Developing Environmentally Sound Methods and Strategies to Control Zebra Mussels at Public Facilities

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Abstract

In response to the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (Public Law 101-646) the U.S. Army Corps of Engineers initiated a program to develop methods and strategies to control zebra mussels at public facilities. Research is being facilitated by working groups that deal with the following structures: 1) locks and dams; 2) vessels and dredges; 3) power facilities; and 4) reservoirs, water intakes, gages, and pumping stations. Each working group consists of individuals with expertise in zebra mussel control, biology and ecology of zebra mussels, and design, construction, or operation of the facility of concern.

A central theme to the research is demonstration projects conducted at specific facilities along waterways. Findings from laboratory and field research are being further tested with these demonstrations. This paper describes three demonstration studies: 1) the use of water drawdown to kill zebra mussels at Black Rock Lock on the Niagara River, New York; 2) the use of a copper-containing epoxy coating to protect a tugboat used in the Great Lakes near Detroit, Michigan; and 3) installation of a chlorine injection system for zebra mussel control at hydropower plants along the Cumberland River, Tennessee.

Introduction

Zebra mussels *(Dreissena polymorpha),* first reported in North America in 1988 (l), have rapidly spread throughout waterways of the United States, mostly via commercial navigation traffic (2). It is likely that this species will negatively affect many facilities in the inland waterway system. The U.S. Army Corps of Engineers (USACE) maintains and operates 195 locks, 75 hydropower stations, 461 reservoirs, and 2,260 vessels and dredges. With the exception of those in brackish waters, many are susceptible to zebra mussel infestations.

In response to the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (Public Law 101-646) the USACE initiated a program to develop methods and strategies to control zebra mussels at public facilities. "Public facilities" includes locks, dams, reservoirs, commercial dredges and vessels, as well as non-Corps structures such as intakes for power generation, potable water, and sewage treatment. Research was designed to develop new and evaluate existing zebra mussel control methods and strategies, and study the biology and ecology of this pest species. Studies are being conducted at the U.S. Army Engineer Waterways Experiment Station (WES) in Vicksburg, Mississippi, and the U.S. Army Construction Engineering Research Laboratories in Champaign, Illinois.

Laboratory studies are being conducted on the effects of reduced and elevated temperature and humidity on the duration of aerial exposure needed to kill zebra mussels. Attachment strength of mussels to different types of materials is being analyzed. Chemicals, coatings, and cleaning techniques are being evaluated. Field studies on environmental impacts to native biota, zebra mussel density, growth rates, and demography of newly established populations are under way.

Multidisciplinary Working Groups

In September 1991, the USACE held a planning meeting on zebra mussels in Fort Mitchell, KY. Over 50 scientists and engineers with experience in the design, operation, or maintenance of locks, darns, and reservoirs attended. The purpose was to identify facilities and structural components likely to be affected by zebra mussels. In addition, attendees prepared a preliminary list of strategies to deal with infestations. A summary of the meeting was prepared that provided the basis for further research (3).

Following that meeting, four working groups were formed to deal specifically with facilities of concern. The approach was based on programs developed by Ontario Hydro and the U.S. Coast Guard. Facilities subject to infestation and of concern to the USACE were placed into one of four categories:

1. Locks and dams;
2. Vessels and dredges;
3. Power facilities; and,
4. Reservoirs, water intakes, gages, and pumping stations.

Each working group consisted of individuals with expertise in zebra mussel control, biology and ecology of zebra mussels, and design, construction, or operation of the facility. A typical working group consisted of 20 members and had representation from academia, state agencies, municipalities, Canada, the U.S. Army Corps of Engineers, or other Federal agencies. Continuity **among** groups was ensured by having representation from WES at all meetings. Working group members were tasked with the same two objectives of the 1991 planning meeting: 1) identify components of the facility susceptible to infestation and, *2)* devise environmentally sound strategies to control zebra mussels.

For example, working group members that dealt with navigation locks identified two particularly vulnerable components. These were gage wells used to house water-level sensing equipment, and raw water systems used for fire protection. The working group recommended the following to protect raw water systems:

* Ensure that the system is truly stagnant.
* Install screens over the entrance of intake pipes.
* Periodically treat with chemicals.
* Switch to chlorinated water if possible.
* Periodically drain and inject steam or hot water

The group recommended that gaging wells be inspected frequently by deploying inexpensive monitoring devices such as ceramic tile, concrete blocks, or PVC plates suspended from rope or cable that could be easily removed for examination. The interior of gaging wells could be treated with small amounts of chlorine. The pipe that enclosed meters or led to raw water could be heated with an anti-foulant coating.

Meetings that dealt with other facilities were structured in a similar manner. Group members with knowledge of each facility identified components of concern and recommended methods and strategies applicable to each. Recommendations included use of antifoulant paints and biocides, installation of screens, pigging (cleaning a pipe with a mechanical device), and treatment with desiccation, hot water, or steam.

Groups meet once per year, and individuals recommend methods and strategies for specific facilities. Recommendations are based on results of government research as well as findings from the U.S. Coast Guard, Ontario Hydro, academic institutions under contract to WES, and others studying zebra mussels. Between 1991 and 1994, more than 275 individuals have participated in these working groups meetings (Table 1).

Demonstration Studies

An important component of the Corps' zebra mussel program are demonstration projects. These are designed to apply findings from previously conducted research to a specific facility. In addition to determining the efficacy of control strategies or methods, information on cost, environmental compatibility, and application methods is obtained. The following is a brief summary of these demonstrations.

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Freezing to Kill Zebra Mussels at Black Rock Leek

Laboratory studies have shown that zebra mussels are relatively intolerant to aerial exposure at subfreezing temperatures (4). For example, the LT_{100} values of mussels exposed to air at -10.0°C, -7.5°C, and -5.0°C approximately equal 1.5, 2.0, and 5.0 hours. As temperature increases to approximately -1.5°C to 0.0°C and mussels are exposed in clusters instead of as individuals, survival time increases to >48 hours. Even in cold climates, during winter dewatering of a facility, it is possible that factors such as occasional warming of air, leaking water and ice formation, and clustering of mussels will increase tolerance times over those observed by McMahon et al. (4) for individual mussels in the laboratory.

In January 1994, studies were conducted during winter drawdown of Black Rock Lock, U.S. Army Engineer District, Buffalo, in Black Rock Canal (a side charnel of the Niagara River in Buffalo, New York) to determine tolerance times and exposure conditions of zebra mussels. Constant recordings of air temperature were made at the top of the lock chamber during dewatering and at the bottom of the chamber after dewatering was complete. Zebra mussel samples were collected along a vertical transect down the lock chamber wall just as dewatering was nearly complete, and then approximately 18 hours later. Mussels were brought indoors, the shell length of each was measured, and gently probed (4) to determine if they were alive.

Near the end of the dewatering process, a cold front moved through the area and air temperatures dropped from near freezing to less than -10.0°C within 24 hours. This blast of sustained subfreezing air rapidly killed all mussels on the chamber wall. Usually there was close agreement between mortality observed in this field demonstration and the laboratory studies.

This lock had also been dewatered for maintenance and inspection during January and February 1992. Air temperatures had remained moderate, with frequent warming above freezing during that dewatering. The Dockmaster reported a slower kill of mussels in previous years than was observed in 1993 (Gary Dye, personal communication). Nevertheless, samples taken from outside the chamber (i.e., at a location never exposed to air) and inside the chamber in January 1994 (i.e., exposed to air in early 1993 and again in early 1994) clearly indicated the general effectiveness of the first winter drawdown. Only settlers from the 1993 recruitment cohort occurred in the lock chamber, whereas the population outside the lock chamber consisted of three cohorts.

In summary, even very brief exposure (<24 hours) to air < 3°C is an effective method of controlling zebra mussels. Sustained winter drawdown (several weeks) is sufficient to control mussels even if subfreezing temperatures are not consistently sustained.

Use of a Copper-Containing Epoxy Material to Protect a “Bay Class” Tug from Zebra Mussel Infestations

In March 1992, the U.S. Army Engineer District, Detroit protected the hull of a “bay class” tug, the *Tawas Bay,* from zebra mussel infestations. The tug is 45 feet long, with a beam of 13 feet and a draft of 7 feet. It is used as a vessel tender or in support of larger tugs for strike removal and repair operations in the Detroit and St. Clair Rivers, Michigan. In 1991 it was operated for 70 to 80 days.

The *Tawas Bay* was coated with EPCO-TEK 2000(tm) which is produced by the Hi-Tek Chemical Corporation, Hempstead, New York. The material was applied by Quality Marine Finishers, Mobile, Alabama. The coating is made by mixing epoxy with copper powder, wetting agents, and other materials to produce abrasion resistance and flexibility. The resultant paint is spray able, hard, smooth, scratch-resistant, flexible, barnacle and mollusc repelling, and nontoxic. It also acts as a water-diffusion barrier. In addition to protecting the hull from zebra mussels, this coating will decrease friction in the water, thus increasing fuel efficiency.

Prior to application, the tug was completely sandblasted below the waterline to remove old paint and other foreign material. A high-profiled surface was produced by using 12/20 grit media. Immediately following sandblasting the surface was cleaned to remove all dust, since the antifoulant paint ultimately accentuates marks or unevenness (unfairness) in the substrate because of its enamel-like finish. After the surface was cleaned, a primer was applied. This was a low-viscosity 100% epoxy undercoat, with high “ wicking” characteristics. As soon as the primer became tacky, a single undercoat, which was a thick epoxy that gave an enamel-like finish, was applied to a thickness of 0.0006 inch.

The tug was then painted with five coats of the epoxy/copper coating. The first coat (0.001 to 0.002 inches) consisted of a thinner mixture (25% more than the usual amount of solvent was added). The second coat (0.005 to 0.007 inches thick) contained 15% additional solvent. Each new coat was applied within 30 minutes. The next coat was applied whenever the previous coat felt tacky. The final thickness was approximately 0.017 to 0.020 inches. The painter attempted to achieve a slightly higher thickness on the stem of the vessel to protect the vessel from abrasion caused by sediments stirred up by the propeller.

Development of a Zebra Mussel Control Strategy for Hydropower Plants

Personnel of the U.S. Army Engineer District, Nashville, developed a strategy for controlling zebra mussels at the District's power stations. Two aspects were central to the development of this strategy: 1) keeping the facilities operational regardless of zebra mussels and 2) implementing environmentally sound strategies that would meet the goals of the National Environmental Policy Act.

The Cheatham Project was the sixth of nine projects with hydropower built for the Nashville District. It was completed in 1960 as a navigation and hydropower project. The plant is a low-head design with three 20,000-horsepower vertical shaft kaplan (propeller-type) turbines with a design operating head of 22 feet. The generators are 3-phase, 60-cycle, 13. 8-kv units rated at 13,333 kva and 60 rpm.

As is typical with hydropower generators and turbines of this design, excess heat is removed from turbine bearings, generator bearings, and the generator windings by raw water-cooled heat exchangers. The water for the heat exchangers is drawn from the river, circulated, and returned to the river. Much of the piping for these systems is embedded in concrete and has sharp bends. This dependence on raw river water for cooling the critical generator and turbine components makes Cheatham and other hydropower plants particularly vulnerable to the effects of zebra mussel infestations. Left unprotected, the Cheatham hydropower plant could be completely shut down due to fouling of the raw cooling water piping.

In the spring of 1992 the District developed a design for chlorine injection systems that would be installed at raw water systems at all USACE hydropower plants in the District. The principal system components are 1) a variable rate chemical injection pump that feeds the chlorine into the raw water system at its source; 2) storage tanks designed to hold a 30-day supply of chlorine; 3) an analyzer that measures chlorine concentration in the discharge water and automatically signals a program logic controller to adjust the chemical feed pump to maintain the desired chlorine concentration, and 4) a control panel. containing a strip chart recorder which continuously records chlorine concentration in the discharge water.

In the summer of 1992 a contract was let with Prominent Fluid Controls, Inc., of Pittsburgh, Pennsylvania, for the fabrication and installation of chlorine injection systems for the raw water piping systems for Cheatham and Barkley Power Plants. Installation of the systems has been completed, and they are currently undergoing final tests.

When veligers are detected at the plant, the chlorine injection systems will be activated. Initially, the system will be operated to produce continuous total residual chlorine at the raw water system discharge point of 0.5 ppm. However, personnel at Cheatham Power Plant will experiment with different concentration levels and injection intervals to determine a suitable protocol for their plant.

In addition to the technical aspects of zebra mussel infestation control, the environmental aspects must also be considered, At the same time the chlorine injection systems were being designed and installed, an Environmental Assessment was being conducted by personnel of the Nashville District and the Tennessee Valley Authority for all power generation facilities being operated by both organizations. During the process of conducting the Environmental Assessment it was determined that Cheatham Power Plant would be required to obtain a National Pollution Discharge Elimination System (NPDES) permit from the State of Tennessee to operate the chlorine injection system. The permit applications have been submitted and are now being processed. In the event that an infestation begins prior to approval of the NPDES permits, it will be necessary to request interim permission from the State of Tennessee to operate.

Having protected its most vulnerable component, the cooling raw water systems, Cheatham Power Plant is now prepared for zebra mussel infestations. However, attention must also be given to the many other system components that will be affected. Unlike the raw water systems, these components are physically accessible for the application of other control methods.

Zebra mussel infestations pose a major threat to all electric power production facilities. Facilities that rely on single-pass raw water cooling water systems are particularly at risk. However, with thorough study and planning, electric power production facilities can continue operations unaffected as zebra mussel infestations occur.

summary

Environmentally sound control methods and strategies must be available for immediate use when zebra mussels are first detected at a facility. Applied

chemical, engineering, and biological studies are used to develop control methods. Those who design, operate, and maintain facilities are best able to develop strategies based on their own experience and research findings. As zebra mussels spread throughout the inland waterway system, control strategies will be tested at selected facilities. Success will be determined after evaluation of operational impacts, degree of control, and possible environmental effects. If successful, recommendations to other facility managers will be made. If strategies are not successful, working groups will reassess the problem and recommend new techniques.

No single control agent or method will eliminate zebra mussels from this Nation's waterways. Facility-specific methods and strategies are needed that reduce zebra mussels locally. Methods and strategies must be economical, easy to use, and must not harm native aquatic organisms.

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Table 1
Attendance at working group meetings to develop strategies for zebra mussel control at public facilities. In 1994, two combined working groups meetings were held.

Meeting	1991	1992	1993	1994
Initial Strategy	53	--	--	--
Locks and Dams		25	24	23
Vessels and Dredges		18	19	
Power Facilities		27	26	23
Reservoirs, Intakes, Gages, and Pumping Stations		14	24	
Total Attendees	53	84	93	46

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