



RESEARCH REPORT
2021



Funding for MAISRC is provided by:



Greetings from MAISRC!

Minnesota has seemingly countless lakes, rivers, and wetlands, and we each have our favorite. For me, it is Leech Lake, where my family has spent the summers since 1934. Although I was expecting it, finding the first adult zebra mussel this year was devastating. In addition, my young son found Eurasian watermilfoil, rusty crayfish, and mystery snails near our beach (with starry stonewort recently confirmed across the lake). He will grow up with a different lake than I remember, and a very different one from my great grandfather. This is just one lake, one of many, infested with aquatic invasive species.

Hope is not lost, however. I'm reminded and inspired by the oft-used quote from my son's other favorite 'Dr.'... "*Unless someone like you cares a whole awful lot, nothing is going to get better. It's not.*" –The Lorax, Dr. Seuss. I believe that with ambitious management, a committed public, and innovative research we can make things better.

The Minnesota Aquatic Invasive Species Research Center (MAISRC) was created in 2012 with the mission to develop research-based solutions to our aquatic invasive species problems and advance knowledge to inspire action by others. As of 2021, we are well on our way. This last year was highlighted by major scientific advancements and continued progress on critical lines of research. Our research teams have worked tirelessly in the field, lab, and at their computers to generate and analyze data that is informing evidence-based decisions from the end of your dock to the State Capitol. The incremental steps are making a difference, leading to big wins, and eventually solutions for the seemingly impossible problems in front of us.

I have long been an advocate for team science – everyone is smarter than anyone. I am encouraged by the interdisciplinarity of our research teams, their willingness to think outside the box, and active engagement with managers and other stakeholders at every step in the process. This 'co-creation of research' has (and will!) improve the process from asking the right question to implementing the results. We acknowledge, however, that not everyone is at the table and are working to bring diverse perspectives into the conversations. I am looking forward to building on existing partnerships and creating new ones in the coming year.

On behalf of everyone at MAISRC, I would like to say "thank you!" to everyone that has supported us over the last year. We are all stretched thin, and your support means more now than it ever has. We are grateful to the Environment and Natural Resources Trust Fund and the Minnesota Legislature for their investments in sustaining MAISRC's research program. We are also thankful to the many lake associations, foundations, and individual donors for their generosity and commitment to finding research-based solutions to our aquatic invasive species problems. Lastly, we are thankful for the countless contributions of time, advice, advocacy, and words of encouragement. We are pursuing solutions together and could not do it without you.

The next year promises to be an exciting one and I look forward to seeing you all, in person, soon!

Dr. Nicholas Phelps
Director, Minnesota Aquatic Invasive Species Research Center



2012 Minnesota Aquatic Invasive Species Research Center

At the most basic level, aquatic invasive species are water-dwelling organisms that are not native to the area they are currently in and cause, or have the potential to cause, harm to the environment, economy, or human health. Aquatic invasive species in Minnesota, such as zebra mussels and Eurasian watermilfoil, are a real and growing threat to our state's environment, economy, and way of life.

Created in 2012 with support funds from the Minnesota legislature and the Minnesota Environment and Natural Resources Trust Fund, the Minnesota Aquatic Invasive Species Research Center (MAISRC) has become the nexus of research and management—bringing together the brightest minds and institutions to create clear priorities both in species of study and lines of research. By serving this central role, MAISRC is able to amplify the impact of research findings, reduce overlap and minimize gaps, and create the pipeline that advances innovative research initiatives to real-world applications.

MAISRC's team of researchers have incredible diversity in their areas of expertise—from microbiology, engineering, freshwater ecosystems, toxicology, quantitative ecology, genetic modification, diagnostic validation, risk assessment, epidemiological modeling, and more! This broad spectrum of knowledge creates a powerful, innovative, and intellectually expansive environment for research that results in groundbreaking findings.

Our core mission is to develop research-based solutions for Minnesota's aquatic invasive species problems. Our projects focus on:

- Prevention—not allowing an invasive species to enter a new area
- Control—containing or reducing an invasive species once it is introduced
- Management—restoring the balance to ecosystems during and after an invasion
- Advancing knowledge on aquatic invasive species to inspire action by others.

Moved promising research from the lab to the lake and conducted the largest-ever experimental treatment to suppress established zebra mussel populations.

First in the world to map the zebra mussel genome. We then released the data publicly, providing a road map for scientists to develop high-precision control methods.

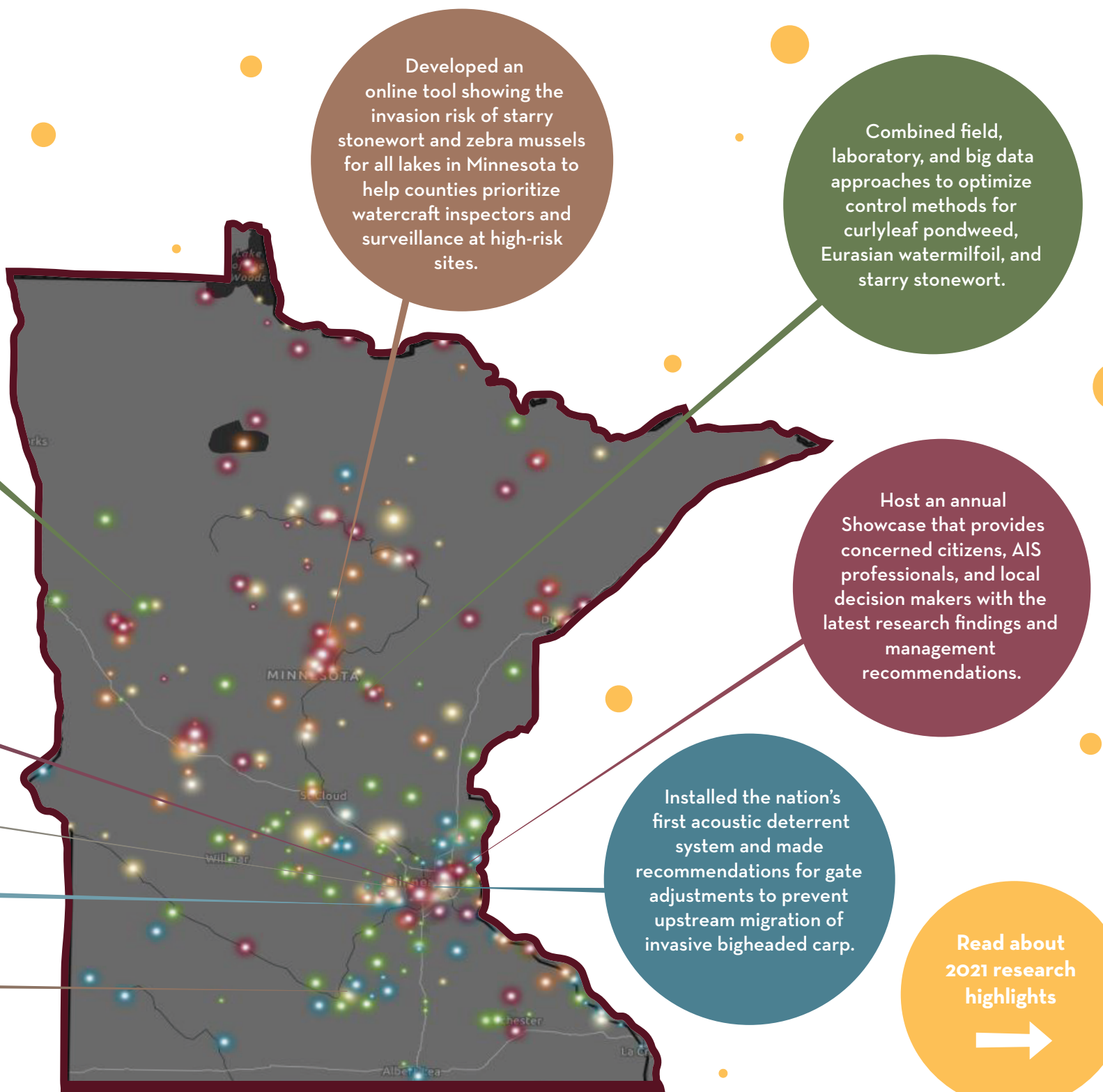
Mobilized 70+ volunteers and partners to survey and map invasive *Phragmites* across Minnesota. Identified 470+ populations and developed a management plan—continues to support local level implementation efforts to this day.

Created and continue to support the award-winning Aquatic Invasive Species Detectors program, with ~300 certified citizen scientists. Participants at an affiliated event have found 21% of the starry stonewort infestations in Minnesota, which led to rapid response in multiple lakes.

Common carp research projects were proven effective and inspired the launch of an independent company to successfully manage carp populations.

2021 Working Across Minnesota

MAISRC has built a solid foundation of research and continues to launch exciting new projects every year. From spiny water fleas in the Northeast to common carp in the Southwest, and everything in between, MAISRC is well-positioned to leverage past successes and inform real-world solutions for aquatic invasive species throughout Minnesota. View some of our past research highlights in the bubbles below. You can also explore an interactive online map of our work across Minnesota at: www.z.umn.edu/MAISRCfieldworkmap



Aquatic Invasive Invertebrate Research

MAISRC is proud to be a national leader when it comes to aquatic invasive invertebrate research. From sequencing the zebra mussel genome to developing a paint additive that could prevent the settlement of zebra mussels on boats, docks, and other hard structures—we are at an exciting turning point from foundational to solutions-focused research ready for implementation. In addition:

Copper for Zebra Mussel Suppression

Building off of previous work, in the summer of 2021, MAISRC researchers set up a lakeside mobile laboratory at Pelican Lake in Crow Wing County to test the effects of different copper concentrations on zebra mussels and native species. They pumped lake water into the mobile lab and used the unique water chemistry metrics to predict the lowest effective dose for zebra mussel suppression. Researchers plan to validate the results and further refine recommendations with an in-lake trial at a different site in 2022. maisrc.umn.edu/copper-control

Timeline of Spiny Water Flea Invasion

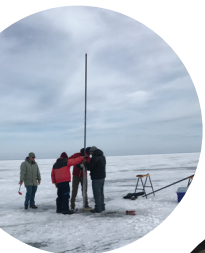
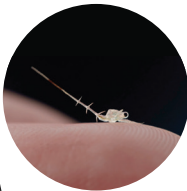
Spiny water fleas are an invasive zooplankton that are widely assumed to have been introduced to the Great Lakes by ballast water from cargo ships. However, MAISRC researchers have now found exoskeleton remains of spiny water fleas in lake sediment predating the 1970s. These findings are unexpected and challenge the current accepted invasion narrative. Researchers and managers alike are exploring possible future research to validate these findings and understand management implications. maisrc.umn.edu/swf-invasion

Raising Zebra Mussels in the MAISRC Lab

Despite zebra mussels being wildly successful at reproducing and spreading in Minnesota lakes, they are incredibly difficult to maintain and propagate in a lab setting. This presents a challenge for researchers because many studies require multiple generations of zebra mussels to assess the viability of control options, particularly genetic and biochemical methods. In 2021, MAISRC began a collaboration with the Minnesota Zoo to develop a zebra mussel propagation system in the MAISRC containment lab. The project, which is using tanks more commonly used in jellyfish rearing, has made important advancements and is moving in a promising direction. maisrc.umn.edu/raising-zm

Using Multibeam Sonar for Early Detection of Zebra Mussels

Sonar works by sending a sound signal to the bottom of a body of water and then analyzing the strength and pattern of the sound waves that return. In this study, researchers are field-testing methods using multibeam sonar in Minnesota lakes to differentiate between various sediments with and without native and zebra mussels. In 2021, a dive team also surveyed the test sites to validate method accuracy. If successful, multibeam sonar could prove to be a time- and cost-effective early detection and monitoring tool for zebra mussels. maisrc.umn.edu/zm-sonar



Freshwater Golden Clam Discovery and Monitoring

It was previously thought that golden clams were unlikely to survive Minnesota winters without an artificial heat source, such as discharge from a power plant. During the 2020 Starry Trek citizen science event, a young volunteer discovered these invasive clams in Briggs Lake. Shortly after the discovery, MAISRC launched a monitoring project to conduct a population survey throughout the winter of 2020 and into the summer of 2021. This rapid response project verified that golden clams are not only surviving, but are also reproducing. Due to this surprise finding, golden clams were moved on to MAISRC's priority species list for future research. maisrc.umn.edu/goldenclams

Gene Targeting in Zebra Mussels for Control Options

A new MAISRC project launched in 2021 is working to identify zebra mussel genes that can be targeted using RNA interference, a genetic biocontrol strategy that does not involve heritable manipulation of the zebra mussel genome. So far, the team has identified 20 genes of interest and are currently exploring delivery options. For example, the RNAi could be used to interfere with the genes responsible for byssal thread formation. If researchers could disrupt this gene's expression in zebra mussels, this could disrupt their ability to settle on lake and river bottoms or to spread through attachment to surfaces. maisrc.umn.edu/rna-biocontrol

Anti-Biofouling Coatings for Zebra Mussel Suppression

Biofouling is the accumulation of microorganisms, plants, algae, or small animals on an underwater surface. This is problematic as it provides a means for aquatic invasive species, such as zebra mussels, to spread to different bodies of water through the attachment to boats. MAISRC researchers are developing an innovative, environmentally friendly paint additive that inhibits biofouling, and therefore has the potential to reduce or prevent zebra mussel spread. Exciting preliminary results from the additive demonstrated antifouling activity and zebra mussel attachment prevention. These encouraging results were then followed by efforts to improve the paint formulation in lab settings as well as challenging it on a more dynamic surface—the hull of a boat in Lake Minnetonka that was used recreationally all season by its owners in summer 2021. Results from these experiments are currently being analyzed and will guide the future path towards technology translation.

maisrc.umn.edu/coatings

Invasive Fish Research

MAISRC's invasive fish research currently has a strong focus on invasive carp—common carp and bigheaded carps, both of which can cause massive ecological changes to Minnesota waters. Silver carp, another species of bigheaded carp, are known to jump out of the water when startled. Starting in 2021, researchers began testing the added use of CO₂ bubbles to previously developed acoustic deterrents in the MAISRC lab. If successful, the strategy will be moved to real-world testing in invaded river systems to prevent upstream migration. In addition:

Social Influence Among Common Carp

Researchers placed tracking tags in over 300 common carp and set bait stations in Parley Lake to monitor the movement patterns and social dynamics of common carp. Results indicated that a small number of fish acted as 'superfeeders' and influenced the movement of larger groups. Researchers are now working to identify how to target the superfeeders to more efficiently remove carp. maisrc.umn.edu/carp-biocontrol

KHV for Future Biocontrol Efforts

Common carp feed by rooting in lake bottoms—stirring up sediment and nutrients and causing massive changes to lake ecosystems. MAISRC researchers looking for effective and efficient ways to combat common carp infestations found that the endemic virus, Koi Herpesvirus, has a high mortality rate for common carp and does not cause disease in native fish species. The high species specificity of the virus makes it a desirable candidate for potential pathogenic biocontrol. maisrc.umn.edu/native-pathogens



Genetic control of common carp

Researchers in the MAISRC lab have successfully developed a year-round laboratory spawning and transgenesis workflow for engineering common carp. The test fish have been given a gene to glow under fluorescent light so the researchers can identify successful modifications (upper right photo). In the future, they will use genetic engineering to create sterile males that could be released to the wild, resulting in a collapse of the common carp population.

maisrc.umn.edu/genetic-carp





Aquatic Invasive Plant Research

From starry stonewort and curlyleaf pondweed to *Phragmites*, cattails, and more—MAISRC’s research on aquatic invasive plants is both broad in the number of species addressed and depth in the amount of knowledge gained. Additionally, with current climate models showing warmer lake temperatures in the future, the need for adaptation and tools to address invasive vegetation will only heat up. MAISRC researchers are currently modeling invasion patterns under multiple climate predictions for optimal management scenarios. In addition:

Restoring Lakes After Invasion

Methods to restore native aquatic plants after invasive plants have been controlled is a critical knowledge gap and an important step in restoring invaded lakes. During the summer of 2021, MAISRC researchers wrapped up a four-year experiment focused on restoring native species after invader control. Their work advanced our understanding of how to store, process, and sow aquatic plant seeds; explored new strategies for planting and re-vegetating in lakes; and allowed researchers to analyze the role invasive species and poor water clarity have in suppressing native plants.

maisrc.umn.edu/native-restoration

Native Alternatives for Invasive *Phragmites*

Non-native *Phragmites*, which can grow up to 15-18 feet tall, has been deliberately planted in some Minnesota wastewater treatment plants for dewatering settling beds. This contributes to spread across the landscape, since *Phragmites* can escape from treatment plants. MAISRC researchers are now studying whether strains of *Phragmites* native to Minnesota could be effective substitutes for invasive strains used in wastewater operations. maisrc.umn.edu/native-phragmites

Cattail Removal for Improved Shorelines

Hybrid cattails replace native plant communities with tall, dense, homogeneous stands. This can be harmful for native plant and fish communities and a nuisance for lakeshore residents and recreationists. In 2021, MAISRC researchers mechanically removed hybrid cattails at test sites in nine lakes across Minnesota. In the summer of 2022, they will compare the water quality and fish and plant communities at the removal sites against control sites to determine if hybrid cattail removal increases ecosystem health.

maisrc.umn.edu/cattails



Chanhassan



Lake Koronis



Cross-Cutting Research

In the scope of MAISRC research, the term ‘cross-cutting’ is used to describe projects that are studying multiple species and/or the systems in which the species live or move. Cross-cutting research helps to address complex issues that often lie at the intersection of social, economic, behavioral, and biological sciences.

Improving the Coordination of Watercraft Inspections

On-site watercraft inspections are an important tool to help prevent new infestations, conduct passive surveillance, and promote awareness of aquatic invasive species. MAISRC researchers are building on predictive models to examine how to maximize the effectiveness of state-level coordination and between-county cooperation of watercraft inspection plans. Preliminary data suggests that statewide plans could be optimized, allowing for cost savings and/or increased risk-based inspections, by adjusting the location of watercraft inspection effort. maisrc.umn.edu/watercraft-inspections



AIS Explorer Interactive Dashboard

MAISRC researchers developed an online dashboard—AIS Explorer—that both forecasts the introduction risk of aquatic invasive species to individual waterbodies and provides decision-making support for optimizing watercraft inspection efficacy. Since its launch in 2020, the dashboard has become an important resource in the planning toolkit of many county and local government resource managers. Thanks to feedback from users, AIS Explorer expanded in 2021 to include Tribal boundaries, updated lake names, and improved usability. In 2022, users can look forward to the incorporation of new features and updated data. aisexplorer.umn.edu





Paying to Protect Minnesota's Waters

Minnesota is renowned for its beautiful lakes, but do residents place a high value on the state's water quality, habitat, and recreational opportunities? If so, would recreational water users in Minnesota be willing to pay for aquatic invasive species management at the lake that they use? To begin the study, researchers conducted in-person surveys at four Minnesota lakes. Upon analysis of the results, of the 994 people who completed the survey, roughly half were willing to pay a modest daily user fee that would be applied to aquatic invasive species management at the lake that they use. Notably, there was no significant difference in daily willingness to pay between any of the surveyed lakes—the lakes were chosen specifically for their varied characteristics (invasion status, size of lake, proximity to a large city). maisrc.umn.edu/public-values



Using Environmental DNA Water Samples to Detect Invaders

Currently, most aquatic invasive species surveillance and early detection is done by physical methods of observation or capture such as snorkeling, dive teams, vegetation rakes, trapping and netting. These strategies are very labor- and cost-intensive for resource managers. Now, imagine finding a new zebra mussel population simply by testing the water itself. MAISRC researchers are working to establish optimal methods for collecting, filtering, and testing water for the environmental DNA (eDNA) of invasives. In 2021, the researchers visited 15 Minnesota lakes, collecting over 1,500 water samples using various protocols designed to identify method combinations which work best, including what time of year to sample. The samples will be analyzed over the winter for their accuracy in detecting four invasive species known to be present in study lakes (zebra mussels, spiny water flea, rusty crayfish, and common carp). The team will visit an additional eight lakes in 2022 to validate their results. maisrc.umn.edu/edna-monitoring



Why Anglers Release Their Unused Baitfish

The use of live baitfish, such as fathead minnows or golden shiners, is a common practice among anglers in Minnesota. Despite it being illegal to do so, some anglers will dump their remaining bait into lakes at the end of their trip—risking the introduction of parasites and viruses from the baitfish to native fishes. To better understand why anglers are releasing their bait, MAISRC researchers have surveyed Minnesota fishing license holders. Initial survey results found that bait release is a huge problem: 20-35% of anglers released leftover live bait fish at least once in the last year. On-going survey work will help examine demographic and psychological factors to see what explains angler bait release behavior and identify opportunities for improved management.

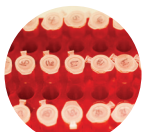
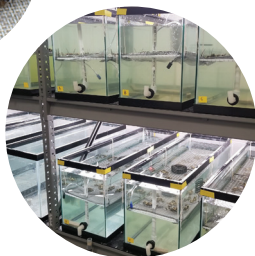
maisrc.umn.edu/baitfish-risk



Public Perceptions and Attitudes on Genetic Biocontrol

In 2021, MAISRC researchers began a project delving into the complexities of public perceptions, attitudes, and levels of support when it comes to using genetic techniques for controlling aquatic invasive species in Minnesota. The team will engage tribal communities, management agencies, lakeshore property owners, and more. This is a first-of-its-kind project focused on aquatic invasive species and promises to inform future management and research on the topic of genetic biocontrol.

maisrc.umn.edu/risk-perceptions



MAISRC Outreach

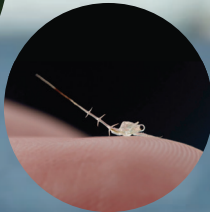
At MAISRC, our work doesn't stop at the end of a research project. A key part of our mission is sharing what we've learned and making sure stakeholders and resource managers have the best information and tools in-hand when making management decisions. Our team translates research findings into digestible presentations, factsheets, and workshops/trainings that can be shared with anyone interested in aquatic invasive species, including resource managers, policy makers, and concerned members of the public. maisrc.umn.edu/connect

Research Translation

MAISRC's Research Outreach Specialist, Meg Duhr, presented to over 1,065 people at events in 2021, helping translate our science into action. She visited lakeshore associations, local government organizations, the MnDNR, and even neighboring states as they began their battle against zebra mussels. Exciting outreach in 2022 will include a major emphasis on common carp management and partnership work to increase awareness about aquatic invasive species issues among wilderness users.

Research and Management Showcase

In 2021, the MAISRC Research and Management Showcase was hosted fully online for the second year. The online Showcase continued to allow researchers, resource managers, lakeshore association members, members of the public, and local/state agency staff to come together to learn about the latest in aquatic invasive species research and how the findings could be applied. In a post-event survey, 91% of respondents ranked the Showcase as either "very good" or "excellent."



Stop Spiny Campaign

Based on recent MAISRC research, it is recommended that individuals wipe down fishing lines and gear, bait buckets, and livewells when leaving an infested lake to prevent the spread of spiny water flea. To promote this message, MAISRC staff and researchers collaborated with over 40 outside organizations, including local governments, lakeshore associations, and nonprofits to distribute cleaning cloths printed with "Stop Spiny" recommendations. In 2021, over 17,000 cloths were distributed by MAISRC staff in Minnesota. MAISRC also created publicly available Stop Spiny factsheets, videos, radio scripts, posters, and more for use by partners looking to do additional outreach. stopspiny.org





AIS Detectors Program

The AIS Detectors program is jointly supported by MAISRC and University of Minnesota Extension. This past year, the Detectors program moved the program's flagship Core Course fully online, allowing citizen scientists from across the state and beyond to become certified AIS Detectors. In the course, participants learn how to report invasive species, best practices for preventing the spread of invasive species, relevant rules and regulations, and how to search for invasives on their own. maisrc.umn.edu/ais-detectors

Starry Trek

In August 2021, the AIS Detectors program hosted the fifth annual Starry Trek event across Minnesota. Over 200 volunteers gathered at rendezvous sites and searched a total of 281 public accesses on 222 water bodies for starry stonewort and other aquatic invasive species. Since its start in 2016, Starry Trek volunteers have found four new populations of starry stonewort in Minnesota waters. Although there were a few other aquatic invasive species discoveries during the 2021 event, including Eurasian watermilfoil in Dakota County, there were no new infestations of starry stonewort to report.

maisrc.umn.edu/starrytrek

AIS Management 101

AIS Management 101 is an educational course for those who would like to be more informed about what's happening in their lake and lake management practices. The fully online course debuted in 2020 and returned in 2021. Course participants engaged with multimedia learning materials detailing a range of topics including aquatic invasive species regulations, target species, management options, monitoring strategies, and more. To date, 111 participants have completed AIS Management 101. The course will be offered online again in 2022 with registration opening in January.

maisrc.umn.edu/ais-management101

Detectors Webinars

The AIS Detectors program collaborates with MAISRC researchers to offer webinars on active MAISRC projects. The webinars give the public the opportunity to hear updates on research underway and ask questions directly to researchers. The program has hosted 13 webinars with over 4,000 total registered attendees. The webinars are also uploaded to the program's YouTube channel after their live debut for those who want to watch at a later date.

maisrc.umn.edu/webinars



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351
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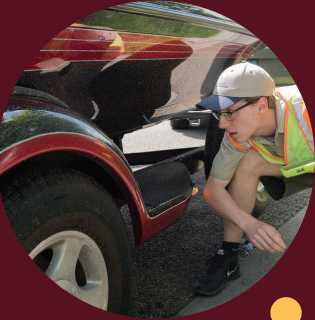
Now available fully online!

maisrc.umn.edu/ais-detectors

MAISRC Research in Action

Coordinating the watercraft inspection program for Crow Wing County means we have to decide which of our county's 400+ lakes will be staffed by an inspector. With limited staffing resources, we want to make sure that they are working in the locations where they'll have the most impact. MAISRC's AIS Explorer online dashboard has become an essential tool in this process. When we compare the outputs of the models with our own County inspections per hour data, I feel confident that we are making the most informed decisions possible to protect Crow Wing County lakes. ”

**Nicole Erickson, Environmental Services Specialist
Crow Wing County**



The new knowledge and guidance coming from MAISRC is critical for guiding my work with lake groups. Currently, I am really excited about the effort by Mike Verhoeven in Dr. Dan Larkin's lab to curate a public database of past aquatic plant surveys from around the state. Up until now, past survey results have been difficult to track down and were often only available as paper reports. Having access to the raw data from hundreds of past plant surveys will allow researchers and managers to track historical changes in the plant community of individual lakes, but more importantly, will allow us to look for patterns of plant community change across many lakes due to AIS management, climate change, or the expansion of new invasive species. Much of AIS management has been based on a few case studies to guide what works and what doesn't. This database will enable new big-data analyses that will help to ensure that we are using the best strategies for different lakes. ”

**James Johnson, Aquatic Ecologist; MS, CLM
Freshwater Scientific Services**



Successful management of our water and natural resources in the watershed is directly tied to invasive species' relative presence and threat. For this reason, applied research coming out of the Center is essential to how we conduct our business. For instance, our lasting partnership with the Center was a crucial factor in our long-term success in managing common carp, resulting in improved lake water quality. ”

**Bill Bartodziej, Natural Resources Specialist
Ramsey-Washington Metro Watershed District**





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