RECLAMATION
Managing Water in the West

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Special Edition:
Zebra and Quagga
Mussel Research

Science & Technology Highlights

Zebra and Quagga Mussels Invade the West

Zebra and quagga mussels are invasive, freshwater, bivalve mollusks with a zebra-like pattern on their shells. Originally from Eurasia, zebra mussels were first introduced in the Great Lakes in the mid-1980s and have spread to the western U.S. A single female mussel can produce hundreds of thousands of eggs a year, which produce microscopic, swimming larvae (veligers) that are transported by water currents. Once they reach their settling stage, the veligers attach to hard surfaces and continue to grow.

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In early 2008, larval zebra mussels were confirmed to be present in Pueblo Reservoir in Colorado, and adult zebra mussels were found in San Justo Reservoir in California; which has since become heavily infested. Adult quagga mussels were discovered in Lakes Mead, Mojave, and Havasu on the Colorado River in early 2007. Since then, populations have exploded and are now impacting Hoover, Davis, and Parker Dams. More recently, both zebra and quagga larvae have been detected in several other Reclamation reservoirs in Colorado, most notably those of the Colorado-Big Thompson project. In addition to California and Colorado, mussels are in Arizona, Kansas, Nebraska, Nevada, and Utah.

Quagga mussels on intake trashracks at Hoover Dam.

Zebra and quagga mussels can clog intakes, trashracks, strainers, pipes, fire control systems, cooling water systems, and fish screens, resulting significant costs to protect water and hydropower systems. They have an enormous capacity to filter water and out-compete other filter feeders. This filtering also increases water clarity, resulting in the potential for significantly increased aquatic weed loads that can also impact water diversion, distribution, and hydropower operations and maintenance. Impacts also include alterations in aquatic ecosystems, thus adversely affecting native organisms and endangered species. In essence, zebra and quagga mussels can harm almost every aspect of water and related resources.

Western environmental conditions appear to be very favorable for mussel growth and spread. While many water resources management agencies have made considerable efforts to increase public awareness as a primary strategy for prevention, so far, those efforts have only delayed the spread to Western water bodies. Nevertheless, delaying the spread is still valuable as it provides the lead-time needed for response planning and evaluation of potential impacts associated with new infestations.

Mussel infestations are a growing concern among water management organizations throughout the West. Flow restriction is the foremost concern because mussel infestations reduce pumping and conveyance capacities and threaten water delivery and hydropower reliability. Knowledge and experience from the Eastern U.S. indicates that once introduced, these mussels are almost impossible to eradicate. Economic impacts associated with zebra and quagga mussel infestations in the Great Lakes region are significant, for example, maintenance costs for hydropower facilities have increased by orders of magnitude after an infestation. While Eastern experiences provide a valuable guide, what works in the East may not always work in the West where the vastness and intricacies of water distribution systems compound the problem. Water resources managers in the West need updated information and improved methods, solutions, and strategies to assess and minimize the impacts to our Western water resources infrastructure.

Dead mussel debris in cooling unit.

Reclamation's Research Emphasizes Solutions


Clogged pipe.

To address invasive mussel issues, Reclamation has established an invasive mussel corporate task force to focus on a four-part strategy: (1) outreach and education, (2) research, (3) monitoring and prevention of infestation, and (4) control and mitigation. This task force is helping guide Reclamation in the most effective and efficient use of staff and resources, focusing on facilities that are either already impacted by mussels or that will likely be impacted in the future.

Reclamation also actively participates in the Western Regional Panel for Aquatic Nuisances Species, the Columbia River Basin Rapid Response Plan, and the multi-agency Aquatic Nuisances Species Task Force. Reclamation has held numerous training sessions, and recently hosted the Western Invasive Mussel Management Workshop in May, 2009. Further information has been posted on Reclamation's mussel web site, http://www.usbr.gov/mussels/.

Recognizing that Reclamation facilities are already exposed to infestation and need immediate solutions, Reclamation's Research & Development Office has committed to invasive mussel research as a top priority for fiscal years 2009 and 2010. Under Reclamation's Science and Technology Program, zebra and quagga mussel research is being directed to identify, develop, demonstrate, and deploy effective monitoring and control solutions while improving our understanding of ecological impacts to satisfy Reclamation's primary mission of water and hydropower delivery reliability. The Program intends to provide best practices for the broadest and most effective response by evaluating and, in some cases, enhancing available technologies through coordinated field demonstration projects that meet Reclamation's requirements. Results are also expected to produce widely applicable benefits for our managing partners. Current research topics include:

- **Monitoring:** Monitoring for the earliest possible detection of new infestations provides resource managers with information to assess and respond to the situation and affords lead time to address future budget requirements for protecting impacted facilities. Such lead time is critical to successfully planning and deploying effective control strategies that either minimize or eliminate impacts to water-related infrastructure and ensure reliable water and power delivery. The American Recovery and Reinvestment Act (ARRA) has funded an intensive early detection monitoring program to determine the current extent of mussels in about 60 high priority water bodies at or near Reclamation facilities. This will allow Reclamation to prioritize, plan, and respond to new infestations as well as guide outreach, education, and prevention activities for water bodies not yet infested.

- **Control:** Conventional control strategies are generally considered to be either proactive (i.e., excluding mussel from critical water systems) or reactive (i.e., removing mussels from water systems after they settle). The Program is evaluating, developing, and demonstrating improved conventional and new methods to cost-effectively control mussels on hydraulic structures and in water systems such as intakes, trashracks, fish screens, water delivery pipelines, gates and valves, cooling water systems, instrumentation, and safety systems. Adequate control methods depend on the type of system and associated operating requirements (e.g., certain systems that cannot be shutdown require proactive control methods). While conventional chemical treatment has been shown to be effective, it is costly, often requires permitting, and can result in environmentally adverse byproducts. Reclamation researchers are pursuing innovative treatment methods and testing them in the field to control mussels without these drawbacks.

- **Ecological impacts:** A wealth of experience in the Great Lakes region over the last decade has demonstrated that zebra and quagga mussel infestations create significant long-term ecological changes. While some impacts are known or can be predicted, it is not yet clear how water ecosystems in the Western U.S. will respond. This Program will continue to investigate ecological impacts from invasive mussels at or near Reclamation facilities (including changes in water quality, food webs, aquatic weed production, fishery resources, and endangered species). These findings are expected to help anticipate problems and inform management of actions to deal with adverse environmental impacts.

These research projects highlight the FY 2009 invasive mussel activities:

- ARRA Invasive Mussel Detection Program for 60 western water bodies
- Improvement of optical techniques for detection of mussel veligers
- Veliger enumeration method validation
- Early detection of zebra and quagga mussels using polymerase chain reaction (PCR)
- Evaluation of filtration for excluding zebra and quagga mussel veligers from cooling water systems
- Evaluation of ultraviolet (UV) treatment to prevent mussel settlement in water systems
- Field trials to demonstrate control of quagga mussels using *Pseudomonas fluorescens* (*Pf*)
- Modifications to Davis Dam domestic intake to enable alternative treatments
- Coatings evaluations to prevent or minimize mussel attachment
- Fish screening technologies to reduce impacts of mussels at screened diversions
- Controlling zebra and quagga mussels with natural predators
- Scoping-level study for quagga mussel control using copper-ion generators
- Effects and spread of zebra and quagga mussels in river and stream environments
- Impact of zebra mussels on the physical, chemical, and biological attributes of Lake Pueblo, Colorado

Collaborating and Coordinating to Succeed

Reclamation's zebra and quagga mussel research efforts integrate biological and engineering approaches with an eye toward broad application across Reclamation. Success involves close coordination and cooperation between Reclamation Regional, Area, and Project managers; Reclamation's managing partners, private industry; and other State and Federal agencies, including the 100th Meridian Initiative – an interagency organization dedicated to preventing the spread of invasive mussels and promoting sound approaches to their management. Establishing multi-agency and industry partnerships is helping to expedite the deployment of promising solutions.

The successes achieved thus far in addressing mussel-related impacts would not have been possible without the close collaboration and partnership with Reclamation's Lower Colorado Regions' Dams Office. Regional and Area Office management and staff participation as well as access to facilities such as Hoover, Davis, and Parker Dams have all been crucial to advancing Reclamation's invasive mussel research goals and—more importantly—in leading the way for demonstrating and implementing practical facilities protection solutions.

High Priority Research to Develop Solutions

Pseudomonas fluorescens: Killing Mussels Using a Common Bacteria

Research conducted at New York State Museum (NYSM) and funded in part by the Department of Energy (DOE) through their National Energy Technology Laboratory resulted in the discovery of Pf, a naturally occurring bacterium, as lethal to zebra and quagga mussels, yet benign to other aquatic organisms. The bacterium has been shown to destroy their digestive system when zebra and quagga mussels feed on Pf, resulting in high mortality in relatively short periods of time (depending on environmental factors). In 2008, Marrone Bio Innovation (MBI) (formerly Marrone Organic Innovations) was awarded a Small Business Innovation Research (SBIR) grant through the National Science Foundation to develop this discovery into a commercially viable product (Zequanox™). Reclamation, through efforts from the Research and Development Office and the Lower Colorado Region's Dams Office, has established a commercial partnership with MBI to demonstrate the effectiveness of Zequanox, which is comprised of dead Pf.

Reclamation has been working with MBI to establish a Cooperative Research and Development Agreement (CRADA) for field trials near Laughlin, Nevada at Davis Dam, a facility heavily infested with quagga mussels. This CRADA is intended to cover small-scale formulation testing, full-scale domestic pipeline testing, ecotoxicity studies, and perhaps other future field studies using Zequanox. MBI is also in the process of EPA registration for Zequanox and has secured Experimental Use Permits from the States of Arizona and Nevada for closed system testing. While this product is still under development, it could lead to broad application for invasive mussel control and may be commercially available as early as 2010.

Water Jetting to Control Quagga Mussels in Pipes


High pressure water jetting nozzle.

Water jetting is commonly used to remove mussels from pipes and structures in the East and Mid-west. In the Great Lakes region, mussels' reproductive cycles are limited to periods with suitable water temperatures. This provides a window of time each year to remove mussels from fouled structures. Unfortunately, quagga mussel proliferation in the lower reaches of the Colorado River has been observed to be year round, which is expected to require multiple mechanical cleanings per year. Normally, water jetting requires divers using water jetting wands to remove mussels from trash racks or other similar structures. In other cases, water jetting nozzles with multiple openings are used to clean smaller diameter pipes and drain lines. While there are a variety of systems, some have been found to be either ineffective or minimally effective for removing mussels.

High pressure water jetting pump.

Davis Dam was chosen for the demonstration site as a heavily fouled domestic intake was readily available during a regularly scheduled unit shutdown for routine maintenance. The domestic intake is about 80 feet below the water surface inside one of the unit trash racks.

10-in domestic water line at Davis Dam before water jetting.

Reclamation evaluated a water jetting system that consists of a pumped arrangement to deliver pressures ranging from 5,000-10,000 pounds per square inch (psi) to the nozzle. Prior to water jetting, an inspection camera was inserted into the 10-inch-diameter pipe to observe the conditions. Divers then inserted the water jetting equipment from the reservoir side of the intake. This demonstration was completed in December 2008.

10-in domestic water line at Davis Dam after water jetting.

Outcomes

Before water jetting, heavy mussel attachments (settlement) as well as biofouling and rust nodules were observed throughout the 105-foot length of pipe. After water jetting, the pipeline was inspected again. (Video documentation is available for both pre- and post-cleanout inspections.) The results demonstrated that this system is highly effective for removing mussels and other growths.

However, some rust nodules and some minimal biofouling remained after cleaning. Furthermore, some of the coating was removed (although it should be noted that rust nodules observed before cleaning showed that

coating failures already existed). Cleaning and coating removal was not uniform, presumably because the nozzle head was inserted along the bottom of the pipe rather than along the centerline. Using a crawler is recommended whenever possible to overcome these deficiencies. Reduced operating pressures may also prevent or limit coatings removal.

Acknowledgements

Thanks to staff from Reclamation's Technical Service Center, Materials Engineering and Research Laboratory in Denver, CO including Coatings Specialist Allen Skaja, PhD (askaja@usbr.gov); LC Dams Office coordinator Leonard Willett (lwillett@lc.usbr.gov) and Mechanical Engineer Aaron Muehlberg (amuehlberg@usbr.gov) for support and coordination with Davis Dam staff; and Davis Dam management and staff for providing access and support during this demonstration.

Using Filtration to Exclude Mussels from Raw Water Systems

New self-cleaning filtration technology is being developed to filter invasive aquatic species from ship ballast water. These filters have been identified for use in Reclamation facilities to prevent mussels from getting mussels inside intake pipes, distribution systems, power plants, etc. Filtration for facilities could replace costly chemical methods to control zebra and quagga mussels. To explore the possibility for applying this technology at Reclamation facilities, a field demonstration at Parker Dam was recently completed. Parker Dam was chosen for the test site because it is heavily infested with quagga mussels and there is an urgent need to maintain operation of the raw water supply system.

The filtration system was sized for in-line installation with a flow capacity of 450 gallons per minute (GPM). It consists of interchangeable 40- and 80-micron woven mesh screens, and it was installed on the domestic raw water supply line at Parker Dam. At Parker Dam, raw water is delivered from the forebay, through the dam, to the power plant via a 300-foot-long, 8-inch-diameter pipeline. The filter was installed just downstream of an existing 3/16-inch strainer to protect downstream raw water supply system components from mussels.

450 GPM filter installed at Parker Dam.

In February 2009, RNT Consulting under contract with the filter supplier conducted the initial performance evaluation while Reclamation staff independently observed the testing. Several 1,000-liter water samples were collected immediately upstream and downstream of the filter during testing for both the 40- and 80-micron screens. These samples were then analyzed under a microscope to determine the number and size of veligers in the water samples.

Outcomes

In general, the 40-micron (57 microns absolute) filter screen showed 100 percent exclusion of veligers greater than 100 microns in size, but the 40 micron screen did allow some veligers up to 100 microns in size to pass. The reason for passage of sizes larger than the screen opening is because the shell of a veliger is somewhat flexible allowing it can squeeze through the mesh. Alternatively, the 80-micron (120 micron absolute) screen excluded 95 percent of veligers greater than 200 microns in size, but allowed some 220-micron sized veligers to pass. Although, these tests showed effective exclusion of the ready-to-settle veligers in the size range of 250-450 microns, there appeared to be very few individuals in this size range present during testing.

Further testing will be performed in the coming year when larger numbers and size ranges of veligers are expected as water temperatures increase throughout the spring and summer months.

Acknowledgements

Thanks to staff from Reclamation's Parker Dam for providing filter installation support and access to the facilities; Leonard Willett (lwillett@usbr.gov), LC Dams Office for coordinating with Parker staff; Fred Nibling (fnibling@usbr.gov) and Denise Hosler (dhosler@usbr.gov) from Reclamation's Technical Service Center in Denver, CO; and Renata Claudi from RNT Consulting for performing the initial performance evaluation.

Evaluating Coatings to Prevent Mussel Attachment

Flame sprayed zinc metalizing contrast between plates (minimal flowing conditions) and grates (flowing conditions).

Coatings and alternative material that effectively prevent zebra and quagga mussel attachment would have a wide range of applications across Reclamation. Trash racks, intake grates, and small diameter pipes in particular are most vulnerable to reduced flows from mussel clogging and would benefit from preventative coatings.

Uncoated steel grate.

Non-toxic foul release coated steel grate.

Twenty different commercially available coatings and materials are being tested at Parker Dam. Parker Dam was chosen for the test site because it is heavily infested with quagga mussels that have rapid growth rates. From May – December, 2008, panels were suspended from the dam face at a depth of approximately 50 feet and grates were suspended from the trash rack structure in flowing conditions.

Outcomes

The panels and grates were retrieved for inspection after 7 months of exposure. Fouling rates differed, with some coatings showing complete coverage while other coatings had no mussel attachment. Grates exposed to considerable flow had more mussel attachment and fouling than plates exposed to minimal flow. Following initial testing, sixteen coatings were removed from the study as they showed moderate or heavy fouling. Four coatings that may prevent attachment of mussels were identified as they had minimal or no fouling. Two of these coating systems are antifouling (i.e., prevent mussel attachment) and the other two are foul-release (i.e., easier to remove mussels following attachment).

Further studies are needed to fully evaluate coating performance as well as durability to obtain projected service life information. This study is expected to continue and may include additional products as they are identified. However, it is recommended that testing include applications of promising products to trashracks under actual service conditions.

Acknowledgements

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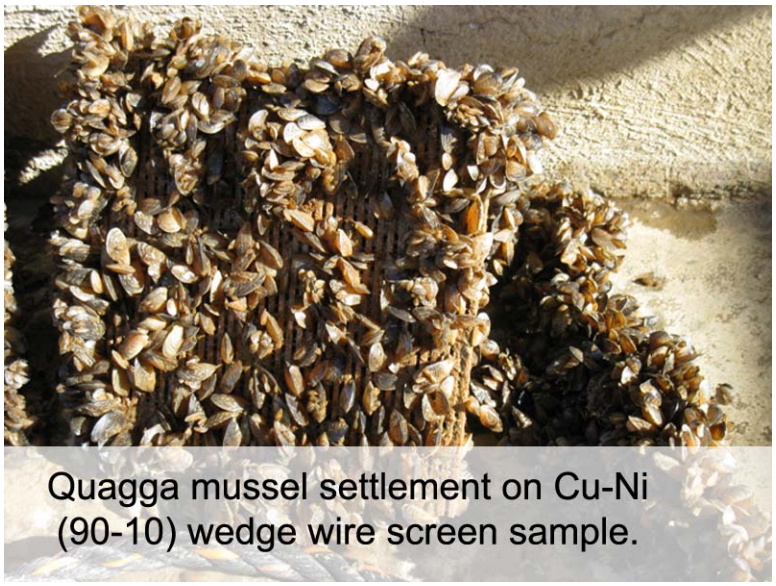
Evaluating the Mussel Fouling Potential of Cu-Ni Fish Screen Material



Quagga mussel settlement on Cu-Ni (90-10) wedge wire screen sample.

Materials that effectively prevent zebra and quagga mussel settlement could be used in a wide range of applications across Reclamation. However, typical construction materials for positive barrier wedge wire fish screens are not expected to prevent zebra and quagga mussel clogging. Clogging of these fish screens could significantly impact Reclamation's ability to maintain reliable water deliveries and protect endangered fish species. Other construction materials, such as a copper-nickel alloy, have been suggested for preventing mussel settlement. Many wedge wire screen manufacturers currently supply products using this alloy as an alternative to stainless steel for applications where biofouling is expected to be severe. However copper-nickel alloys are considerably more expensive than conventional materials.

Outcomes

To preliminarily evaluate the potential of copper-nickel alloys to prevent mussel fouling, two flat one-foot square wedge wire screen test panels were exposed to mussels at Reclamation's Parker Dam, which impounds Lake Havasu and has been infested with quagga mussels since 2007. The panels were suspended from the dam face at a depth of approximately 50 feet from September to December, 2008. After this 4-month initial test period, both screen panels were heavily fouled with mussels, suggesting that this alloy is susceptible to nearly complete occlusion in a very short period of time for the conditions at Lake Havasu.

Conditions for mussel colonization in Lake Havasu are very favorable. Whether other regions of the western U.S. will be as susceptible to such extensive infestation remains to be realized. It should also be noted that this study was not conducted under actual service conditions. However, it is anticipated that the results would likely remain unchanged for typical fish screen service conditions.

The next steps toward identifying solutions for preventing mussel clogging of fish screens will involve testing various fish screen configurations and cleaning technologies under typical service conditions. That project, lead by Reclamation Fishery Biologist Steve Hiebert (shiebert@usbr.gov), is expected to identify the most effective commercially available fish screening technologies, help direct developing new technologies, and assist in providing guidance for existing fish screen facilities retrofit and future fish screen facilities design.

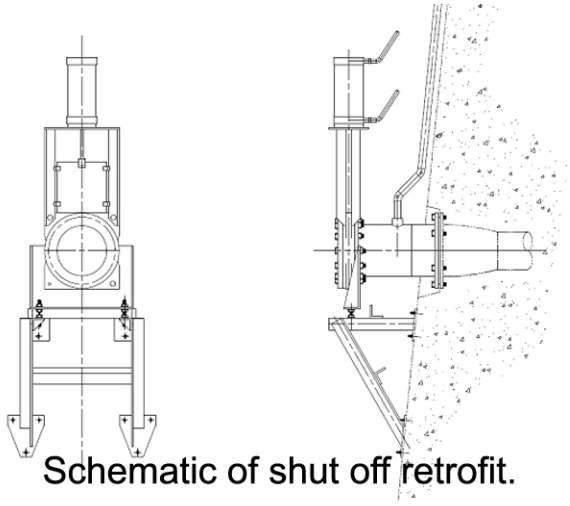
Acknowledgements

Thanks to staff from Reclamation's Technical Service Center in Denver, CO including Coatings Specialist Allen Skaja, PhD (askaja@usbr.gov) for working these wedge wire screen panels into the on-going coatings study at Parker Dam; LC Dams Office, Leonard Willett (lwillett@lc.usbr.gov); Parker Dam management and staff for providing access and support.

Modifying Water Intakes to Enable Treatment and Maintenance

Much of Reclamation's existing infrastructure was not originally designed to control zebra and quagga mussel fouling. In many cases, domestic and cooling water intakes are not regulated at the beginning of intake pipes, and the nearest control valve may be inside the dam or power plant. Without being able to shut off pipelines at the water—and mussel—source, considerable lengths of intake piping are susceptible to mussel fouling. These infestations make maintaining pipes (i.e., chemically treating or manually cleaning) difficult and costly. The heavily fouled domestic water intake grating at a depth of 80 feet at Reclamation's Davis Dam, highlights the difficulties in keeping such a system operable.

Heavy quagga mussel fouling on domestic intake at Davis Dam.



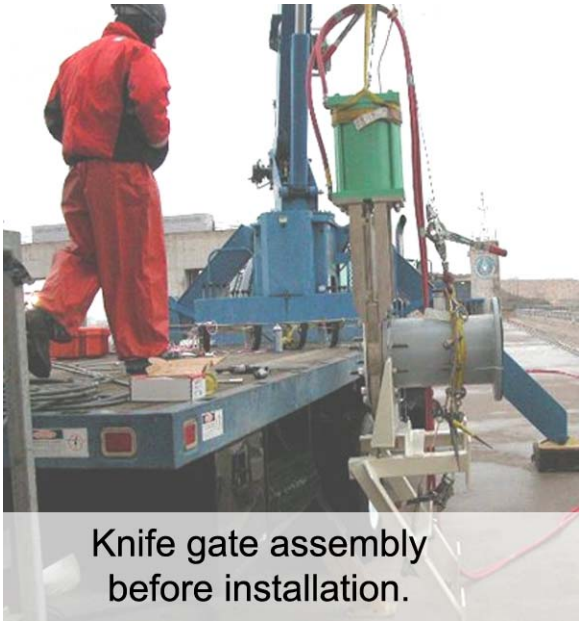
Schematic of shut off retrofit.

To maintain the domestic supply system at Davis Dam, the intake was modified to allow shut off at the reservoir. The retrofit uses a pneumatically operated knife gate. In December 2008, divers installed the valve assembly at Davis Dam. The knife gate assembly consisted of a two-foot-long, ten-inch-diameter pipe extension connected to the existing intake grating flange.

The extension was equipped with a two-inch-diameter female coupling connected to a two-inch-diameter feed line running up to the surface. Finally, a support structure was included for the entire valve assembly which was attached to the dam face.

Outcomes

The domestic intake retrofit at Davis Dam is expected to provide considerable flexibility for controlling quagga mussel fouling in the domestic supply system. Furthermore, this retrofit will allow for testing a promising bacterial product *Pseudomonas fluorescens* and other chemical or biological treatment options without discharging any of the treated water. Furthermore, project management will now have the option for manual cleanout from inside the plant to maintain the 105-foot intake pipeline, thus eliminating the need for costly diver support.



Knife gate assembly before installation.

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