1992

Hydraulic Structures Versus Zebra Mussels

John J. Ingram
U.S. Army Corps of Engineers

Andrew C. Miller
U.S. Army Corps of Engineers

Published in Hydraulic Engineering: Saving a Threatened Resource—In Search of Solutions: Proceedings of the Hydraulic Engineering sessions at Water Forum '92.
Baltimore, Maryland, August 2–6, 1992. Published by American Society of Civil Engineers.

Hydraulic Structures Versus Zebra Mussels

by

John J. Ingram[1], M ASCE and Andrew C. Miller[2]

Abstract

The United States Army Corps of Engineers (USAE) has begun a four-year research program to develop environmentally sound control strategies for zebra mussel (*Dreissena polymorpha*) infestations at public facilities. The USAE Waterways Experiment Station has initiated research for these facilities which include water-intake structures, navigation locks, gated dams, outlet works, pumping plants, hydropower plants, drainage structures, dredges and commercial vessels.

Introduction

Zebra mussels (*Dreissena polymorpha*) are small, brown and white striped animals, related to clams and oysters, native to eastern Europe (Figure 1). They are now found within North American waters and are a potential threat to the current operation and maintenance practices associated with hydraulic structures and public facilities. The threat arises because of the potential for clogged intakes, reduced flow capacity, overheating of pumps, blockage or impairing of complete valve closure, etc.

Zebra mussels were discovered in Lake St. Clair in 1988, and scientists believe the mussels arrived in Ontario in 1985 or 1986, probably in freighter ballast water taken on in a European port (Roberts, 1990). These mussels have spread quickly in Ontario and large colonies have been found in lakes Superior, Huron and

[1]Chief, Water Resources Engineering Group, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS 39180

[2]Research Limnologist, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS 39180

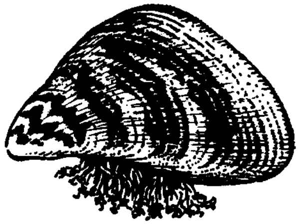

Figure 1. Side view of a zebra mussel (*Dreissena polymorpha*).

Michigan, and in the St. Lawrence, St. Clair, Detroit, Niagara, Illinois, Upper Mississippi, Susquehanna, Lower Tennessee, and lower Ohio rivers. The mussels survive by attaching themselves to solid underwater surfaces and live in colonies of tens to hundreds of thousands per square meter. The potential exists for the mussels to infest and impact the operations of hydraulic facilities throughout the United States (Figure 2).

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, Public Law 101-646 (Congressional Record--House, 27 October 1990) specified that the Assistant Secretary of the Army, Civil Works, will develop a program of research and technology development for the control of zebra mussels. As a result of this legislation, the U.S. Army Engineer Waterways Experiment Station (WES) initiated a four-year program to develop strategies for environmentally sound prevention and control of zebra mussel infestations at public facilities (Miller, 1991). The program stresses the development of strategies that use physical rather than chemical methods to ensure that native biota and potable water supplies are not adversely affected. Desired strategies are meant to address facility operation modifications, new maintenance practices, or design modifications. Facilities to be assessed include water-intake structures, navigation locks, gated dams, outlet works, pumping plants, hydropower plants, drainage structures, dredges and commercial vessels. This paper presents findings of the initial research.

Basis for Concern

Zebra mussels are a potential threat to operation and maintenance practices associated with hydraulic structures and

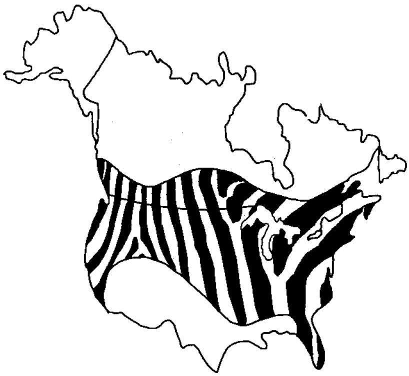

Figure 2. Estimated area of North American zebra mussel infestations.

public facilities within North America. The threat is due to the new species' rapid spread and their potential to clog intakes leading to overheating pumps and impairing other facility operations.

Typically an exotic species produces extremely high densities immediately after colonizing a new habitat. Zebra mussels have already achieved higher densities in North America than are present in Europe; therefore, infestations are likely to be a much greater threat to North American facilities than those in Europe. Scientists estimate that these infestations are likely to persist for 10 to 20 years. Their densities will then decline as natural predators and diseases begin to act as control agents.

Life Cycle

Zebra mussels are of separate sexes and release sperm and eggs into the water for external fertilization. The embryo develops in the egg within a required temperature range of 12 to 24 degrees Centigrade (or 54 to 75 degrees Fahrenheit). The species then hatches as a microscopic planktonic "veliger" larva. Next, the veliger can be dispersed by water currents, settle in raw water systems, and grow into an adult having a 3 to 5 centimeter shell length with byssal threads attached to a hard surface. The adult mussel may attach to other zebra mussels and populations may be achieved at tens to hundreds of thousands per square meter (McMahon and Tsou, 1990).

Zebra mussel reproductive seasons, growth rates, and life spans are dependent upon environmental conditions. Regarding reproduction, veligers may maximally occur in North American source waters from May to October depending upon water temperature (Mackie et.al, 1989). The greatest growth rates occur in habitats having high temperatures and food levels (such as suspended algae and bacteria).

Although veliger settlement occurs at flow velocities less than 1.5 to 2.0 meters per second, once attachment has occurred, adults can tolerate much higher velocities. Similarly, the adult mussel can tolerate temperatures well beyond that required for embryo development. With these environmental tolerances, the potential zebra mussel life span is 6 to 7 years.

Control Strategies

Control strategies may be grouped for early detection, infestation removal, and preventive actions. Operations personnel should be concerned with each of these groupings, and designers will mostly be concerned with preventive actions which may be introduced through design modifications. Those implementing control strategies should keep in mind that although the strategies will assist in providing optimal project operations, they will not eliminate zebra mussel infestations all together. Therefore, concern should always exist for detection and removal.

Early Detection

Existing hydraulic facilities should incorporate early detection strategies or monitoring devices, as soon as zebra mussel infestations are anticipated in the area. Monitoring devices may be a portion of the existing structure or an additional device located near critical operating portions of the facility or approaches to the same.

Settlement of the juvenile mussel can be monitored with most any hard surface placed in the intake waters or embayments. The only type of surface materials not suitable for monitoring are those surfaces containing toxins, a means of control to be discussed later. Submerged floats and nets also make good settlement monitoring devices (Szlauer, 1974). And, sidestream devices may be used to monitor settlement in piping systems, such as in hydropower plants.

Infestation Removal

Once settlement has been detected, follow-on inspection is necessary to determine whether all, a portion, or any of the infestations require immediate removal. Many approaches to removal have been proposed by vendors and many of these approaches should be effective; however, all of the approaches have neither been proved effective nor shown to be environmentally safe.

The greatest difficulty associated with removal surrounds the zebra mussel's byssal thread adhering strength. For this reason, mussels may be removed by physical or chemical means. Physical measures include suction or scrapping devices used by divers, robotic devices that reach areas a diver cannot safely get to, filtration, electroshocking, ultrasound, pigging, and the use of steam at dewatered facilities. Chemical measures which lead to death and detachment include chlorination and ozonation, the use of hydrogen peroxide, potassium permanganate, and molluscicides or biocides.

Preventive Actions

Although not a solution for the permanent exclusion of zebra mussels at a facility, preventive actions will inhibit the settlement and growth of the mussels. Thus, since a total exclusion of the mussels will not likely occur, at least a manageable population will result. Preventive actions include the introduction of toxic plants in the area, the use of toxic coatings, and facility design modifications. With regard to the toxic materials, caution must be taken such that unacceptable toxin types and levels are not introduced to the environment. The main intent with the toxic plants and coatings is to inhibit settlement in critical facility locations, such as conduit inlets of a lock or the embayment of a pumping station. Design modifications may consider the development of flow boundary layers that will permit the use of a biocides in limited quantities; the duplication of facility components, such that one component can be shut down and cleaned with a continuation of facility operations; or the oversizing of a facility component, such that the infestations will not inhibit operations.

Future Concerns

Control strategies developed for use by the Corps of Engineers will be based on modifying existing operation, maintenance, or design features of the facilities. Nondisruptive procedures that reduce the severity of zebra mussel infestations and decrease costs associated with total shutdown of equipment will be instituted. As part of the program, laboratory studies are being conducted by the WES in conjunction with other research organizations to evaluate the tolerance of zebra mussels to desiccation, elevated temperatures, and hypoxia. WES is also monitoring the biology, physiology, physical condition, and size demography of naturally occurring populations of zebra mussels at key sites in major waterways. Field laboratories have been established in the Hudson and Illinois Rivers, and in 1992, field studies will be initiated in the upper Mississippi and Ohio Rivers. Finally, the impacts of spread and colonization of zebra mussel on native biota, especially freshwater mussels, will be evaluated (Miller, 1991).

Acknowledgments

The tests described and the resulting data presented herein, unless otherwise noted, were obtained from research conducted under the Environmental Impact Research Program (EIRP) of the United States Army Corps of Engineers by the U.S. Army Engineer Waterways Experiment Station. Permission was granted by the Chief of Engineers to publish this information. Reviews by E. A. Dardeau, Jr. and Michael R. Palermo are gratefully acknowledged.

References

Mackie, G. L., Gibbons, W. N., Muncaster, B. W., and Gray, I. M., The Zebra Mussel, Dreissena Polymorpha: A Synthesis of European Experiences and a Preview for North America, p. 48, London, Ontario, Canada: Great Lakes Section, Water Resources Branch, Ontario Ministry of the Environment, 1989.

McMahon, Robert F., and Tsou, John L., "Impact of European Zebra Mussel Infestation to the Electric Power Industry," Presented at the American Power Conference, Chicago, April 23-25, 1990.

Miller, A. C., "The Corps of Engineers Initiates Studies on Zebra Mussels," Dreissena Polymorpha Information Review, Vol 2, p. 1, 1991.

Roberts, L., "Zebra Mussel Invasion Threatens U.S. Waters," Science, pp 1370-1372, September 21, 1990.

Szlauer, L., "Use of Steelon-net for Protection of the Hydro-engineering Works against *Dreissena polymorpha* Pall," Pol. Arch. Hydrobiol., Vol 21, pp 391-400, 1974.