of the North American Benthological Society*. 18:74-98.
- Thorp, J.H. and A.P. Covich. 1991. *Ecology and classification of North American Freshwater Invertebrates*. Academic Press, San Diego, California. 911 pp.
- Toczlowski, S.A., R.D. Hunter, & L.M. Armes. 1999. The role of substratum stability in determining zebra mussel load on unionids. *Malacologia* 41:151-162.
- Veinott, G.I. & R.J. Cornett. 1995. Identification of annually produced opaque bands in the shell of the freshwater mussel *Elliptio complanata* using the seasonal cycle of  $\delta^{18}\text{O}$ . *Canadian Journal of Fisheries and Aquatic Sciences* 53:372-379.
- Waller, D.L., S. Gutreuter, & J.J. Rach. 1999. Behavioral responses to disturbance in freshwater mussels with implications for conservation and management. *Journal of the North American Benthological Society* 18:381-390
- Watters, G.T. 1993. *A guide to the freshwater mussels of Ohio*. Division of Wildlife, The Ohio Department of Natural Resources. 106 pp.

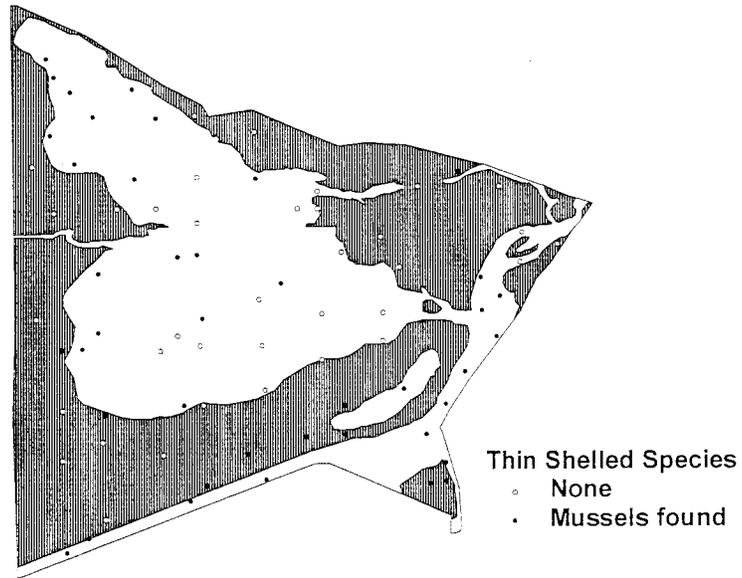
Williams, J.D., M.L. Warren Jr., K.S. Cummings, J.L. Harris, & R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. *Fisheries* 18: 6-22.



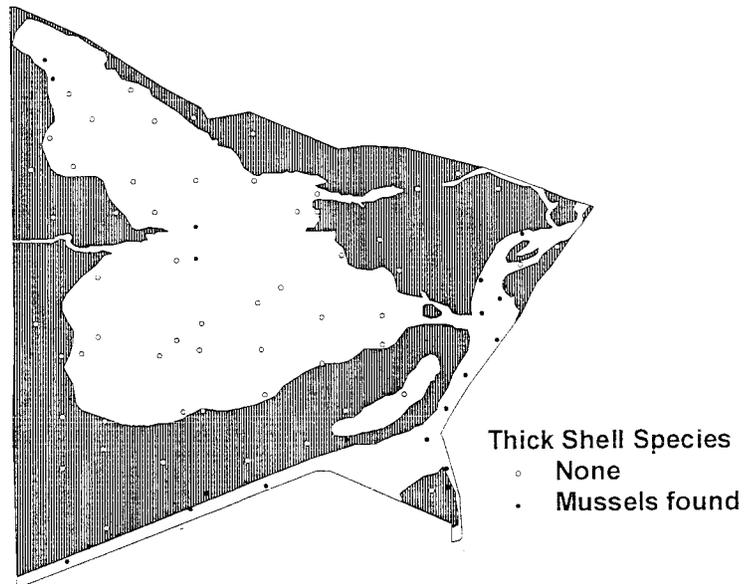
**Figure 1.** Distribution of the sample sites at Crane Creek Marsh. The dikes surrounding the marsh are shown outlining the map. Symbols indicate the locations of the sampling plots.



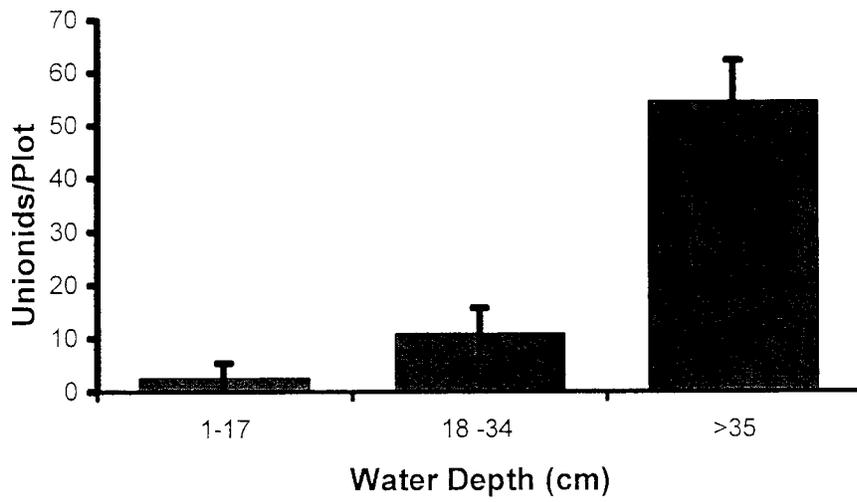
**Figure 2.** Unionid densities in Crane Creek Marsh. Symbols indicate the number of mussels collected in each 50 m x 50 m sample plot. The creek channel extends along the south and east edge of the wetland. The darkened areas are the mudflats that were exposed on 15 September 2001.



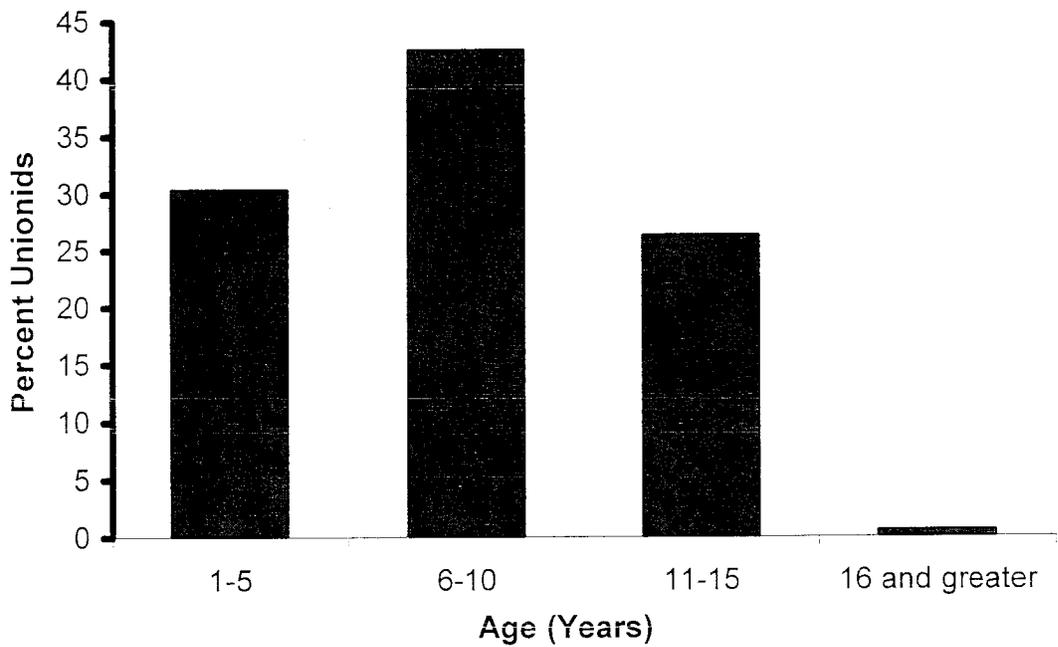
**Figure 3.** Distribution of thin shelled unionids in Crane Creek Marsh. The creek channel extends along the south and east edge of the wetland. The darkened areas are the mudflats that were exposed on 15 September 2001.



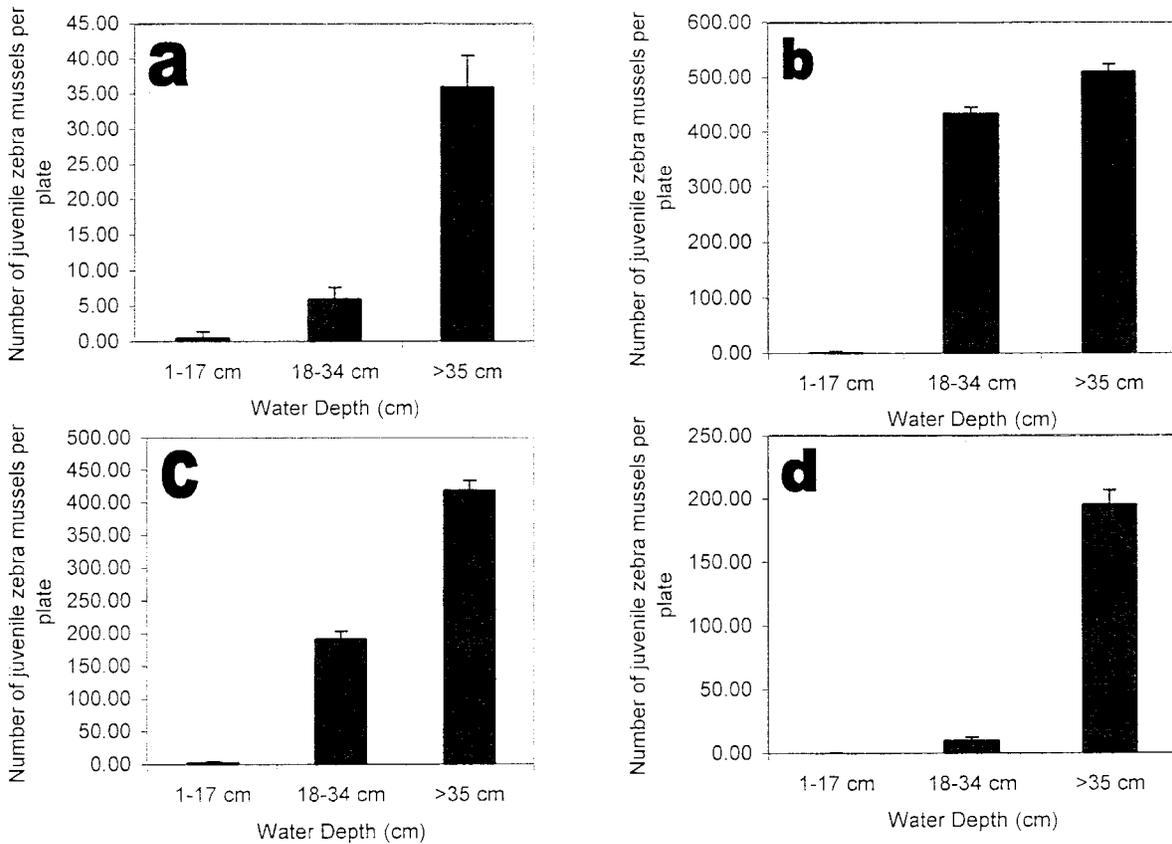
**Figure 4.** Distribution of thick shelled unionids in Crane Creek Marsh. The creek channel extends along the south and east edge of the wetland. The darkened areas are the mudflats that were exposed on 15 September 2001.



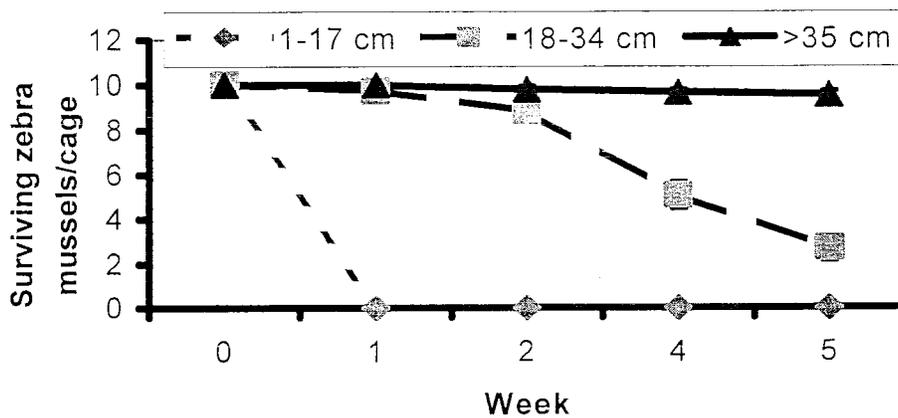
**Figure 5.** Number of unionids collected per 50 m x 50 m sampling plot in different water depths. Error bars are one standard error.



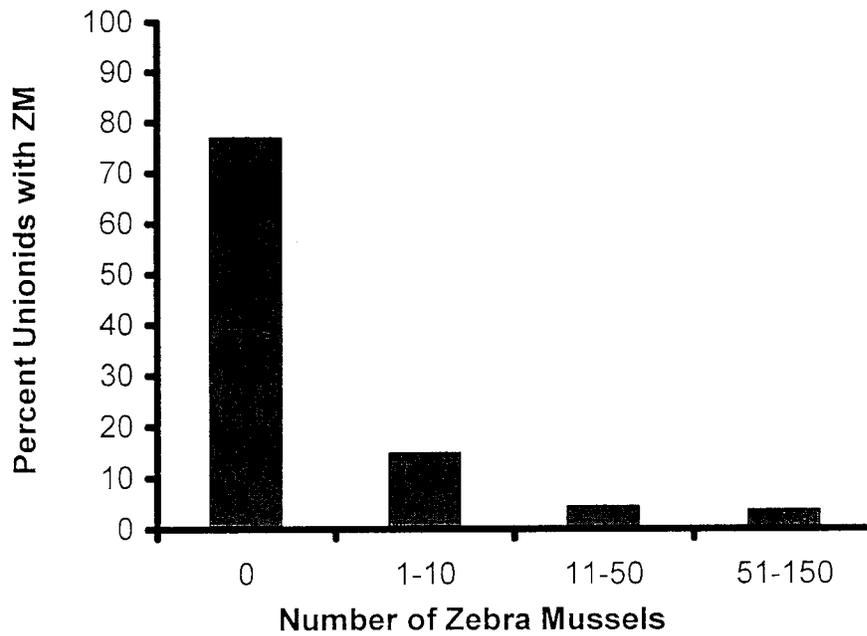
**Figure 6.** Percent unionid mussels in each age cohort. Ages were estimated by counting annular growth rings on the shell. Numbers are the percent of all unionids collected over the entire study.



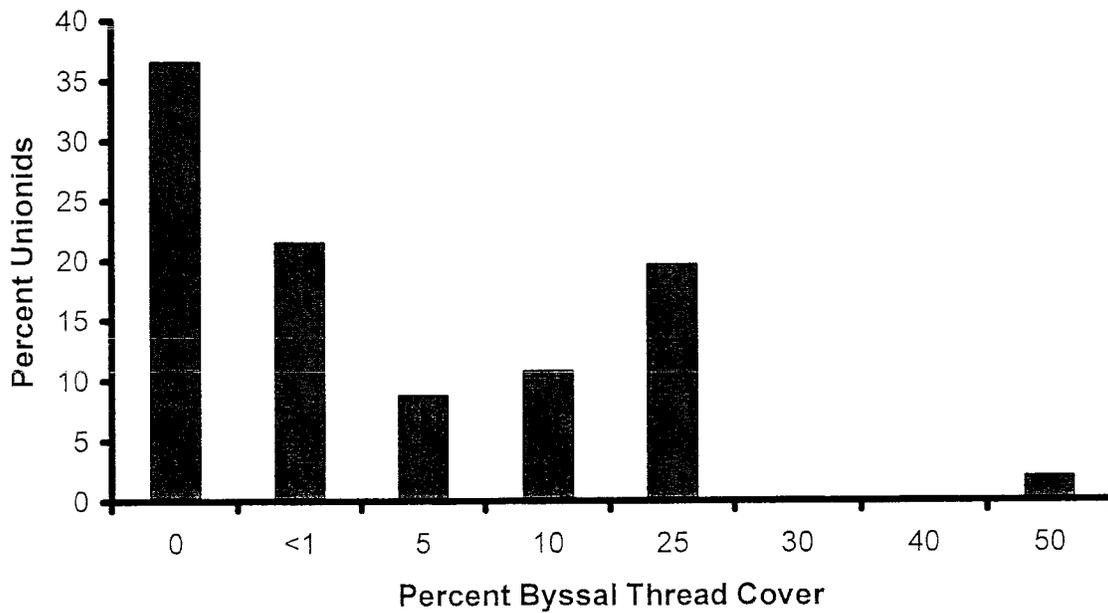
**Figure 7.** The number of zebra mussels colonizing the PVC colonization plates at different depths at four locations: a. was in the creek above the marsh; b. was in the creek channel where the creek enters the marsh; c. was in the creek channel midway towards the mouth of the marsh at Lake Erie; and, d. was at the opening of the dike where the marsh was connected to Lake Erie. Error bars are one standard error.



**Figure 8.** Number of zebra mussels surviving per cage each week at different water depths. Error bars are one standard error.



**Figure 9.** Percent of unionids with attached live zebra mussels. Values are percent of total unionids with different numbers of zebra mussels on their shell.



**Figure 10.** Percent zebra mussel byssal thread cover on unionids. Values are percent of total unionids with different amounts of byssal thread cover on their shell.

Table 1. Percentage and shell thickness of unionid species collected at Crane Creek Marsh. *U. imbecillis* was not collected as part of the survey but was observed after the survey was completed. Shell thickness based on descriptions by Cummings and Mayer (1992).

UNIONIDAE SPECIES	% OF TOTAL (N=1129)	Shell Thickness
<i>Quadrula quadrula</i>	42	Thick
<i>Leptodea fragilis</i>	24	Thin
<i>Amblema plicata</i>	18	Thick
<i>Pyganodon grandis</i>	8	Thin
<i>Potamilus alatus</i>	3	Thin
<i>Quadrula pustulosa</i>	2	Thick
<i>Toxolasma parvus</i>	1	Thin
* <i>Obliquaria reflexa</i>	1	Thick
<i>Fusconaia flava</i>	1	Thick
<i>Lasmigona complanata</i>	<1	Thin
<i>Lampsilis siliquoidea</i>	<1	Thick
* <i>Truncilla donaciformis</i>	<1	Thin
* <i>Truncilla truncata</i>	<1	Thin
* <i>Unio tetralasmus</i>	<1	Thin
<i>Utterbackia imbecillis</i>	observed	Thin

\*State listed as threatened species or of special interest.