Zebra mussels in the Great Lakes: The invasion and its implications

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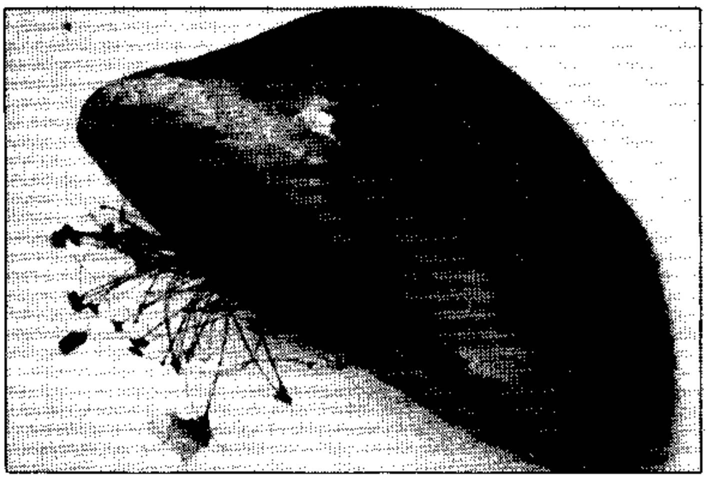
Zebra mussels (*Dreissena polymorpha*) were almost unheard of by Great Lakes shoreline residents until 1989. By the autumn of 1989 zebra mussels had colonized the surfaces of nearly every firm object in Lake Erie. Zebra mussels have now been reported in all other Great Lakes—Ontario, Huron, Michigan, and Superior—as well as spreading into New York via the Erie Canal and down the St. Lawrence River. Ultimately, experts predict zebra mussels will spread beyond the Great Lakes region and can colonize most lakes and rivers in Canada and the United States.



Close-up of a zebra mussel shows the tuft of byssal threads used for attachment. Particles on the ends of the threads are debris.

Where did they come from? How will they impact flora, fauna, and human uses? Can they be controlled? Is the problem being studied? Questions about zebra mussels abound, but finding answers is much more difficult. What follows are some answers to the questions posed here.

The invasion

Western and central Europe have experienced zebra mussel problems for nearly 200 years. Most available information comes from European sources, often needing translation into English. Comparing the Great Lakes situation to European lakes won't predict the impact on any Great Lake with accuracy. Europe's industries and commerce developed on water bodies already populated with zebra mussels. *Dreissena* arrived in Lake Erie to find an industrialized, plankton-filled Great Lake that is home to tens of millions of walleye and other important species.

Dreissena polymorpha originated from the Ponto-Caspian region of western Russia. Canals built during the late 1700s allowed the mussels to begin spreading throughout eastern Europe. During the early 1800s, canals were built across the rest of Europe. The canals made bulk shipping much easier but also allowed rapid expansion of the zebra mussels' range. By the 1830s the mussels had covered much of the continent and had invaded Britain.

The successful introduction of zebra mussels into the Great Lakes appears to have occurred in 1985 or 1986 when one or more transoceanic ships discharged ballast water into Lake St. Clair. The freshwater ballast, picked up in a European port, contained zebra mussel larvae, and possibly juveniles. Being a temperate, freshwater species, zebra mussels have found the plankton-rich Lakes St. Clair and Erie to their liking.

The zebra mussel's reproductive cycle is one key to its rapid spread and high abundance. Egg production starts when the water temperature warms to about 54° (12° C), usually early May in Lake Erie, and continues until the water cools below 54°, generally in October. In Lake Erie, spawning (the release of eggs and sperm) peaks during July and August at water temperatures above 64° (20°). A fully mature female mussel produces over 30,000 eggs per season.

Eggs are fertilized outside the shell, and within a few days develop into free-swimming larvae veligers. Veligers remain suspended in the water for three to four weeks, drifting with the currents. If they don't settle onto firm objects in that time period, they die. The vast majority actually suffer this fate. Those that find a hard surface quickly attach themselves and transform into the typical, double-shelled mussel shape and are then considered to be juveniles. A zebra mussel becomes mature within a year. Mussels grow rapidly, nearly an inch in their first year, adding another one-half to one inch their second year. European studies report mussels can live four to six years.

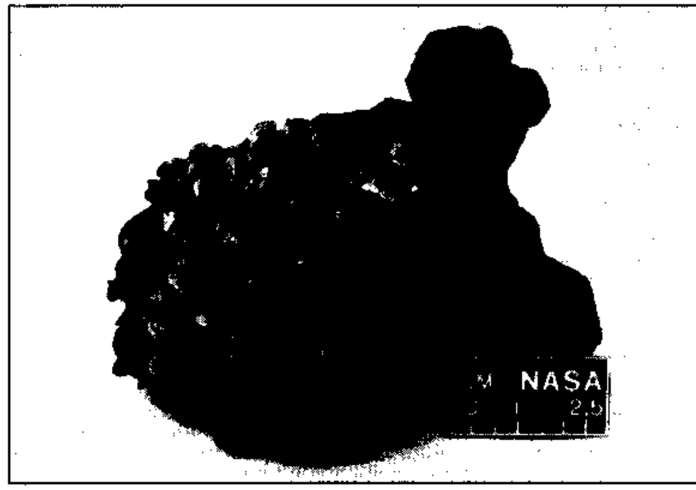
Zebra mussels generate a tuft of fibers known as byssus, or byssal threads, from a gland in the foot. The byssus protrudes through the two halves of the shell. These threads attach to hard surfaces with an adhesive secretion which anchors the mussels in place. Juveniles can break away from their attachments and generate new, buoyant threads which allow them again to drift in the currents and find a new surface.

Any firm surface that is not toxic can be colonized by zebra mussels. Rock, metal, wood, vinyl, glass, rubber, fiberglass, paper, plants, other mussels—the surface need only be firm. Beds of mussels in some areas of Lake Erie now contain over 30,000, and sometimes up to 70,000 animals per square meter.

Zebra mussel colonies show little regard for light intensity, hydrostatic pressure (depth), or even temperature when it is within a normal environmental range. Colonies grow rapidly wherever oxygen and particulate food is available and water currents are not too swift (generally less than six feet per second). Thus, colonies are rare in wave-washed zones except for sheltered nooks and crevices. In most European lakes the greatest densities of adult mussels occur at depths ranging from 6 to 45 feet. The most extreme depth on record comes from an Italian researcher who measured colonies of 20,000 zebra mussels per square meter at a depth of 164 feet in Italy's Garda Lake.

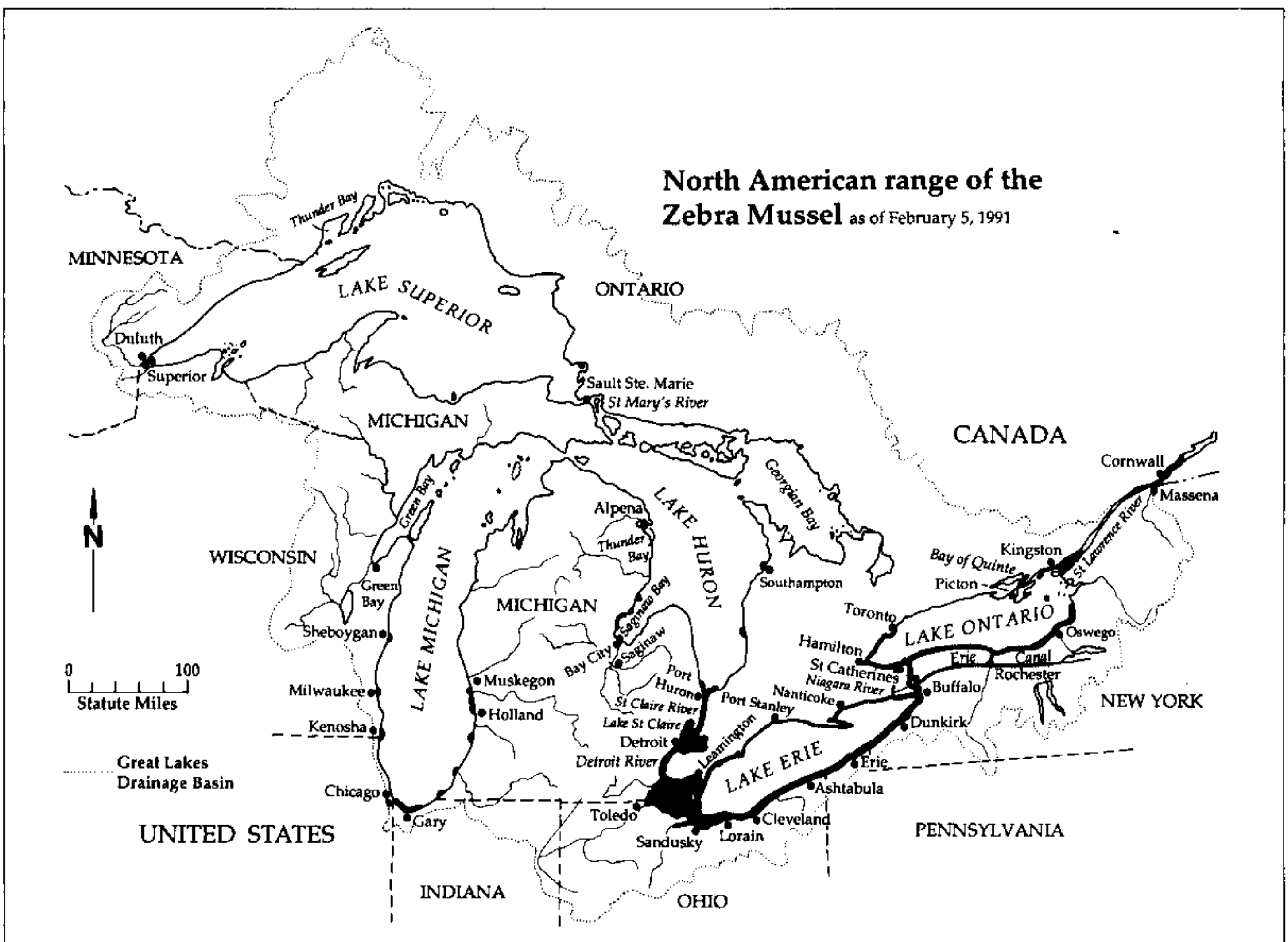
Surprisingly, zebra mussels can also colonize soft, muddy bottoms. Hard objects deposited in or on the mud, such as pieces of native mussel shells, act as substrate (base) for settling veligers. As a few mussels begin to grow, they in turn serve as substrate for additional colonization. In this way, extensive mats of zebra mussels can form on soft lake bottoms.

The free-swimming veligers usually reach their greatest abundance at depths of 10 to 23 feet, and usually do not descend below the thermocline. As veligers, zebra mussels are the most sensitive to low temperature. Juveniles are more sensitive to low temperature than adults. All life stages are sensitive to low levels of dissolved oxygen, particularly as temperature increases. Some juveniles migrate from shallow habitats occupied in late summer to deeper areas, increasing densities of zebra mussels found in deeper waters during winter.



Jim Hurst

While reported to grow nearly two inches in length, most zebra mussels are the size of a fingernail. Tiny zebra mussels (juveniles) readily attach to older ones, causing colonies to grow rapidly to depths of several inches.



Biological and ecological concerns

The feeding method of zebra mussels points to one of the growing concerns in regard to Lake Erie's food chain. Each adult mussel is capable of filtering about one liter of water per day. Nearly all particulate matter, including phytoplankton, is strained from the water. The zebra mussels eat mostly algae, but select primarily the 15-40 micrometer size range for consumption. Instead of passing uneaten phytoplankton back into the water, mussels bind it with mucous into pellets called pseudofeces. Pseudofeces are ejected and accumulate among the shells in the colony. Thus, zebra mussels remove significant amounts of phytoplankton from the water. Phytoplankton represent the food source for microscopic zooplankton, which in turn are food for larval and juvenile fishes, and other plankton-feeding forage fish supporting Lake Erie's sport and commercial fisheries. This competition for phytoplankton, the base of the food chain, may have a long-term negative impact on these Great Lakes fisheries. Other Great Lakes fisheries less dependent upon plankton as a food base may experience fewer impacts from zebra mussels.

Canadian researchers have calculated that if zebra mussels achieved a uniform density of 7,000 animals per square meter over western Lake Erie, they may possibly filter the entire Western Basin every day. However, much of the Western Basin is mud flats that aren't colonized, therefore it would take the mussels several days to filter all the water. Researchers (as well as many boaters) have noted greatly increased water clarity in Lake Erie during 1989 and 1990, and this change has been partially attributed to filtering activities of zebra mussels.

Biologists were also concerned about zebra mussel colonies covering rock reefs. Most rocky areas in Lake Erie are almost completely covered with mussels. Zebra mussels attach to each other, sometimes forming layers that are several inches thick. In laboratory observation, the accumulation of pseudofeces in these beds creates a foul environment. As waste particles decompose, oxygen is used up and the pH becomes very acidic. Such poor environmental conditions may hinder normal egg development of reef-spawning fish (walleye, white bass, and smallmouth bass). Results of initial American and Canadian studies indicate eggs and fry of walleye developed normally on mussel-covered reefs. However, more research is needed.

Zebra mussels are known to be intermediate hosts for a number of parasites that can also infect fishes and birds. While the European experience with *Dreissena* has not indicated a major problem with disease or parasites, it merits further observations in North America.

Industrial, commercial & recreational concerns

The zebra mussels' proclivity for hard surfaces located at moderate water depths has made water intake structures, such as those used for power and municipal water treatment plants, susceptible to colonization. During 1989, plants located on the Michigan and Ontario shorelines of Lake Erie reported significant reductions in pumping capabilities and occasional shutdowns due to zebra mussel encrustment.

Several approaches to zebra mussel control on intake structures have been examined, including prechlorination, preheating, electrical shock, and sonic vibrations. Control methods that currently appear most feasible include prechlorination, ozone, and potassium permanganate injection and sand bed filtration. Prechlorination has been the most common treatment used to date; but it also raises concerns about the toxicity of chlorinated compounds to other aquatic organisms.

Zebra mussels are very sensitive to high temperature. Researchers have obtained 100 percent mortality after five hours at 90°F, but after only 15 minutes at 104°F. Other reports show minor variation around these figures, but clearly indicate that heat can be an effective control for zebra mussel infestations. It is, however, difficult to safely apply heat to large underwater structures.

Recreational industries along Lake Erie have been impacted by zebra mussels. Unprotected docks, breakwalls, boat bottoms, and engine outdrives were rapidly colonized during 1989. There have been numerous reports of boat engines overheating due to cooling water inlets being clogged by colonies of zebra mussels. Boaters probably will need to make frequent inspections of these areas in the future. Boats painted with approved antifouling paints containing copper have been effective in resisting zebra mussel attachment. However, copper-based paints corrode aluminum. Paints containing slow-release polymers of tributyltin (TBT) are also effective. However, these paints are banned in Michigan and restricted in other states. For more information on approved antifouling paints, contact your state's Department of Agriculture.

Beaches are also affected by zebra mussels. By autumn of 1989, extensive deposits of zebra mussel shells could be seen on many Lake Erie beaches. The extent of these deposits varied with successive periods of high wave activity. Sharp-edged shells accumulating along swimming beaches is a hazard.

Zebra mussel control

Lakewide control of zebra mussels is simply out of the question. After 200 years of infestation, the European community hasn't been able to develop a chemical toxicant for lakewide control that isn't deadly to other aquatic life forms.

In some parts of Europe, large populations of diving ducks have actually changed their migration patterns in order to forage on beds of zebra mussels. The most extreme case occurs in Germany's Rhine River, which hosts the highest densities of zebra mussels ever found in central and western Europe. Overwintering diving ducks and coots were seen to consume up to 97 percent of the standing crop of mussels each year, although the mussel population was replenished each summer by mass migrations of yearlings.

In the Great Lakes, the most likely duck species to prey on zebra mussels are scaup, canvasbacks, and oldsquaws. However, scaup populations are depressed to the point that the special late hunting season for them was curtailed in 1989, and canvasbacks are so rare that they are totally protected. Oldsquaws rank in the rare visitor category. Also, western Lake Erie is ice covered during much of the winter when diving ducks would be present.

Some fish species are likely to include zebra mussels in their diet, but research is needed to determine which species will act as predators and how many mussels they can eat. Freshwater drum, or sheepshead, have been known to feed substantially on zebra mussels, and yellow perch have been reported to sometimes contain a small zebra mussel or two. Much needs to be learned about natural predators.

The prodigious filtering of water by zebra mussels may increase exposure risk to humans and wildlife to organic pollutants (PCBs and PAHs). Early studies have shown that zebra mussels can rapidly accumulate organic pollutants within their tissues to levels over 300,000 times greater than concentrations in the environment or can deposit these pollutants in their pseudofeces. The fate of the chemicals depends in part on the suitability of the food source. These pollutants from algae and sediments are persistent, and can be passed up the food chain. Any fish or waterfowl consuming zebra mussels will also accumulate these organic pollutants. Likewise, human consumption of fish and waterfowl from areas with zebra mussels would be associated with increased exposure to these same pollutants. The implications for human health are unclear, and zebra mussel pollutant uptake and transfer up the food chain is currently being studied.

Potential for spread to inland waters

Zebra mussels could potentially spread from the Great Lakes to inland waters either as veligers transported in water, or as adults attached to boat hulls, engines, and fish cages, or on any number of other items. Veligers attached to boats don't survive drying but they can survive in any residual water source. Waterfowl and other wildlife may also disperse zebra mussels, carrying veligers and/or adults in wet fur or feathers.

Adult zebra mussels are very hardy, and with their shells closed can survive drying for several days. In moist environments, they can survive out of the water even longer.

Before transferring a boat from Lake Erie to inland waters, wildlife agencies urge boaters to clean boat hulls, trim tabs, outdrives, and outboard lower units or to leave the boat out of the water for 10 to 14 days. Live wells and bilges should be disinfected with one part chlorine bleach to 10 parts water for several hours. This solution should not be discharged into lakes or streams due to its toxicity to aquatic life. An effective alternative is to coat all boat and engine surfaces exposed to water with approved antifouling paints. (Do not paint the inside of live wells or bait wells.)

Veligers can be transported very easily in water used in live bait containers. Minnows or crayfish used or collected in lakes containing zebra mussels should be transferred to well water or aged chlorinated tap water before carrying them to other bodies of water.

Other significant pathways for spreading of zebra mussels to inland waters are existing diversions of Great Lakes water to other watersheds. The Chicago Sanitary Canal carries water each day from Lake Michigan to the Mississippi River. Likewise, water from Lake Erie enters Lake Ontario via the Erie Canal, and from these flows into the Hudson River via the Mohawk River.

Most authorities consider the spread of zebra mussels across North America to be a certainty. The southward spread probably will be limited by average summer water temperatures above 81°F. The northward spread might be limited by soils deficient in calcium or by summer water temperatures below 54°F. But the broad region having favorable environmental conditions for zebra mussels extends from the East Coast to the West Coast and from Canada to the southernmost states.

The zebra mussel is now a permanent part of the Great Lakes environment. Increased support for research is needed to gain understanding of its effects upon the lakes' ecosystems and industries, and of its economic implications. Theoretically, zebra mussel populations should peak a few years after initial infestation and then decline, depending upon predation and on each lake's carrying capacity. There is little doubt that the zebra mussels' impact will be felt by great numbers of people who use the Great Lakes.

Sea Grant's role

Sea Grant is a national university-based program dedicated to the wise use and conservation of marine and Great Lakes resources for the public benefit. Funding comes primarily from the U.S. Department of Commerce's National Oceanic and Atmospheric Administration with matching funds provided by states, universities, and industries.

Anticipated roles of agencies in the Great Lakes include:

Sea Grant—research, education, & technology transfer
Fish & Wildlife—monitor and research
Coast Guard—regulatory activities
Environmental Research Lab, NOAA—research
Fishery Commission—research
Great Lakes Commission—policy development and coordination

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For further information about zebra mussels, subscribe to *Twine Line*. This bimonthly, eight-page newsletter includes updates on zebra mussel colonization, findings on the impact on the lakes' ecosystems and industries, economic implications, and control alternatives. To subscribe for one year send $4.50 (payable to The Ohio State University) to the Columbus address listed above.

The Great Lakes Sea Grant programs are members of the **Great Lakes Information Network,** a consortium of Great Lakes communications and information specialists in Canada and the U.S. working to exchange information on Great Lakes issues and to provide opportunities for cooperative communications efforts among the region's organizations. For more information about this consortium, contact the Ohio or Michigan Sea Grant offices.