

Fall 2015  
Research and  
Development Office  
Newsletter 2015-04

## *The Knowledge Stream*

**Invasive Mussels Issue**



This newsletter is available at:  
[www.usbr.gov/research/docs/ks-2015-04.pdf](http://www.usbr.gov/research/docs/ks-2015-04.pdf)  
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U.S. Department of the Interior  
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**TRACKING GENETIC CHANGES  
IN QUAGGA MUSSEL  
POPULATIONS IN THE  
WESTERN UNITED STATES**

**REGIONAL DIRECTOR  
RESEARCH NEEDS PROJECTS  
STATUS UPDATE**

**TECHNOLOGY CHALLENGES  
UPDATE—RECLAMATION'S FIRST  
WATER PRIZE COMPETITION**

**DO REDEAR SUNFISH EAT  
QUAGGA MUSSELS?**

# Chief's Message

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Hello and welcome to the fall 2015 edition of *The Knowledge Stream*! In this issue, you can learn about Research and Development Office efforts to address water and power management challenges facing Reclamation and its customers and stakeholders. You will find articles covering a variety of program activities, including technology challenge prize competitions, updates on studies that are addressing critical issues identified by Reclamation's Regional Directors, and results from recently completed research and development projects.

This edition spotlights research on invasive quagga and zebra mussels monitoring, early detection, and control, which is one of the Science and Technology Program's priority areas of research. Invasive quagga and zebra mussels have the potential to adversely affect Reclamation facilities through increased operation and maintenance costs and/or interruption in water delivery and power generation functions. Depending on levels of infestation and facility operating conditions, mussel-related impacts stem from "fouling" (live mussel attachment) and "clogging" (due to fouling or release of mussel shell debris) that may occur in a number of water delivery and hydropower systems. This includes intakes and penstocks, gates and valves, bypasses and air vents, cooling water systems, raw water fire protection systems, service and domestic water systems, instrumentation, and drainage and unwatering systems.

Since the discovery of quagga mussels in Lake Mead, Lake Mohave, and Lake Havasu on the Colorado River (Arizona/Nevada) in January 2007, Reclamation has implemented a coordinated response through a Reclamation-wide Mussels Task Force. This response addresses issues in prevention, monitoring and detection, and control and mitigation. The Research and Development Office, through its Science and Technology Program, plays a key role in this response, supporting development and testing of new monitoring, detection, and control technologies in collaboration with other agencies, and in partnership with United States industry representatives by utilizing technology transfer authorities. Field tests of multiple promising control methods are underway (e.g., foul-resistant coatings, ultraviolet- or turbulence-based schemes in closed pipe systems, pulse pressure technology, etc.). Many of these technologies are highlighted in this edition. We hope you enjoy!

*Levi Brekke,  
Chief of Research*

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## Research and Development Office Budget Analyst



**Jennifer Arends is our new budget analyst. Jennifer has been with the Federal Government for 12 years. She has an associate's degree in Network and Systems Administration, and is just about to finish her Bachelors in Business Administration from the University of Maryland.**

**Jennifer has been a budget analyst for the Navy, Air Force, and Army, most recently at U.S. Army III Corps in Fort Hood, Texas. She has traveled the world with her active duty Army spouse, which is what led to her extensive U.S. Department of Defense experience.**

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# Recent and Upcoming Events

The list of events below is for informational purposes only and does not necessarily constitute an endorsement by Reclamation. These events may be of interest to the science, research, and related communities and are not necessarily hosted by Reclamation. A list of recent and upcoming events can also be found at: [www.usbr.gov/research/events](http://www.usbr.gov/research/events).

## Structure From Motion Photogrammetry—Community of Practice Workshop

June 23 through 25, 2015 | Weaverville, California

The Trinity River Restoration Division in Reclamation’s Mid-Pacific Region hosted and presented a “Structure From Motion Photogrammetry Workshop” to help further establish a community of practice in this area. This research project workshop was funded through Reclamation’s Science and Technology Program.

Contact and additional workshop and project information:

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[www.usbr.gov/research/projects/detail.cfm?id=3835](http://www.usbr.gov/research/projects/detail.cfm?id=3835)



## HydroVision International—Conference and Exhibition

July 14 through 17, 2015 | Portland, Oregon

The HydroVision International Conference and Exhibition is the largest gathering of hydro professionals worldwide. This year’s conference and exhibition highlighted perspectives on the role of hydropower, explored issues affecting hydro resources, and helped participants develop a vision to meet challenges and ensure the future sustainability of hydro.

Additional conference and exhibition information:

[www.hydroevent.com/index.htm](http://www.hydroevent.com/index.htm)

## Climate Science to Engineering Operations for Watershed Management: A CCAWWG Workshop for Scientists, Engineers, and Water Resource Managers

August 25 through 27, 2015 | Seattle, Washington

Reclamation and other Climate Change and Water Working Group (CCAWWG) agencies co-hosted a workshop to share information about agencies’ change and variability research progress and experiences applying climate science to support adaptation activities. This workshop brought together scientists, engineers, and water resource managers to 1) review and discuss progress and accomplishments since 2011, 2) present and share different perspectives on recurring and emerging needs for climate science and climate change information, and 3) provide attendees with a fuller scope and context for their mainstreaming work within their agencies. Representatives from Reclamation’s Regions, Policy and Administration Office, Research and Development Office, and Commissioner’s Office attended.



Contact and additional workshop information:

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Post workshop information: [www.ccawwg.us](http://www.ccawwg.us)



## **Tessel: Delivering Reclamation Geospatial Information—Webinars**

September/October 2015 | Denver, Colorado

Tessel is a web mapping application that delivers Reclamation enterprise geospatial data via the web, along with a suite of base maps and external web services that allow Reclamation users to create context-rich dynamic maps of Reclamation features. A series of short webinars will be pre-recorded and then made available to help users quickly learn all the new things they can do with the newly released version of Tessel. The new version is Reclamation-wide in scope and will replace existing Region versions of Tessel.

Contact and additional webinar information:

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Kurt Wille | 303-445-2285 | [kwille@usbr.gov](mailto:kwille@usbr.gov)

<http://intra.usbr.gov/borgis/tesselstart.html>

## **The Western Regional Panel on Aquatic Nuisance Species—Annual Meeting 2015**

September 2 through 4, 2015 | South Lake Tahoe, California

This annual gathering, hosted by the Tahoe Regional Planning Agency, will include updates and pre-panel meetings, a business meeting, the annual meeting, and field trips to local freshwater locations to learn about aquatic nuisance species and coastal issues, and strategies for preventing the spread of aquatic invasive species.



Contact and additional meeting information:

Leah Elwell | 406-222-7270 | [leah@stopans.org](mailto:leah@stopans.org)

[www.fws.gov/answest/meetings.html](http://www.fws.gov/answest/meetings.html)

## **2015 North American Invasive Species Management Association—Annual Conference**

October 19 through 22, 2015 | Vancouver, British Columbia, Canada

The North American Invasive Species Management Association (NAISMA) is a network of professionals challenged by invasive species. NAISMA's members are a diverse group of individuals who are involved in implementing invasive species management programs at any scale and at any phase. NAISMA's mission is to promote and empower invasive species management in North America.

Contact and additional conference information:

Phil Banks | 575-649-7157 | [marathonag@zianet.com](mailto:marathonag@zianet.com)

[www.naisma.org/events/invasive-species-a-grand-view](http://www.naisma.org/events/invasive-species-a-grand-view)



# Features Faces



Jacquie Keele

[www.usbr.gov/research/projects/researcher.cfm?id=2509](http://www.usbr.gov/research/projects/researcher.cfm?id=2509)



Jacquie Keele setting up a polymerase chain reaction in the clean room.

## Jacquie Keele, Biologist

Jacquie Keele is a molecular biologist working with the Reclamation Detection Laboratory for Exotic Species (RDLES) in Reclamation's Technical Service Center in Denver, Colorado. Jacquie earned her Bachelors of Science in both Cellular Biology and Industrial Chemistry at the University of Northern Colorado in Greeley. She then continued her education at the University of Wyoming in Laramie, where she completed a Doctorate in Molecular Biology. After earning her degree, Jacquie became a post-doctoral research fellow at both the University of Cincinnati, Ohio, and the University of Wyoming. Her initial research focused on the study of heart attacks, then branched into maize genetics. The laboratory skills she learned in these diverse fields, such as DNA extraction, polymerase chain reaction (PCR), and DNA sequence analysis, have helped her research at Reclamation.

In 2012, Jacquie joined Reclamation as a biological technician, where her job duties included the analysis of water samples by PCR for the early detection of quagga and zebra mussels. Recently, Jacquie became a biologist for Reclamation. During this time, she has participated in several water sampling trips, including travel to the Salt River Project, Arizona, to sample for quagga mussels. One of Jacquie's particularly memorable trips took place in 2013, when she and Denise Hosler, also with Reclamation's Technical Service Center, traveled to Belo Horizonte, Brazil, to teach a weeklong workshop on detection methods for golden mussels (*Limnoperna fortunei*). In addition, she has participated in public outreach with laboratory tours and water festivals for students.

Jacquie's research has focused on developing additional PCR assays for invasive species of concern, as well as endangered species. Her research has been highlighted in many technical memorandums, a peer-reviewed article, and presentations to a wide range of audiences. Some of Jacquie's Reclamation Science and Technology Program research projects have centered on optimizing early detection methods for invasive mussels with PCR. This work resulted in an increase of the sensitivity of the PCR assay for the detection of the invasive mussels. Additional projects have examined veliger degradation during storage, the importance of buffering samples, and the stability of quagga mussel eDNA. Another project involved analyzing a wide range of samples (bird feathers, fish clips, and other organisms) using DNA barcoding methods to identify the organisms from which the samples were taken. In DNA barcoding, an organism can be identified by taking a fragment of a conserved gene, such as cytochrome oxidase I (COI), amplifying it by PCR, sequencing it, and then analyzing the sequence using a database. All of these projects have furthered the goal of increasing the molecular testing methods for the RDLES laboratory. Currently, Jacquie is creating tables of pathogens and chemicals of concern for water reuse.

Jacquie enjoys reading novels written by a wide range of authors. Some of her hobbies include knitting, spinning, and weaving. When not at work, she can be found at her favorite knitting store or visiting her parents in northern Colorado.

## ... Highlighting People That Contribute to Reclamation Research and Development

### **Sherri Pucherelli, Biologist**

Sherri Pucherelli is a biologist in the Environmental Applications and Research Group in Reclamation's Technical Service Center in Denver, Colorado. Sherri has a Bachelors of Science in Environmental Biology from Western State Colorado University in Gunnison, Colorado. While earning her degree, she also worked for the U.S. Department of Agriculture's Forest Service, where she assisted with a forest fire deterioration monitoring project and identified fungi. Sherri earned a Masters of Science in Bioagricultural Sciences and Pest Management, with a specialization in Entomology, from Colorado State University in Fort Collins, Colorado. Her master's thesis focused on the Russian wheat aphid, a significant invasive pest of wheat crops. The research was designed to determine potential sources of genetic diversity by examining the pest's ecology and reproduction on noncultivated grass hosts in high elevation environments.

Sherri began working for Reclamation as a student in 2005 and became a permanent employee in 2012. Since then, she has been applying her experience to the invasive mussel research effort. Sherri has worked closely with Reclamation's Science and Technology Program to conduct a variety of innovative quagga mussel treatment research projects at Reclamation facilities in the Lower Colorado Region. This research has helped her become an expert at analyzing living mussel larvae and collaborate with some of the top researchers in the field. Sherri tested ultraviolet light treatment for the prevention of quagga mussel settlement in hydropower generator cooling systems at Reclamation's Hoover and Davis Dams (Arizona/Nevada). She is currently testing the impact of turbulence on mussel larvae damage and settlement prevention in collaboration with the Hydraulic Investigations and Laboratory Services Group in Reclamation's Technical Service Center. These treatments show significant promise for the prevention of mussel biofouling in hydropower facilities.

Sherri has also worked with Reclamation's Science and Technology Program to determine accurate quagga mussel habitat suitability parameters for predicting quagga mussel spread in the Western United States. She works closely with the Reclamation Detection Laboratory for Exotic Species in Reclamation's Technical Service Center to conduct research related to improving early detection methods of invasive mussels. In addition to mussel research, Sherri assists with aquatic and terrestrial invertebrate monitoring projects.

Sherri enjoys yoga and spending time outdoors biking, hiking, and cross-country skiing. Most recently, she went fishing in Alaska and backpacking in Norway.



*Sherri Pucherelli*

[www.usbr.gov/research/projects/researcher.cfm?id=2511](http://www.usbr.gov/research/projects/researcher.cfm?id=2511)



*Sherri Pucherelli sampling quagga mussels at Lake Mead, Nevada.*



# Multimedia Around Reclamation

## Quagga Mussel Research—Six-Year Report, October 2014

Reclamation has released a report titled, *Coatings for Mussel Control—Results From Six Years of Field Testing*, summarizing 6 years of testing coatings to control the attachment of quagga and zebra mussels to water and power facilities. Since the research study began in 2008, Reclamation has tested more than 100 coatings and materials.



The testing was conducted at Parker Dam (Arizona/California) on the Colorado River. Invasive mussels at this location reproduce year-round and have a high growth rate. Each coatings system was tested in static and flowing water conditions at the dam and evaluated twice annually, in May and November.

The research was funded by the Research and Development Office where research is conducted to develop and deploy successful solutions to improve water management practices, increase water supply, and ensure cost-effective power generation operations. Published on October 21, 2014.

See: [www.youtube.com/watch?v=jIoflXY9zy8](http://www.youtube.com/watch?v=jIoflXY9zy8)

Report: [www.usbr.gov/mussels/docs/MERL2014-64Coatings.pdf](http://www.usbr.gov/mussels/docs/MERL2014-64Coatings.pdf)

Project: [www.usbr.gov/research/projects/detail.cfm?id=809](http://www.usbr.gov/research/projects/detail.cfm?id=809)



## Reclamation's "Quagga and Zebra Mussels" Website

The presence of quagga and zebra mussels in Western United States waters is a top priority for Reclamation's Science and Technology Program. The program is directing research and development to detect and control invasive mussels throughout Reclamation.

See: [www.usbr.gov/mussels/](http://www.usbr.gov/mussels/)

[Home / Quagga and Zebra Mussels](#)

## Reclamation's Lower Colorado Region "Quagga Mussels on the Lower Colorado River" Website



In January 2007, quagga mussels were discovered at Lake Mead (Nevada/Arizona). The discovery generated instant concern, as these mussels can potentially colonize water supply systems at hydroelectric powerplants and similar facilities to the point of disrupting operations. Reclamation's Lower Colorado Region immediately embarked on a concerted effort to learn more about these mussels.

See: [www.usbr.gov/lc/region/programs/quagga.html](http://www.usbr.gov/lc/region/programs/quagga.html)

## 100th Meridian Initiative Website—Zebra/Quagga Mussels and Multimedia

The 100th Meridian Initiative is a cooperative effort between local, state, provincial, regional and Federal agencies to prevent the westward spread of quagga and zebra mussels and other aquatic nuisance species in North America.

See: [www.100thmeridian.org/zebras.asp](http://www.100thmeridian.org/zebras.asp)



# Regional Director Research Needs Projects

For the past 3 years, Reclamation's five Regional Directors have been asked to identify critical issues that could benefit from brokered research and development projects. In response, the Research and Development Office, Regional Science and Technology Coordinators, and others have developed research to address these issues. Status updates are listed below for a few of these Regional Director Research Needs projects:

## Great Plains Region

### Using a Geographic Information System to Help Manage Water Quality in a Colorado Mountain Lake

#### *Modeling hydrology, sediment, and nutrient transport in a managed watershed*

#### Problem

Grand Lake, Colorado's largest and deepest natural lake, lies within the headwaters of the Colorado River near Rocky Mountain National Park. Reclamation's Colorado Big-Thompson Project West Slope Collection System (West Slope C-BT Project) uses Grand Lake as a conveyance to assist with moving water from the west slope of the Rocky Mountains to the agricultural lands and communities of the east slope of Colorado. This area includes Lake Granby, Shadow Mountain Reservoir, and Grand Lake (known as the Three Lakes Watershed). The State of Colorado, Water Quality Control Commission accepted a proposed numeric water clarity standard for Grand Lake, currently scheduled for implementation in 2017. Water clarity is a measure of how much material is suspended in the water and how much that decreases the passage of light through the water—how turbid or cloudy the water looks to a person. In Grand Lake, it is a function of several factors including, but not limited to, organic and inorganic particles.

Currently, it is poorly understood how the effects of storm water or non-point source runoff and associated sources of suspended sediments/nutrient loading from tributaries and surrounding lands affect water clarity and/or algal production in the West Slope C-BT Project. Additionally, there was no analytical model available for synthesizing data to address potential watershed issues.

#### Solution

A geographic information system (GIS)-based computer model was implemented using a variety of data input. The model was based on the Soil and Water Assessment Tool (SWAT), originally developed by the U.S. Department of Agriculture collaborating with Texas A&M University, U.S. Environmental Protection Agency, and Natural Resource Conservation Service. The data input included soil, topography, hydrology, land cover, climate, and various other point source data. The completed and calibrated model produced flow data for 19 subbasins within the watershed.

#### Application and Results

The development of the model involved direction and data from the Three Lakes Technical Committee, a local Colorado stakeholder group made up of local, state, and Federal agencies interested in water quality/clarity conditions in the Three Lakes watershed and associated West Slope C-BT Project. Various scenarios for flow and nutrient movement within the watershed were produced.

## More Information

See page 15 in the spring 2015 issue of *The Knowledge Stream* at:

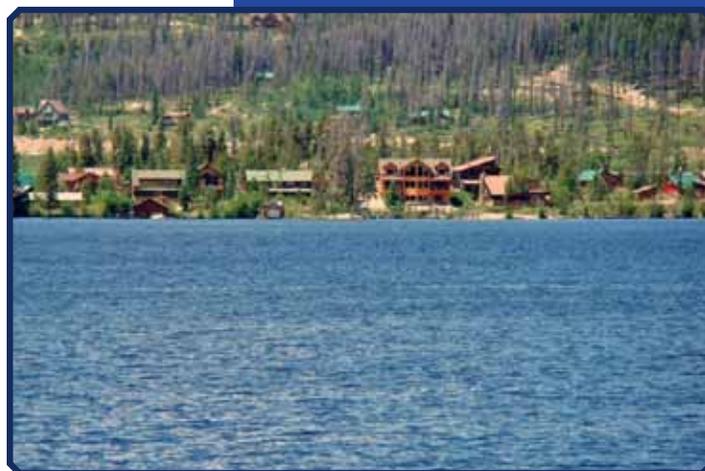
[www.usbr.gov/research/docs/ks/ks-2015-02.pdf](http://www.usbr.gov/research/docs/ks/ks-2015-02.pdf)

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Grand Lake, Colorado.

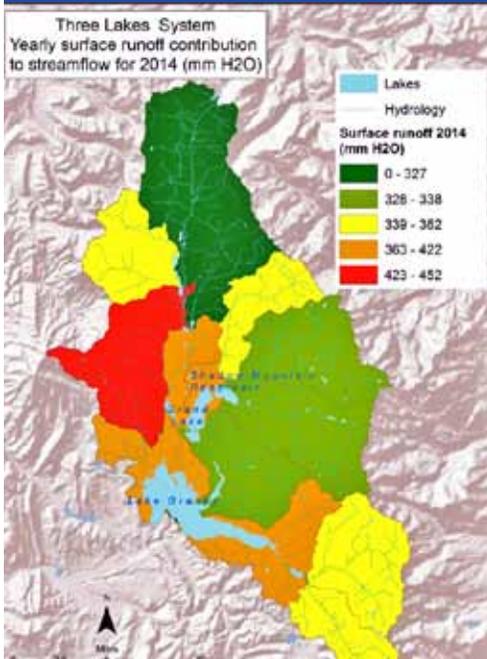
— continued



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# Regional Director Research Needs Projects

— continued



The figure (to the left) provides a visual of one specific non-point source pollutant, showing the basin area surrounding the populated areas, such as the town of Grand Lake as a hotspot. With a functional model, proposed land use changes could be incorporated to determine potential changes to hydrology, sediment, and nutrient transport within a watershed. Existing conditions may also be identified as “areas of concern.” Quantifiable input values may also be incorporated into existing reservoir or lake models. In other words, the model could provide additional understanding of Reclamation’s operations to support clarity-based operational/management decisions for the West Slope C-BT Project. The methods used in this study could also be applied in other Reclamation regions as public awareness of water quality and water clarity issues increases.

## Future Plans

The model could be calibrated to include additional sediment and nutrient parameters as needed. In addition, within the next year, the Three Lakes Technical Committee is expected to direct further investigations within the Three Lakes Watershed using the model. For example, the model could be used in conjunction with the existing water quality and hydrologic models for the Three Lakes System to identify operational alternatives to meet clarity standards. Finally, the model is anticipated to be used in any number of other watershed projects within Reclamation.

## Great Plains Region

### Identifying Nitrosamines as Disinfection Byproducts in Regional Rural Water Systems

#### *A Mni Wiconi Rural Water System case study*

## Problem

Under existing project authority, Reclamation’s Great Plains Region, **in collaboration with the sponsors**, is authorized to operate and maintain the Mni Wiconi Rural Water Supply Project (see maps on next page), where operators are currently challenged with monitoring and managing disinfection byproducts.

Emerging byproducts of interest are nitrosamines. Six nitrosamines, including N-Nitrosodimethylamine (NDMA), are included on the Unregulated Contaminant Monitoring Rule 2 list for monitoring. The U.S. Environmental Protection Agency (EPA) currently classifies nitrosamines, especially NDMA, as probable human carcinogens. This monitoring provides a basis for future regulatory actions to protect public health.

Previous findings across the State of California discovered that NDMA was found to be a Disinfection Byproduct (DBP) for surface water treatment plants using chlorine, ozone, or chloramine disinfection. It is presumed that the precursors instrumental in the formation of nitrosamines are present in the finished water at the Oglala Sioux Rural Water Supply System Water Treatment Plant (WTP) in Fort Pierre, South Dakota. Given current regulations in other states and NDMA detections associated with drinking water sources and treatment, NDMA is a good candidate for future regulation. This case study focused on identifying the presence of nitrosamines in the distribution system and evaluating a preferred method of action for reducing the formation of this DBP, if required.

— continued

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## Collaborators

The Mni Wiconi Rural Water System Project includes three Tribal sponsors (Lower Brule Sioux Rural Water System, Rosebud Sioux Rural Water System, and Oglala Sioux Rural Water Supply System) and one non-Tribal entity (West River/Lyman-Jones Rural Water System), all interconnected.



— continued

The methodology used in this case study could be applied to other Reclamation authorized regional rural water systems, such as Fort Peck Reservation/Dry Prairie Rural Water System, Rocky Boy's/North Central Rural Water System, etc., which use similar disinfection methods for treating surface water.

## Solution

Research shows that concentration of nitrosamines increases the residence time within the distribution system. It is predicted that higher concentrations of nitrosamines are at locations further away from the WTP. Preliminary testing at four locations throughout the system was completed on August 14, 2014, which shows a presence of NDMA. Three locations were chosen along the south core distribution line (Vivian, Murdo, and Kadoka) and one location on the north core distribution line (Philip). These locations were chosen because they vary in distance away from the WTP—Vivian is 35 miles away, Murdo is 50 miles away, and Kadoka and Philip are both approximately 100 miles away from the WTP.

EPA Method 521, which uses solid phase extraction and capillary column gas chromatography with large volume injection and chemical ionization tandem mass spectrometry, is the approved testing method for determination of nitrosamines in drinking water. Reclamation predicts there are trace amounts of nitrosamines in the Mni Wiconi Rural Water System as multiple precursors are present, such as the use of polymers softening to reduce scale formation and chloramines used as a disinfectant for the treatment of surface water.

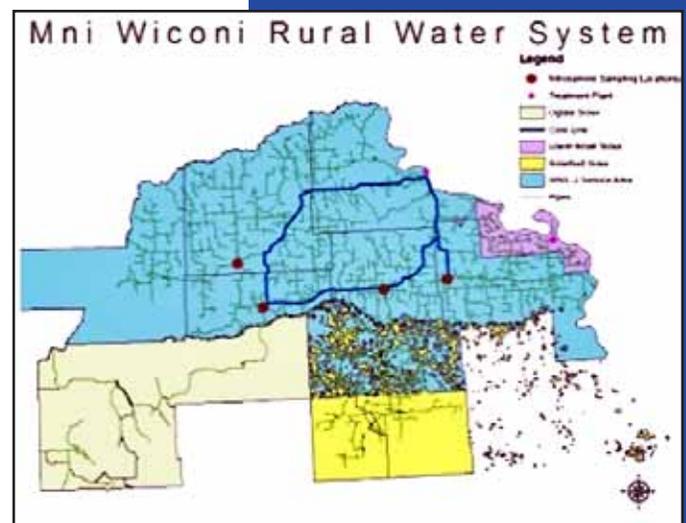
Other contributing factors that lead to their formation in the distribution system include the mere size of the system. Reclamation anticipates quarterly monitoring for 1 year. The monitoring will establish a baseline for further research (see “future plans” in sidebar).

The research project will produce sampling and laboratory methodology for the detection of small amounts of nitrosamines and a written report summarizing the findings within the study area.

## Application and Results

The final report will document the process, provide the findings, and document the metadata as a case study for other regional rural water systems throughout Reclamation. The resulting data could provide statistical formation potential of the contaminant that may affect the ultimate water quality of the Mni Wiconi Rural Water System.

Mni Wiconi Rural Water System samples for third and fourth quarter testing are still pending.



## Future Plans

The first-year monitoring will establish a baseline for further research. Second-year project scope will include performing research to mitigate nitrosamines formation, as well as the elimination and/or reduction of precursors in the Mni Wiconi Rural Water System, which can be applied to other regional rural water systems. If implementation of any mitigation strategies can be identified and applied for the Mni Wiconi Rural Water System during the second year, the elimination and/or reduction results will be included as part of the case study.



# Regional Director Research Needs Projects

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## Lower Colorado Region

### Project Tracking/Portfolio Management Software

*Incorporating project management methodology with earned value management to assist with project oversight, tracking, reporting, and change control*

### Problem

The Engineering Services Office (ESO) in Reclamation's Lower Colorado Region is a full cost recovery fee-for-service organization that provides design, technical, and construction services to Reclamation and other Federal agencies upon request. Services include project management, engineering analysis and assessments, special engineering studies, field investigations, field surveying, field and design data, designs, specifications, cost estimating, pre-award contracting technical activities, and construction inspection and testing, up to and through commissioning, acceptance, and operation. The success of projects completed by the office requires efficient costs tracking, scheduling, and integrated change control. ESO actively manages approximately 200 projects annually, with a cumulative value of over \$30 million.

The system ESO currently uses to accomplish project tracking/portfolio management involves multiple Microsoft Excel spreadsheets, many of which are interlinked and contain complex formulas to derive statistics needed to monitor each project's status. This multiple-spreadsheet approach has the potential to create significant errors as a single break in one of the formulas or links can propagate to other dependent cells

and/or worksheets resulting in incorrect calculations and invalid conclusions. These errors can be time-consuming and difficult to find. In addition, recent Reclamation financial system changes have made importing up-to-date financial information to the project tracking spreadsheets very labor-intensive, resulting in staff needing to develop new methods to integrate this information into the existing, multiple-spreadsheet framework. As it currently exists, the process is inefficient and requires staff to devote a considerable amount of time and attention to ensure project status information is accurate.

### Solution

A more efficient and disciplined project management process is essential to ensure ESO's success in meeting customer needs and expectations, and to safeguard the integrity of data. Having a project tracking/portfolio management software solution that can streamline the project and earned value management processes from service agreement startup through project closeout will

ensure that on time and within budget performance is maintained for ESO's projects, and will significantly reduce the threat of errors inherent in the spreadsheet-based process currently employed. Additional benefits include an increase in efficiency by allowing staff more time to focus on project-related tasks as opposed to unnecessary interference from troubleshooting activities, and the ability to keep clients and stakeholders better informed of their projects' status, risks, changes, and earned value.

### Results

In fiscal year 2015, ESO received Reclamation Science and Technology Program funding to perform market research of available project tracking/portfolio management solutions. As a product of this market research, ESO has conducted numerous



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interviews and participated in several screen-sharing sessions to better identify software solutions that meet the business needs. A comprehensive matrix listing project tracking/portfolio management functionalities was developed to compare the capabilities and costs of each software package. ESO is presently drafting the final report and evaluating each solution.

### Future Plans

This research has helped identify several solutions that may meet ESO's business needs. Moving forward, ESO will be requesting additional S&T Program funding in fiscal year 2016 to perform a pilot test of the project tracking/portfolio management solution identified in the matrix as meeting the highest number of required and optional functions.

If a successful pilot test can be achieved, ESO plans to adopt the software and phase out its existing practices by mid-fiscal year 2017.

ESO's findings will be fully documented and shared so that other offices throughout Reclamation can determine if this solution would help meet their business needs and improve project tracking efficiency.

### Mid-Pacific Region

#### Balancing Groundwater Pumping and Land Subsidence

##### *Simulating the groundwater pumping–land subsidence relationship near the Delta-Mendota Canal*

### Problem

Land subsidence near the Delta-Mendota Canal (DMC) in Reclamation's Mid-Pacific Region can impair the canal's ability to deliver water by reducing freeboard, reversing hydraulic gradients, and causing structural damage. Preventing subsidence in the area of the DMC is thus critical to Reclamation's mission. Historically, subsidence has occurred in this area primarily due to overreliance on groundwater for agricultural water requirements (tectonic activity and possibly petroleum and gas development have also played a role). The Central Valley Project (CVP) alleviated this problem largely by importing surface water and decreasing the demand for groundwater pumping. However, in dry periods, groundwater is still relied on heavily to augment dwindling surface water supplies. Recent U.S. Geological Survey studies have also demonstrated significant subsidence in the area—even during wet periods in some places. It is thus important to model groundwater pumping and land subsidence. Accordingly, this research effort has developed a groundwater subsidence model that simulates the relationship between pumping and subsidence, particularly for wells near the DMC.

### Solution

A total of 27 scenarios have been formulated that probe the impacts of different groundwater pumping magnitudes, locations, and timing patterns. The model scenario simulations are currently running and completed results will then be documented in September 2015. These results will help inform Reclamation and water managers on the most important factors governing the occurrence of subsidence resulting from groundwater pumping so that subsidence risks may be minimized, while using groundwater as an important resource for augmenting water supplies.

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### Collaborators

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# Regional Director Research Needs Projects



Photograph showing the ruptured Delta-Mendota Canal lining due to land subsidence.

## Principal Investigator

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## Collaborators

- Reclamation's Pacific Northwest Region Employees
- University of North Carolina's Healthy Solutions Team in the Department of Health Behavior

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## Application and Results

It is expected that the model scenario simulations will be completed in July 2015. The results are expected to identify the most important factors governing the occurrence of subsidence resulting from groundwater pumping along the DMC. These results will help guide water management in the area to augment surface water supplies with groundwater pumping in the most effective way possible, while also protecting the DMC from the negative impacts of subsidence. Related projects in the area may also benefit from the results of this project. For example, results of this study may provide important insights into infrastructure projects, such as the proposed high-speed rail, by identifying areas near the DMC that are at most vulnerable to subsidence.

## Future Plans

To enable evaluation of the factors contributing to this subsidence over a longer hydrologic period, the scenario simulation period will be extended from 1961-2003 to 1961-2013 to capture recent hydrology and more recent periods of observed subsidence. In addition, a comprehensive sensitivity analysis will be conducted to better examine the relationships between groundwater pumping and land subsidence.

## Pacific Northwest Region

### Understanding the Culture of Safety in Reclamation's Pacific Northwest Region

*Assessing the power and influence of the "soft" side of safety—beyond hard rules and equipment*

## Problem

The Pacific Northwest Region (PN Region), like most Reclamation regions, is large and diverse in its geographic extent and in the types of work that make up Reclamation's mission. Reclamation is involved in construction, operation and maintenance of large water conveyance and power facilities, natural resource fieldwork and data collection, design, office work, and other activities. Together, the diversities greatly add to the challenge of ensuring a culture that promotes safety in consistent and effective ways. The need to improve safety and lower risk is amplified by the potential consequences involved in much of the PN Region's work. The PN Region is actively trying to determine the underlying safety culture within its many offices and facilities to explain cultural phenomena that can affect staff safety.

## Solution

A collaborating University of North Carolina (UNC) team will assess safety and occupational health conditions at select PN Region locations. The UNC team specializes in organizational systems research and uses a combination of information and data evaluation, along with participation from staff to incorporate perspectives and experiences that exist within the work environment being assessed. The enhanced quality of data and interpretation from this participation informs system adjustments based on "bottom-to-top" (employee to management) and internal-external (Reclamation to outside Reclamation) perspectives that might otherwise be overlooked.

Such a tailored approach is uniquely helpful in organizations where prior attempts to assess and enhance systems have come up short. These methods use

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a multidisciplinary approach, resulting in a more holistic set of recommendations that may help remove cultural roadblocks to change. The UNC team will assess and compare “safety culture” benchmarks with select high-reliability organizations functioning at a similar organizational scale and facilitate the development of recommendations from the assessment findings to the PN Region. The UNC team will adapt and tailor their multidisciplinary methods on policy and systems improvements to conduct research on safety and occupational health in the PN Region.

## Application and Results

The 2-year research project has just begun. Reclamation is still providing data, studies, reports, and information to the UNC researchers for their meta-analysis. This will help the UNC team narrow in on what is working, and what may not be, so they can develop a plan for further data collection.

## Future Plans

Ultimately, this work is about polishing and improving employee safety. The results from this research will be a set of recommendations for improving the PN Region safety culture. The second phase of this work will be implementing the recommendations.

### Upper Colorado Region

#### Can We Reduce Fish Entrainment at Water Diversion Sites?

##### *A new fish weir reduces the entrainment of fish in canals*

### Problem

The diversion of river water for irrigation or power-generating purposes can have serious consequences for fish. The fish either become entrained into water diversion intakes or impinged on intake screens. Fishes with drifting early life history phases (i.e., young-of-year) are likely to become entrained into water diversions as they are passively transported downstream with the current. Highly mobile fish species (juvenile and adults) are also likely to become entrained into water diversions, often because of their seasonal movements throughout the river channel. During certain portions of the irrigation season, water diversions can take a large proportion of the water from a river. Both the Colorado pikeminnow (*Ptychocheilus lucius*) and razorback sucker (*Xyrauchen texanus*) are known to move extensive distances throughout the Colorado River Basin. The extensive movement inherent in these fish increases their risk of becoming entrained in irrigation canals, such as the Hogback Diversion Canal on the San Juan River near Shiprock, New Mexico. A previous study at this canal showed that the entrainment of fish at this diversion was extremely high (more than 12,000 fish in 1 year), especially during irrigation season when the diversion can take more than 50 percent of the water in the river.

The scope and magnitude of this problem has also been recognized in other river basins in the Western United States (U.S.), where policies have been implemented to help minimize the mortality of fishes caused by water diversions. The California Department of Game and Fish has adopted a statewide fish screening policy to exclude salmon, steelhead, and federally (Endangered Species Act) listed species from irrigation diversions. Fish screens are now mandated in California for any new or modified diversions and for all diversions within the critical habitat boundaries of federally listed species. Construction of fish screens to minimize entrainment is the recommended alternative throughout the Western U.S., although there are many

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### Principal Investigator

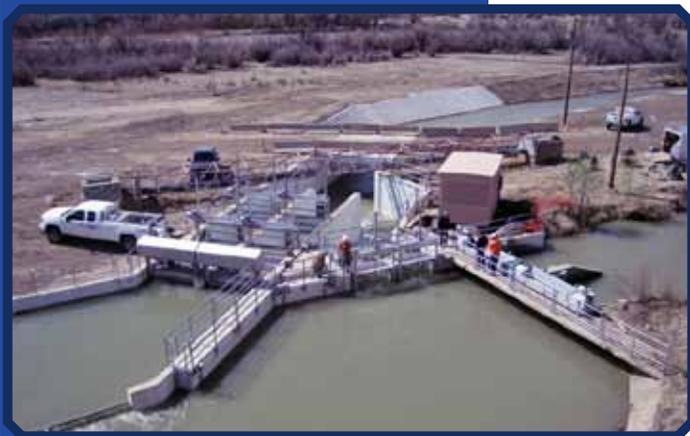
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### Collaborators

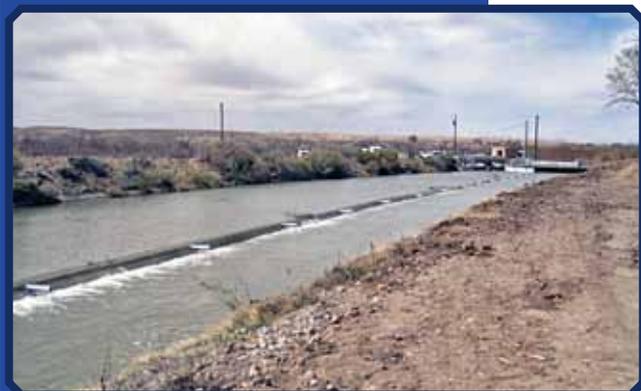
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  - ◇ Scott Durst
  - ◇ Manuel Ulibarri
- Navajo Nation:
  - ◇ Chris Cheek
- Biomark:
  - ◇ Peter MacKinnon
- American Southwest Ichthyological Researchers, L.L.C.:
  - ◇ Steven Platania
  - ◇ Howard Brandenburg



# Regional Director Research Needs Projects



View looking downstream toward the lateral gates from a mid-point of the fish weir. The lateral (saloon-type) gates allow the water to be checked up so that the water in the canal is high enough to go over the weir.



View looking downstream of the fish weir. Approximately 6 inches of water is passing over the top of the weir.

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problems that arise with the use of screens. Heavy debris loads often clog the screens, which then require extensive maintenance or costly and unreliable cleaning mechanisms. Furthermore, even though screens may exclude larger fish, the larvae are still susceptible to passing through the screens and becoming entrained.

## Solution

In 2007, a Value Engineering (VE) team was commissioned to develop and evaluate various proposals to modify the Hogback Diversion Canal to continue to deliver water yet eliminate, or drastically reduce, the entrainment of fish in the canal. VE is a systematic method to improve the value of a product by increasing the function, reducing the cost, or both. The ultimate goal with VE is to obtain the best results for the least cost. Members of the VE team

included fish biologists, construction engineers, cost engineers, design engineers, and irrigation specialists.

The San Juan River carries a high load of sediment and debris during runoff, and one of the requirements was to allow passage of fish and debris while still delivering water to the canal. Several concepts were discussed by the VE team including

traditional screening, electric barriers, and infiltration galleries. The VE team concluded that the most cost-effective and -efficient means of reducing fish entrainment was to construct a 550-foot weir approximately 8 feet tall at an oblique angle in the canal, with the goal of passing a few inches of water over the top of the weir that would be diverted into the canal and, at the same time, maintaining a flow in the canal along the upstream side of the weir that would eventually transport fish and debris into a return channel back to the San Juan River. The VE Team believed that the fish would stay near the bottom as they entered the headgate to the canal. As they moved downstream in the canal, they would encounter the weir wall and move downstream with the flow until they finally exited the canal into a return channel back to the river.

The decision was made to pursue this approach and construction of a weir wall, with the required facilities and water-regulation devices, was completed by April 30, 2013. The cost of the weir was approximately \$3.5 million. No fish-exclusion device of this type had ever been constructed or tested. This concept was new and, if it worked, would represent a significant improvement over screens and other exclusion devices that tend to be very costly to maintain and are often not operational due to impingement of screens and grates with debris. Several other locations in the Colorado River Basin lend themselves to this design and, if this approach works, may be pursued at these locations.

## Application and Results

The research was conducted at the Hogback Irrigation Canal on the San Juan River near Farmington, New Mexico. Reclamation installed several Passive Integrated Transponder (PIT) tag antennas in the facility to detect movements of PIT-tagged fish as they moved through the canal and interacted with the weir. Reclamation stocked over 800 PIT-tagged, endangered Colorado pikeminnow and razorback suckers in the intake canal and determined their movements using the PIT tag antennas. Entrainment of these endangered fish was reduced by 97 percent.

## Future Plans

Reclamation is continuing to stock other native fish at the intake structure to refine the numbers on entrainment. Researchers felt the weir design might also work for excluding larval fish. To test that idea, Reclamation is currently conducting tests with larval fish and how they use the facility. Plans to complete the work with larvae are scheduled for 2016. Thus far, the results look promising for the effectiveness of the weir on larval fish.

# Technology Challenges Update — Reclamation's First Water Prize Competition

## New Concepts for Remote Fish Detection

Reclamation is seeking innovative fish tracking technologies in its first prize “challenge” competition. Effective tracking methods are vital to monitor ecosystem health and recovering threatened and endangered fish species. Reliable, affordable detection and tracking provides vital information about:

- How many fish are present
- Where do they move to and why
- How healthy are the populations
- Where and why mortality occurs
- Where and why species thrive

With this information, fish recovery program managers can pursue targeted and more effective actions to help reduce mortality rates, improve habitat, and increase survival rates while continuing to meet Reclamation's mission—delivering water and power.

Current fish tracking methods rely on capturing and handling fish to implant or attach tags—a costly and complex process which can also stress fish. Addressing the need for improved technology will have practical applications for Federal, state, and private industries.

While research communities have explored advancements to these technologies, Reclamation's Water Prize Competition Center encourages breakthrough ideas by inviting innovative solutions from a national community. “Reclamation's science and engineering expertise is known throughout the world, but we can benefit from innovative ideas from individuals with varied specialties, backgrounds, and industries,” said Reclamation Science Advisor, David Raff. “Discovering new concepts and technologies significantly improves our ability to monitor threatened and endangered fish species and their ecosystems,” said Reclamation Commissioner, Estevan López. “This search for new fish tracking methods gives us a way to collaborate with private industries and the public to find innovative and creative solutions to problems we all currently face.”

The “New Concepts in Remote Fish Detection” water prize competition, which ran from July 27 through August 26, 2015, will award a total of \$20,000 in prize money for solutions that reduce costs and improve fish tracking methods. A total of 195 problem solvers signed up to see if they could help Reclamation find the next generation of fish tracking methods. Submitted solutions will be evaluated by a panel of judges composed of scientists, engineers, and telemetry experts from the private sector, Tribal Nations, Reclamation, and other collaborating Federal agencies. The winners of the water prize competition will be announced by November 9, 2015.

The “New Concepts in Remote Fish Detection” water prize competition can be found at:

[www.challenge.gov/challenge/new-concepts-for-remote-fish-detection](http://www.challenge.gov/challenge/new-concepts-for-remote-fish-detection)

[www.innocentive.com/ar/challenge/9933646](http://www.innocentive.com/ar/challenge/9933646)

[www.nature.com/openinnovation/](http://www.nature.com/openinnovation/)

[www.scientificamerican.com/openinnovation/](http://www.scientificamerican.com/openinnovation/)

## Lead Designers

Mark McKinstry, Fisheries Biologist in Reclamation's Upper Colorado Region, worked with Patrick Connolly in the U.S. Geological Survey's Western Fisheries Research Center to design and launch this initial water prize competition.



Mark McKinstry, Fisheries Biologist. See the video at:

[www.usbr.gov/research/challenges](http://www.usbr.gov/research/challenges)

## Collaborators

Reclamation partnered with other Federal agencies to obtain further technical input to, and support for, this initial water prize competition:

- U.S. Geological Survey's Western Fisheries Research Center
- U.S. Fish and Wildlife Service
- National Oceanic and Atmospheric Administration's National Marine Fisheries Service
- U.S. Army Corps of Engineers

## More Information

[www.usbr.gov/research/challenges](http://www.usbr.gov/research/challenges)

U.S. Geological Survey's Western Fisheries Research Center:

<http://wfrc.usgs.gov/>



U.S. Department of the Interior  
Bureau of Reclamation

# Invasive Mussels

## More Information

[www.usbr.gov/mussels](http://www.usbr.gov/mussels)



STOP AQUATIC  
HITCHHIKERS!™



Quagga mussel  
(*Dreissena rostriformis bugensis*)



Zebra mussel (*Dreissena polymorpha*)



## Introduction

Quagga and zebra mussels (*Dreissena rostriformis bugensis* and *Dreissena polymorpha*) are invasive, freshwater, bivalve mollusks. Originally from Eurasia, zebra mussels were first introduced in the Great Lakes in the mid-1980s and have spread to the Western United States. A single female mussel can produce hundreds of thousands of eggs a year, which produce microscopic, swimming larvae (veligers). These veligers spread in numerous ways, mainly by floating in the currents of the water body or by hitching a ride on a boat or other water vessels that are used in infested water and then transported to another water body. Once they reach their settling stage, the veligers attach to hard surfaces and continue to grow. They clump onto these hard surfaces, clogging infrastructure and damaging operation and maintenance for water storage, water delivery, and hydropower structures and systems; recreational use; and aquatic ecosystems. After they settle, the mussels are almost impossible to eradicate in water bodies and facilities like Reclamation's.

These invasive mussels are now found throughout the Western United States. Reclamation is concentrating on proactive measures to help reduce the post-introduction spread and impacts of the mussels to Reclamation facilities and structures, thereby lessening the need for time-consuming and most costly measures of control. One control method does not fit all circumstances. Mussels react differently at different facilities because of water temperature, chemistry content differences, and a host of other unknown factors.

Reclamation is working with partners to:

- Share information and coordinate the response to the present infestation
- Inform the public how they can prevent the spread of mussels
- Implement an action plan for mussel detection strategies and, if necessary, preventive maintenance activities

The Research and Development Office has allocated funding to study potential operation and maintenance and control measures. The activities being pursued include testing antifouling and other coatings, evaluating biocides (new, experimental bacterial biocides as well as traditional chemicals), investigating other repelling and operational techniques, assessing mechanical removal methods, experimenting with exclusion of larvae through filtration of intake water, and supporting foreign exploration for natural enemies. Researchers are also improving ways of monitoring and detecting mussels in western waters.

## Keeping Alert for Mussels at the Reclamation Detection Laboratory for Exotic Species

Early detection of invasive quagga and zebra *dreissenid* mussels in water systems is critically important for Reclamation planning for prevention and action. A challenge to early detection is that mussels settle in low light areas, making visual detection difficult. As a single adult female can produce over one million eggs, with several spawning events a year, even a few mussels going undetected can create severe problems quickly. If adult mussels are detected early, facility operators may have about 3 to 5 years before the populations explode to pose a real threat to structures and operations. Early detection, comprehensive risk assessments of suitability for survival and reproduction, and evaluations of vulnerable points in a facility help managers budget and prioritize activities to minimize mussel impacts.

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If larvae (veligers) could be detected even earlier, managers may have more time to prepare and request funding in a 3-year budget cycle. Although veligers range from an approximate width of only 80 to 462 microns and require many detection methods to find them, veliger detection is performed because there are larger numbers of them and they remain suspended in the water for about a month before settling, making it more likely to detect them rather than the adults.

The Reclamation Detection Laboratory for Exotic Species (RDLES) in Denver, Colorado, is one of the leading laboratories in the Western United States for detecting invasive *dreissenid* mussel populations from raw water samples. RDLES tests samples from reservoirs, lakes, canals and other water bodies. This laboratory won the “Colorado Labs 2012 Governor’s Award for High Impact Research” for its improved early detection and DNA testing methods.

This research has produced testing techniques that may be applied to numerous species, including other invasive and exotic species as well as endangered, threatened, and other species of concern. RDLES conducts studies to optimize every aspect of the detection process, from sample collection to increased polymerase chain reaction (PCR) sensitivity. For example, RDLES modified the microscopic techniques to discover degraded veligers even when the microscopic and PCR test results do not match. Denise Hosler, Invasive Mussel Research Laboratory Manager, invented a venoset collection apparatus at the bottom of an Imhoff settling cone that allows the veligers (microscopic early stages of the mussel) to settle at the bottom of the tube. The bottom 15 milliliters of the water sample are collected from the cone and evaluated by microscopy for the presence of veligers. Almost all of the veligers are found in that settled portion of the sample. The passive venoset allows technicians to control the volume of sample delivered from the bottom of the cone. Testing this method demonstrated minimal damage to the veliger, and studies conducted in 2009 demonstrated improved population counts with a 98-percent recovery rate of veligers in a settled Lake Mead (Arizona/Nevada) sample.

RDLES has helped others worldwide. In 2013, RDLES staff was asked to assist the Brazilians with the detection testing for the golden mussel, an invasive species introduced from China. The golden mussel, similar to the quagga mussel has the potential to move into the United States. RDLES will be able to accurately test for the presence of the golden mussel.

RDLES is also developing a relational database that will help compare parameters of western waters and mussel population status. RDLES staff, in cooperation with Reclamation’s regions, is working with the U.S. Army Corps of Engineers-Engineer Research and Development Center (USACE-ERDC) on a predictive modeling project to help with mussels as well as other species that may provide challenges in the future.

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## More Information

[www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=45025](http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=45025)



“Colorado Labs 2012 Governor’s Award for High Impact Research.” From left to right: Jeremiah Root, Kevin Bloom, Kyle Rulli, Ben Roske, Chris Holdren, Denise Hosler, Craig Albertsen, Sherri Pucherelli, Jacque Keel, Tanna George, and Curt Brown.



Denise Hosler in the RDLES laboratory with several sampling Imhoff cones in background.



Modified Imhoff cones used for settling raw water samples.



# Invasive Mussels

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## Testing

RDLES uses multiple testing methods, including:

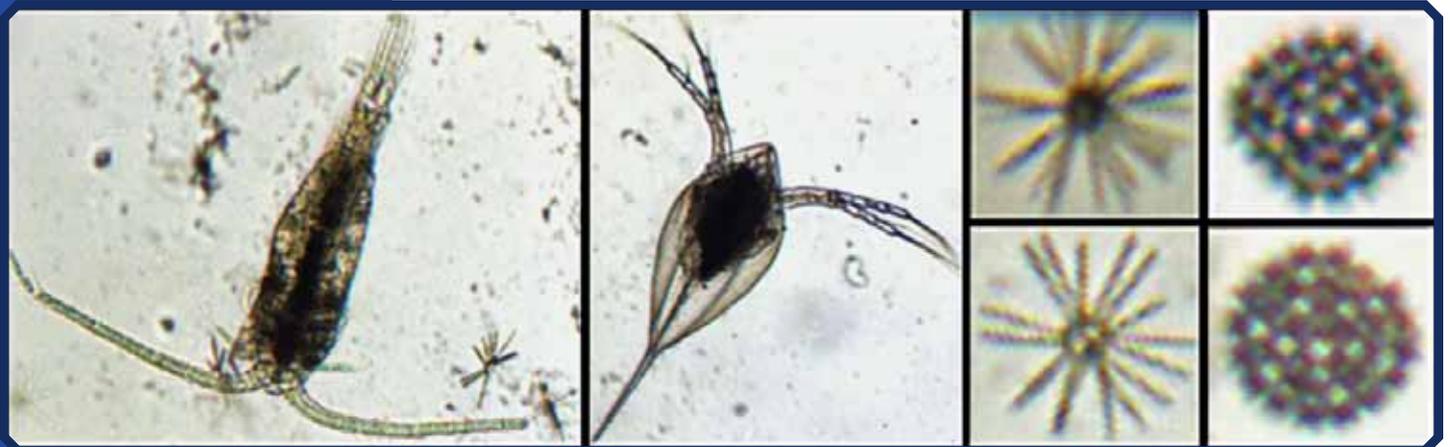
- **Cross polarized light microscopy (CPLM).** The veliger shell is comprised of 40 percent calcium carbonate. As light passes through the cross polarizing filter, it reacts with the calcium carbonate shell causing the veliger to glow, creating a distinctive Maltese cross pattern against a dark background (shown in photograph on next page).
- **Scanning electron microscopy (SEM).** SEM produces high magnification photographs that reveal the intricate details of the outer shell so trained taxonomists can distinguish these invasive mussels from other mussels (such as Asian clam veligers or ostracods).
- **Polymerase chain reaction (PCR).** PCR analysis determines the presence or absence of *dreissenid* DNA in raw water samples. This test only confirms the presence of *dreissenid* mussel tissue after the DNA is extracted. To confirm the PCR result, positive samples are sent to a second independent laboratory for gene sequencing.
- **Flow cell cytometry.** This technology monitors water quality based upon the zooplankton that are present in the water. *Dreissenid* mussels filter large quantities of water, improving water clarity in a reservoir, but may lead to unseasonable algal blooms (mostly blue-green algae) that is known to be toxic to animals and cause digestion issues in humans.
- **VeligerCam™.** To examine the effectiveness of control techniques and studying the population dynamics in infested waters, RDLES uses the VeligerCam™. The VeligerCam™ is an advanced microscopic tool RDLES helped develop through a cooperative research and development agreement. This tool provides side-by-side images of light microscopy and CPLM, which provides more accurate diagnostics of water samples. This modified flow cell cytometry technology takes both light microscopy and CPLM pictures of veligers as they pass through the flow cell. In known samples, the VeligerCam™ has a 95- to 100-percent veliger count accuracy—useful for veliger counts and population monitoring when veliger counts are high.

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Photograph shows the VeligerCam™ (on the left) used to image mussels.

Flow cell cytometry photographs of (from left to right) copepod, cladocern, asterionella, and volvox (Jamie Carmon, 2013).



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The American Recovery and Reinvestment Act (ARRA) of 2009 provided RDLES with funds to expand from the previously one-man laboratory, processing a few hundred samples a season, into a large full-scale processing laboratory, analyzing thousands of samples a season. Reclamation's Science and Technology Program and regional offices continued to assist with RDLES funding for mussel research activities when the goals of the ARRA project had been met.

## Sampling

Early detection of *dreissenids* in raw water has some inherent issues with variability in sampling and analytical methods. Different techniques, analytical methods, and inconsistent results cause concern for groups monitoring raw water samples for invasive species. When a single veliger body is discovered by microscopy in a water body with no other findings during the sampling season, it is considered a “variable” or “disparate” result. Single findings of this type generate management dilemmas for classification and management of that water body for the future.

RDLES has a Quality Assurance Plan that contains all of the Standard Operating Procedures (SOP) for the field and laboratory aspects of *dreissenid* mussel sampling. RDLES has also devised new methods of sampling:

- *Improving Accuracy in the Detection of Dreissenid Mussel Larvae* ([www.usbr.gov/mussels/docs/MusselLarvaeDetectionReport.pdf](http://www.usbr.gov/mussels/docs/MusselLarvaeDetectionReport.pdf))
- *Polymerase Chain Reaction: Preparation and Analysis of Veliger Water Samples* (PCR SOP Version 4) ([www.usbr.gov/mussels/docs/PCRPreparationAnalysisVeligers.pdf](http://www.usbr.gov/mussels/docs/PCRPreparationAnalysisVeligers.pdf)).

## Training

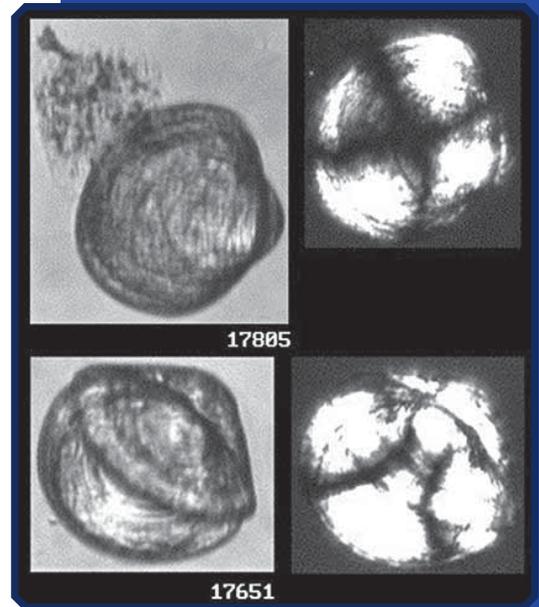
Early detection for invasive species requires a high level of training, not only to identify veligers and run the equipment, but also to control points of possible cross contamination. RDLES has developed a strong program in the Western United States for the detection of invasive mussels, in part, due to the intensive training protocols and multiple test methods, including flow cell cytometry and PCR.

## Cross Contamination

Discovery of a suspected positive water sample, either by microscopy or by PCR, is always met with concern. The first step is to rule out the possibility of contamination either in the field or in the laboratory through evaluation of equipment use and decontamination procedures. RDLES routinely performs testing to determine if cross contamination can be documented. Veliger body contamination is unlikely due to the decontamination procedures in place, which degrade any veligers that may be lingering on the net in between sample locations so they are not detectable by microscopy. New glass pipettes are used in the laboratory with every sample, and petri dishes are thoroughly decontaminated before use. Studies indicate that cross contamination is not a prevalent issue for the early detection of invasive mussels at RDLES.

## Summary

RDLES continues to develop and apply the best methods for early detection of quagga and zebra mussels. Ongoing monitoring over time will tell if the detection to infestation period is increased, and if the ability to predict infestations is improved when the focus of early detection is on a veliger detection program. Using the veliger detection program with the biologic and environmental data that have been collected for waters of the Western United States will help Reclamation manage these invasions more effectively.



*VeligerCAM™ images of dreissenid veligers, showing the Maltese cross and the umbonal bump on the shell's hinge (Scott O'Meara and Kevin Bloom, 2012).*

## More Information

See the “Impact of Sample Preservation on Detection of Invasive Mussels” research update on pages 36 and 37 in this issue.



# Invasive Mussels

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## More Information

[www.usbr.gov/research/projects/detail.cfm?id=9084](http://www.usbr.gov/research/projects/detail.cfm?id=9084)

## Understanding Quagga Mussel Life History in the Lower Colorado River

Invasive quagga mussels are becoming well established and widespread in the Western United States, in particular the lower Colorado River and associated diversion canals, yet little is known of their life history in western water bodies. Currently, habitat suitability parameters derived from zebra mussel biology in the Great Lakes is used when discussing quagga mussel characteristics. However, it appears that quagga mussels are behaving differently in the Western United States than the Great Lakes or their native range. Quagga mussel die-offs and low densities have been observed, yet the biological/environmental factors helping to control this invasive species remain a mystery. This Reclamation Science and Technology Program research will describe monthly variation and abundance of the various life history stages throughout the lower Colorado River.

This research conducts monthly sampling throughout the year to estimate density and growth of each quagga mussel life history stage in the forebays at Hoover and Davis Dams (Arizona/Nevada) and Parker and Imperial Dams (Arizona/California). Glen Canyon Dam (Arizona) was added earlier this year, with bimonthly samples. Vertical plankton tows are used to collect larval quagga mussels or veligers. Settlement plates are used to track the older life history stages (preveliger, juvenile, and adult). Water quality data are also collected monthly and will be used, together with historical data, to describe quagga mussels' life history.

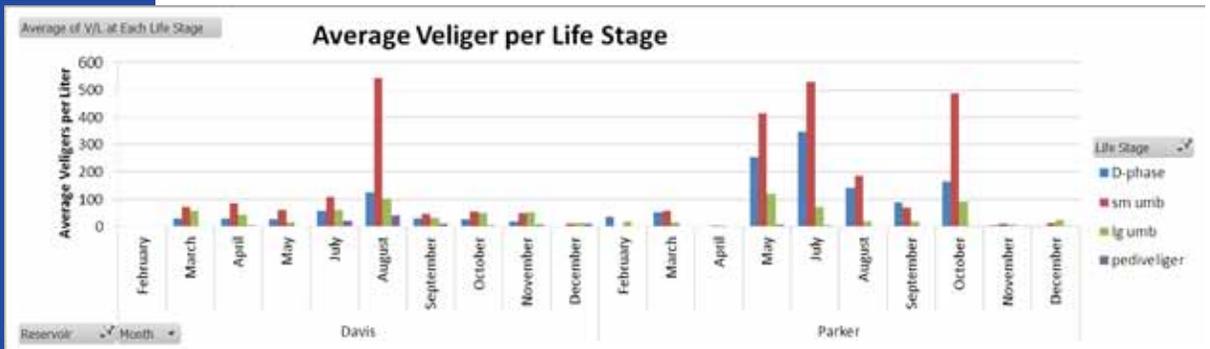


Collecting settled mussels by scraping settlement plate.

Preliminary data suggest quagga mussels are reproducing year-round in the lower Colorado River, but there may be a single midsummer peak in the Davis Dam forebay and a midsummer/fall peak at Parker Dam (data from these and other sites are under analysis).



Quagga mussel veliger collection with plankton tow net.



Preliminary veliger data from the forebays at Davis Dam (Arizona/Nevada) and Parker Dam (Arizona/California).

## Habitat Suitability Parameters for Invasive Mussels at Reclamation-Managed Facilities and Waters

Managing invasive mussels is a challenge at many facilities throughout the Western United States. Managers of facilities in areas where *dreissenid* mussel infestations have not yet occurred are faced with preventing and/or preparing for mussel establishment. Understanding site-specific habitat suitability for invasive mussel infestation can be an important factor for managers to prioritize, budget, and make decisions. This accurate understanding could also be used to develop mussel treatments for small-scale systems (e.g., cooling lines of hydropower generators). For example, water quality parameters could be artificially altered to be outside of the acceptable limits within these systems to prevent mussel settlement with minimal environmental impacts. However, published water quality parameters related to the proliferation of invasive mussels have proven to be inaccurate in the Western United States in several instances. Most of this literature describes studies and distributional records of zebra mussels, while quagga mussels are the dominant species infesting western water bodies. There is evidence that quagga mussels have different tolerances for certain environmental conditions than zebra mussels.

This Reclamation Science and Technology Program research is helping to develop a better understanding of quagga mussel habitat suitability parameters by investigating mussel population variations in the lower Colorado River system. Dense infestations of mussels occur at every major reservoir along the lower Colorado River. However, less dense infestations have been reported downstream from Parker Dam near Imperial Dam (Arizona/California). The questions for this research are:

- What factors downstream from Parker Dam are prohibiting large-scale and dense infestations of mussels?
- What are the implications of these factors to other Reclamation water bodies in terms of their suitability for mussel infestations, as well as the level of infestation they could support?
- Can manipulation of suitability parameters be used to prevent settlement in small-scale systems at Reclamation facilities?

This research is monitoring seasonal dynamics of mussel veliger populations to examine potential correlations with fluctuations in water quality parameters on the lower Colorado River from Lake Mohave to Imperial Dam. Over the past 3 years, eight sites along the river have been sampled monthly for water quality and quagga mussel veligers. Settlement substrates have been deployed to monitor settlement density throughout the system.

Veligers have been found in every sample collected and data indicate a general decline in veliger densities as they travel downstream. Water quality also exhibited various trends as the river moves downstream and over time, but the largest and most consistent differences between upstream and downstream sites are higher conductivity and total suspended solids downstream. The effects of these parameters on mussel establishment are not entirely clear, but they are potentially causal to the lack of establishment seen at Imperial Dam.

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# Invasive Mussels

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To further investigate the impact of conductivity on mussel settlement, a controlled settlement experiment was set up at Davis Dam (Arizona/Nevada). Two bio-boxes plumbed into the cooling lines were used to compare mussel settlement at upstream and artificially created downstream conductivity levels. The conductivity in the “downstream” bio-box was manipulated by a steady drip of a concentrated salt solution, creating conductivity readings similar to those recorded near Imperial Dam. This research is investigating different ion and concentration combinations to assess potential settlement suppression.



**Settlement substrate at Davis Dam (Arizona/Nevada) after 1 year of settlement.**

Settlement plates installed at Davis and Imperial Dams were analyzed after 1 year of deployment in 2014 and 2015. As expected, there was significantly more settlement at Davis Dam in comparison to Imperial Dam. The total number of mussels collected per plate at Imperial Dam ranged from 0 to 11 mussels, and the total number of mussels per plate at Davis Dam ranged from 5 to 5,525 mussels. The mussels settled at Imperial Dam were significantly larger than the mussels settled at Davis Dam. Settlement substrates were also deployed in the river at sample sites. Comparisons between river sites were difficult due to variability in stream conditions, specifically flow and depth, which appeared to alter the settlement suitability at some sites and, therefore, these substrates were not re-deployed after year one. Settlement significantly decreased from below Davis Dam (about 3,256 mussels per brick) to the middle section of the river (1 mussel per brick below the I-10 Bridge in Blythe, California). No mussels were collected from in-river substrates between Blythe and Imperial Dam.

Settlement substrates at the Senator Wash Reservoir and Pump Intake (California) had an average of 153 mussels settled per brick.



This research will conclude at the end of fiscal year 2015 and will include an assessment of all water quality variables that may be considered for future research into mussel habitat suitability and limitations for potential settlement management.

*Quagga mussel veliger sampling with a plankton tow net on the lower Colorado River.*

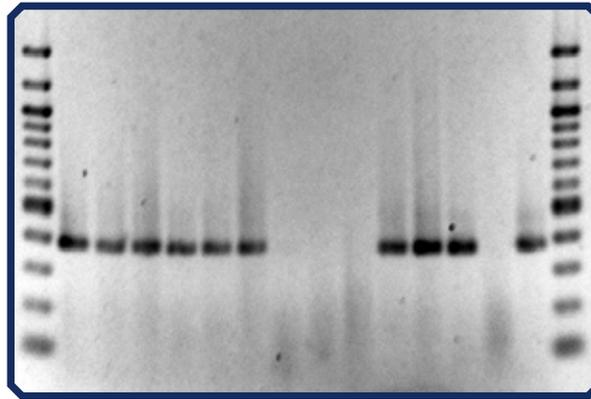
## Tracking Genetic Changes in Quagga Mussel Populations in the Western United States

The quality of Reclamation waters will continue to shift with droughts and climate variation. When faced with these changes, aquatic organisms such as mussels must either have a wide range of tolerances or be able to adapt to maintain or expand populations. Several studies have investigated the limits of water quality parameters associated with the quagga mussels' ability to sustain and reproduce. However, the ability for a quagga mussel population genetics to change may alter their suitable habitat parameters, allowing for continued range expansion or modification. Understanding the genetic variability within quagga mussel populations throughout the Western United States can provide Reclamation with insights into genetic weaknesses or genes that could be targeted for control purposes. This also provides valuable information that may help predict future mussel distribution patterns and impacts to Reclamation waters. Moreover, without a clear understanding of a population's genetic diversity, control measures may fail to target the entire population.

Preliminary analyses of quagga mussels in the Western United States, conducted by the University of Arizona, have found a significant degree of genetic diversity, even within the same system. Analyzing microsatellites (repeated DNA segments) can provide information about genetic diversity within a species, including gene flow, genetic variants, and population structure. More information regarding the genetic diversity and distribution of invasive mussels will provide better estimates of habitat suitability, which will be highly useful to Reclamation managers in preparing for—and preventing or minimizing—the impacts of infestation. Enhanced confidence regarding suitability levels would allow prioritization of budget allocation and decision processes for water bodies that are at high risk for problematic infestations.

This Reclamation Science and Technology Program research is investigating quagga mussel genetic variability within the lower Colorado River system. Each reservoir along the lower Colorado River has unique water quality characteristics and established mussel populations. Microsatellite analysis may be able to uncover variability within the system and within a single reservoir.

In 2015, adult mussels from six Reclamation water bodies with established mussel populations were collected, preserved, and sent to the Reclamation Detection Laboratory for Invasive Species from: Lake Mead, Lake Mojave, Lake Havasu, Imperial Dam, Senator Wash Reservoir, and Lake Powell (Arizona/California/Nevada/Utah). Phenotypic descriptions, photographs, and measurements were taken of each adult mussel. DNA was extracted from 30 adults from each location, and the extracted DNA was sent to the U.S. Army Corps of Engineers-Engineer Research and Development Center (USACE-ERDC) genetics laboratory for microsatellite analysis.



*Gel showing extracted quagga mussel DNA, which will be sent for microsatellite analysis.*

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[www.usbr.gov/research/projects/detail.cfm?id=9120](http://www.usbr.gov/research/projects/detail.cfm?id=9120)



*Adult mussels collected from Senator Wash Reservoir, California.*

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# Invasive Mussels

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Analysis will be conducted on the cytochrome oxidase one gene and at least eight microsatellite markers to determine the historical lineage of the individual. As these data are collected, a database will be developed to record the phenotypic data and genetic information gathered from the different populations. Existing water quality data for each location will be included in the database to determine if genetic variability can be tied to water quality attributes. If warranted, additional sites will be included in the analysis for comparison. This database will enable researchers to examine existing diversity and potential for adaptations in quagga mussel populations over time.

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## Evaluating Commonly Used Fish Screens to Resist Quagga Mussels

Many sizes and types of fish screens are in place or are being considered for installation in the Western United States. However, increasing establishment of the invasive quagga mussel may clog the screen openings. This Reclamation Science and Technology Program research sought to answer: How well can existing fish screen systems function in mussel infested water, and what modifications may improve screen efficiency?

Test fish screens included cylindrical and flat plate stainless steel wedgewire screens (Intake Screens, Inc. [ISI]) and a vertically traveling nylon screen (Hydrolox™). Some tests included rotating brush cleaning systems. Tests were conducted on a modified pontoon boat moored on Lake Mead (Nevada/Arizona). A mixer provided flow into the test channel. The Hydrolox™ traveling screen operated continuously for 2 years, travelling at about an inch a second and staying out of the water about 43 percent of the time during a rotation (figure 1). Although mussels attached to the frame, inside support structure, and test channel, there was no mussel attachment to the main screen (figure 2).

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Figure 1.—Front view of Hydrolox™ traveling screen (note absence of mussels).



Figure 2.—Mussel settlement on the inside of the Hydrolox™ screen frame and roller bar, but not the traveling screen itself.

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Sections of Hydrolox™ samples used as controls suspended off the back of the test platform at about 10 feet (3.05 meters) deep became heavily infested with quagga mussels (figure 3). Two sections of the Hydrolox™ screen mounted on a rotating shaft 10 feet deep also became infested with quagga mussels. These preliminary results suggest that a Hydrolox™ traveling screen that rotates out of the water inhibits mussel fouling, while those that remain submerged do not.

The ISI stainless steel wedgewire drum screen (with a mesh opening of 0.07 inches or 1.78 millimeters) and brushing system ran mostly continuously for 2 years. The screen was generally mussel free (inside and out) in areas where brushing occurred (figure 4). Mussel attachment did occur on any area that was not brushed (figure 5). However, mussel attachment on the inside of the screen was not common and did not seem to significantly reduce flows through the screen. Portions of the frame and internal flow baffle were coated with a mussel resistant Fuji silicone coating, which was somewhat effective at preventing mussel settlement. However, some of the Fuji coating peeled off and allowed mussels to attach over time. Running the brush in both forward and reverse directions (which is already common practice) probably helped prevent mussels from settling in between the rib supports on the inside. Control samples of stainless steel wedgewire suspended at 10 feet (3.05 meters) deep were heavily fouled (figure 6). The brushing system on the ISI cylindrical screen operated continuously with no problems.

The pontoon boat test facility was modified to test flat plate screen systems with a combination of brush cleaning and screen coatings (Jotun SeaLion Resilient) in 2015 and 2016, to encompass at least four mussel reproduction cycles and to make changes to test variables, if needed. The new setup also includes rotating Hydrolox™ and stainless steel wedgewire pieces to help determine if the action of lifting out of the water dislodges mussels or inhibits quagga mussel settlement.



Figure 3.—Mussel settlement on a piece of Hydrolox™ suspended off the back of the test platform.



Figure 5.—Some mussel attachment on inside surfaces where brushes could not reach.



Figure 6.—Quagga mussel settlement on a piece of stainless steel wedgewire suspended off the back of the test platform.



Figure 4.—Mussel attachment on the screen structure (note cleaned screen due to brushing in figure 5).

# Invasive Mussels

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## Using Turbulence to Control Mussels in Pipelines

Recent results from field tests at Davis Dam Powerplant (Arizona/Nevada) indicate that turbulence is having a physical impact to some veligers that pass through the generator. Intense turbulence could be generated to prevent mussel settlement in closed piping systems. If effective, this concept could be applied to a wide variety of piping systems in dams, powerplants, pumping plants, water treatment facilities, and irrigation systems. Inducing turbulence does not require chemicals, simplifies and reduces maintenance, and costs less than most mussel control methods. In 2013, the turbulence treatment system was installed and tested in the main cooling pipe gallery of the Davis Dam Powerplant (figure 1). The 2013 configuration showed some potential for mussel damage and reduced settlement, but was not completely effective. In 2014, the turbulence treatment design was modified and tested in the same facility and showed improved results. Testing continues in 2015, to further refine the design and, hopefully, to reduce mussel settlement by a significant amount.

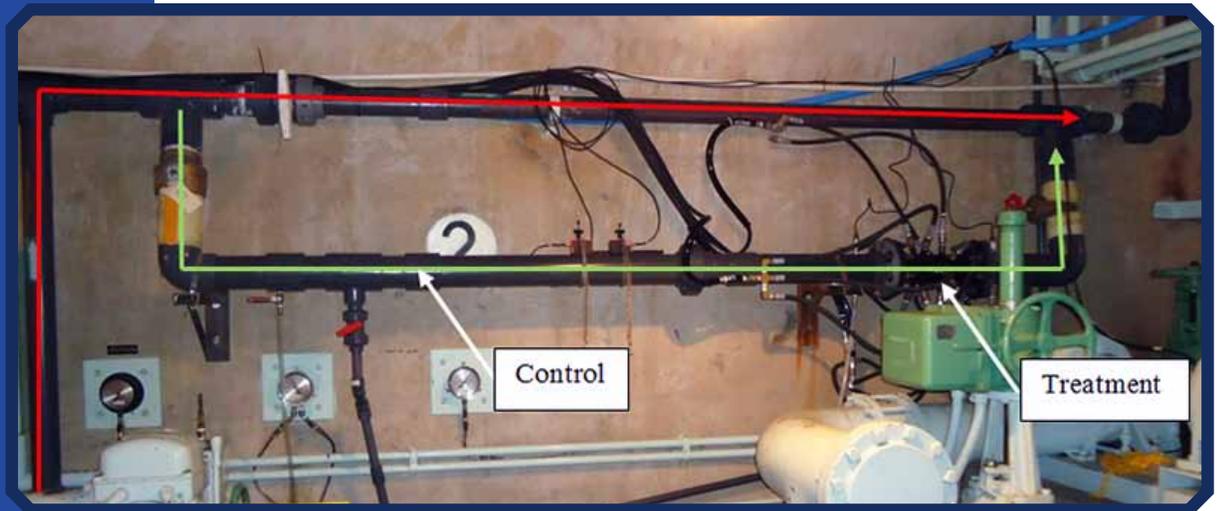


Figure 1.—Test design with control and turbulence treatment sections on a 3-inch cooling pipe at Davis Dam Powerplant (Arizona/Nevada).



During 2013/2014, the effects of turbulence on veliger settlement, growth, and shell damage were assessed. Settlement and growth were analyzed by diverting sub-samples of turbulence-treated and -untreated water into bio boxes from the main experimental water line in the turbulence test facility (figure 2).

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Figure 2.—Cooler bio box containing 30 (10.2 by 11.4 centimeters) glass settlement plates for monitoring mussel settlement and growth, and a YSI multiprobe for monitoring water quality parameters.

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Sample ports were installed to collect mussel samples for analysis. Samples were collected upstream and downstream from the turbulence treatment to determine if turbulence created any physical damage to the veligers. The Reclamation Detection Laboratory for Exotic Species analyzed these samples with a continuous imaging particle analyzer (VeligerCam™; figure 3). The VeligerCam™ provides a detailed image of individual mussels so that large

numbers of mussels can be examined for microscopic damage and abnormalities. Mussel images were separated into size classes (straight-hinged mussels between 50 to 100 microns, umbonal mussels between 100 to 200 microns, and pediveligers between 200 to 500 microns) and the number of damaged mussels per size class was determined. The total number of mussels, per size class, collected in each sample was also recorded to determine if one size class was being destroyed beyond recognition.



Figure 3.— VeligerCam™ used to collect images of mussels, which were used to analyze mussels for microscopic damage and abnormalities.

The results indicate that some pediveliger mussels exposed to turbulence experience significant shell damage (figure 4). Mussels in the pediveliger stage, unlike the smaller larval stages, are able to settle within the closed piping system. Because a proportion of pediveliger mussels are damaged, settlement reduction was observed in these controlled experiments.

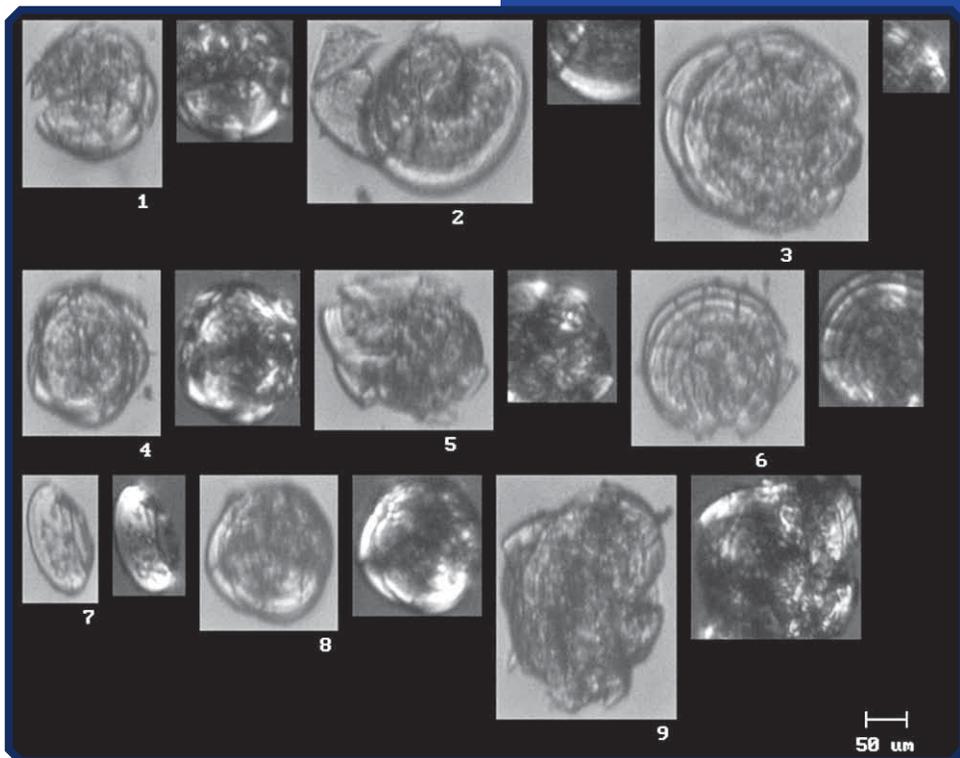


Figure 4.—VeligerCam™ images of turbulence-treated veligers with cracked and broken shells.

# Invasive Mussels

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## Coatings Research—Parker Dam Field Test Results

### *Field Evaluation of Mussel Resistant Coatings*

The coatings team in the Materials Engineering and Research Laboratory (MERL) at Reclamation's Technical Service Center has been researching coatings for quagga and zebra *dreissenid* mussel control for the past 7 years at Parker Dam on the Colorado River (Arizona/California border). Their research has included evaluating more than 100 coatings and materials to mitigate and prevent mussel attachment.

The initial field observations of test samples occurred in December 2008, following 7 months of exposure to the mussel-laden water. The coatings team observed that silicone foul-release coatings prevented mussel attachment. In contrast, an uncoated steel grating (a positive test control) was completely fouled and water flow was greatly reduced through the grate. This freshwater performance of the foul-release coatings was somewhat surprising. These coating systems are designed to allow some fouling of marine organisms to docked ships, but these fouling organisms would be washed from the coating surface at the ship's departure.

During this first inspection, the coatings team also found that mussel populations accumulated to a greater degree in flowing water exposure compared to static water. All previous research by others evaluated coatings in static water exposure only. Another finding determined during the course of this study was that antifouling paints did not work under flowing water conditions. Most of the copper alloys examined prevented mussel attachment in static exposure; the 90/10 copper nickel alloy is the exception.

### *Durable Foul-Release Coating*

Most major manufacturers of silicone foul-release coatings provide products that prevent mussel attachment for at least 5 years in the conditions evaluated. These include products evaluated from Sherwin Williams, International Paint, PPG Protective & Marine Coatings, Hempel, Jotun, CMP Global, and Nusil. The concern with these products was that they were soft and damage could be incurred by gouging, abrasion, and impact. Over the past few years, several manufacturers developed products that claim to have better gouging, abrasion, and impact resistance. During the evaluation, most of these systems that were evaluated allowed mussel attachment and were not easily cleaned. In December 2013, a Material Transfer Agreement partner's experimental hard foul-release coating formulations

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From left to right:  
Silicone foul-release  
coating, steel, and  
90/10 copper nickel  
alloy after 7 months of  
exposure.

— continued

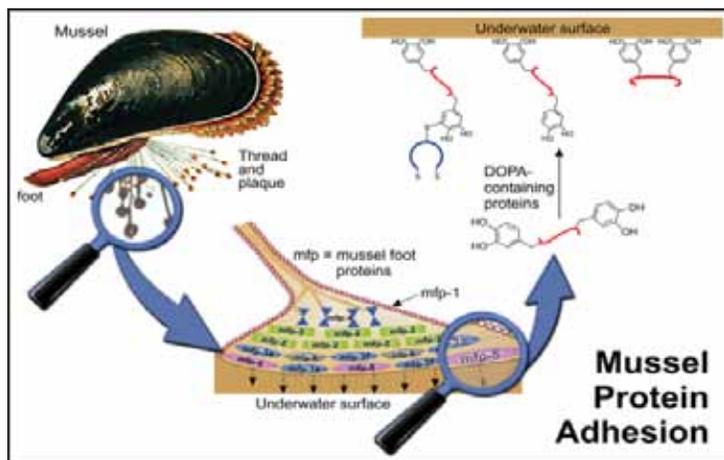
were evaluated and found to prevent mussel fouling. In addition, Jotun Sealion Resilient, a newly developed commercially available hard foul-release coating, was introduced to the market in 2013. This product allowed mussels to attach after 2 years of exposure, but was easily cleaned. It may prevent fouling under higher flow conditions.



Material Transfer Agreement partner's durable foul-release coating (left) and Jotun Sealion Resilient easy-clean system (right).

### Mussel Adhesion Mechanism

In 2011, the coatings team examined the quagga and zebra mussel adhesion mechanism to understand and improve their ability to predict the coatings and materials that would prevent mussel attachment. Mussels adhere to most surfaces, primarily through strong bonds formed by 3,4- dihydrophenylalanine (DOPA), including a bidentate hydrogen bond or metal complex. The silicone polymers used in foul-release coatings prevent mussel attachment by not having available hydrogen-bonding sites, among other factors. The coatings team had a manufacturer remove the oil release additive from the formulation to verify the hydrogen-bonding concept. This sample has prevented mussels from attaching for nearly 3 years of exposure at the Parker Dam field test site.



— continued

Various adhesive interactions for DOPA (modified reproduction of figure 1, Wilker, 2011) (top left). Silicone foul-release coating without release oil additive after 3 years (right).



# Invasive Mussels



Reclamation formulations reinforced with 10-percent fumed silica.

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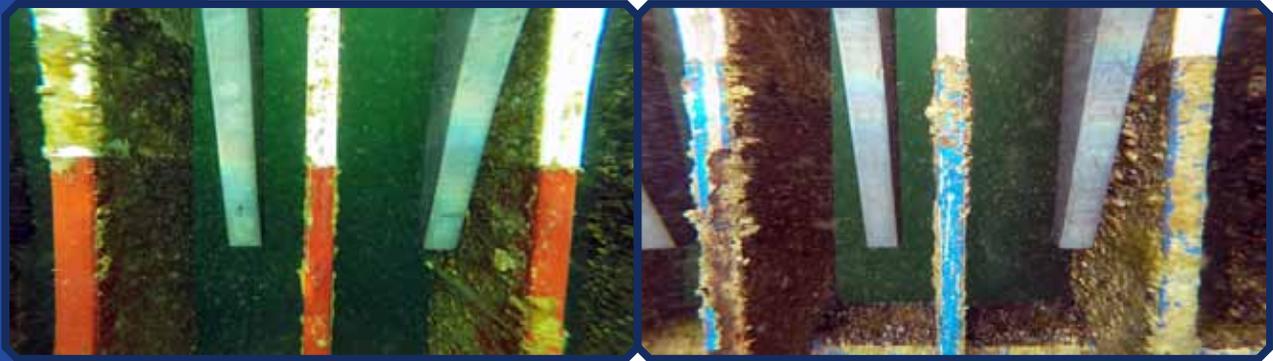
## *Developing a Durable Foul-Release Coating*

In March 2014, Reclamation signed a Cooperative Research and Development Agreement with an industrial partner to develop a gouge, impact, and abrasion resistant coating that prevents mussel attachment. The goal is to develop durable foul-release coatings that maintain a mussel-free surface. To date, this work has produced foul-release coatings with better properties, while maintaining satisfactory fouling prevention.

## *Scale-Up Trashrack Coated With Foul-Release Coatings*

In 2012, a clamshell-style trash rake was installed at Parker Dam to manage debris along the trashrack structure. In 2013, a trashrack demonstrating three silicone FRCs and one durable FRC was installed to evaluate each product's durability. Surprisingly, the hard foul-release coating (Seacoat SeaSpeed V5) is experiencing more damage from the trash rake than all three silicone foul-release coatings.

Underwater photograph of trashrack grate. Left: sigmaglide (red) and intersleek (white). Right: Seacoat Seaspeed V5 (blue) and Fuji (white).



## More Information

See the “Multimedia Around Reclamation” segment in this issue for a video regarding the quagga and zebra mussels research testing at Parker Dam (Arizona/California border).



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# Research Updates

## Bulletin Title, Quote, and Website

Page



### Impact of Ultraviolet Light Treatment on Quagga Mussel Larvae

*“UV light treatment for the prevention of invasive mussel settlement is promising and it is important to understand how UV exposure impacts veligers so that the treatment can be used in other applications.”*

Sherri Pucherelli, Biologist  
Reclamation’s Technical Service Center

[www.usbr.gov/research/docs/updates/2015-12-uv-treatment.pdf](http://www.usbr.gov/research/docs/updates/2015-12-uv-treatment.pdf)

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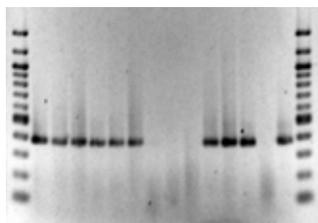
### Impact of Sample Preservation on Detection of Invasive Mussels

*“Early detection of invasive mussels is the only way to protect our waters from devastating infestations, but it is like looking for a needle in a haystack. Proper sample preservation greatly increases sample integrity and increases the likelihood of detecting the ‘needle’.”*

Sherri Pucherelli, Biologist  
Reclamation’s Technical Service Center

[www.usbr.gov/research/docs/updates/2015-13-sample-preservation.pdf](http://www.usbr.gov/research/docs/updates/2015-13-sample-preservation.pdf)

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### Detecting Free-Floating Quagga Mussel DNA

*“PCR testing of dreissenid mussels with early detection samples is a valuable tool that is capable of detecting signs of dreissenid presence that may otherwise be missed by microscopy alone.”*

Sherri Pucherelli, Biologist  
Reclamation’s Technical Service Center

[www.usbr.gov/research/docs/updates/2015-14-mussel-dna.pdf](http://www.usbr.gov/research/docs/updates/2015-14-mussel-dna.pdf)

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### Do Redear Sunfish Eat Quagga Mussels?

*“Invasive species, such as the quagga mussel, are an unplanned biological experiment gone awry. While redear sunfish generally consumed quagga mussels, their overall response varied. Therefore, they are not likely to eradicate quagga mussel infestations.”*

Cathy Karp, Fish Biologist  
Reclamation’s Technical Service Center

[www.usbr.gov/research/docs/updates/2015-15-redear-sunfish.pdf](http://www.usbr.gov/research/docs/updates/2015-15-redear-sunfish.pdf)

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### Monoclonal Antibodies for Improved Detection of Dreissenid Mussel Larvae

*“Quagga mussels are a huge issue for us in the Lower Colorado Region. We have reservoirs with quagga mussels, and those without that we really would like to keep that way. Therefore, finding new ways to detect mussels early is critical to us in protecting our water infrastructure. This research will help us do just that.”*

Nathaniel Gee, Supervisory Civil Engineer  
Reclamation’s Lower Colorado Region

[www.usbr.gov/research/docs/updates/2015-16-monoclonal-antibodies.pdf](http://www.usbr.gov/research/docs/updates/2015-16-monoclonal-antibodies.pdf)

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### Controlling Nuisance Aquatic Plants in Canals

*“Many districts ‘treat when we see the plants appear on trashracks,’ but this proves to be expensive and difficult. A better approach would be to monitor vegetation and to treat when plants are easier to remove. Like taking care of dandelions in your yard, treat when you see the first one—not the field.”*

Clyde Lay, Water Quality Specialist  
Reclamation’s Pacific Northwest Region

[www.usbr.gov/research/docs/updates/2015-17-nuisance-aquatic.pdf](http://www.usbr.gov/research/docs/updates/2015-17-nuisance-aquatic.pdf)

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## Research Update

Fall 2015  
Bulletin 2015-12

### Bottom Line

Ultraviolet (UV) light treatment of generator cooling system water has been found to reduce invasive mussel settlement. This research helped determine how UV exposure reduces settlement by examining the immediate and delayed effects of exposure on quagga mussel larvae.

### Better, Faster, Cheaper

UV light irradiation is a valuable tool for preventing mussel settlement because, unlike conventional treatments, it does not require discharge permitting and has no detrimental effects to the environment.

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## Impact of Ultraviolet Light Treatment on Quagga Mussel Larvae

*Examining how ultraviolet light treatment prevents quagga mussel settlement in Davis Dam cooling lines*

### Problem

Quagga and zebra mussels are aggressive biofoulers that threaten water delivery and hydropower reliability. Conventional treatment methods such as chlorine or mechanical removal can be costly, environmentally adverse, and require discharge permitting. Reclamation needs innovative treatments to prevent or limit mussel colonization in our facilities.

Ultraviolet (UV) light irradiation is a promising treatment because it does not require discharge permitting and has no detrimental effects to the environment. In 2013, a full-sized medium pressure UV system was installed on a cooling line at Davis Dam (Arizona/Nevada) to test settlement reduction. Reservoir water (containing veligers) entering the cooling system passes through the system and is treated with UV light.

Claudi et al. (2014) found significant settlement reduction at 50, 40, and 20 millijoules per square centimeter ( $\text{mJ}/\text{cm}^2$ ). Although the treatments were effective, the impact of exposure on veligers was still unknown. Understanding the treatments mode of action will help determine how UV can be useful in other mussel management applications.

### Solution

This Reclamation Science and Technology Program research project evaluated the impacts of four doses (100, 50, 40, and 20  $\text{mJ}/\text{cm}^2$ ; previously tested for mussel settlement reduction) on veligers to understand why UV light treatments reduced settlement. Treated and untreated veliger samples were collected to determine if the doses produced physical damage, behavior changes, and/or immediate or latent mortality.

The impact of UV exposure was evaluated for each veliger stage (d-stage, umbonal, and pediveliger) to determine if one is impacted over another. Veligers were examined immediately after exposure to determine if UV caused behavior changes that might prevent settlement. Images of veligers exposed to UV light treatments were collected and analyzed with a VeligerCam™ to detect physical damage. Immediate and latent mortality of veligers exposed to each UV dose was determined by observing veligers immediately after UV exposure and at 24-hour periods for a total of 120 hours post-exposure. Mortality rates were observed in the early and late summer.



*UV unit installed at Davis Dam (Arizona/Nevada) for mussel treatment.*

## Application and Results

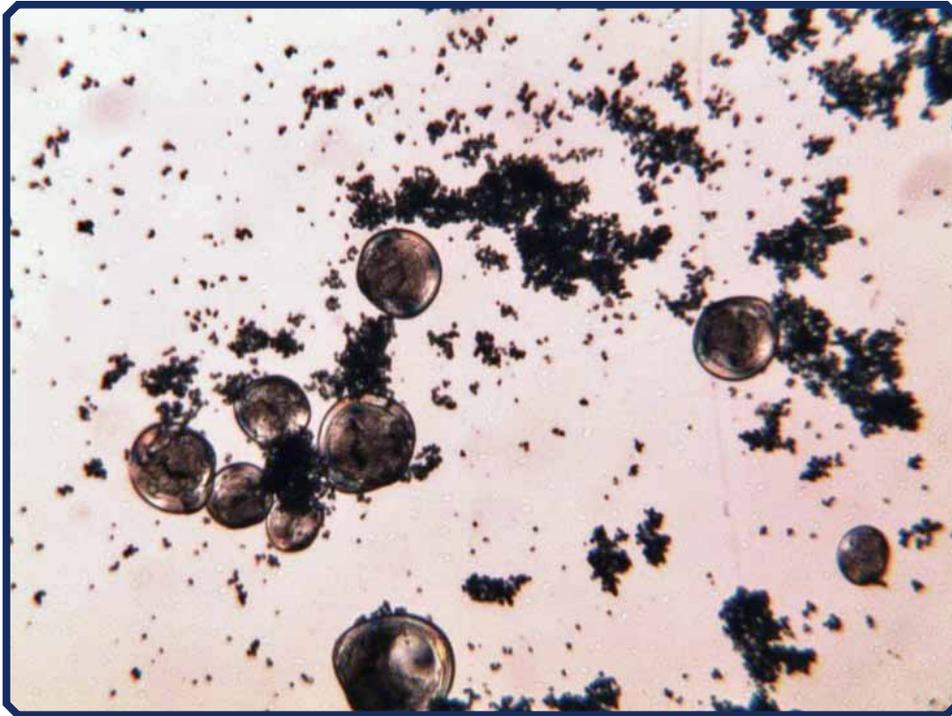
UV does not appear to impact veliger behavior or inflict visible physical damage. Settlement reduction is likely a result of delayed veliger mortality, as most veligers were alive immediately and several hours after exposure at all doses. Veliger mortality was variable at each dose, veliger size, and during each month tested. In general, smaller veligers died sooner and at greater rates than larger veligers. Treatments produced less mortality in the early summer months when compared with late summer months, even at the same dose. This variation may be due to environmental variables such as temperature, which has been found to impact mussel robustness.

Although the effectiveness of each dose tested was variable throughout the year, the significant settlement reduction should be appealing to facility managers as most do not require 100 percent settlement inhibition. The mortality and settlement rates were similar between the 50 and 100 mJ/cm<sup>2</sup> doses, suggesting that the lower dose could be used to reduce electrical and equipment costs.

## Future Plans

Although this specific UV system was found to cause veliger mortality and limit settlement, it cannot be assumed that the same results would be achieved in every situation with every UV system, as water quality and site-specific conditions will vary. Before a UV system is deployed for mussel treatment, it is important to conduct similar testing for each specific set of circumstances.

This research, and the research conducted by Claudi et al. (2014), indicate that UV light treatment for the prevention of quagga mussel settlement in hydropower generator cooling systems is effective. The results may also be useful for water managers interested in using UV to control mussels in other applications. There are situations where immediate and complete veliger mortality is the main objective, in which case, a significantly higher dose would need to be tested.



*Microscopic view of quagga mussel veligers.*

***“UV light treatment for the prevention of invasive mussel settlement is promising and it is important to understand how UV exposure impacts veligers so that the treatment can be used in other applications.”***

**Sherri Pucherelli**  
Biologist, Reclamation’s  
Technical Service Center

## Collaborators

- Reclamation:
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  - ◇ Lower Colorado Region
- RNT Consulting, Inc.

## More information

[www.usbr.gov/research/projects/detail.cfm?id=891](http://www.usbr.gov/research/projects/detail.cfm?id=891)

**Claudi R., T.H. Prescott, and H. Coffey. 2014. *Atlantium Technologies Medium Pressure UV Dose Required for Minimizing Downstream Settlement of Quagga Mussel Veligers*. IDIQ Contract R13PD80500. Bureau of Reclamation.**

## Research Update

Summer 2015  
Bulletin 2015-13

### Bottom Line

Early detection of quagga and zebra mussel veligers is difficult because the organisms are microscopic and sensitive to degradation from both water chemistry and organic matter. This research study determined the most effective way to preserve samples to maintain veliger integrity over time.

### Better, Faster, Cheaper

Detecting mussels at the onset of colonization alerts facility managers early and allows time to enact control measures. However, proper sample preservation is critical for accurate and early detection.

## Impact of Sample Preservation on Detection of Invasive Mussels

*How sample preservation impacts the early detection of invasive mussels by microscopy and polymerase chain reaction*

### Problem

Invasive *dreissenid* mussels disrupt facilities and greatly increase operation and maintenance costs. These invasive quagga and zebra mussels also affect the overall ecology of a reservoir by filtering large amounts of water and decreasing the zooplankton populations that fish and other animals need to survive. Eventually, these shifts in ecology can cause algal blooms and proliferation of weeds.

The Reclamation Detection Laboratory for Exotic Species (RDLES) has been successfully monitoring for the early detection of quagga and zebra mussel veligers (larvae) in the Western United States since 2007. This monitoring effort alerts facility managers at the onset of mussel colonization, allowing time to enact control measures.

Early detection of veligers includes identifying veliger bodies via microscopy and/or detecting small amounts of free-floating DNA via polymerase chain reaction (PCR). Both the veliger body and the DNA are sensitive to degradation. If the veligers shell or tissue is degraded, it will not be detected. Therefore, it is important to maintain the integrity of samples after collection. Mussel shells are composed of calcium carbonate, and acids can degrade these shells. Acids can be introduced, either from surrounding organic materials in the reservoir water (inhibitors) or from preservatives (alcohol). Ineffective sampling methods could result in unnoticed mussel infestations, which can delay treatment and containment.

Developing a standard operating procedure (SOP) for early detection sample preservation is a consistent, effective method that allows Reclamation and its partners the best opportunity to spot mussel invasions early.

### Solution

This Reclamation Science and Technology Program research study project built on previous studies to help determine the best preservation method for early detection samples analyzed by microscopy and PCR. Unlike previous studies, this research determined how samples containing additional organic material and reservoir water affect veliger degradation. This research study tested the impact of eight sample

preservation scenarios on veliger detection by microscopy and PCR. The preservation scenarios tested combinations of variables, including presence or absence of alcohol, presence or absence of buffer, and high or low levels of zooplankton (inhibitors). Five replicates of each preservation scenario were prepared in a controlled laboratory setting. Veliger shell and DNA degradation were assessed after veligers had been preserved for 1, 6, 21, and 42 days.



Correctly preserved (top left) versus incorrectly preserved (right) quagga mussel veligers after 21 days in solution.



## Application and Results

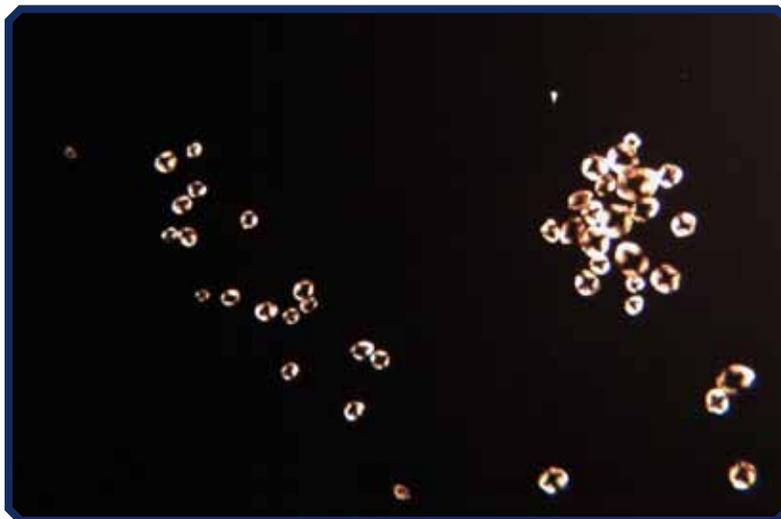
The results of this research study suggest that regardless of alcohol content, veliger detection by microscopy is reduced as samples age and when samples are not buffered and contain high inhibitors. Veliger shell morphology can be maintained for 42 days after collection if samples are preserved with 20 percent alcohol per volume and buffered with 0.02 gram per liter of baking soda. PCR detection of veligers was also best when samples were preserved with both alcohol and buffer but, overall, detection was reduced as holding time increased. The results of this research study indicate that correct sample preservation is critical to maintain veliger integrity over time, especially because both water chemistry and organic content appear to impact veliger degradation.

## Future Plans

Reclamation's mussel detection program involves several agencies who collaborate to sample multiple water bodies across the Western United States. Because this program has so many collaborators, sample collection and preservation methods are not always uniform.

These results benefit Reclamation and RDLES by explaining how veliger morphology and detectability are impacted by improper preservation in "real world" water samples over time. The results of this study and previous studies (Carmon et al., 2014) have been used to develop an SOP for field collection of quagga and zebra mussel veligers.

Reclamation needs to be able to present this data to its collaborators for the consequences of improper sample preservation to be fully understood and appreciated.



Mussel veligers under cross polarized light microscopy.

## More Information

[www.usbr.gov/research/projects/detail.cfm?id=3157](http://www.usbr.gov/research/projects/detail.cfm?id=3157)

Carmon, J. and D. Hosler. 2013. Field Protocol: *Field Preparation of Water Samples for Dreissenid Veliger Detection*. Field Standard Operating Procedure, Version 4. Technical Memorandum No. 86-68220-13-01. Bureau of Reclamation. [www.usbr.gov/mussels/docs/FieldSOPPreparationandAnalysis.pdf](http://www.usbr.gov/mussels/docs/FieldSOPPreparationandAnalysis.pdf)

Carmon, J., J.A. Keele, S.F. Pucherelli, and D. Hosler. 2014. "Effects of buffer and isopropanol alcohol concentration on detection of quagga mussel (*Dreissena bugensis*) birefringence and DNA." *Management of Biological Invasions*, 5(2):151-157.

***"Early detection of invasive mussels is the only way to protect our waters from devastating infestations, but it is like looking for a needle in a haystack. Proper sample preservation greatly increases sample integrity and increases the likelihood of detecting the 'needle'."***

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## Research Update

Fall 2015  
Bulletin 2015-14

### Bottom Line

Reclamation uses both microscopy and polymerase chain reaction (PCR) for the early detection of dreissenid mussels. PCR results are variable, and it is possible to get a negative result by microscopy and a positive result by PCR on the same sample. This research increases understanding of the factors that lead to variable test results.

### Better, Faster, Cheaper

Invasive mussels are aggressive biofoulers that threaten water delivery and hydropower reliability. Using microscopy and PCR for sample analysis can increase the chance of mussel detection. Early detection will allow water managers additional time to prepare for the impacts of a new infestation.

PCR gel with positive bands indicating the presence of quagga mussel DNA in each sample.

## Detecting Free-Floating Quagga Mussel DNA

Examining factors that impact successful detection of quagga mussel DNA

### Problem

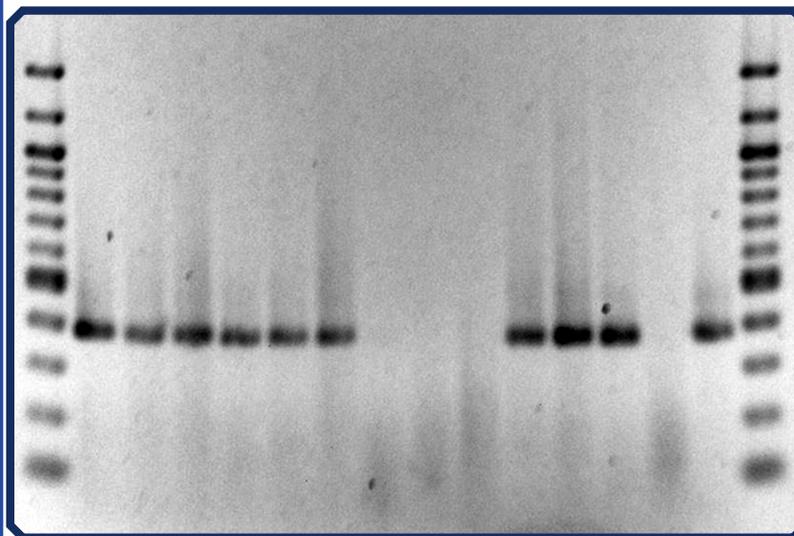
The quagga mussel (*Dreissena rostriformis bugensis*) is an introduced freshwater bivalve that is spreading across the Western United States. The mussel is negatively affecting water ecology and impacting infrastructure such as dams, water intakes, and water treatment facilities. The Reclamation Detection Laboratory for Exotic Species (RDLES) in Reclamation's Technical Service Center is dedicated to the early detection of invasive, threatened, and endangered species, and it has been responsible for advancing the science of invasive mussel early detection. Cross polarized light microscopy is the preferred and standard method for detecting mussel larvae (veligers) in raw water samples; however, degradation of the veliger shell may result in false negative microscopy findings. Veligers are microscopic, which makes identification difficult, especially if the sample contains significant amounts of sediment, organic material, or other bivalves.

RDLES has included polymerase chain reaction (PCR) testing for detecting DNA in addition to the microscopy analysis of raw water samples. This test helps reduce the likelihood of false negatives and verifies species identification, as needed. PCR is capable of detecting the presence of veligers that are degraded beyond the point of microscopic detection. PCR testing is complex and takes time to optimize because the test includes multiple steps and reagents. These complexities lead to results that can be variable and inconsistent. This Reclamation Science and Technology Program research project was designed to explain this variability.

### Solution

The goal of this research study was to demonstrate how multiple factors, including DNA extraction kit type, amount of DNA in the sample, number of days to analysis, and presence or absence of DNA inhibitors, impact PCR detection of quagga mussel DNA. PCR success rate was observed in four sample scenarios, including detecting

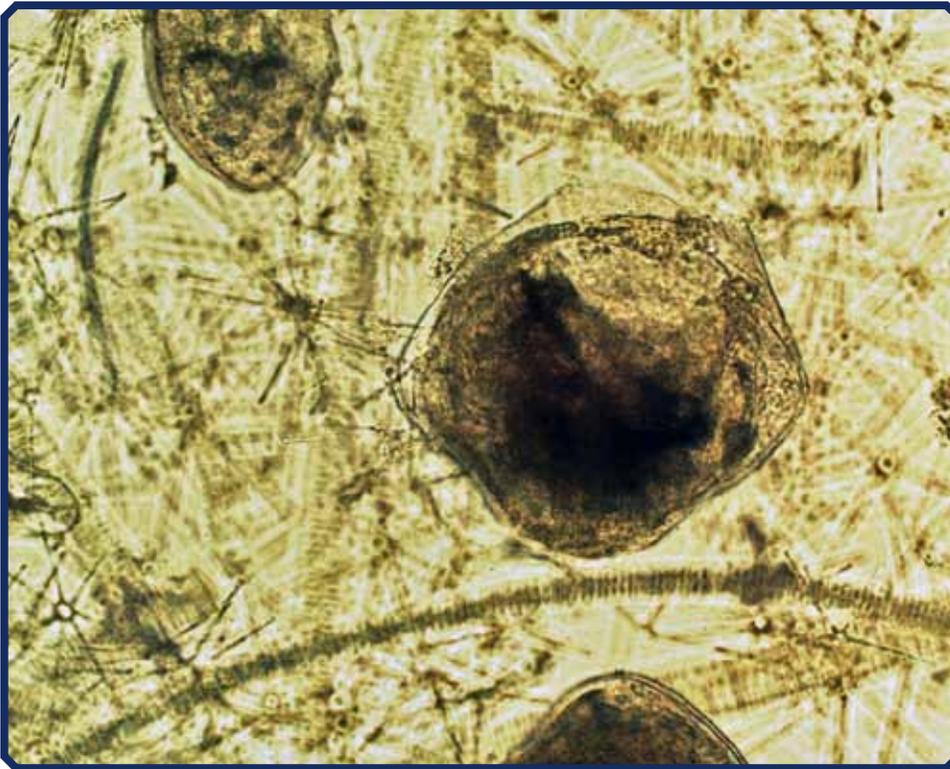
whole veliger bodies in water without inhibitors and in water with inhibitors, and detecting broken veligers, degraded veligers, and two concentrations of free-floating adult DNA in water with inhibitors.



## Application and Results

Overall, the research study results indicate that a positive PCR result can be achieved on a water sample that previously tested negative by microscopy. This is possible because PCR can detect free-floating DNA and veligers that are degraded and broken apart. Unfortunately, many of the PCR results in this study were negative, even though a known source of DNA was present in the sample. These results suggest that early detection PCR will likely produce more false negatives than false positives.

More research is necessary to determine how water quality and chemistry affect the DNA extraction chemistries of the DNA extraction kits. While microscopy is an important aspect of *dreissenid* early detection, this research study indicates that PCR testing of *dreissenid* early detection samples is a valuable tool that is capable of detecting signs of *dreissenid* presence that would otherwise be missed by microscopy alone.



*Degraded veliger not detected by cross polarized light microscopy.*

## Future Plans

Further research is necessary to better understand and optimize the PCR methods for detection of *dreissenid* veliger DNA in early detection samples.

***“PCR testing of dreissenid mussels with early detection samples is a valuable tool that is capable of detecting signs of dreissenid presence that may otherwise be missed by microscopy alone.”***

**Sherri Pucherelli**  
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[www.usbr.gov/research/projects/  
detail.cfm?id=8912](http://www.usbr.gov/research/projects/detail.cfm?id=8912)

## Research Update

Fall 2015  
Bulletin 2015-15

### Bottom Line

This research project tested redear sunfish's ability to reduce quagga mussel settlement through predation. Results showed that some fish will consume significant amounts of quagga mussels and some will not. Thus, redear sunfish and other predators may contribute to controlling mussels, but probably will not eradicate them in areas where the species co-occur.

### Better, Faster, Cheaper

No single effective control measure can eliminate quagga mussels from infested water. However, resident redear sunfish may help to reduce, but not eradicate, quagga mussel in areas where they co-occur.

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## Do Redear Sunfish Eat Quagga Mussels?

*Experiments to evaluate predation of quagga mussels by redear sunfish*

### Problem

Zebra and quagga mussels in the United States have, and will continue to have, far-reaching negative economic and ecologic impacts. Mussel infestations clog water intake and conveyance structures and reduce water delivery, pumping, and hydropower capabilities. Additionally, quagga and zebra mussels filter substantial amounts of water, which negatively alters the food web of infested waters, in part by increasing water clarity. They also generate and potentially concentrate toxic waste that may pass up the food chain.

Possible mussel control measures include:

- Chlorination (and other chemicals)
- Oxygen deprivation
- Thermal, electrical, sonic, and pressure shock
- Desiccation
- Antifouling coatings
- Toxic bacteria
- Predation

Fish predation of invasive mussels may be one type of biological control that can contribute to reducing impacts of mussels in Reclamation facilities and water delivery structures.

### Solution

This Reclamation Science and Technology Program research project evaluated whether fish predation on quagga mussels could help reduce mussel colonization in the lower Colorado River. Redear sunfish were selected for this research study because they are known molluscivores in Southeastern United States and, in some areas, occur with quagga mussels (e.g., Lake Havasu, Arizona/California). These redear sunfish were captured in upper Lake Havasu soon after the mussel invasion with quagga mussels in their stomachs. Bluegill were also included in the laboratory experiments because

they co-occur with redear sunfish and quagga mussels in some areas of the lower Colorado River.

This research study conducted laboratory and field enclosure replicated experiments to determine the ability of the fish to potentially reduce mussel infestations. Both sets of experiments confined quagga mussels with one or two redear sunfish (and bluegill in the laboratory).



*A redear sunfish.*

## Applications and Results

The laboratory experiments were conducted in the Boulder City, Nevada, Fish Laboratory in Reclamation's Lower Colorado Region as both quagga mussels and redear sunfish were easily accessible. In the laboratory experiments, most fish consumed quagga mussels (89.3 percent of redear sunfish and 71.4 percent of bluegill). Consumed quagga mussels averaged 12.4 millimeters (mm) long (3.0 to 26.8 mm) and 7.4 mm high (2.2 to 16.2 mm). The larger fish ate larger mussels. Ingested mussels were mostly crushed and shell pieces regurgitated and defecated by the redear sunfish. Conversely, ingested mussels were not crushed by bluegill.

The field enclosure experiments were conducted in Lake Havasu (Arizona/California) as both redear sunfish and quagga mussels are well established there. In these experiments, the redear sunfish significantly reduced mussel density by as much as 25.3 percent, although this was not observed in all enclosures. Mussel density did not decline in enclosures without fish, and new mussel settlement was minimal. Redear sunfish that survived to study completion averaged 280.3 mm in length and weighed 488.2 grams (gm) (235 to 348 mm; 241 to 1,115 gm). Quagga mussels ranged in length from 4.4 to 24.6 mm.

Both laboratory and field experiments suggests that redear sunfish may help to reduce quagga mussel colonization in areas where the two species co-occur. While redear sunfish can significantly reduce mussel densities, they also consume other prey (e.g., redswamp crayfish), if available. As their response is variable, redear sunfish may help to control mussel infestations, but are not likely to eradicate quagga mussels where the two species co-occur. Thus, the findings do not suggest stocking redear sunfish to control quagga mussels.

***“Invasive species, such as the quagga mussel, are an unplanned biological experiment gone awry. While redear sunfish generally consumed quagga mussels, their overall response varied. Therefore, they are not likely to eradicate quagga mussel infestations.”***

**Cathy Karp**  
Fish Biologist, Reclamation's  
Technical Service Center



*Aquaria used in laboratory experiments (note settled quagga mussels).*



*Fish/quagga mussel enclosure pen.*



*Enclosure pens deployed in a cove.*

## Future Plans

Quagga mussels are well established in the lower Colorado River and in some associated water delivery facilities and canals. This research suggested that fish control of mussels may contribute to reducing mussel colonies, but releasing redear sunfish to control quagga mussels is not recommended.

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## Collaborators

Lower Colorado Region

## More information

[www.usbr.gov/research/projects/detail.cfm?id=9508](http://www.usbr.gov/research/projects/detail.cfm?id=9508)

## Research Update

Fall 2015  
Bulletin 2015-16

### Bottom Line

*Dreissenid* mussel management efforts designed to limit or prevent secondary invasions and damage to water delivery infrastructure depend on accurate monitoring and efficient information dissemination. An important component of detection monitoring programs is the ability to accurately and reliably detect, as early as possible, the introduction of these mussels into a pristine water body.

### Better, Faster, Cheaper

Developing the most reliable and sensitive method of detection for the presence of *dreissenid* mussels will help safeguard Reclamation water delivery infrastructure, with the goal of early mitigation of costly operations and maintenance issues before they occur.

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## Monoclonal Antibodies for Improved Detection of *Dreissenid* Mussel Larvae

*A novel method for the early detection of quagga and zebra mussels*

### Problem

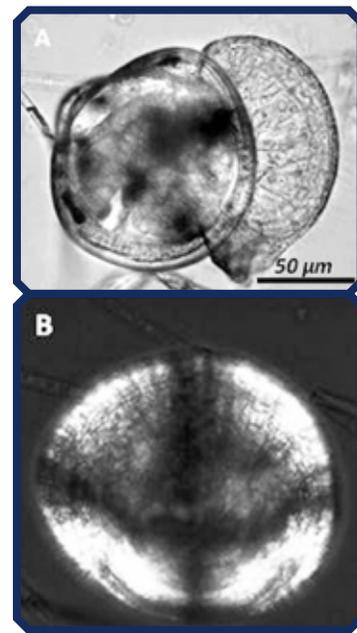
The expansion of *dreissenid* mussels into the Western United States has generated an increased need for reliable early detection methods, especially for larvae (veligers), which are a primary transport vector and an indicator of spawning adult mussels. Following initial introduction into an aquatic system, mussels attach to most submerged surfaces, resulting in serious consequences for the drinking water and hydroelectric power industries, industrial cooling facilities, agricultural irrigation, and recreational use of water. Colonies of mussels clog intake trashracks, pipes, valves, siphons, and irrigation and fire suppression systems. Consequently, it is critically important to detect infestation in the early stages so that timely and cost effective response plans and control strategies can be developed.

The mussel life cycle includes microscopic, planktonic larval stages (veligers) that are typically detected using cross polarized light microscopy on plankton net concentrates. However, other plankton species and inert materials also produce similar results and can be confused for quagga or zebra mussel veligers. In addition, concentrated water samples usually contain many other organisms and debris that can interfere with veliger detection. Therefore, tools and methods are needed to simplify and improve veliger detection to ensure maximum confidence in the results of monitoring programs.

During a nationwide double-blind, round-robin study involving 19 independent laboratories, available detection methods were found to generate both false positive and false negative errors, even in relatively clean water samples. Federal and State authorities have called for standardized *dreissenid* monitoring or quality assurance standards, and there is a growing consensus that laboratory certification and quality assurance programs would be useful for management communities responsible for monitoring and mitigating new invasions and spread of *dreissenid* mussels.

### Solution

This Reclamation Science and Technology Program research project developed monoclonal and polyclonal antibodies (mAb, pAb) that can be used to label veligers with fluorescent tags and purify veligers from complex samples using magnetic capture technology. Organism-specific antibodies have previously been used to improve detection and identification of many organisms in environmental waters, including marine mussel larvae and human pathogens. An antibody that recognizes quagga and zebra mussel veligers, coupled to fluorescent tags or magnetic beads, would greatly improve detection and identification of veligers in aquatic systems.



Quagga mussel veligers (umbonal life stage) viewed by conventional microscopy. (A) White light microscopy image with extended vellum (B) Cross polarized light microscopy image.

## Application and Results

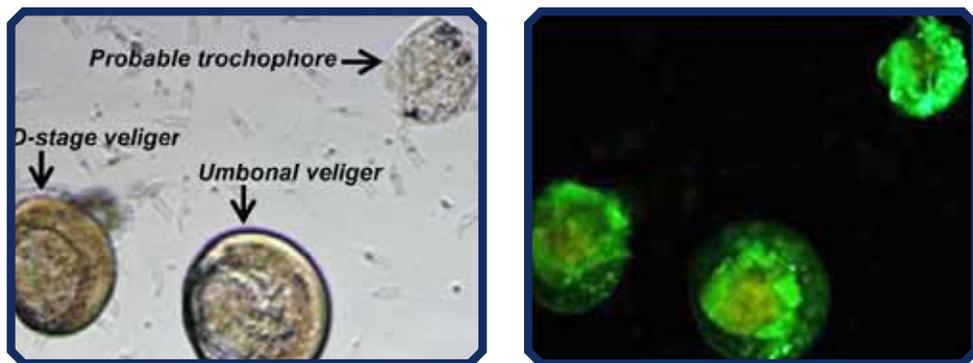
These antibodies will be used to purify veligers from complex environmental water samples using magnetic capture technology and to label veligers with fluorescent tags. Fluorescently labeled organisms are much easier to detect and enumerate by microscopy. Organism-specific antibodies have been used in many fields to aid in isolating organisms from complex samples and to label those organisms with fluorescent tags, thus aiding detection and identification. For example, the U.S. Environmental Protection Agency's approved method, which is used nationwide for detecting the protozoan parasites *Cryptosporidium* and *Giardia* in water, uses antibodies for immunomagnetic purification and detection by fluorescence microscopy. Of more direct relevance to the current project, monoclonal antibodies have been used to detect and identify larvae of the economically important mussel, *Mytilus galloprovincialis*. Sensitive molecular methods have been developed to detect quagga and zebra mussel veligers and other invasive mussels. Compared to conventional microscopy-based methods, they are most useful as early warning monitoring tools, while direct observation by conventional microscopy remains the most appropriate approach for monitoring sites that are already infested and assessing the level of infestation.

The goal of this research project was to produce a mAb that selectively binds to quagga mussel veligers. A variety of mAbs were produced as unpurified, laboratory-scale preparations and as purified, reagent-grade reagents in milligram quantities. These antibodies stained veligers, generating a variety of fluorescence staining patterns when observed by indirect immunofluorescence microscopy. The project successfully demonstrated the feasibility of generating mAbs that recognize and bind to quagga mussel veligers. The antibodies produced by this project provide tools that could simplify detection and identification of veligers in water samples.

## Future Plans

Additional specificity testing is necessary, along with testing the performance of mAbs against veligers in more complex matrices. Continued development of the immunocapture technique is also required. All of the antibody-producing cell lines developed for this project are stored as frozen (-80 °C) stocks. These frozen cell stocks can be used to generate additional purified antibody for further research efforts in collaboration with interested stakeholders and research institutions.

Additional work to further develop and refine these antibody-based veliger detection tools is recommended: 1) evaluate staining patterns and intensity with all larval stages of quagga mussels (D-shaped, umbonal, and pediveligers); 2) thoroughly evaluate specificity and quantification of false positives and false negatives with a variety of nontarget organisms; 3) improve reduction of autofluorescence; 4) evaluate different sized paramagnetic beads, including <100 nm beads; 5) assess alternative secondary bridges linked to magnetic beads to improve magnetic capture with mAbs; and 6) identify and characterize the protein antigen(s) recognized by the antibodies using protein separation by polyacrylamide gel electrophoresis and Western blotting.



D-stage and umbonal veligers and a possible trochophore stained with cell culture supernatant from a hybridoma subclone. White light microscopy (left) and epifluorescence microscopy (right).

**“Quagga mussels are a huge issue for us in the Lower Colorado Region. We have reservoirs with quagga mussels, and those without that we really would like to keep that way. Therefore, finding new ways to detect mussels early is critical to us in protecting our water infrastructure. This research will help us do just that.”**

Nathaniel Gee  
Supervisory Civil Engineer,  
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[www.usbr.gov/research/projects/detail.cfm?id=9640](http://www.usbr.gov/research/projects/detail.cfm?id=9640)

Frischer, M.E., K.L. Kelly, and S.A. Nierzwicki-Bauer. 2012. “Accuracy and reliability of *Dreissena* spp. larvae by cross-polarized light microscopy, imaging flow cytometry, and polymerase chain reaction assays.” *Lake and Reservoir Management*, 28:4, 265-276.

<http://dx.doi.org/10.1080/07438141.2012.731027>

White Paper. 2012. *Validation of PCR-Based Assays and Laboratory Accreditation for Environmental Detection of Aquatic Invasive Species*. Invasive Species Advisory Committee (ISAC), National Invasive Species Council (NISC).

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## Research Update

Fall 2015  
Bulletin 2015-17

### Bottom Line

The overall cost to treat nuisance aquatic plants keeps increasing, and chemical treatments are becoming more difficult to implement given the strict environmental regulation associated with the herbicides.

### Better, Faster, Cheaper

By understanding the conditions that influence the growth of aquatic weeds, more comprehensive solutions to the problem can be found, allowing irrigation districts and canal operators to control nuisance aquatic plants without severe offsite and nontarget impacts or high labor and material costs.

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## Controlling Nuisance Aquatic Plants in Canals

*Controlling the conditions to prevent aquatic weed growth in water delivery systems*

### Problem

The Western United States depends on a network of reservoirs and canals to distribute water—the lifeblood of agriculture, cities, and industry. Aquatic weeds (from algae to rooted plants like pondweeds) are a growing problem in these systems—reducing flow, impairing the performance of intake structure and pumps, and even damaging systems. These nuisance aquatic plants are widespread and can be very costly to control. Canal operators and irrigation districts must expend their budget on physical labor to continuously remove plant material from the systems and/or purchase and apply aquatic herbicides. It is also becoming increasingly time-consuming to obtain use permits for the aquatic herbicides.



*Intake structure blocked by Hydrilla and water hyacinth.*

### Solution

This Reclamation Science and Technology Program research scoping project assembled a team of resource specialists and managers who have practical experience with aquatic weed issues and represent Reclamation's broad geographic extent to outline a systematic approach to studying this issue. The team provided information (reports, records, and discussion) describing the current state of aquatic weeds control and the primary issues they were encountering.

A resounding need for a combined set of tools, technology, and resources that could answer the “what, when, where, and how” considerations that must be addressed in optimizing the treatment effect on aquatic weeds was universally apparent.

## Application and Results

The team reviewed several previously published investigations showing that while relationships between environmental variables and proliferation of aquatic weeds can be made, translating these findings into cost-effective and practical methods for controlling aquatic weeds is problematic. The team decided that tracking and mapping aquatic weed growth in water delivery systems would provide more useable information that could be directly applied to improving aquatic weeds control. To gather this information, researchers would need to collect field data to monitor growth, and distribution could provide the information to help address that need. The scoping project proposal recommended:

- Identifying water quality and physical characteristics of canals that may influence the growth of aquatic weeds in water delivery systems
- Determining ways to manage the underlying influences that promote and/or discourage the aquatic weed growth for alternative or complementary control measures to herbicidal treatments

## Future Plans

This Reclamation Science and Technology Program research scoping project (Project ID 6688) focused on identifying alternative solutions to aquatic weeds control using mechanical removal and herbicides. Based on the results of this research scoping project, future work will focus on making current treatment methods more efficient and effective.

An ongoing Reclamation Science and Technology Program research study project (Project ID 1725) is developing a suite of tools to track the growth and distribution of nuisance aquatic plants. These tools will provide irrigation managers the information required to make treatments more targeted and timely. Products will include:

1. Spreadsheet(s) template(s) designed to track location, condition, and treatment of aquatic weeds throughout their annual life cycles
2. A how-to guide to convert data for viewing in Google Earth or geographic information systems (GIS)
3. Instructions on assembling an affordable vegetation biomass mapping unit (preferably remote-controlled) from readily available parts and components
4. A report assessing how to use measurements of dissolved oxygen levels during the day and night to estimate the quantity of aquatic vegetation in irrigation canals
5. A full report of the completed 3-year study with findings and recommendations, including benefit-cost ratio for using the proposed tools to schedule aquatic weeds control treatments



*Aquatic weeds and algae congesting water column.*

***“Many districts ‘treat when we see the plants appear on trashracks,’ but this proves to be expensive and difficult. A better approach would be to monitor vegetation and to treat when plants are easier to remove. Like taking care of dandelions in your yard, treat when you see the first one—not the field”***

Clyde Lay  
Water Quality Specialist,  
Reclamation’s Pacific Northwest  
Region

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## More information

[www.usbr.gov/research/projects/detail.cfm?id=6688](http://www.usbr.gov/research/projects/detail.cfm?id=6688)

## 2015 Research:

[www.usbr.gov/research/projects/detail.cfm?id=1725](http://www.usbr.gov/research/projects/detail.cfm?id=1725)

# Recent Invasive Mussels Research Products

To get the information generated by research quickly into the hands of end users and the broader public, our researchers and partners publish their results in peer-reviewed journals, technical memoranda, research reports, and other venues.

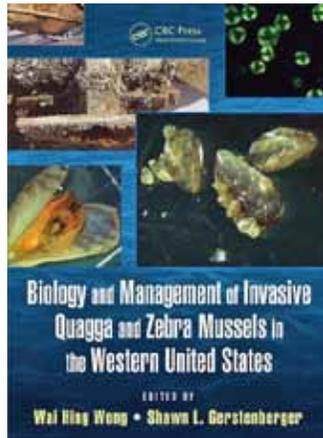
Contact the authors/principal investigators for information about these documents or research projects. To access contact information or the documents themselves, use the search function at: [www.usbr.gov/research/projects/search.cfm](http://www.usbr.gov/research/projects/search.cfm).

Wong, W.H and S.L. Gerstenberger, Editors. 2015. *Biology and Management of Invasive Quagga and Zebra Mussels in the Western United States*. CRC Press, Taylor & Francis Group, LLC., Boca Raton, Florida. Available at:

[www.crcpress.com/Biology-and-Management-of-Invasive-Quagga-and-Zebra-Mussels-in-the-Western/Wong-Gerstenberger/9781466595613](http://www.crcpress.com/Biology-and-Management-of-Invasive-Quagga-and-Zebra-Mussels-in-the-Western/Wong-Gerstenberger/9781466595613)

Reclamation chapters include:

- Moore, B., G.C. Holdren, S.L. Gerstenberger, K. Turner, and W.H. Wong. Chapter 2. "Invasion by Quagga Mussels into Lake Mead, Nevada–Arizona."
- Carmon, J. and D.M. Hosler. Chapter 10. "Understanding *Dreissenid* Veliger Detection in the Western United States."
- Nelson, H., B. Spaulding, S. O'Meara, K. Bloom, S. Pucherelli, and D.M. Hosler. Chapter 11. "Automated Method for *Dreissenid* Veliger Detection, Identification, and Enumeration."
- Merten, B.J., A.D. Skaja, and D. Tordonato. Chapter 28. "Mussel Byssus and Adhesion Mechanism."
- Skaja, A.D., D. Tordonato and B.J. Merten. Chapter 29. "Coatings for Invasive Mussel Control."



Carmon, J., J.A. Keele, S.F. Pucherelli, D.M. Hosler. 2014. "Effects of Buffer and Isopropanol Alcohol Concentration on Detection of Quagga Mussel (*Dreissena bugensis*) Birefringence and DNA." *Management of Biological Invasions*, 5(2): 151-157.

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## Regional Science and Technology Coordinators Contact Information

Whether you are a regional researcher, Reclamation partner or customer, or just have an idea for a project that can help your region, the Regional Science and Technology Coordinators can help you with your research ideas, proposals, and projects.



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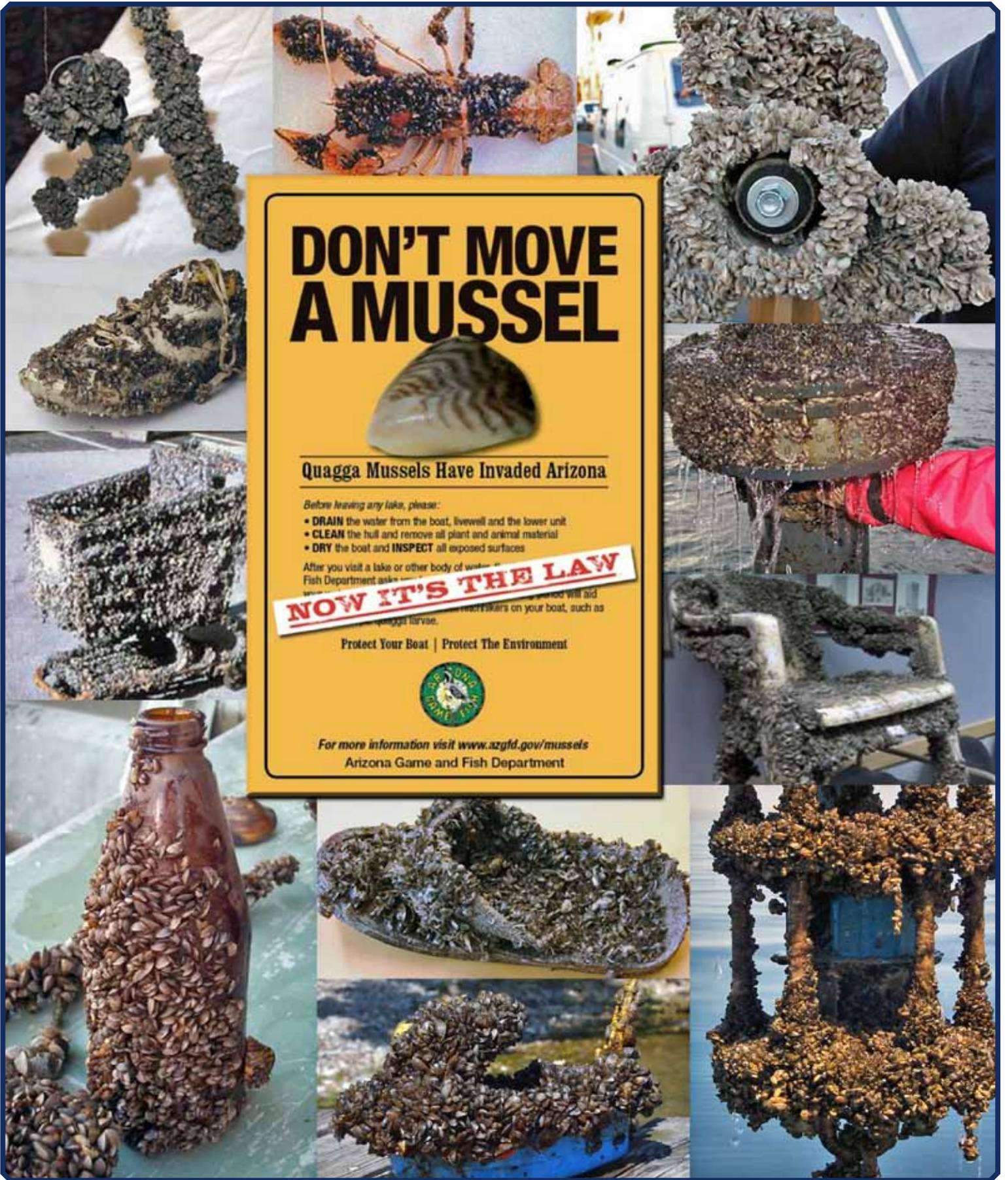
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Thanks,

Research and Development Office





# DON'T MOVE A MUSSEL



## Quagga Mussels Have Invaded Arizona

Before leaving any lake, please:

- **DRAIN** the water from the boat, livewell and the lower unit
- **CLEAN** the hull and remove all plant and animal material
- **DRY** the boat and **INSPECT** all exposed surfaces

After you visit a lake or other body of water, the Arizona Game and Fish Department asks that you help prevent the spread of mussels. You will aid in the prevention of mussels on your boat, such as mussels and quagga larvae.

**NOW IT'S THE LAW**

Protect Your Boat | Protect The Environment



For more information visit [www.azgfd.gov/mussels](http://www.azgfd.gov/mussels)  
Arizona Game and Fish Department

Collage of mussels infestation photographs. See Invasive Mussels section on pages 18 through 32 for details and more information.



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