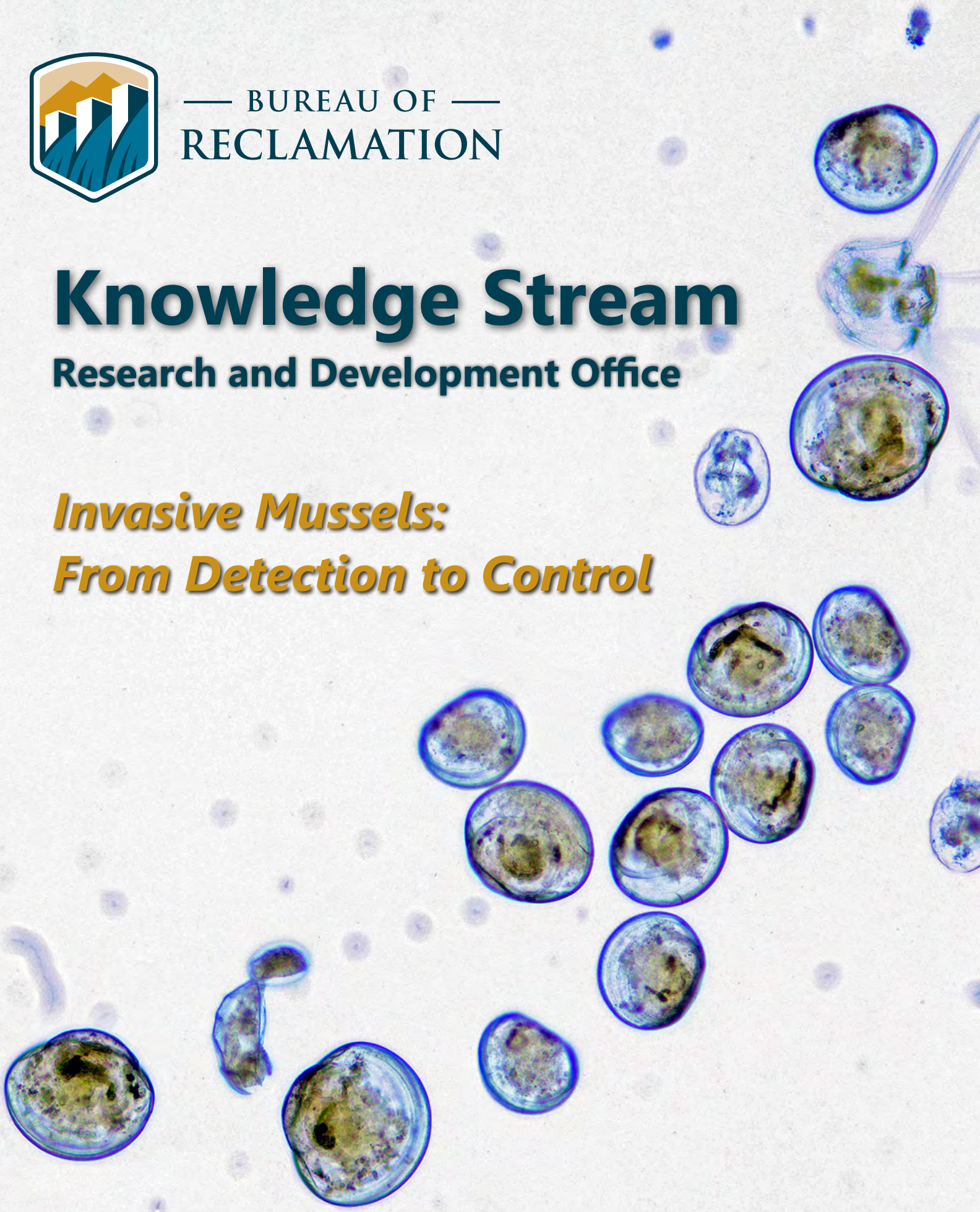
BUREAU OF RECLAMATION

Knowledge Stream

Research and Development Office

Invasive Mussels: From Detection to Control



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Message from R&D

Welcome to the Fall 2021 issue of the *Knowledge Stream!* In this issue we highlight Research and Development (R&D) Office efforts to address the challenges posed by invasive zebra and quagga mussels on Western U.S. water management. Identifying better ways to detect mussel settlement, predict spread, combat impacts on facilities, and control populations in lakes and reservoirs is a key component of Reclamation's efforts to control and mitigate mussels impacts on Reclamation's water infrastructure and in managed waterways. In this issue you'll learn about the innovative work of Reclamation scientists, engineers, and program specialists to make such advancements, including:

- Efforts by Reclamation's Integrated Pest Management Program to coordinate strategic response to mussels impacts across the bureau.
- Advances in mussel detection by researchers at Reclamation's Technical Service Center – Ecological Research Lab.
- Technologies that can mitigate mussel settlement impacts at hydropower plants.
- Foundations for developing biologically based control of mussel populations in lakes and reservoirs, including mussels genome development, developing genetically engineered biocontrol, and searching for natural biocontrol from the mussels' native Eurasian region.

In addition to mussel-related innovation activities, you'll also read about Reclamation's R&D Office response to wildland fire challenges, supporting research to better understand post-fire impacts on reservoir inflow, sedimentation, and water quality; and an April 2021 workshop convening Reclamation programs and other government partners to identify wildland fire research needs.

As always, we appreciate you reading about innovation funded by Reclamation's R&D programs. Please enjoy this issue of the Knowledge Stream and offer us any feedback for improving our strategies to transfer solutions to users.

About the *Knowledge Stream*

The *Knowledge Stream*, published by the Bureau of Reclamation's Research and Development Office, is a quarterly magazine bringing mission-critical news about the agency's innovations in the following:

- Science and Technology Program
- Desalination and Water Research Purification Program
- Prize Competitions
- Open Water Data
- Technology Transfer...and more.

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Back Cover: Quagga mussels settled on submerged equipment at a Lower Colorado River reservoir.

Community Needs

Progressing from Mussel Detection to Mussel Control

By Sherri Pucherelli
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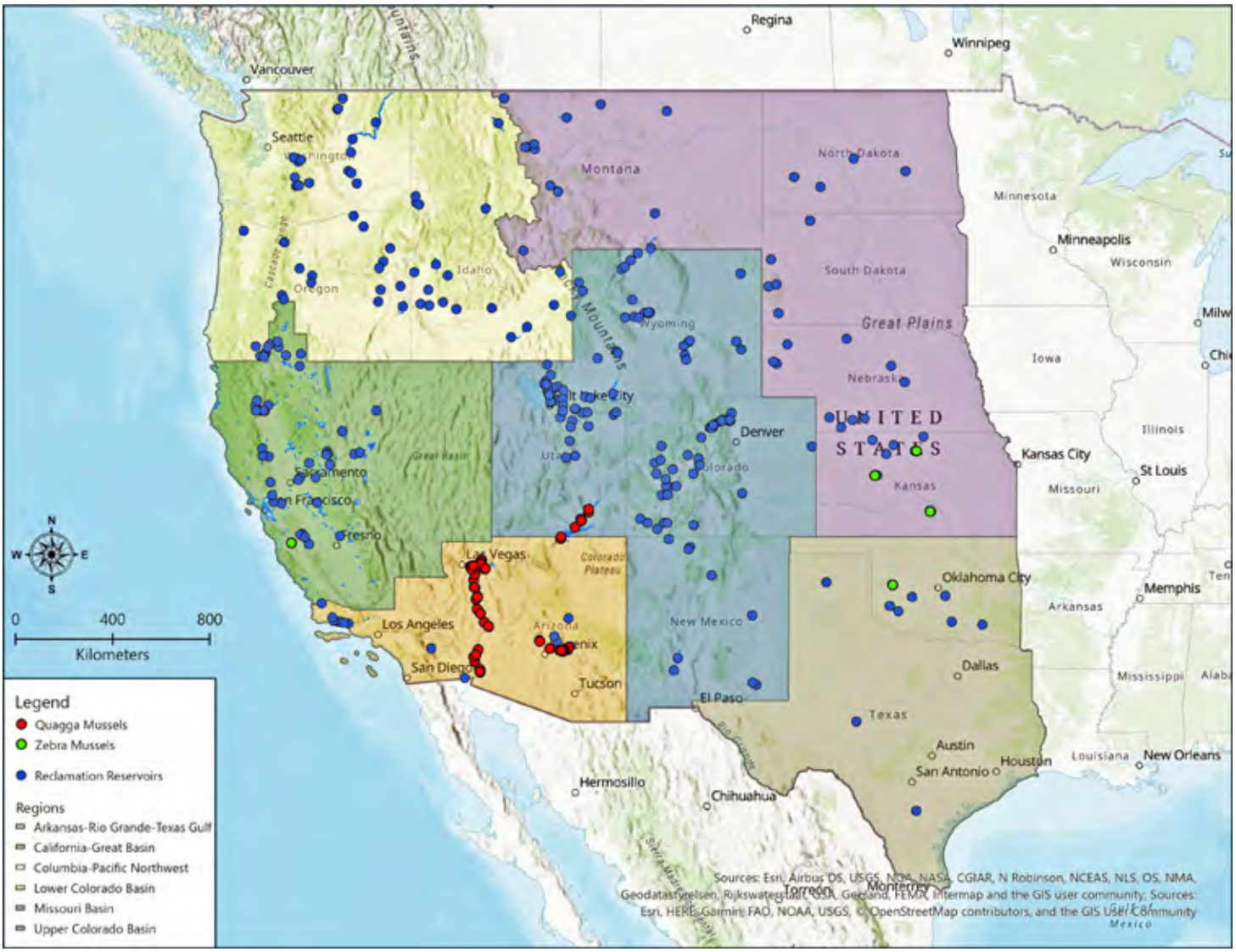
The Reclamation Science and Technology Program has invested in the development of invasive dreissenid mussel (quagga and zebra mussels) detection and control methods since quagga mussels were first detected in Lake Mead in 2007. The mussels impact the operation and maintenance of Reclamation hydropower plants because they are prolific breeders that can settle on any hard surface they encounter. This behavior is problematic for hydropower facilities because the mussels settle on submerged surfaces such as water intakes, trashracks, pipes, and other hydraulic equipment that are utilized for water delivery and hydropower production. When mussel populations are dense, they will begin to settle on top of each other, which can restrict flow in critical systems, leading to increased maintenance and unplanned outages. Reclamation's research on this topic supports a nationwide effort focused on early detection, prevention of spread, and control of populations and their impacts.

Established quagga and zebra mussel populations exist in all Reclamation regions, except the Columbia Pacific Northwest Region. Early detection of mussel populations is critical for limiting the spread and impacts of mussels. The Science and Technology Program has supported research into optimizing detection methods which has improved Standing Operating Procedures and genetic analysis capabilities, including implementation of environmental DNA (eDNA) monitoring practices. Current research is focused on identifying innovative detection methods such as automated sample analysis, scent detection, and emerging genetic techniques. Development of modeling tools is also being pursued to better predict locations where mussel establishment is probable.

Control of established mussel populations has proven difficult. Reclamation researchers and partners are beginning to focus on the development of open water control methods to reduce mussel populations in large reservoirs. This research includes searching for potential parasites of closely related mussel species to be utilized as biological control agents and development of genetic control tools. Genetic control methods are a relatively new area of study, and Reclamation researchers are helping to advance the science by recently sequencing the quagga mussel genome and partnering with the winning solver of a Prize Competition to develop mussel cell culture and gene transfer methods.

Much of the research of the past 10 years has focused on the development and implementation of environmentally compliant control strategies for settlement prevention and shell debris mitigation at hydropower plants. Reclamation researchers and contractors have developed and tested a variety of mussel control methods along with site-specific testing of commercially available products. Reclamation has examined the following control methods:

- Self-Cleaning Microfiltration
- Antifouling and Foul Release Coatings
- Ultraviolet (UV) Light Treatment
- Zequanox
- Turbulence
- pH Manipulation
- Endothall
- Copper Ion Generator
- Conductivity Manipulation
- Laser-Generated Pulsed Pressure
- Centrifugal Separator



Reclamation reservoirs and locations with invasive mussel populations. Locations with red dots have established quagga mussel populations, and green dots are locations with established zebra mussel populations.

Ultraviolet light treatment has been the most implemented method at Reclamation hydropower plants to control mussel fouling in generator cooling systems, but this method is not feasible for all locations, so research into new control methods continues. Researchers have also identified several effective coatings and continue to test next-generation foul-release and resistant coatings. New research includes investigation of the effectiveness of carbon dioxide, ultrasound, electrical methods, and self-cleaning strainers.

Invasive mussels are considered one of the most devastating invasive species in the United States, and over the past 10 years, Reclamation has played an important role in the fight against invasive mussels in the West. Outreach, participation in national interagency working groups, and working closely with State partners and experts in the field has been critically beneficial and has resulted in important partnerships and advancements.

Key Perspectives

Reclamation's Integrated Pest Management (IPM) and Invasive Species Program

By Jolene Trujillo
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In order to strategically manage the spread of invasive and other harmful pest species, coordination and collaboration across an organization is crucial. To meet that goal, the Bureau of Reclamation has an Integrated Pest Management (IPM)/Invasive Species Program that is led by the Policy and Programs Directorate, Environmental Compliance Division, based in Denver, Colorado.

Reclamation's IPM/Invasive Species Program is authorized by two pieces of legislation- The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) – which directs all federal agencies to use IPM and the Fish and Wildlife Coordination Act (FWCA)- which authorizes Reclamation to manage invasive species. The requirements laid out in FIFRA and FWCA are stepped down into the Reclamation Manual- which directs how Reclamation does business. For IPM/Invasive Species these are ENV P02 (Policy) and ENV 01-01 (Directive and Standards). These documents were revised in 2020 and are foundational to the IPM and Invasive Species Program at Reclamation.

At Reclamation, invasive species issues fit underneath the umbrella of IPM, which is a management strategy based on the following:

- Taking preventive measures
- Monitoring the site for the level of the pest(s)
- Assessing the potential for pest damage, and
- Choosing appropriate actions; including cultural practices, biological control agents, pesticides, mechanical methods, and physical barriers.

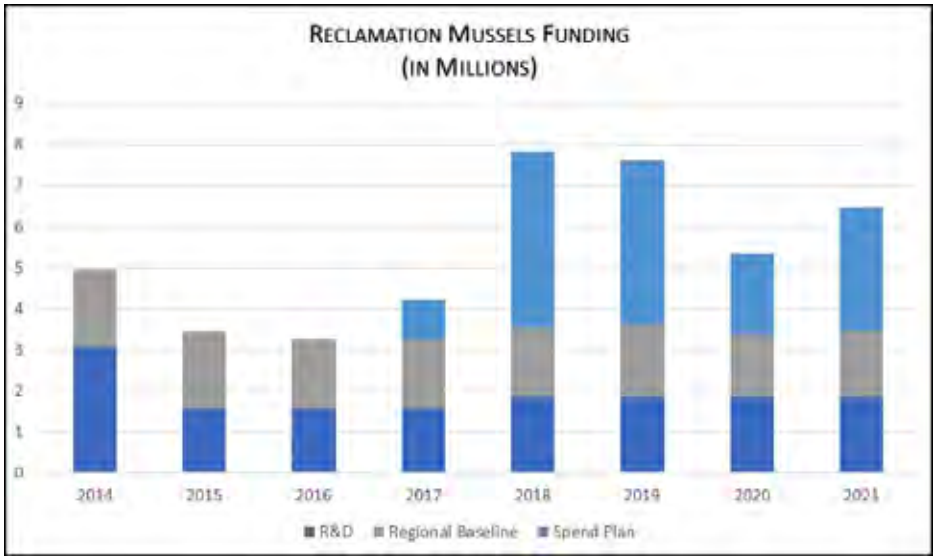
In IPM, these tactics may be combined into a plan that best suits the situation. It is a comprehensive approach dedicated to removing causes rather than just treating symptoms.

Reclamation's IPM/Invasive Species Program currently focuses primarily on invasive dreissenid mussels (quagga and zebra); however, we do work on other taxa of invasive/pest species as they impact Reclamation infrastructure and utilize IPM Plans to address specific management concerns.

In response to the substantial impacts to Reclamation's water infrastructure by quagga and zebra mussels, Reclamation has engaged in a variety of strategies to help mitigate the risk and reduce the impacts caused by these organisms. Specifically:

- The creation of a Corporate Mussels Task Force
- Utilization of facility specific vulnerability assessments
- Financial support to partnerships for watercraft inspection and decontamination efforts
- Education and outreach on quagga and zebra mussels
- Early detection water sampling and analysis
- Substantial research

Of key importance to Reclamation's efforts on quagga and zebra management was the 2017 Department of Interiors *Safeguarding the West from Invasive Species Actions to Strengthen Federal, State, and Tribal Coordination to Address Invasive Mussels* initiative which was a set of federal commitments for improving the prevention, eradication, and containment of quagga and zebra mussels in the west. It focused on reducing the risk of mussel introduction into the Columbia River Basin through coordinated support of containment in the Lower Colorado River and across the west.



Invasive mussel funding at Reclamation.

Safeguarding the West concluded at the end of 2020; however, as part of this effort, starting in 2017, Reclamation began internally allocating additional dollars to baseline mussel funds to support the implementation of *Safeguarding the West* and Reclamation's regional priorities pertaining to mussel management. These funds are allocated through yearly spending plans. Cumulatively through these plans, Reclamation has provided over $13 million on over 100 mussel management activities, with much of this support primarily going toward watercraft inspection and decontamination efforts with partners across the 17 Western States.

As observed, Reclamation's wide-ranging IPM/Invasive Species Program will continue to support the mission of Reclamation to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public into the future.

Reclamation's Mussel Website.

Reclamation's Ecological Research Lab - Supporting Mussel Detection

By Diane Mench
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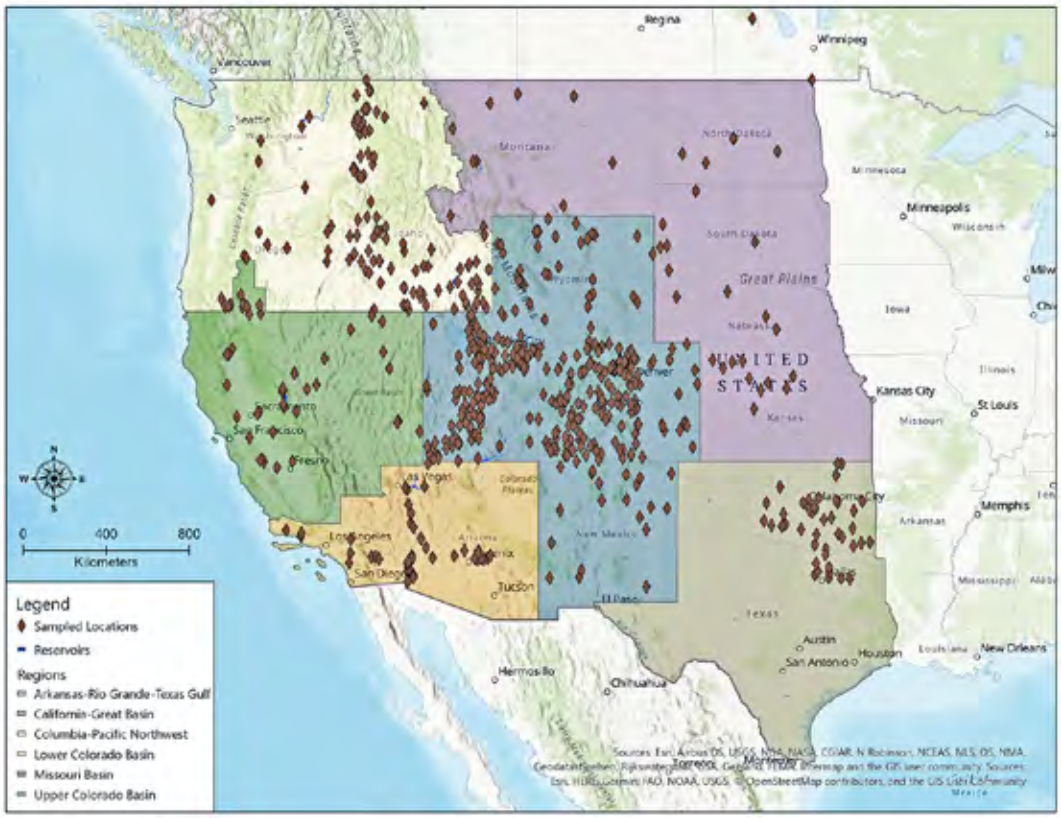
The Ecological Research Laboratory (Eco Lab) has been analyzing invasive mussel early detection samples since 2008. The Eco Lab has analyzed approximately 22,500 invasive mussel samples from 600 waterbodies in 17 States. Identification of mussel larvae (veligers) during the early stages of establishment provides critical information to water body managers that will allow for containment of the population and will provide hydropower plant managers approximately 3 to 5 years to implement preventative control measures before major impacts are experienced.

Significant progress was made in the last 3 years on optimization of sample collection, preservation, and analytical methodologies as well as evaluation and development of laboratory capabilities. In 2019, Eco Lab staff began analyzing more samples for the presence of environmental DNA (eDNA), including genetic testing of samples from waterbodies where mussels have not previously been detected. In the past, these samples would only have received microscopic analysis. The Standing Operating Procedure for the collection of samples was updated to include the collection of field blanks to confirm that all sampling gear was clean of mussel DNA contamination that might interfere with accurate sample results.

Sample preservation methods were evaluated and optimized to increase the likelihood that veligers and DNA will be detected. This evaluation resulted in the decision to increase the amount of alcohol added to each sample from 20 to 75% of the sample volume. Additionally, the Eco Lab stopped using baking soda as a buffer because, when used in excess, it settles out and can make sample preparation and microscopic analysis a major challenge. These challenges are eliminated with the use of 4M Tris, a buffer that maintains the integrity of veliger shells so they can be easily identified by cross-polarized light microscopy.

In 2021, Eco Lab staff conducted an S&T funded project to assess how suspended solids, like zooplankton or algae, affect mussel veliger settlement in an Imhoff cone. Settling plankton tow samples in Imhoff cones is a critical step in the Eco Lab's sample analysis process. Since veligers have a calcium carbonate shell, they are expected to settle to the bottom of the cone. For the study, water samples with varying levels of zooplankton and algae were spiked with a known number of veligers and settled in Imhoff cones. Initial results indicate that large quantities of zooplankton and algae can interfere with mussel settlement. Additional studies are planned to address this issue.

Water samples spiked with mussel veligers and settled in Imhoff cones to observe settlement efficiency.



Waterbodies where invasive mussel samples have been collected and then sent to the Eco Lab for analysis.

Other achievements include moving from an outdated laboratory space with high cross-contamination concerns to a new, modern space with a dedicated air handler, fume exhaust, and layout. During the COVID pandemic, the Eco Lab remained fully staffed and operational, receiving and analyzing more than 2,300 samples during the period from the beginning of the pandemic to the present.

It is expected that aquatic invasive species will be able to expand their range in the face of climate change due to warming water temperatures; therefore, it is anticipated that Bureau of Reclamation (Reclamation) reservoirs will continue to be impacted by new invasive species in the future. A potential benefit of this work is that the sampling and analysis infrastructure developed to detect mussels can easily be adapted to include detection of other invasive species of concern to Reclamation. The Eco Lab methods can quickly be modified for a variety of aquatic species, and multiple analyses can be performed in parallel. The genetic analysis techniques (qPCR and metabarcoding) utilized and optimized each year by the lab can be applied to a wide range of Reclamation projects that require identification of invasive, threatened, and/or endangered species.

Extracting eDNA from bulk water samples.

Controlling Invasive Mussels

Case Studies: Impact and Control of Invasive Mussels at Hydropower Plants

By Sherri Pucherelli & RNT Consulting, Inc.
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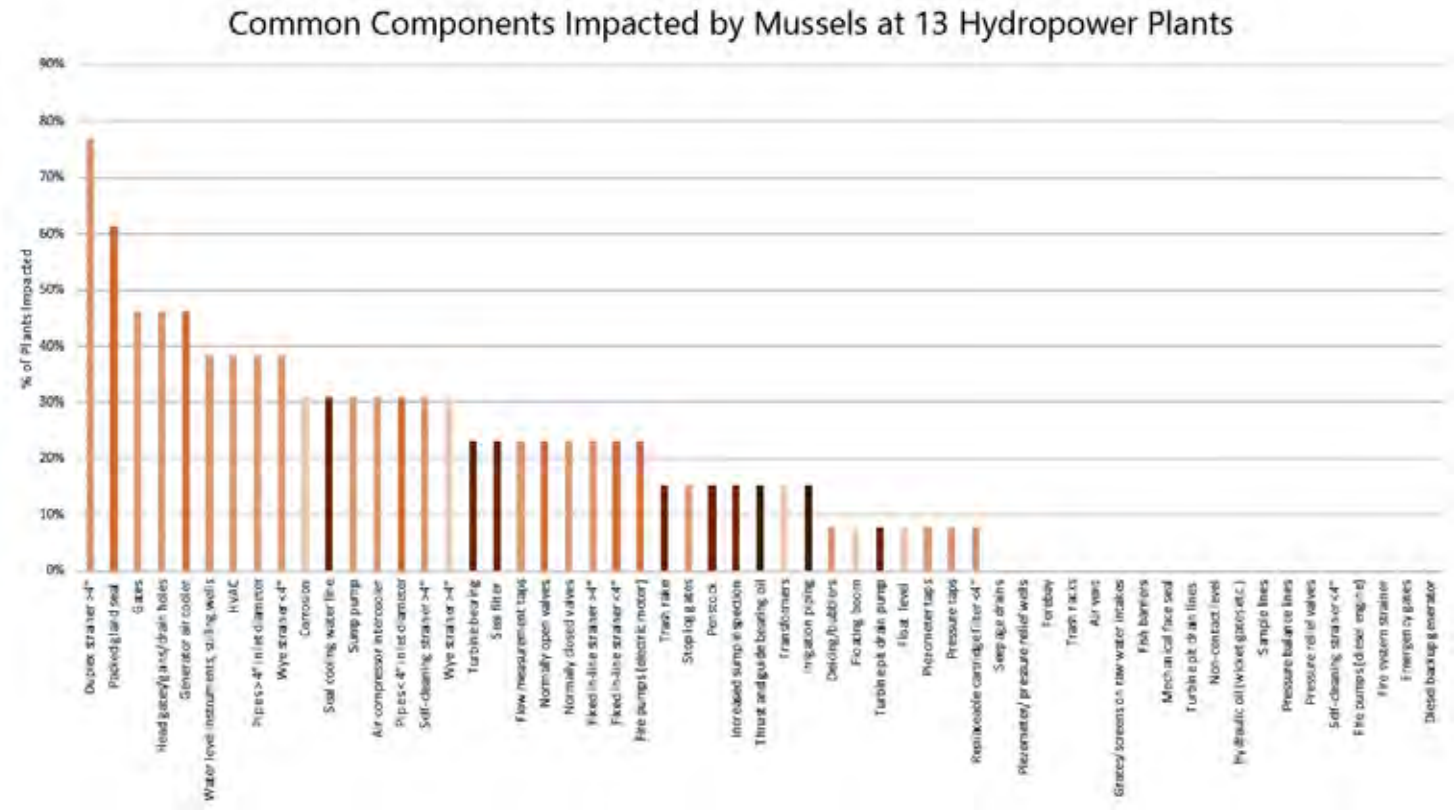
S&T Project page: www.usbr.gov/research/projects/detail.cfm?id=1876, https://data.usbr.gov/catalog/4487

Invasive mussels became an issue for Reclamation in 2007 after quagga mussels were detected in reservoirs along the lower reaches of the Colorado River in Arizona and Nevada. Several large hydropower facilities have been impacted, and Reclamation is anticipating that mussels will impact other locations in the future. The purpose of this study was to meet with hydropower facilities across multiple agencies throughout the United States and Canada who currently have invasive mussel infestations to learn more about how mussels are impacting operation and maintenance and the types of control methods that have been implemented. When possible, information about the cost of mussel control and maintenance was gathered. These case studies can be used by Reclamation facility managers and others throughout the United States and Canada who are preparing for a potential mussel invasion or those that are re-evaluating their current treatment approach.

Reclamation and RNT Consulting, Inc. selected thirteen hydropower plants to be interviewed. The questions were designed to develop a comprehensive understanding of the plant's experience with mussels. Four of the 13 plants interviewed are operated by Reclamation, 6 plants are in Canada, and 3 are operated by other agencies in the United States. The case studies included hydropower plants with two (144 MW total) to thirty-six (1899 MW total) generator units, a range of raw water system designs and usage in the plants, and 1 to 31 years of experience with mussel fouling.



Common components impacted by invasive dreissenid mussel fouling at 13 hydropower plants in the United States and Canada. Darker colored bars indicate components where mussels caused more severe problems, and lighter colored bars indicate components where mussels caused less severe problems.

Staff at two of the plants considered mussel impacts to be significant, eight considered the impacts to be moderate, and three experienced little to no impact. This study confirms that mussel impacts are primarily dependent on the design configurations of hydropower plants and how they utilize raw water. The size or number of generators at a plant does not usually correlate to the severity of impacts or expenditures. Mussel population size and dynamics also influence the impacts experienced.

Mussel fouling in hydropower plants results in increased maintenance to remove mussels from locations where they accumulate, reduce flow, and result in overheating. Five of the plants included in this study are currently managing mussel fouling by relying on increased cleaning, physical removal, or implementing design and operational changes. Eight plants have implemented preventative control treatments to prevent mussel fouling. Preventative control treatments include those that reduce or eliminate mussel fouling before it occurs by deactivating or interfering with the ability of the mussels to attach, grow, and cause clogging. The most common preventative control treatments utilized by the plants in this study were chlorine and hydro-optic disinfection (HOD) ultraviolet (UV) light. The reported capital investment to install chlorine treatment ranged between $100,000 and $1.3 million. The reported capital investment to install HOD UV ranged between $1 million and $2.1 million. While these treatments are effective at mitigating mussel fouling, they will not always be appropriate for every hydropower plant due to site-specific limitations, including discharge permitting requirements and water quality parameters.

Five of the 13 sites have experienced, or are currently experiencing, forced outages because of mussel fouling in the generator cooling systems. Cost estimates associated with preventative control measures, increased maintenance, unplanned outages, and monitoring are provided in this report, but it is difficult to provide exact costs associated with an infestation because most plants do not usually record and track all expenses.

Quagga mussel fouling on a fixed wheel gate at Glen Canyon Dam.

Quagga mussel shells accumulated in a strainer at a Lower Colorado River hydropower plant.

Best practices such as mussel monitoring, facility vulnerability assessments, and formulation of response plans can help facilities prepare for and mitigate significant operational impacts at plants. Seven of the 13 plants in this study had prepared for a mussel infestation by conducting a facility vulnerability assessment or developing a response plan. All the plants that had prepared indicated that the assessment or plan was useful for detecting mussels sooner and implementing control methods before fouling became unmanageable. Mussel vulnerability assessments and the information provided by these case studies can be utilized by hydropower plant managers that are preparing for a mussel infestation.

Sequencing and Analysis of the Quagga Mussel Genome for Development of Genetic Biocontrols

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www.usbr.gov/research/projects/detail.cfm?id=1866,
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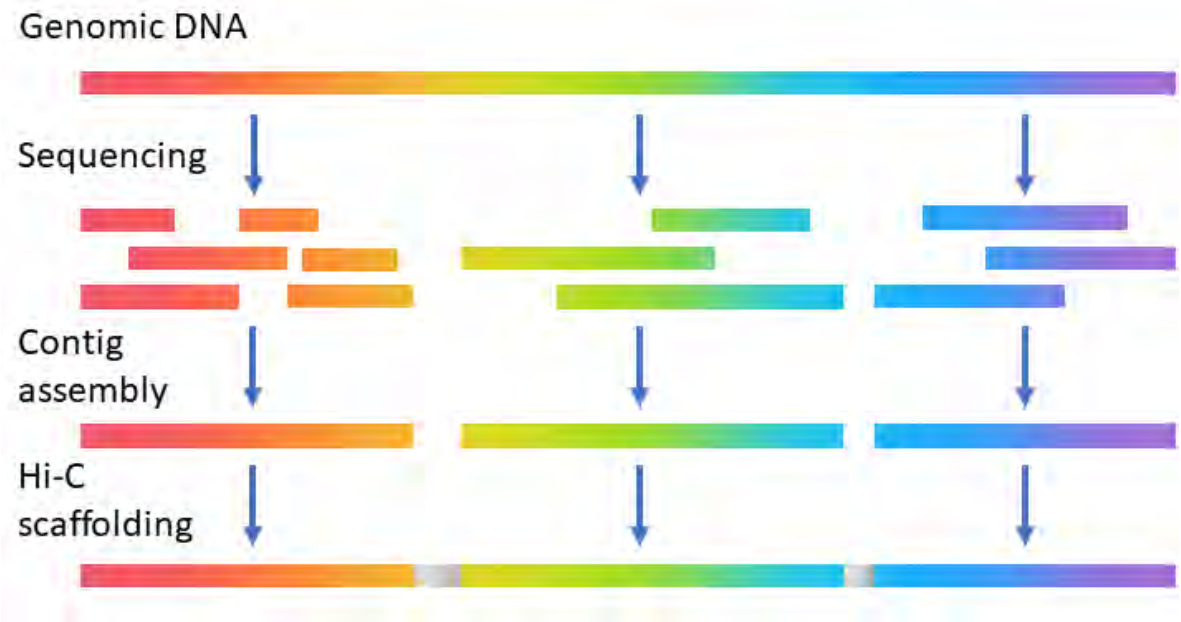
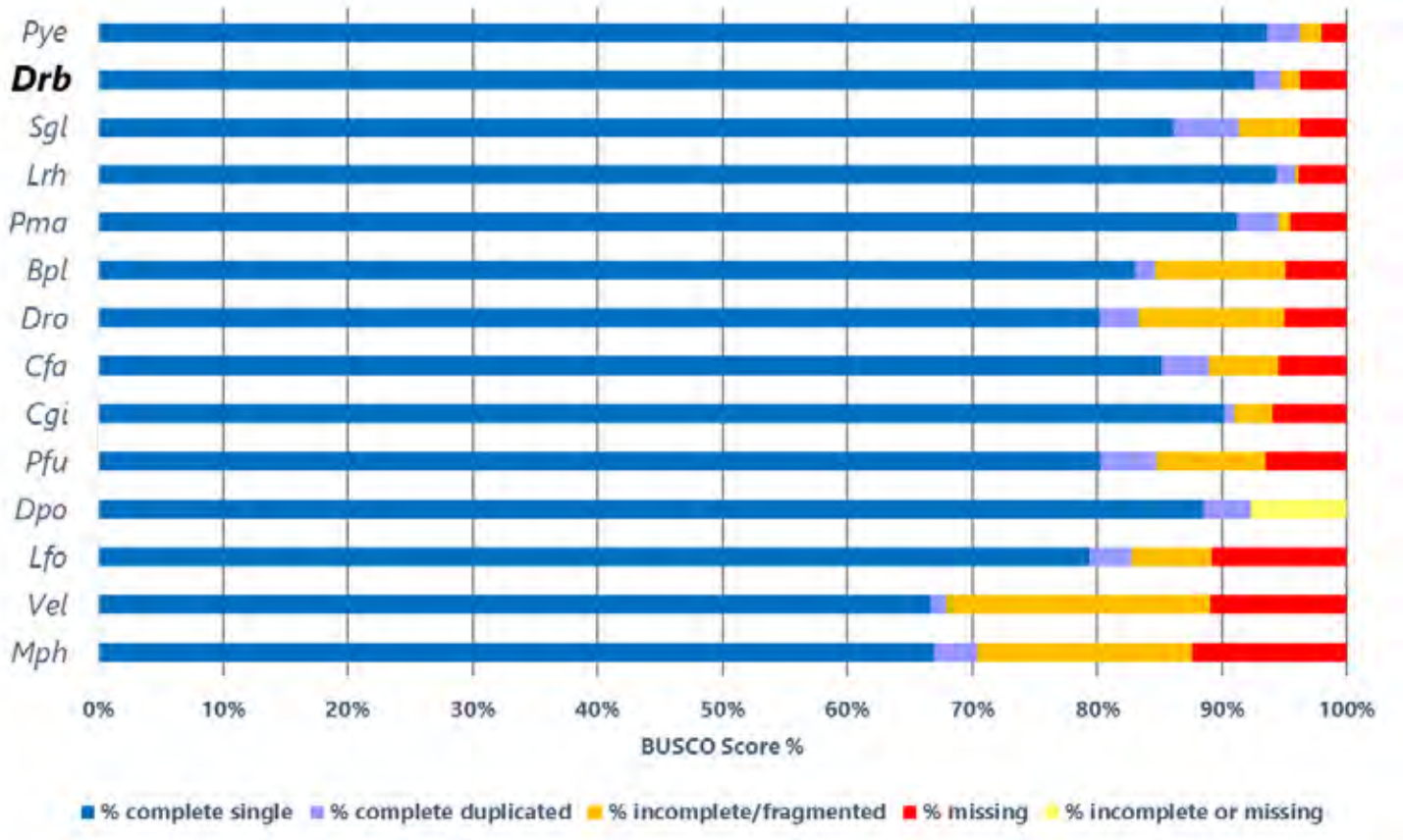
Sequencing and decoding the genome of the quagga mussel has significant potential to enable development of new controls for this problematic invader. Research on development of genetic biocontrols, based on working with an organism's genome, is being undertaken for a variety of invasive species and disease vectors. This revolution in biocontrol has been driven by new DNA sequencing technologies and tools for genome modification, such as the CRIPSR/Cas9 system. Reclamation has undertaken research to study the quagga mussel genome as a tool for development of such controls. In the Science and Technology Program funded project "Sequencing of the quagga mussel genome as a tool for biocontrol" (S&T ID 1866), the Technical Service Center's Ecological Research Laboratory (Eco Lab) worked with Dr. Kevin Kocot of the University of Alabama and private companies to sequence and assemble the quagga mussel genome. The genome was sequenced using two complementary technologies, Illumina HiSeq and PacBio Sequel. Sequencing produced short DNA reads that were assembled into contigs, in a process comparable to assembling jigsaw puzzle with four colors and 675 million overlapping pieces. Contig data were then further organized into 16 large scaffolds using Hi-C technology. The resultant draft genome assembly is 1.6 billion base pairs in length (approximately half the size of the human genome), with the 16 scaffolds matching the number of chromosomes that comprise the genome. This chromosome-scale assembly was found to contain more than 96% of the conserved genes expected to be present, making it one of the most complete bivalve mollusk genomes developed to date.

Work on the quagga mussel genome is ongoing as part of a second S&T funded project, "Analysis of the quagga mussel genome for development of biocontrols" (S&T ID 21024). While the previous project successfully developed a draft genome assembly for the quagga mussel, the genes and other features that make up the genome remain largely unexplored. The problem is analogous to having a book written in a foreign language but lacking a dictionary with which to translate and decipher it. In the current project, a variety of bioinformatic tools will be employed to identify and characterize genes and other components of the genome. The result will be an annotated roadmap that can guide researchers to areas of interest in the genome. The project will also use the approach of functional genomics to identify critical features of the genome that could present vulnerabilities to be targeted for developing genetic biocontrols. This will focus on characterizing genes involved in aspects of reproduction, which has been a successful avenue to the development of both traditional and genetic biocontrols in other organisms. To date, relatively little is known about the mechanisms controlling sex determination and reproduction in quagga mussels, but available data suggest that they diverge from the systems we are familiar with in humans and other mammals. Finally, the current project will investigate methods for genome modification of the quagga mussel genome. Such tools are not yet available for the quagga mussel, but they will be critical for the development and implementation for any genetic biocontrol strategy.



A schematic diagram depicting the steps in sequencing and assembly of the quagga genome. The source genome was sequenced in millions of relatively small and fragmentary DNA reads (hundreds to thousands of base pairs in length). These reads were computationally reassembled into fragments of contiguous sequence, referred to as "contigs." The resultant contigs were further grouped into scaffolds using Hi-C technology, with the aim of matching the order and organization of genes in the chromosomes of the quagga mussel.



BUSCO scores for the quagga mussel genome assembly, Dreissena rostriformis bugensis (Drb), and other representative published bivalve genomes. BUSCO scores calculate the proportion of conserved genes observed in the genome assembly, a comparable measure of completeness. Species are ordered from lowest to highest percentage of missing BUSCOs. The mussel genome assembly is second only to that of the scallop Patinopecten yessoensis (S. Wang et al., 2017) with respect to completeness.

Development of Methods for Invasive Mussel Genetic Biocontrol

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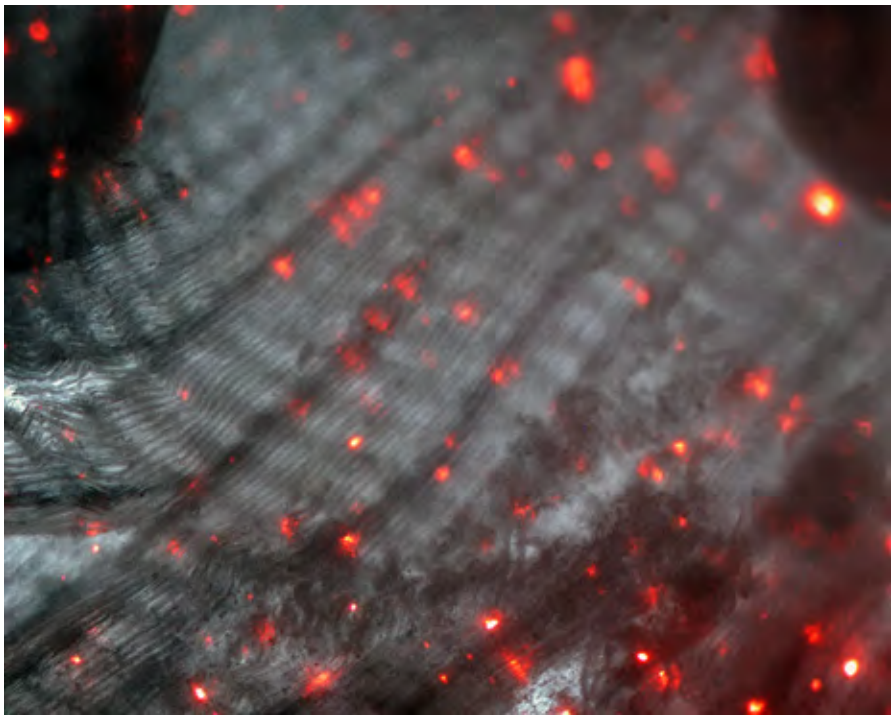
Quagga and zebra mussels housed at the Biomilab aquaculture facility in Michigan.

Control of established invasive quagga and zebra mussel populations is difficult because they live in a complex aquatic ecosystem that includes many similar and sensitive species that may be impacted by control treatments. Developing control methods that target invasive mussels without harming non-target species and the local biome has proven challenging. Existing control methods are too costly to apply at a large scale because they require manual application across a reservoir, and chemical control methods may have unintended effects on other species. The complexities of this problem inspired Reclamation to run a prize competition soliciting novel theoretical methods for mussel control in large reservoirs. The winning solvers of this 2018 prize competition were Steve Suhr and Marie-Claude Senut, who run Biomilab, LLC, a company out of Lansing, Michigan. The proposed solution was to achieve population control of invasive mussels using genetic engineering to create a lethal, transmissible cancer known as a "disseminated neoplasia" that could engraft and spread only within invasive zebra or quagga mussel populations in targeted reservoirs. In the last few years, disseminated neoplasias have been found responsible for large-scale die-offs of several marine bivalve species, and the proposed strategy aims to re-target this natural disease mechanism to specific freshwater species of bivalves that threatens native biodiversity and water resources. Reclamation has since entered into a cooperative agreement with Biomilab to pursue the winning solution.

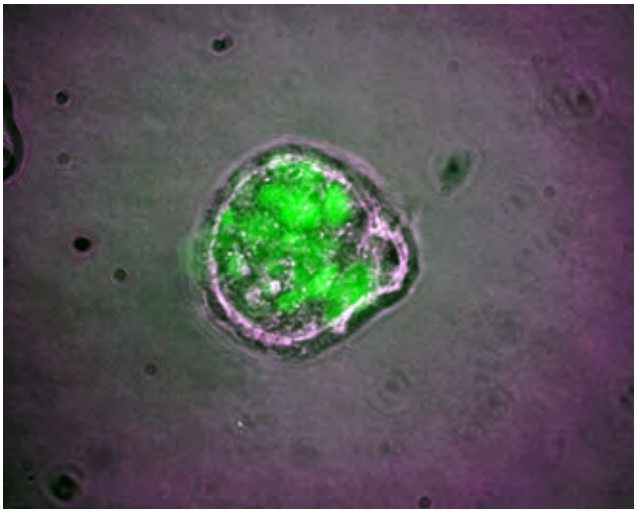
The proposed method has the potential to overcome both the seemingly intractable issue of target specificity and the considerable costs associated with chemical products and their repeated application. The engineered disseminated neoplasia will only affect quagga and zebra mussels and would require very limited effort to apply to a large reservoir because the engineered mussel cancer cells would naturally spread through the population. This method would result in progressive lethality, so dramatic nutrient spikes would be less of a concern than with other controls. Additionally, water chemistry and temperature would not impact the efficacy of the control method. If the method is found to be effective and safe, it has the potential to be utilized at any water body in the United States, benefiting all Reclamation regions and beyond. Even if this specific method is not found to be effective, the research effort will have benefits that will advance the field of study and may provide ideas for alternate and possibly superior methodologies for invasive mussel control.

During the first 2-years of this study, Biomilab has made significant progress on the research and has accomplished the following goals:

- Established a facility to maintain and culture live zebra and quagga mussels for use in experimentation.
- Completed characterization of target genes and gene products for use in genomic modification utilizing information from the sequenced and assembled quagga mussel genome, which was recently accomplished by Reclamation's Dr. Yale Passamaneck.
- Tested a variety of methodologies and molecular tools for cell culture.
- Tested a variety of methodologies to transfer novel genetic material into cultured cells.



Red fluorescent beads in the gills following injections in live quagga mussels.



Cell division (green) in a developing quagga mussel embryo.

Data from the first 18 months of this project indicate the single greatest obstacle to success thus far is a lack of cell division in explanted dreissenid tissues and absence of gene transfer to mussel cells in vitro or in vivo. Given that project objectives cannot be fully achieved until difficulties of gene transfer and induction of mitosis are overcome, the project will continue to prioritize strategies that address these issues. Once these challenges are overcome, research objectives will move toward testing of engraftment, documenting toxic effects, and determining the time course of dissemination, pathology and death. After the impact of the cancer on quagga and zebra mussels is understood, testing will begin to make sure the cancer cells do not impact other species such as the closely related native mollusk species. Guidance on nontarget testing will be obtained from regulatory agencies and mollusk experts.

Searching for Biocontrol Parasites in Eurasia to Control Invasive Quagga and Zebra Mussels

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The goal of this project is to find parasites in Eurasian Dreissena (dreissenid) mussel species, which are closely related to zebra and quagga mussels, and then to determine if the parasites can cause mortality to zebra and quagga mussels. If a candidate parasite can be identified, it has the potential to be used as a biological control (biocontrol) agent to control invasive zebra and quagga mussels in North America in an economical and environmentally benign way. The advantage of utilizing host-specific biocontrol agents is that they can self-reproduce and self-spread and, thus, could be economical enough to use in large waterbodies where the high cost of chemical treatment programs is prohibitive. Since 2017, Reclamation has collaborated with Dr. Dan Molloy (Molloy & Associates, LLC) in the search for such potential biocontrol candidates in Eurasia. Since North American populations of zebra and quagga mussels have never encountered the parasites from their close dreissenid relatives in Eurasia, an infection could prove lethal because they have not co-evolved with these Eurasian parasites and they may, thus, have little ability to fight off infection.

Dr. Molloy performing transinfection experiments in the field research laboratory in Montenegro.

Over the last three years, Dr. Molloy has established and staffed a field research laboratory in Montenegro. Despite the COVID19 pandemic, his staff was able to continue research and was able to travel to collect dreissenid mussels from Turkey, Bulgariam, and Montenegro. Quagga mussels from Bulgaria were also brought to the field research laboratory for long-term transinfection studies. The project has attracted an international team of over a dozen Eurasian collaborating scientists to assist in identifying Eurasian sample sites, obtaining sampling permits, conducting sample collection trips, and identifying the parasites found infecting the dreissenids.

Several dreissenid species, including *Dreissena caputlacus*, *D. anatolica*, *D. blanci*, *and D. carinata*, have been collected and transported to the field laboratory where some are dissected and assessed for parasites and others are used in long-term transinfection studies with quagga and zebra mussels. To date, over 5,000 dreissenid dissections have been completed, and over a dozen parasites have been identified.

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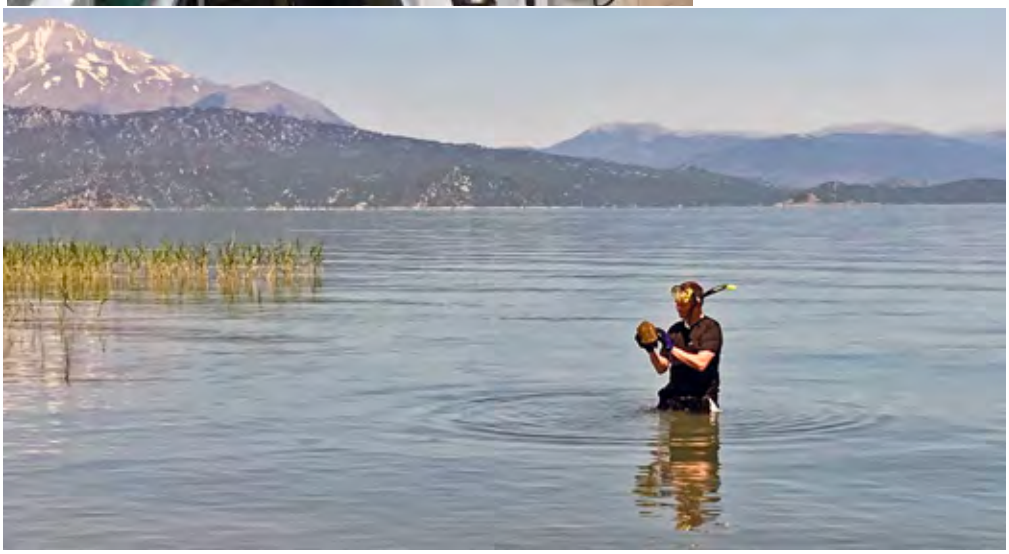


Dr. Molloy collecting Dreissena anatolica from Lake Beysehir, Turkey.

Map showing the region where dreissenid mussels are being collected for analysis of parasites.

—Continued from page 16

The laboratory has been equipped with flow-through aquaria where mussels can be kept alive and where long-term transinfection studies can be conducted. Transinfection studies involve exposing quagga and zebra mussels to other dreissenid species in an aquarium and, over time, dissecting to assess for the presence of parasites and evaluating each mussel for signs of illness. These long-term transinfection studies are key to finding potential biocontrol agents. In Montenegro's Sasko Lake (a water body where zebra mussels invaded several decades ago), two proof-of-concept transinfection study have already been successfully conducted. In both tests, zebra mussels present in the lake were moved into underwater containers holding the dreissenid species D. carinata that is native to Montenegro. In both field trials, parasites were confirmed to have been successfully transmitted from the D. carinata into the zebra mussels.

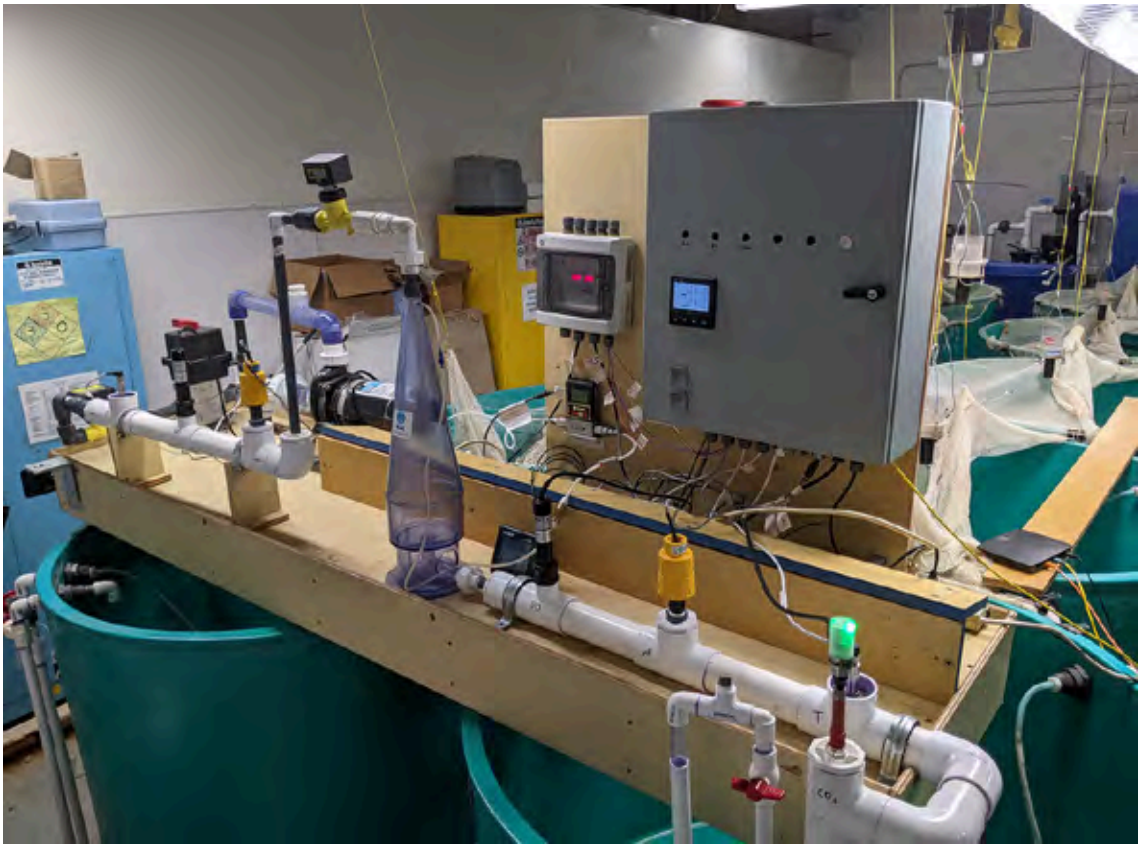
A new research proposal has been submitted to continue this project for an additional 3 years. Once a candidate parasite is identified, the project will begin to focus on assessing the parasites lethality through a series of additional more comprehensive transinfection trials. In these tests, both the biotic and abiotic factors that may affect the parasite's lethality will be evaluated. Some of the factors tested for will be pH, water temperature, and parasite life stage. Formal discussions with regulatory organizations will be carried out as soon as a potential biocontrol candidate is identified to ensure that the necessary studies can be performed, including host specificity testing to ensure that the parasite does not create a risk to the native mussels of North America. The search for an open water biocontrol agent is key if we want to be able to control quagga and zebramussel populations in the open waters of North America, and this project is uniquely designed to achieve that result.

Alternate Control Strategies for Dreissinids

By Kevin L. Kelly, Ph.D., with Project Partners; Environmental Quality Operations, & USGS Upper Midwest Environmental Sciences Center
kkelly@usbr.gov
S&T Project page: www.usbr.gov/research/projects/detail.cfm?id=1852
www.usbr.gov/research/projects/detail.cfm?id=19147
www.usbr.gov/research/projects/detail.cfm?id=19186

Quagga and zebra mussels (Dreissena ssp.) are major macrofouling species that impact the operation and maintenance of Reclamation water delivery systems. There is a need for economical and environmentally safe control strategies for these invasive mussels within Reclamation structures. TSC scientists from the 86-68540 Materials & Corrosion Laboratory Group and the 86-68560 Hydraulic Investigations & Lab Services Group are working on several S&T projects described here focusing on alternative control strategies, including the use of carbon dioxide, the development of a species-specific chimeric biopesticide, and electrical methods.

Carbon Dioxide (Project ID 21066). Recent laboratory and field studies have shown success using carbon dioxide in causing mortality and a reduction in the rate of byssogenesis (settlement and colonization). In collaboration with the TSC Water Treatment Group (86-68190), scientists from the USGS Upper Midwest Environmental Sciences Center, and personnel from Davis Dam, we have investigated the most efficient method of carbonating raw water using a Speece Cone and the effect of carbon dioxide in preventing settlement and colonization of quagga and zebra mussels within the raw-water cooling lines of the hydropower generation systems at Davis Powerplant. The Speece Cone system operates by pumping a side stream of raw water through a conical-shaped carbon dioxide transfer reactor. The reactor functions as a down-flow bubble contactor between the carbon dioxide gas and the raw water. A field study is also being planned at Davis Dam to determine the most effective carbon dioxide treatment strategies for reducing dreissenid mussel biofouling in hydropower generation cooling lines at Davis Powerplant.



Speece Cone apparatus for the carbonation of raw water.

Apparatus for electrical testing on live dreissenid veligers.

Development of a Chimeric Biopesticide (Project ID 19186). Through this project, the development of biopesticides utilizing the immunotoxin technology approach has been investigated. A previous research project developed the use of species-specific monoclonal antibodies to detect quagga and zebra mussels at the earliest stage of colonization (PI Kelly, Project ID 9640). Based on these monoclonal antibodies, immunotoxins specific to quagga and zebra mussels were developed in collaboration with Environmental Quality Operations (EQO). Since quagga and zebra mussels are primarily phytoplankton suspension feeders, chimeric biopesticides (immunotoxins) delivered in micro-algae production vectors may offer a low-dosage, low-production cost approach to eliminating quagga and zebra mussels from Reclamation facilities.

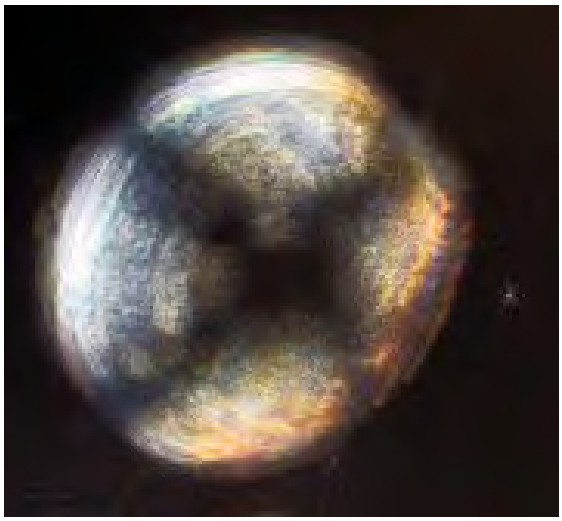


Image of a dreissenid veliger as seen under cross-polarized microscopy.

Electrical Methods (Project ID 19174). Alternative methods utilizing electricity have been shown to impact mussel behavior, including mortality and a reduction in the rate of byssogenesis . This project is focusing on the use of an electrical field to inhibit or prevent the passage of quagga and zebra mussel veligers (larvae) within small-diameter raw water pipes such as passage through the cooling lines of hydropower generation systems at Davis Powerplant. In collaboration with the TSC Hydropower Diagnostics & SCADA Group, a benchtop test apparatus has been constructed with plans to subject captive veligers to various electrical dosages or power densities at different electrical waveforms to determine their survival and byssus attachments. If data from the benchtop testing prove this approach to be feasible, pilot scale testing may be initiated at Davis Powerplant.

Costs Associated with Invasive Mussel Impacts and Management

By Jolene Trujillo, Nicholas Rumzie, Randy Christopherson, Scott O'Meara, Sherri Pucherelli, Yale Passamaneck, & Aaron Murphy
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S&T Project page: www.usbr.gov/research/projects/detail.cfm?id=8142

This study explored the preventative costs associated with Watercraft Inspection and Decontamination (WID) efforts in comparison to costs of operation and maintenance (O&M) expenditures to mitigate mussel-related damages at hydropower facilities and potential costs of increased capital investments. This study also incorporated a literature review on a suite of ecological impacts caused by mussels and where available costs associated with those impacts were summarized.

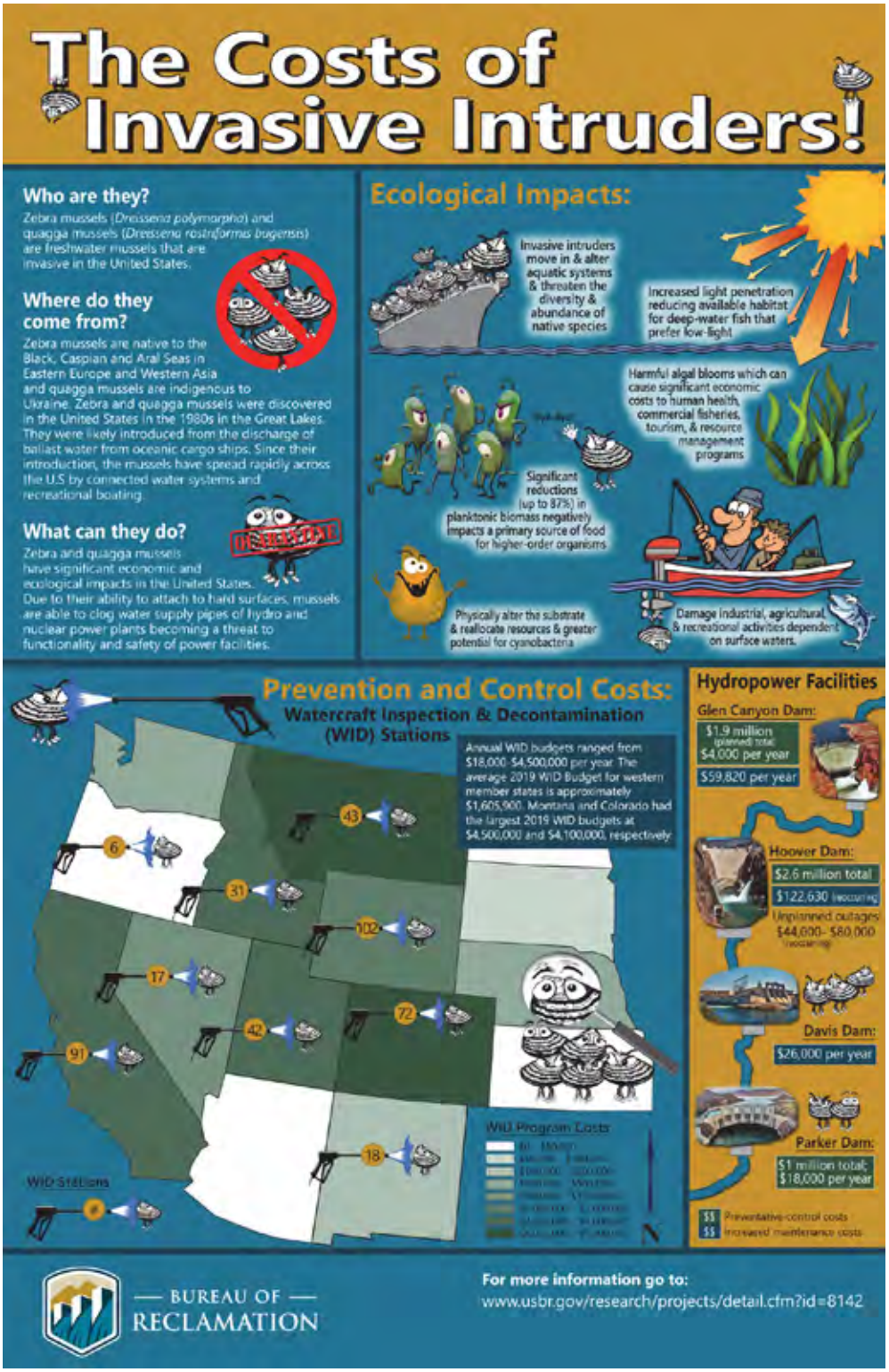
Invasive mussel fouling on a stop log at Davis Dam.

The dreissenid invasion of North America has posed both ecological and economic risks to the Nation. Watercraft inspection and decontamination is the primary strategy used to prevent the spread and introduction of dreissenid mussels throughout the Western United States. By implementing consistent and effective protocols, managers have realized success in identifying watercraft and other equipment that pose a risk to uninfested waters. In 2021, nine Western States; California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Wyoming, had webpages that discussed their WID program and station locations. These nine States had a total of 402 stations. The 2019 average annual WID budget was approximately $1,605,900.

This study examined the impact of invasive mussels at hydropower facilities through the concept of control. For our purposes, control is focused on mitigating the damages to hydropower facilities that are affected by a mussel infestation. Cost data associated with control was collected through a literature review and a survey from S&T Project 1876-*Case Studies: Impact and Control of Invasive Mussels at Hydropower Plants.*

The information was collated and determined the potential costs of increased capital investments and operation and maintenance expenditures to control or mitigate mussel-related damages to a set of 13 hydropower facilities.

Information collected from the survey did not represent all the costs a facility may incur if invasive mussels become established, however, of the facilities surveyed approximately $10 million was spent on preventative control measures since mussels were first detected. Nine out of 13 facilities surveyed spend approximately $464,000 annually on increased maintenance. Four out of 13 facilities surveyed did not have annual maintenance but rather maintenance that is reoccurring on an intermittent basis. Total reoccurring maintenance costs for facilities surveyed were $650,000 per occurrence. The facilities surveyed spend approximately $88,000 in total annually on monitoring.



Infographic created as part of this project.

Economic impacts experienced at individual facilities can be lower compared to State WID spending; however, to fully compare and complete an economic benefit-cost (B/C) analysis of measures to prevent the spread of invasive mussels versus measures to control post-invasion impacts to hydropower facilities, this study would also need to include the value of lost ecosystem benefits due to a mussel infestation. Ecological impacts associated with mussels are difficult to estimate and were discussed, but not fully explored, in this study.

In conclusion, this study provides evidence that mussel prevention and control strategies do have substantial costs to the Nation. Efforts to identify the most relevant factors for preventing future mussel invasions and measuring the economic impacts of mussels on the ecosystems they invade, as well as water delivery and power generation facilities, will help provide water resource managers with critical data to develop and fund adequate prevention, containment, and eradication programs for invasive mussels.

A New Establishment Risk Web Interface for Invasive Dreissenid Mussels

By Anthony Prisciandaro, Adam Sepulveda (U.S. Geological Survey), & Tim Counihan (U.S. Geological Survey)
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S&T Project page: www.usbr.gov/research/projects/detail.cfm?id=19007

Reclamation's Science and Technology Program provided funding to the U.S. Geological Survey (USGS) to develop a web interface for viewing dreissenid mussel establishment risk in the Columbia River Basin. Early detection of dreissenid mussels is a major pillar of managing these invaders because early detection helps minimize detrimental impacts and contain their spread to other waters. The web interface can map establishment risk as functions of calcium concentrations or pH, which are analytes critical for mussel growth and physiology and widely viewed as limiting factors. Calcium and pH data were queried from the National Water Quality Portal, which provides a single point of access to the largest standardized water quality database in the United States, with over 300 million water quality records. However, these water quality data were not explicitly collected for inference about dreissenid mussel habitat suitability, so they require scrutiny prior to being used for decisionmaking. This web interface provides critical information to help managers decide where to conduct monitoring activities.

Calcium is required for basic metabolic function and shell building, and dreissenid mussels have higher calcium requirements than most other freshwater mussels. The physiological importance of pH is less clear, as changes in acidification can manifest in a myriad of interacting ways, including shifts in ionic balance, weakening of byssal threads, reduced calcification rates, and shell dissolution. An understanding of the dynamics of calcium and pH over space and time is important when interpreting the information depicted in the web interface. Calcium is the more stable of the two parameters. Carbonic acid, which lowers pH, is created when carbon dioxide (CO_2) is dissolved in water.

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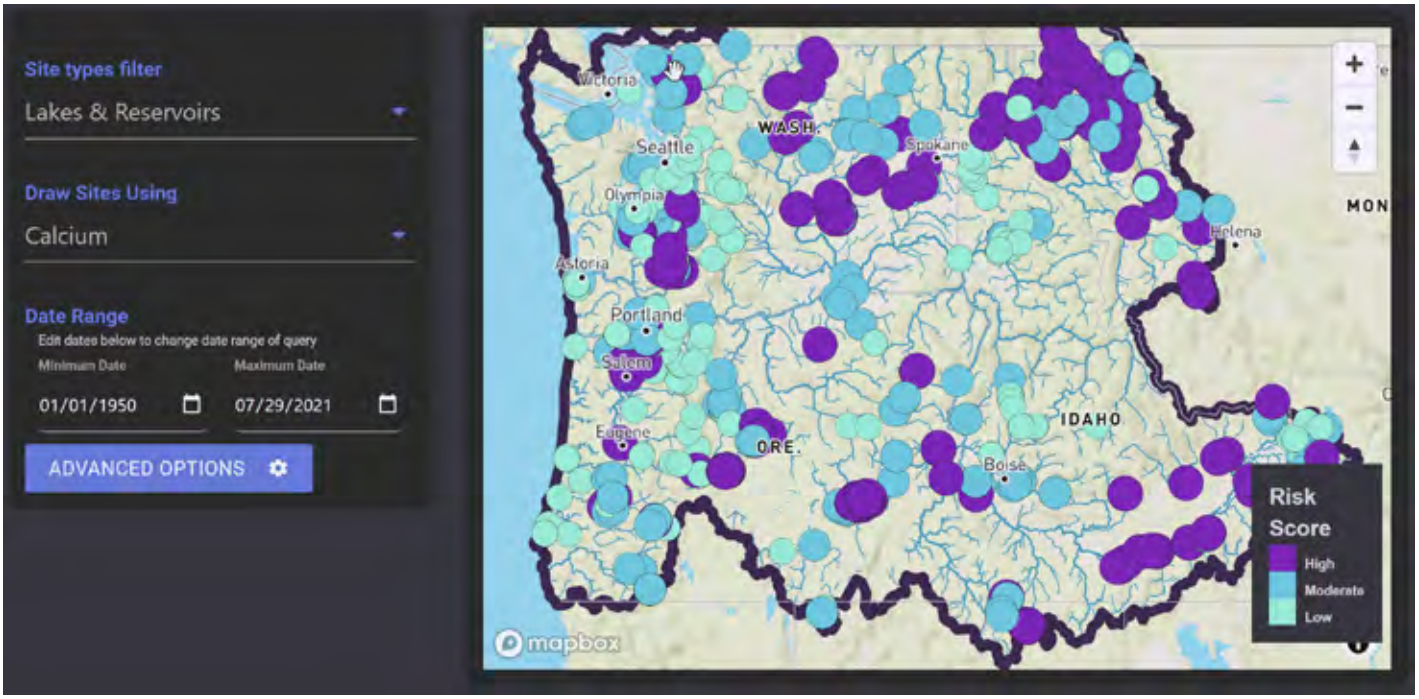

Risk map web interface screen shot showing risk for lentic waterbodies.

Chad Whaley from Teton National Park assisting Reclamation with mussel veliger sampling on Jackson Lake.

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The variability in pH is most often related to spatial or temporal differences in CO_2 concentrations from biological respiration (releasing CO_2, decreasing pH) and photosynthesis (absorbing CO_2, increasing pH). The use of mean values to represent risk is supported by field studies. However, it is important to understand the variability in pH allows some depths or time periods to provide areas of highly suitable habitat even when the overall mean results in a low risk score. The link provided access to the web interface, which includes a user guide and a thorough review on water chemistry-based risk analyses for dreissenid mussels .

Wildfire Research Updates

Post-Wildfire Reservoir Sedimentation at Willow Creek Reservoir

By Kent Collins & Rob Hilldale
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The occurrence of a wildfire within the watershed has the potential to significantly increase the rate of reservoir sedimentation, effectively reducing its useful life and negatively impacting Reclamation's water management and water delivery mission. With climate change, the risk of wildfires and extreme hydrological events is increasing. Willow Creek Dam and Reservoir are located on Willow Creek in Grand County in north-central Colorado approximately 2.5 miles upstream of the confluence of Willow Creek with the Colorado River and 5 miles north of the town of Granby, Colorado. Operated by Northern Water as part of the Colorado-Big Thompson Project, Willow Creek Dam captures about 33,700 acre-feet of excess Willow Creek flows annually for diversion to Lake Granby for storage. In October and November 2020, the East Troublesome Fire burned 91 percent of the watershed that feeds Willow Creek Reservoir. Monitoring sediment deposition in the reservoir over multiple years is needed to determine and possibly predict the watershed and reservoir response to large-scale wildfires. Repeat hydrographic surveys (including above and below water data collection)

Hillslope erosion on Willow Creek Reservoir following the East Troublesome Fire in fall 2020.

and sediment sampling, following spring runoff, are needed to measure the volume and distribution of sediment deposits from the burn area and assess the effectiveness of sediment management activities undertaken prior to runoff. Potential impacts to the Colorado-Big Thompson Project and operations at Willow Creek Reservoir will be identified through this research.

Wildfire Research Updates (continued)

Impacts of Wildfire and Fire Retardants on Water Quality

By Jun Wang
junwang@usbr.gov

Fire retardants such as PHOS-CHEK® are commonly deployed by aircraft to combat wildfire in the western United States.

Calendar year 2020 was one of the worst years on record for wildfires in the Western United States. The problem continues in 2021. Fire retardants such as PHOS-CHEK® are used extensively to combat wildfires. The extent to which fireretardant use may contribute additional N and P to post-fire runoff is not well known. Excess nutrients in post-fire runoff may lead to harmful algal blooms in creeks and reservoirs. A project funded by Reclamation's Science and Technology Program involves a literature survey, laboratory experiments on soils and vegetation affected by fire retardants, and watershed-scale modeling. The project is a collaboration between Reclamation's Interior Region 10 - California-Great Basin, the U.S. Geological Survey's California Water Science Center, and California State University, Chico. To support model validation, funding has been provided to the USGS to collect data at Pope Creek, a tributary to Lake Berryessa, which has an extensive burn area from 2020 wildfires.

Columbia-Pacific Northwest Wildland Fire App

By Kendra Fallon
kfallon@usbr.gov

Screen capture of the App being used to monitor impacts of the Cub Creek 2 and Cedar Creek fires for potential post-fire downstream impacts to restoration sites, and the growth of the Muckamuck fire for potential impacts to Conconully.

The Columbia-Pacific Northwest (CPN) Region's ability to proactively address wildland fires on or threating Reclamation lands, values and assets greatly increased by developing the CPN Wildland Fire App. The App overlays mapped CPN lands and assets along with fire locations, perimeters, and heat signatures, allowing for near real-time assessments of the fire situation across the region. The App provides information to staff across the region for determination of Reclamation-specific protection needs, which can be communicated to the Incident Commander or Management Team. Additionally, the App enables identification of large fires upstream of Reclamation reservoirs for early evaluation of potential post-fire hydrological impacts.

Wildfire Research Needs Workshop (April 6-7, 2021)

By Colin Byrne
cbyrne@usbr.gov

Washington Flats Fire, 2018, Grand Coulee Power Office, Columbia Basin Project – CPN Region.

The Bureau of Reclamation's (Reclamation) Science and Technology (S&T) Program was interested in understanding how research can help improve Reclamation's preparedness for, and response to, wildfires that impact Reclamation infrastructure. To identify the current wildfire research needs, the S&T Program hosted a 2-day virtual workshop with two main goals: 1) identify science and research needs to help Reclamation improve wildfire management, and 2) convene groups of internal staff and external partners to share knowledge and explore possible partnerships to advance priority research needs.

Sixty-five people from 10 Government agencies or groups attended the workshopthat included approximately 30 presentations. As a result of the workshop, several proposals were received by the S&T program for the Fiscal Year 2022 Call for Proposals. Projects Selected for funding are included in the table on the right.

Project ID	Project Title	Lead Researcher Name
22019	Potential impacts of phosphorous loading from wildfire-fighting retardants related to the East Troublesome fire on surface water quality in Willow Creek and Willow Creek Reservoir	Lindsay Bearup
22077	Enhancing Reclamation's Watershed Model to Predict Post-Fire Sediment Delivery to Reservoirs and Assess Management Actions	Benjamin Abban
22097	Evaluating watershed response and increases in sediment loading to Willow Creek and Willow Creek Reservoir due to East Troublesome fire	Kent Collins
22056	Post-wildfire forecasting improvements using non-Newtonian flow processes with a high-resolution, integrated hydrologic model	Drew Loney
22090	Favorably Stabilizing the Flow, Supply and Quality of Water from Public Lands During Forest Management	Dan Deeds
22017	Evaluate and model economical, safe and effective methods to mitigate and remove debris from dam intake structures	Juan Luna

Lake Berryessa Post-Wildfire Modeling

By Daniel Deeds & U.S. Geological Survey
ddeeds@usbr.gov

Hennessey Wildfire 2020.

In fall 2020, California-Great Basin staff collaborated with the U.S. Geological Surveycolleagues to install a flow and sediment gaging station on Pope Creek upstream of Lake Berryessa, a critical component of the Bureau of Reclamation's Solano Project. During the previous summer, two large wildfires burned roughly two-thirds of the Pope Creek watershed. CGB staff will use Pope Creek data to calibrate PFHydro, a post-wildfire watershed model developed under the S&T Program, to assess wildfire impacts on Pope Creek flow, sediment load, and water quality. They will also test a novel application of PFHydro in Upper Putah Creek, the largest tributary to Lake Berryessa, which has limited access where it meets Lake Berryessa and has limited stream gage data.

Other Invasive Species Project Updates

Tunneling Terrors: Burrowing Crayfish in Reclamation Canals

By Aaron Murphy, Scott O'Meara, Ryan Nelson, & Jeremy Hammen
amurphy@usbr.gov
S&T Project page: www.usbr.gov/research/projects/detail.cfm?id=20042

As the climate changes, some invasive species will move into new locations and cause additional problems for Reclamation. Burrowing crayfish have already been observed far outside their native range. During routine maintenance, canal operators have found large crayfish populations within earthen embankments. If uncontrolled, crayfish burrows have the potential to cause widespread damage and catastrophic failure.

The Ecological Research Laboratory has initiated a research project to trap and identify what crayfish species are burrowing into Reclamation canals and to explore control methods to limit damage. This effort will conclude in 2023 and will improve our Integrated Pest Management decision making.

A crayfish guards the entrance to a watery burrow.

Treating Aquatic Vegetation with Ultraviolet Light

By Scott Fennema & the Lahontaon Basin Area Ofice; University of Nevada, Reno; and Inventive Resources, Inc.
amurphy@usbr.gov
S&T Project page:
www.usbr.gov/research/projects/detail.cfm?id=20041

Aquatic plants in canals increase operational risk by increasing the water surface elevation within canals to potentially unsafe levels. Traditional methods to manage aquatic macrophytes can be 1) detrimental to downstream aquatic ecosystems and crops, 2) labor intensive, and 3) expensive. Ultraviolet (UV) treatment systems in the "C" spectrum have been proven to decimate aquatic plants in lakes, laboratories, and concrete-lined canals; however, UV treatment systems have not been tested in unlined canals. Reclamation's Science and Technology Program funded a 3-year project to quantify the efficacy of using UV-C treatments to eradicate aquatic plant biomass in unlined canals. UV-C treatments are currently underway in the Newlands Project.

Aquatic plant treatment using ultraviolet light in the "C" spectrum in an unlined canal in the Newlands Project, Nevada. The goal of this project is to quantify the efficacy of using UV-C treatments to manage aquatic plants in canals.

Featured Faces

Jolene Trujillo & Yale Passamaneck

Jolene Trujillo

Jolene is the Integrated Pest Management (IPM) and Invasive Species Coordinator for the Bureau of Reclamation (Reclamation). She works in the Environmental Compliance Division of the Policy and Programs Office in Denver, Colorado. As Reclamation's IPM and Invasive Species Coordinator, Jolene is responsible for the development and revision of Reclamation-wide policies and directives for the IPM ahnd Invasive Species Programs as well as leading and coordinating the responses to Invasive Species or IPM issues for Reclamation, including U.S. Department of the Interior Initiatives, special projects, technical inquiries, legislative requests, and policy and procedural issues associated with IPM and invasive species.

Jolene is a biologist by training and received her B.S. from the University of New Mexico and an M.S from Arizona State University. Prior to joining Reclamation in December 2015, Jolene worked for the Office of Pesticide Programs, Pesticide Re-evaluation Division, at the Environmental Protection Agency in Washington, DC.

Yale Passamaneck, Ph.D.

Yale Passamaneck has been a biologist with the Ecological Research Laboratory (Eco Lab) in Denver, Colorado, for 6 years. Throughout his career, Yale has actively pursued the development and adoption of novel techniques to improve research outcomes. Yale studied marine biology as an undergraduate at the University of California, Santa Cruz, and did his graduate work in the MIT/Woods Hole Oceanographic Institution Joint Program. During his doctoral and postdoctoral work at Weill Cornell Medical College and University of Hawaii, Yale utilized DNA sequence data, genomic approaches, and molecular biology techniques to study phylogenetics and developmental evolution in a wide variety of understudied invertebrate taxa.

Since joining Reclamation, Yale has worked on the early detection and control of invasive aquatic species, focusing primarily on quagga mussels. This has included developing both microscopic and molecular methods to improve early detection in the Eco Lab. Yale has worked on establishing a variety of environmental DNA (eDNA) assays as well as implementing quantitative PCR (qPCR) techniques to improve the sensitivity and robustness of eDNA assays.

Yale has led a variety of projects funded by Reclamation's Science & Technology Program, including sequencing and assembly of the quagga mussel genome, development of a database integrating 13 years of mussel early detection data from the Eco Lab, and addition of these data to the RISE database to encourage more widespread use of this resource. Yale has also worked on emerging techniques for eDNA metabarcoding, which provides the potential to survey for a wide range of species simultaneously, rather than focusing on detection of single species, as is done in qPCR-based eDNA assays.