Zebra and Quagga Mussels in the United States—Dreissenid Mussel Research by the U.S. Geological Survey

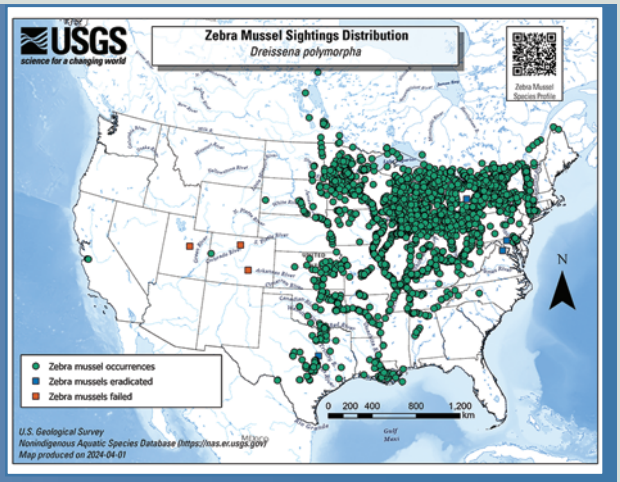
What are Dreissenid Mussels?

Zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis* or *Dreissena rostriformis bugensis*), collectively called dreissenids, are freshwater mussels native to the Ponto-Caspian region of Eastern Europe. They arrived in Lake Erie in the late 1980s, likely in the ballast water of transoceanic vessels (McMahon, 1996). Dreissenids can survive dry conditions for several days on or in boats, motors, and trailers. They also hitchhike on aquarium plants, such as moss balls available at pet and aquarium stores (U.S. Geological Survey, 2021). Zebra mussels were the first to arrive and establish. Where both species exist, quagga mussels frequently replace zebra mussels because they are larger. Since their invasion, zebra mussels have spread to 31 states and quagga mussels to 18 states (U.S. Geological Survey, 2023). Bilge and livewell water of recreational vessels and ballast water of shipping vessels have been the primary vectors of transmission.

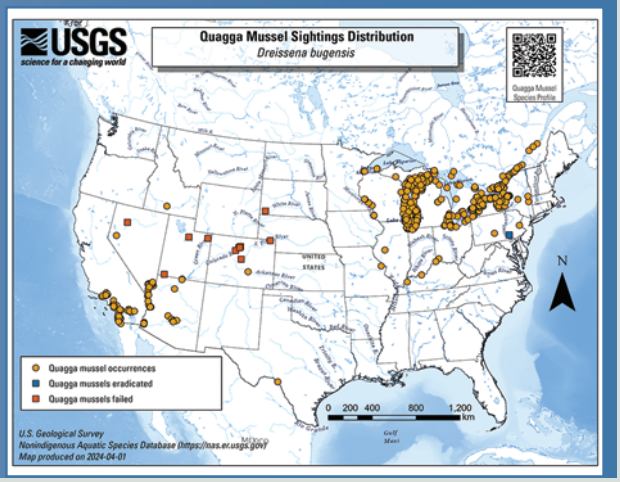
Dreissenid Mussel Research

The U.S. Geological Survey (USGS) delivers high-quality data, technologies, and decision-support tools to help managers both reduce existing populations and control the spread of dreissenid mussels. The USGS researches ecology, biology, risk assessment, and early detection and rapid response methods; provides decision support; and develops and tests control measures.

Photograph by Amy Benson, U.S. Geological Survey.



Photograph by Andrea L. Miehls, U.S. Geological Survey.



Above—a moss ball sold in pet stores containing a zebra mussel. U.S. Geological Survey photograph.

Zebra mussels (top left) and quagga mussels (bottom left) are generally similar in appearance, but shell shape can be used to determine species. Zebra mussel shells have a straight hinge and flat surface along the hinge, whereas quagga mussels have a more s-shaped hinge and are rounded. The USGS Nonindigenous Aquatic Species maps show the distribution of zebra mussels (top right) and quagga mussels (bottom right).

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Basic Biology and Ecological Effects

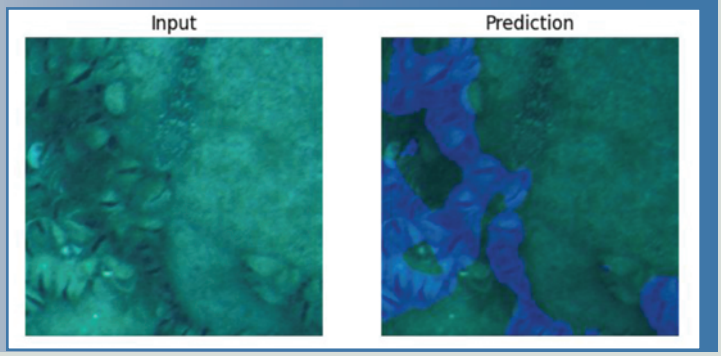
Mussels are filter feeders that consume plankton and bacteria. One dreissenid mussel can filter about one gallon of water a day. USGS research has shown dreissenids reduce nutrient availability (Goodbred and others, 2021) and the abundance of native phytoplankton, amphipods, and fingernail clams (Mehler and others, 2020), which can reduce food availability for native plankton and filter feeders, shifting the food-web structure. In highly infested areas, this can cause a decline in some species of zooplankton and fishes. Spawning success of native Lake Trout is better in areas with fewer dreissenid mussels (Farha and others, 2020). Adult mussels can sometimes survive passage through fish guts, meaning that migratory fishes swimming long distances have the potential to spread the mussels far from their source populations (Gatlin and others, 2013).

These ecological effects reduce recreational opportunities and harm local economies by biofouling boats, docks, and beaches—ultimately reducing property values. Dreissenid biofouling reduces water flow through water intake lines to power plants, municipal water supplies, and industrial facilities; corrodes infrastructure surfaces; and degrades water quality. The cost for prevention and maintenance can be substantial.

Invasive zebra mussels are now part of many of our Nation's lakes and rivers, and USGS science and technical developments are working toward controlling and preventing the farther spreading of these and other damaging mollusks. Photograph by John Byrnes, U.S. Geological Survey.

Controlling Dreissenid Mussels

Photograph by Peter Esselman, U.S. Geological Survey.



Photograph by Angus Galloway, contractor for the U.S. Geological Survey.

The USGS runs 2.5-meter (8.2-foot) long, 50 kg (110 lb.) autonomous underwater vehicles (AUVs) carrying cameras to monitor dreissenid mussels. The cylindrical, yellow and black, torpedo-shaped AUVs were modified to carry a custom camera payload (black 50-cm (20-inch) long section at the middle of vehicle). The robots can collect images continuously for distances of as much as 15 km (9.3 miles) in a 5-hour mission, flying about 1.8 m (5.6 feet) above the lakebed. Artificial intelligence (AI) approaches are being used to train computers to recognize and highlight live dreissenid mussels when they are present in images. Living mussels can be readily identified when they open their shells to feed, showing the inside of their body cavity as a black, linear feature. The AI system uses these patterns to identify pixels that contain mussels (shown in blue on living mussels between large rocks).

Risk Assessment

USGS risk assessment research includes assessing not only the physical characteristics of lakes (Barnes and Patiño, 2020) but also the water quality and chemistry, including pH and concentrations of calcium required for shell development, to determine the potential for dreissenids to establish and thrive in a new body of water (Sepulveda and others, 2023). The USGS is developing web-based data visualization tools to explore dreissenid mussel introduction and establishment risk in the Greater Yellowstone Ecosystem and Columbia River Basin. Another USGS web-based tool will help managers evaluate dreissenid mussel infestation and spread threat in the Missouri River Basin to determine the value of the resources at risk from mussel establishment.

Early Detection and Rapid Response

Early detection and rapid response are critical to locating and responding to new invasions. USGS researchers have led efforts to develop and evaluate several methods to detect dreissenid larva, including physical capture methods using nets (Counihan and Bollens, 2017; Winder and others, 2022) and imaging systems (Hassett and others, 2021). In the Great Lakes, USGS researchers are developing a method for using autonomous underwater vehicles to collect images of the bottom, which are then analyzed using artificial intelligence (AI). Once fully validated, the AI models coupled with robotic data promise the potential to map dreissenid densities over large areas with a high degree of repeatability. When used on spawning beds for bottom-spawning species, areas of live dreissenids can be targeted for removal.

Mapping and Tracking

The USGS Nonindigenous Aquatic Species (NAS) database is a critical tool for risk assessments and early detection efforts for dreissenids. The USGS's NAS database tracks the occurrences of these species across the United States, with historical data and real-time observations from scientists, natural resource managers, and the public. Anyone can report sightings of zebra and quagga mussels to the NAS (https://nas.er.usgs.gov) to be verified by USGS scientists and included in the distribution maps.

Environmental DNA

The USGS is also a leader in developing methods of detecting all life stages of dreissenids using environmental deoxyribonucleic acid (eDNA; Sepulveda and others, 2019a) and to develop standardized best practices for laboratory testing of water samples containing eDNA, including multiple laboratories assessing consistency and repeatability of results (Sepulveda and others, 2020). Taking advantage of the USGS's extensive national streamgage network (https://waterwatch.usgs.gov), USGS researchers are installing automated water samplers at existing streamgages for collecting water samples for eDNA (Sepulveda and others, 2019b).

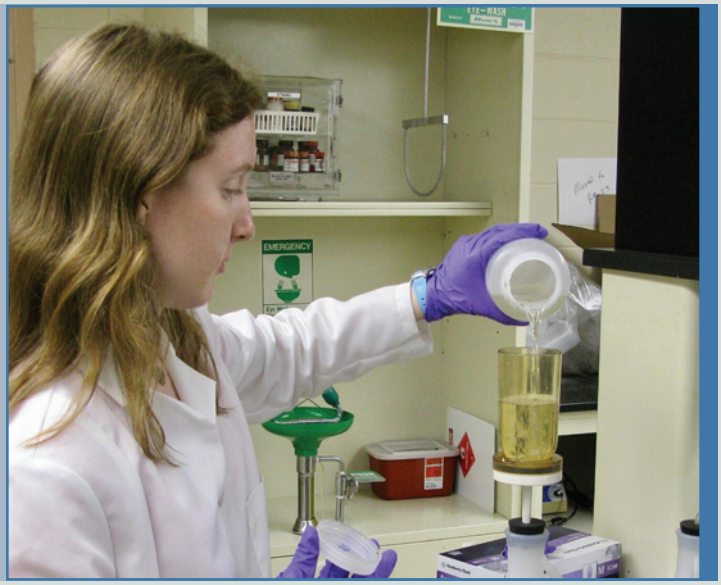
Photograph by J. Freedman, U.S. Geological Survey.

Decision Support

The USGS conducts structured decision making to identify and guide management options. Sepulveda and others (2022) used structured decision making to develop a protocol for deciding how to react to positive eDNA samples in new bodies of water to determine if the positive eDNA detection was indicative of living dreissenids.

Control Methods and Processes

USGS research includes developing and testing approaches for managing invasive mussel populations in closed and open systems. The USGS has developed standard concentrations of chemicals, application methods, and durations of treatment for controlling dreissenids (Luoma and others, 2018; 2019; Barbour and others, 2021). USGS researchers have also identified potential side effects of controls to help inform where and when to target control (Luoma and others, 2018) and developed standardized methods for toxicity tests for potential new pesticides (Waller and others, 2023). USGS research on carbon dioxide (CO_2) demonstrated its ability to prevent dreissenid mussel settlement without adversely affecting other native benthic organisms (Waller and Bartsch, 2018; Waller and others, 2021).



A U.S. Geological Survey scientist filters a water sample for eDNA. Photograph by Gaia Meiggs-Friend, U.S. Geological Survey.

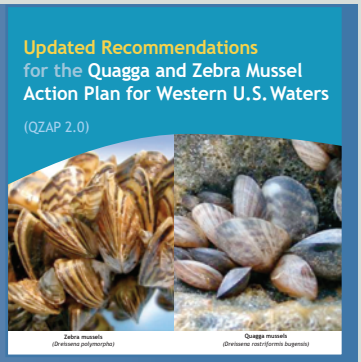
Dreissenid mussels harm native unionid mussels by growing on their shells, preventing them from eating, breathing, and reproducing. The USGS develops control methods to reduce dreissenid mussel populations. Photograph by Kathryn Holcomb, used with permission.

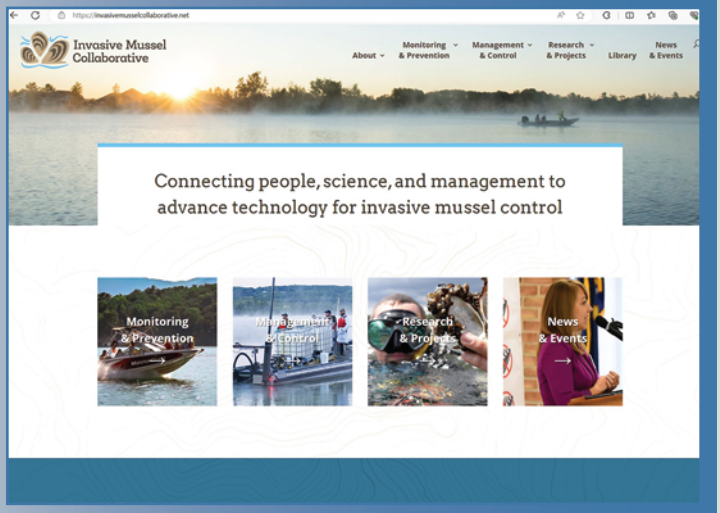
Genetic-based methods are a new area of study that has promise for species-specific control without potential risks to nontarget organisms. Erickson and others (2023) demonstrated using mathematical models that genetically modified “supermales” could be used to cause a dreissenid population to crash. USGS researchers are developing novel synthetic biologic controls for dreissenids. A technique called RNA interference shows promise for species-specific control without nontarget effects, persistence in the environment, or release of genetically modified organisms. The effectiveness and safety of RNA interference controls for zebra mussels is being investigated under controlled laboratory conditions (Hernández Elizárraga and others, 2023).

Interagency Coordination and Collaboration

The USGS works with a variety of agencies, universities, and other institutions to enhance prevention capabilities and foster cross-agency collaboration. The USGS was a founding member of The Invasive Mussel Collaborative (IMC; https://invasivemusselcollaborative.net/), formed to advance scientifically sound technology for invasive dreissenid mussel control designed to produce measurable ecological and economic benefits in the Great Lakes region. The IMC provides a framework for communication and coordination, identifies the needs and goals of resource managers, prioritizes supporting science, and aligns science and management goals into a common agenda. The IMC has a broad membership base of Federal, State, Provincial, and Tribal agencies, and other entities. The USGS is also a key agency in the Department of Interior's strategy of “Safeguarding the West from Invasive Species” from dreissenid mussels in support of the Western Governors’ Association (https://www.doi.gov/sites/doi.gov/files/uploads/safeguarding_the_west_from_invasive_species.pdf). USGS efforts include identifying and prioritizing research needs for dreissenid mussels in the west in support of the “Quagga and Zebra Mussel Action Plan 2.0” (Counihan and others, 2023).

Photograph by Alexander Stephens, U.S. Bureau of Reclamation.





Photograph by Jeremy Wise, U.S. Geological Survey.

Photograph by Diane Waller, U.S. Geological Survey.

Photograph by Diane Waller U.S. Geological Survey.

The USGS partners with other Department of the Interior agencies to meet their management needs. Application systems and treatment regimens are being developed in collaboration with the Bureau of Reclamation to use CO_2 in hydropower facilities to prevent biofouling. The USGS has partnered with the National Park Service to design and test CO_2 systems in select open water to restore high-value habitat and prevent infestation of native mussels.

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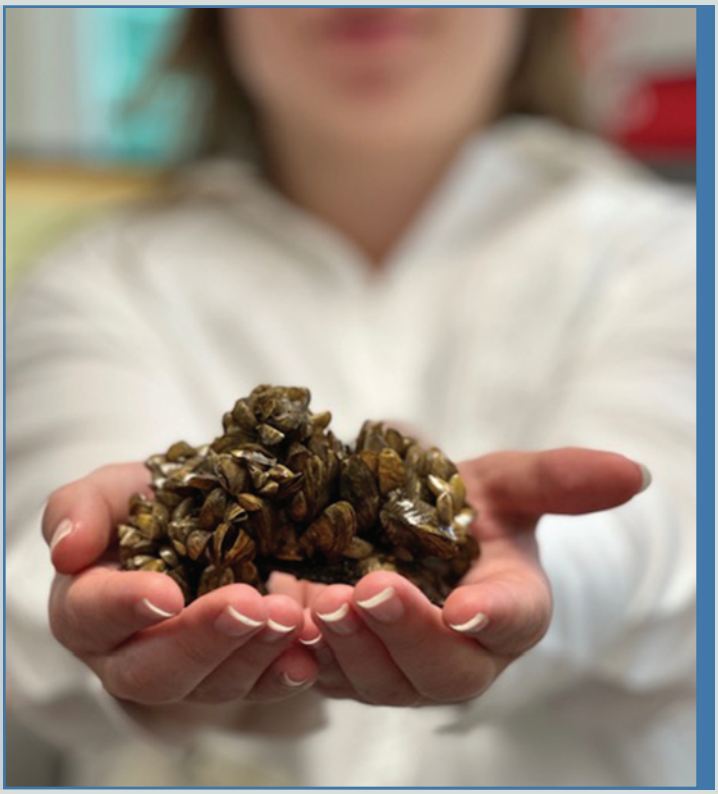

Photograph by Cayla Morningstar, U.S. Geological Survey.

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