A publication of the North American Lake Management Society

# LakeLine

Volume 43, No. 1 • Spring 2023

## Aquatic Invasive Species

# 43rd International Symposium for the North American Lake Management Society

# Great Lakes, Local Solutions

**October 22-26, 2023 - Erie Bayfront Convention Center Erie, PA**

At the time when climate change, invasive species risks, and cultural pressures threaten the natural environment and biodiversity of our fragile ecosystem, the opportunity to highlight and mesh the State of Pennsylvania and its rich diversity of aquatic habitats is long overdue.

The Pennsylvania Lake Management Society is proud to welcome the 2023 North American Lake Management Society Conference to Lake Erie. As we endeavor to highlight our Great Lakes, Local Solutions agenda, Erie Pennsylvania provides the opportunity to explore Presque Isle State Park, a National Natural Landmark and The Tom Ridge Environmental Center, while indulging in the amenities of the Bayfront Convention Center and all that Erie has to offer.

Because **all** lakes are great, we are looking for potential topics on:

- HABs Management in Watersheds and Near Shore Areas
- Stormwater and Wastewater Infrastructure in Lakes
- Multi Regional Climate Outlooks and Strategies
- Urban and Suburban Lakes
- Aquatic Invasive Species
- Emerging Contaminants
- Science Communication
- Environmental Justice
- Green Infrastructure
- Remote Sensing
- Fisheries
- eDNA

& other lake management issues

For sponsorship or general information visit www.nalms.org/nalms2023 or contact nalms2023@nalms.org, 608-233-2863. For other details contact Conference Chair Kate Harms (info@palakes.org) or Conference Coordinator Sara Peel (speel@arionconsultants.com)

# LakeLine

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***On the cover:***
"Mintz Pond, Fayetteville, North Carolina." This photo was the winner of the Editor's Choice category in the 2022 Annual Photo Contest. Photo by Wendy Dunaway.





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# From Amy P. Smagula the Editor

Happy spring! This issue of *LakeLine* focuses on Aquatic Invasive Species (AIS), with contributions from several authors sharing different aspects of AIS work, from the national level to the local level, and from the United States and Canada.

We start off with updates of AIS work from three federal agencies with programs that focus on the subject. First, **Susan Pasko** with the U.S. Fish and Wildlife Service shares an article outlining national priorities for research related to AIS, based on feedback from partners who work with aquatic invasive species across the country. Research priorities include several focus areas, and once complete, will help to direct activities related to AIS in the coming years. Next, **Michael Greer** from the U.S. Army Corps of Engineers, Engineer Research, and Development Center highlights work that the Corps is focusing on, as it relates to various AIS. Our third update on federal initiatives comes from **Ian Pfingsten** with the U.S. Geological Survey (USGS). Ian provides an overview of the USGS Nonindigenous Aquatic Species (NAS) Database, discussing how data come in, maps are made and used, and how anyone can contribute to the database. He also references some other platforms that are available by both professionals and others who are interested in tracking and reporting AIS observations.

As a focus on a problem species, **Brian Ginn** and **Tyler Harrow-Lyle** provide an update on their work with starry stonewort, a macroalga species that has proven to be invasive in some parts of North America. They share new findings and observations from Ontario, Canada.

With AIS being a common problem among our lakes and ponds, many of us adopt the perspective of the more eyes, the better. Having a well-trained, engaged, and active group of volunteer monitors helps with monitoring for and reporting new infestations. **Angela De Palma-Dow** and **Jo Latimore** provide a review of the Exotic Aquatic Plant Watch (EAPW), which is a component of the Cooperative Lakes Monitoring Program of the Michigan Clean Water Corps. Their article focuses on their work to evaluate the EAPW program, based on feedback from evaluations and surveys of program participants. Their findings have helped to strengthen the program and reinforce the valuable contributions of program volunteers.

Because much of AIS work involves public outreach and messaging, social marketing is an important element to couple with the science related to AIS. **Tim Campbell** and **Bret Shaw** discuss the value of combining natural and social sciences in the context of AIS outreach initiatives. They highlight the importance of understanding the target audience and crafting and packaging messaging in multiple ways to convey key messaging and effect behavior change.

**Cathy McGlynn** and **Ceci Weibert** share targeted AIS prevention activities occurring in the Great Lakes and Northeast regions of the U.S. and in some Canadian provinces, in the form of a summer Landing Blitz. The Landing Blitz is a focused event in late June and early July, including courtesy boat inspections and education events at public access sites to promote *Clean, Drain, and Dry* messaging. The events include social media blasts and other means of advertising. It's a great model to follow wherever you are, and it makes for a great way to spread the word during a very popular boating time.

Our final theme article is from **Jesse Smith**, who provides a great overview of important elements to consider when planning for an AIS management program.

The Student Corner article is from **Amber White**. Amber provides an overview of her graduate work looking at the fate and transport of aquatic herbicides.

In addition to the themed articles, there are two contributed articles on recent research work that authors wanted to share. The first is from **Christopher Nietch**, **Paul Gledhill**, **Nathan Smucker**, **Matthew T. Heberling**, **Erik Pilgrim**, **Richard Mitchell**, **Amina Pollard**, and **Lester Yuan** with the U.S. Environmental Protection Agency. They share their work on stream monitoring and benthic algae DNA metabarcoding to inform the development of a Total Maximum Daily Load (TMDL) in a watershed in Ohio. The second recent research article is from **Heather Shaw** and **Paige Thurston**, who share their work tracking climate change in high elevation waterbodies in the Canadian Columbia Basin, including their plans for 2023 and beyond.

Our Lakespert, **Steve Lundt**, shares some remarkable findings regarding AIS in wastewater treatment ponds, that highlight the importance of outreach and prevention on many levels.

Also in this issue, we hear from our NALMS President **Kiyoko Yokota**, and include some important announcements about upcoming NALMS events, and share some great recognition that a group of young students received in New Jersey, thoughtful lake stewards in the making!

We hope you enjoy this issue of *LakeLine*. And please remember, Clean, Drain and Dry your gear – prevention of AIS is key!

**Amy P. Smagula** is a limnologist with the New Hampshire Department of Environmental Services, where she coordinates the Exotic Species Program and special studies of the state's lakes and ponds.

# From the President

Kiyoko Yokota

Happy spring from Upstate New York. I live and work outside of Cooperstown, NY, the home for the Baseball Hall of Fame, where we have had relatively warm weather until February. Now we are back at the seasonable temperature and snow cover, while the lake ice at nearby Otsego Lake has been thin and uneven.

Serving on the NALMS Executive Committee (ExCom; consists of Past President, President, President-Elect, Secretary, and Treasurer) and being in our weekly online meeting, it has very interesting to listen to weather patterns in different parts of the United States and realize the interconnectedness of the hydrologic cycle at the continental scale. Currently, all ExCom members are in the U.S., but many of us are in states sharing borders with Canada – from the west to east, Shannon Brattebo, Treasurer, is in Washington State, I am in New York State, Kellie Merrell, President-Elect, is in Vermont, and Danielle Wain, Secretary, is in Maine. NALMS is aiming for a better representation of North America as a whole, especially Puerto Rico, which is part of NALMS Region 2, and Mexico. If you or your colleagues are working in these areas, please let us know so that our lake management professional and citizen network can better serve your area.

NALMS has been busy with the annual membership renewals and recertification of certified professionals, both of which go by the calendar year. Big applause goes to our Director of Development & Marketing Alyssa Anderson, who returned from parental leave at the end of 2022 and magically caught up with these annual waves of renewals and recertifications. The Professional Certification Program, run by the Program Lead Brendan Wiltse, CLM, and volunteer evaluators who themselves are CLMs, has been carefully evaluating initial certification and three-year recertification applications in a timely manner. Please note that membership and professional certification applications are accepted year-round, and annual membership fees are prorated accordingly. Any time is a great time to join NALMS and get certified!

We wrapped up the last remaining tasks from the NALMS 2022 Symposium in Minneapolis, Minnesota, USA, such as reviewing the survey results and applying what we learned to the planning of the 2023 NALMS Symposium in Erie, Pennsylvania, USA. Please submit your workshop proposals at https://www.nalms.org/nalms2023/call-for-workshop-proposals/ and presentation abstracts at https://www.nalms.org/nalms2023/call-for-abstracts/. We are looking forward to seeing you on the shore of the magnificent Lake Erie.

NALMS Board of Directors (BOD) is having a mid-term meeting on 22-23 April 2023, in Virginia Beach, Virginia, USA, right before the 2023 National Water Quality Monitoring Conference (NWQMC) in Virginia Beach, on 24-28 April 2023. NALMS plays an important role in organizing the biannual NWQMCs for the National Water Quality Monitoring Council, which was created in 1997 and is currently managed by EPA in cooperation with NOAA and USGS. Big thanks to Jeff Schloss for his continued service to NALMS after his retirement from the NALMS Conference Coordinator position by organizing this and the 2025 NWQMCs.

As I write this, I am anxiously waiting for the last shipment of lake data buoy equipment to come back from its wintertime service and repair so that I can re-assemble the buoy system and test it near shore before the planned deployment in April. I imagine many of you are gearing up for the busy field season, which coincides with the peak usage of lakes, reservoirs, and ponds for recreation, a major vector of aquatic invasive species (AIS). Species composition in aquatic biota is dynamic and ever-changing, and certain levels of species introductions and extirpations (= local extinctions) have been normal throughout the history of the earth. The accelerated rates of non-native species introductions by humans, aided by modern transportation, are often beyond the level of resilience afforded by the native plant and animal communities. The common challenge for applied ecologists around the globe is that the native species do not readily bounce back even if we successfully eradicated the invaders, and in the worst-case scenario, another opportunistic invader would quickly take over the vacated niche.

NALMS and its publications, *LakeLine* magazine and the peer-reviewed *Lake and Reservoir Management* journal, have facilitated sharing of valuable information on AIS detection, acute-phase control, and long-term management among lake and reservoir management professionals across North America so that the lessons learned in well-studied systems could be applied to similar systems elsewhere for better management outcomes.

Now, please be seated for the excellent articles by our AIS experts on the following pages and watch out for potential new AIS in your favorite waterbodies. Teach others to do the same and realize the importance of EDRR – early detection and rapid response!

*(From the President, continued on p. 10 . . . )*

# Panther Power Team 1159, a F.I.R.S.T Robotics Challenge Team

## The Academy of Our Lady of Peace, New Providence, NJ

Leo F., Riley M., Chris A., Jonathan L., Wolfgang J., Fisc R., Rosie M., Aidan E.

We are Panther Power Team 1159, a F.I.R.S.T Robotics Challenge team. Through the *FIRST* LEGO League (FLL), teams are introduced to STEM through exciting and fun hands-on learning. Each year, *FIRST* challenges teams to solve a real-world problem through worldwide robotics competitions. We are the team from The Academy of Our Lady of Peace, located in New Providence, New Jersey. Our team is made up of eight students from grades 4 to 8. Each competition consists of a Robot Challenge, Innovative Project, and Core Values/Teamwork Challenge. We looked at many problems but chose the problem of algae and hydro-electric power plants.

Our team was tasked to find a problem about an energy source and create a solution to improve it. We started learning about hydroelectricity and algae. After doing some research, we voted to make a solution to benefit hydroelectric dams. We chose to clean up the water and remove the algae that clogs dams and other hydroelectric power plants and nuclear power plants. Our solution would also remove toxic bacteria associated with the algae that kill wildlife.

To decide on this project, we used a few strategies. First, we used the process of elimination. We looked at many problems then decided which one we were most interested in. We did further research and we talked to experts. Then we discussed and shared what we each discovered so that everyone's opinions could be expressed. Then we voted on our final project

We used all the steps of the engineering process to help define the problem and design a solution. Defining the problem wasn't hard as we had set parameters and we did a lot of research to help us specify requirements and choose a solution. After this we developed ideas for our boat to be used for the final prototype

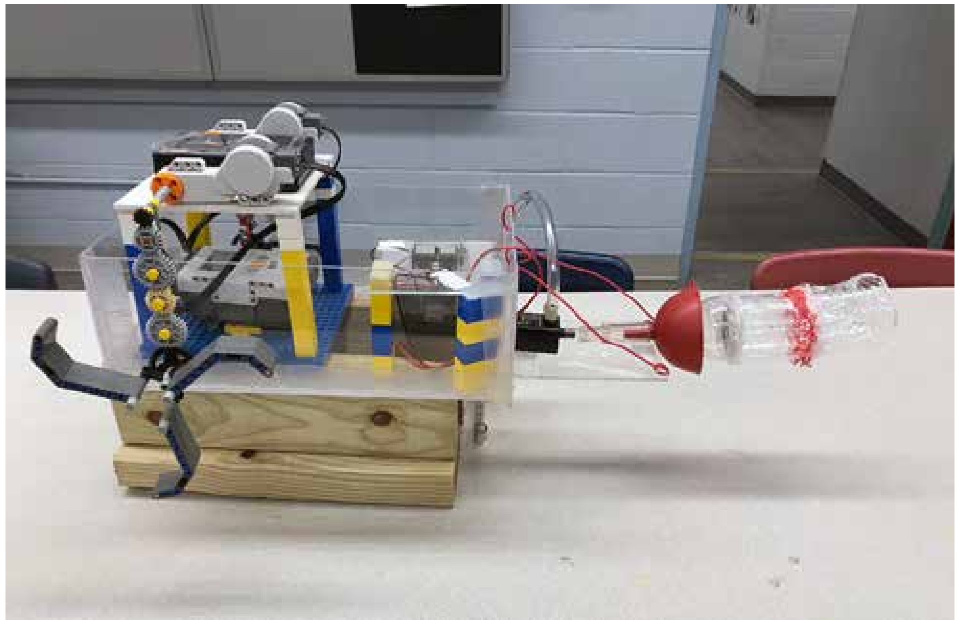
and then we made a working model and tested our solution. We determined that this final prototype met all our requirements, and we communicated our results to our experts, judges at both our regional and state competitions, and our community.

We did experiments to help us understand all the features we might include in our solution. One experiment was with a pump and tubes to suction water from one bucket to another. It taught us about how a pump could suction the water and algae out of the lakes and reservoirs. Also, we tested the mesh and various-sized rocks to see what the best sizes of mesh are to use for our filter. We tested what would be the best material to use for our working prototype. Also, we did an experiment to see if the propellers could work in debris like algae and duckweed.

We talked with some experts, including Dr. Stephen Souza from Clean Waters Consulting LLC, Dr. Jennifer Graham, and Sabrina Perkins from the US Geological Survey (USGS). Dr. Souza is a former President of NALMS (2000-2001) https://www.nalms.org and Dr. Graham is the harmful algal bloom coordinator for the USGS water Mission. They helped us improve our solution by listening and giving us feedback. They suggested that we design removable filters. They also taught us about flocculation. We decided to add alum to our tank of killed toxic microscopic bacteria so that bacteria could be filtered and removed. They also spoke about other methods they are using including nanobubble technology.

Our project is focusing on toxic algae and plant life in reservoirs leading up to hydroelectric dams. Algae and plant life in hydroelectric dams can jam turbines. Cyanobacteria (blue-green algae) is a toxic bacterium that can harm humans and wildlife. This toxic alga can contaminate the water and make it unusable for drinking, irrigation, and recreation. To solve this problem, we designed a rectangular boat with well-researched features to remove the algae and plants.

We have designed a prototype that is a working model made from plexiglass. It uses waterproof tape and caulk to make it watertight. We programmed two Lego propellers to move the boat in a pattern on the reservoir behind the dam to clear the water of debris. Everything in the boat is powered by rechargeable solar batteries. The front of the boat has a working pump that draws water from the reservoir into a series of filters. The filters use different-sized meshes to catch large to small-sized algae and plants. The filter unit is removable, replaceable, and can be cleaned. We can then compost any non-harmful algae and plants from the filters. Microscopic toxic algae, which is not caught on the filters, goes through tubing, and passes an Ultraviolet-C lamp which kills the cyanotoxin and cyanobacteria. The UV lamp is controlled by a switch. These materials are collected and flocculated in a tank using alum and a device to stir the alum with the other materials. The water is filtered through a fine mesh and the cleaned water is then returned to the reservoir.



*Our innovative project, the Hydro-Electric Toxic Algae Cleaner, or H-TAC for short, could help the problem of toxic algae blooms and other plant life that can harm hydroelectric power plants.*

We learned that current methods to prevent harmful algae and plants in water include the addition of peroxides, probiotics, and algaecides directly to the water. Each of these methods could harm wildlife. The use of sonication and nanobubbles have shown some limited effect, some studies show that they may not be able to kill all toxic algae bacteria. There are several advantages to our design. Our design does not put chemicals into the body of water. The filters do not harm fish or other animals. Non-harmful algae and plants can be composted. Many studies have shown that Ultraviolet-C lamps can effectively kill bacteria. Through flocculation and fine mesh filtration, killed toxic bacteria can be removed from the water. The vehicle is unmanned and can be programmed to efficiently clean the algae from many types of waterways. In addition to hydropower plants, harmful algae blooms can affect many types of waterways. Our innovative solution could also be used to treat other waterways including lakes and ponds that have harmful algae blooms.

In conclusion, we worked hard and learned new things about hydroelectric power and how it has problems that need solving. Our innovative project, the Hydro-Electric Toxic Algae Cleaner, or H-TAC for short, could help the problem of toxic algae blooms and other plant life that can harm hydroelectric power plants. This is important since some countries like Sweden and Norway rely on hydroelectric power as a major source of energy.

# **National Priorities for Research** on Aquatic Invasive Species

Susan Pasko

Aquatic invasive species cause tremendous harm to the ecological, economic, and cultural integrity of the Nation's waters and the communities they support. To combat this threat, Congress established the Aquatic Nuisance Species Task Force with the passage of the Nonindigenous Aquatic Nuisance Prevention and Control Act in 1990. Composed of 26 federal and non-federal members, the Task Force works with its partners to create a unified network that raises awareness and takes action to prevent and manage aquatic invasive species. A key component of this network is identifying priority research needs for aquatic invasive species. Although much research has been conducted for some invasive species, there are many species for which little is known. There is a need for increased knowledge to fill gaps and provide natural resource managers the tools and information they need to better protect U.S. waters from the threat of aquatic invasive species.

In 2021, the Aquatic Nuisance Species Task Force's Research Subcommittee surveyed members of the aquatic invasive species community for their highest priority research needs in the areas of prevention, early detection and rapid response, control, restoration, outreach, and general invasive species knowledge. The subcommittee evaluated each response for its practical application, technical feasibility, national significance, and applicability to policy and management. The research needs that ranked highest in these areas were included in a National Priorities List for Research on Aquatic Invasive Species that was approved by the Task Force in November 2021.

The research priorities were intentionally kept at a broad level, in order to be applicable throughout the Nation and to be supported by localized research on priority species or issues. The research priorities were also grouped into the management areas and as needed, management subcategories, listed below.

### Prevention

Preventing harmful introductions before they occur is the most effective means to avoid the risk of aquatic invasive species, yet diverse tools and methods are needed to prevent establishment of species into ecosystems where they are not native. This includes a greater understanding of the risks associated with the movement of organisms through global trade and watercraft operation. Additional study is also needed to better anticipate what species have the potential to become invasive, link biological invasions to the transport of microorganisms and pathogens, and evaluate the effectiveness of existing program and plans that prevent aquatic invasive species. Research priorities described in the "prevention" section of the National Priorities List for Research on Aquatic Invasive Species include:

*Organism in Trade*

- Increase understanding of the "organisms in trade" pathway.
- Increase understanding of the effects of changing trade dynamics on patterns of species introductions.
- Evaluate federal and state authorities to identify gaps that may result in the introduction of an invasive species.
- Evaluate "hitchhiker" organisms on product shipments.

*Watercraft Pathway*

- Evaluate best practices for watercraft design.
- Evaluate the efficacy of watercraft decontamination (Figure 1) protocols for aquatic invasive species and explore ways to improve the efficiency and


*Figure 1. A watercraft inspection/decontamination steward doing an inspection of a vessel.*

cost-effectiveness of watercraft inspection and decontamination.
- Increase understanding of viability of mussel veliger and other aquatic invasive species in residual water from watercraft.

*Ballast Water Management*
- Evaluate tools and methods for rapidly determining organisms' concentration in ballast water (Figure 2) during testing of ships' ballast water discharge.
- Expand the development of ballast water treatment systems to include operationally challenging conditions and streamline the approval process.

*Microorganisms and Pathogens*
- Improve understanding of the invasion risk posed by microorganisms and pathogens.

*Species Risk Analysis*
- Identify and evaluate risk analysis mechanisms to prioritize species of concern based on the likelihood of invasion and potential impacts.

*Aquatic Invasive Species Management Plans*
- Evaluate the effectiveness of state and interstate aquatic invasive species management plans.

**Early detection rapid response**

Despite the best preventive efforts, new species introductions into waters of the United States are expected. Greater effort is needed to increase the likelihood of identifying and detecting new species before they become established. This includes the continued development of species detection tools, increased knowledge on the biological and anthropogenic factors that contribute to successful establishment, and action to encourage individuals to report sightings of suspicious organisms. Research priorities described in the "early detection rapid response" section of the National Priorities List for Research on Aquatic Invasive Species include:

*New and Existing Species Detection Tools*
- Develop and evaluate tools to quickly find and identify high risk aquatic invasive species to aid inspections at airports and seaports.
- Develop and evaluate aquatic invasive species detection tools for marine and coastal species.

*Figure 2. Ballast water being discharged from a vessel.*

- Increase understanding of species establishment and sampling methods that can detect populations before they are too large to be eradicated.
- Develop cost-efficient genetic tools and evaluate their potential and limitations for use.

*Containment*
- Develop and evaluate tools and methods to track movement of organisms more effectively into uninfested locations.
- Evaluate the use of physical barriers to contain aquatic invasive species, considering how use may affect native species.

*Aquatic Invasive Species Reporting*
- Develop and evaluate reporting platforms to encourage reporting of unusual or new species sightings.

**Control and restoration**

Research Priorities for this section focus on encouraging innovation for control methods and approaches to lessen the impacts of aquatic invasive species to public interests and increase the likelihood of eradication. Recognizing that not all control methods are effective, feasible, or environmentally sound for every situation, available tools should be evaluated to guide decisions on the most appropriate means to control invasive populations as well as to restore ecosystems following the application of control measures. Research priorities described in the "control" section of the National Priorities List for Research on Aquatic Invasive Species include:

*Resource Management Decision Making*
- Conduct a comparative analysis of existing aquatic invasive species control options to inform development of control strategies and plans.
- Increase understanding of the importance of population dynamics and life history stages in control efforts and use this information to develop population-based tools to inform eradication or population suppression.
- Evaluate past eradication attempts and long-term control efforts to determine effectiveness and lessons learned.
- Increase understanding of the long-term effects to waterbodies or native species from control methods used to combat aquatic invasive species.
- Increase understanding of the long-term environmental and economic implications to native communities when action to control or remove aquatic invasive species is not taken.

*New or Existing Control Tools*
- Pursue environmentally sound technologies to aid in the eradication or control of aquatic invasive species.

- Evaluate the effectiveness of incentive programs to control aquatic invasive species.

*Habitat Restoration*

- Increase understanding of efforts needed to restore ecosystem function and structure to following the removal of aquatic invasive species.
- Increase understanding of steps and methods needed to re-populate native species in areas where they have been displaced by aquatic invasive species.
- Identify criteria to determine the likelihood of restoration, to assist in prioritization of areas for control and eradication.

**Outreach**

To prevent the introduction and spread of AIS, it is critical that individuals understand why AIS are detrimental and what actions can be taken to reduce this risk. The "outreach" section of the National Priorities List for Research on Aquatic Invasive Species includes priorities to improve the effectiveness of outreach campaigns, ensure consistent messaging, and improve collaboration and innovation in message development:

*Outreach*

- Evaluate outreach campaigns to identify what messages and tools are effective at raising awareness, removing barriers, and measuring behavioral change.
- Evaluate effectiveness of boat stewards and watercraft inspection and decontamination stations in their ability to increase boater awareness and encourage preventative behaviors.
- Increase understanding of public awareness of existing laws in regulating aquatic invasive species.
- Evaluate invasive species teaching resources and activities for their ability to educate students on the impacts of aquatic invasive species and the importance of not releasing potential invasive species into the environment.

**General aquatic invasive**

This final section calls attention to research needed to increase knowledge of the biology, potential impacts, associated control methods, and interaction with climate change and other major drivers of change. This will allow for the most effective management of aquatic invasive species. Research priorities described in the "general knowledge" section of the National Priorities List for Research on Aquatic Invasive Species include:

*AIS Impacts*

- Increase understanding of impacts from aquatic invasive species to ecological systems as well as human, animal, and plant health.
- Increase understanding of the economic impacts of aquatic invasive species.
- Conduct a comparative analysis of existing tools that can be used to measure costs incurred to support a national aquatic invasive species cost estimate.

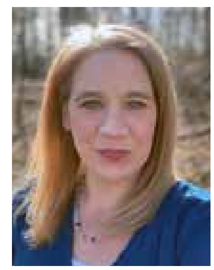
*Climate Change*

- Assess how climate change, including extreme events and human adaptation, may alter invasion patterns, pathways, and probabilities of species establishment.

The priorities listed above have been edited from the original document for brevity; readers are encouraged to review the full National Priorities List for Research on Aquatic Invasive Species document on the Aquatic Nuisance Species Task Force website. There is intent to update the Research Priorities list on a regular basis to capture new or immediate threats and remove priorities that have sufficiently progressed. To inform future revisions, the Task Force is developing a system to track and report ongoing and planned research efforts that advance the research priorities. In addition, it is anticipated that providing such information through the Task Force will foster partnerships by connecting researchers with shared interests and allow agencies better target funding opportunities.

To learn more about these efforts or the Aquatic Nuisance Species Task Force, please contact Susan Pasko, Executive Secretary of the Aquatic Nuisance Species Task Force, at anstaskforce@fws.gov.

**Susan Pasko** is the Executive Secretary of the Aquatic Nuisance Species Task Force, with the U.S. Fish and Wildlife Service.



*(From the President, continued from p. 5 . . . )*

**Kiyoko Yokota**, Ph.D., CLM is a limnologist at the State University of New York (SUNY) Oneonta, USA. She graduated from Saint Cloud State University in Minnesota with B.S. in biology with ecology emphasis (summa cum laude) and qualified as an associate professional engineer while working for a civil engineering consultancy in Tokyo, Japan. She was responsible for environmental assessment and water quality forecasting and management projects for new and existing reservoirs, lakes, and rivers. After earning a Ph.D. in ecology, evolution, and behavior at the University of Minnesota – Twin Cities, Kiyoko completed a short-term postdoctoral training at Netherland Institute for Ecology (NIOO-KNAW) before she started teaching full-time, starting at the University of Tampa in Florida. Kiyoko's service to NALMS includes Region 2 Director (2015-18), Student Programs member (2016-present), Government Affairs Committee member (2018-20), Membership ad-hoc Group member (2018), and Professional Certification Program Lead (2018-2022) and member (2018-present). Her research interests include phytoplankton (incl. cyanobacterial bloom) dynamics, microplastic-phytoplankton interaction, biogeochemical cycling, and the impact of climate change on lakes. Aside from her academic position as associate professor of biology at SUNY Oneonta, Kiyoko serves as the technical advisor for the Otsego Lake Association (Cooperstown, NY) and a member of the Water Resources Working Group of the New York State Climate Impact Assessment.

*LakeLine* encourages letters to the editor. Do you have a lake-related question? Or, have you read something in *LakeLine* that stimulates your interest? We'd love to hear from you via e-mail, telephone, or postal letter.

# The U.S. Army Corps of Engineers' (USACE) Aquatic Plant & Nuisance Species Research Program

Michael Greer

Invasive and nuisance species are increasing worldwide, likely due to a variety of factors such as global trade. In some instances, the impacts of existing invasive species are compounded by climate change. Climate change can create conditions that are suitable for more robust growth or increase the potential invasive range of a species. The estimated cost of invasive species to the U.S. economy varies widely; it is common for estimates to be in the hundreds of millions or billions of dollars annually. Agriculture likely bears the largest monetary impact of invasive species. However, impacts to aquatic resources are significant, although harder to quantify, and are frequently a source of public concern. The adverse impacts of aquatic plants on the economy, and the value of effective aquatic plant management operations, have been conservatively estimated to provide a 10:1 cost/benefit ratio (Rockwell and William 2003). That is, for every $10 spent on managing invasive aquatic vegetation, there is an estimated $100 in benefits.

Congress recognized the impact of aquatic invasive plants to our nation's waterways as far back as late 1880s and early 1890s. It was in this period that Congress authorized the USACE to remove water hyacinth from navigable waters. Over time the Aquatic Plant Control Research Program (APCRP) was officially established as the nation's only federally authorized research program directed to develop technology for the management of non-indigenous aquatic plant species. The research is centered around the development of effective, economical, and environmentally sustainable methods for assessing and managing problem aquatic plants. The goal of the program is to reduce invasive aquatic plant populations to non-problem levels, replace exotic species with native species, and restore healthy and productive aquatic habitats. Similarly, the Aquatic Nuisance Species Research Program (ANSRP) was established by Congress in 1990 to address invasive aquatic animals that are problematic to the nation's waterways and infrastructure. More recently the ANSRP has been amended to include harmful algae species. Both research programs are administered by the Engineer Research and Development Center (ERDC), Environmental Lab, https://www.erdc.usace.army.mil/Locations/EL/.

The Harmful Algal Bloom (HAB) research and demonstration project programs were added to the ANSRP by authorizations contained in the Water Resources Development Act of 2018 and 2020, respectively. HABs continue to be a significant and difficult issue affecting waterbodies across the U.S. Arguably, HABs are one of the most pressing issues in freshwater systems today. HABs result in economic and ecological damage in addition to their inherent health concerns. HAB research is focused on delivering scalable technologies to reduce the frequency and effects of HABs through research, technology development, and demonstration projects. Specific areas of research include prevention, detection, and management.

The research in both programs focuses on producing information on the growth and ecological requirements of problem aquatic species and develops new biological, chemical, and ecological technologies for their management. Specific information on the biology and ecology of problem aquatic species, obtained through research in the programs, has greatly improved the efficacy and diversity of management options, while minimizing adverse effects on the environment.

Research in the programs is primarily directed toward operational needs within the USACE. However, much of the research is broadly applicable. USACE researchers routinely partner with other federal agencies, tribes, state resource managers, academic institutions, private sector, and professional societies to conduct research activities and transfer technology to stakeholders.

Research efforts focus on the development of ecologically based, integrated pest management strategies for aquatic invasive species. Priority species for research include Eurasian watermilfoil, Flowering rush (Figure 1, next page), phragmites, giant salvinia, hydrilla (Figure 2 a and b, next page), Cuban bulrush, harmful algae, zebra and quagga mussels, invasive carp, and several other species that are currently part of the research portfolio.

Additional information on the programs can be found on the program webpages; APCRP – https://apcrp.el.erdc.dren.mil/; ANSRP – https://ansrp.el.erdc.dren.mil/hab.html; and HAB – https://ansrp.el.erdc.dren.mil/hab.html.

## Reference

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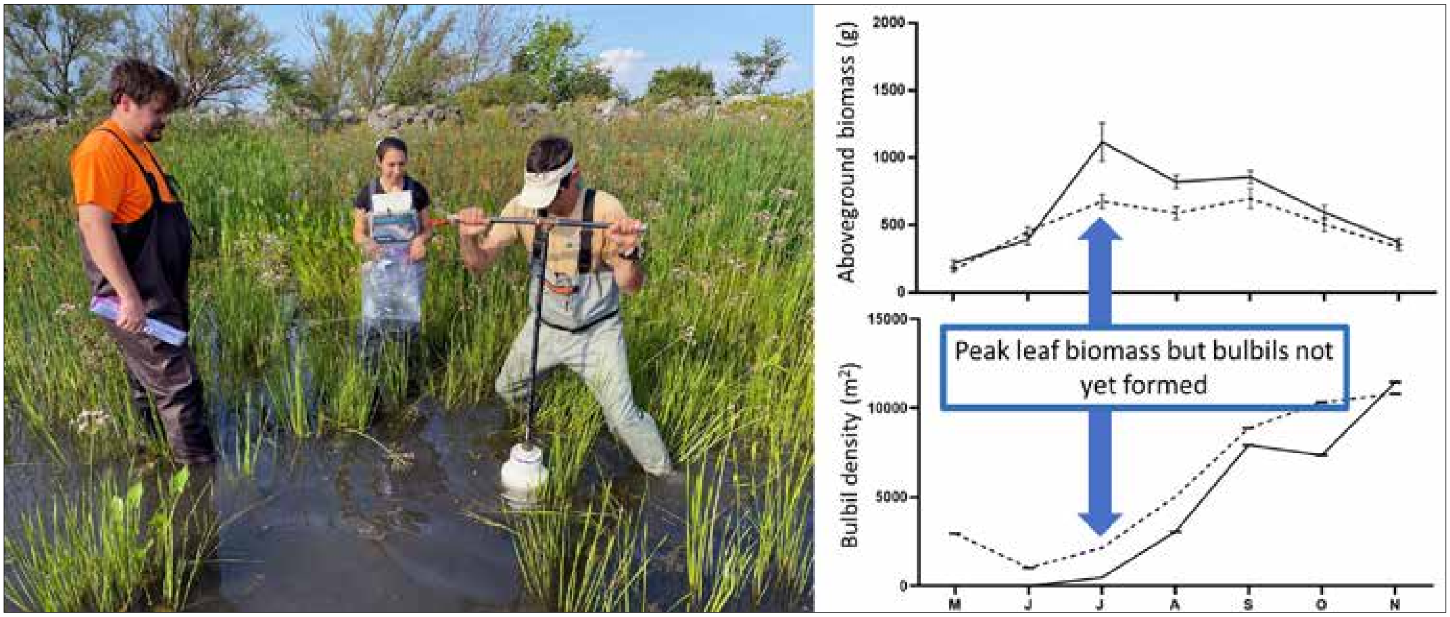


*Figure 1. Phenology studies are being conducted on flowering rush in the Great Lakes and Pacific Northwest to optimize the timing of management. Whole plants were sampled monthly, analyzed for biomass, biomass allocation (roots, shoots, bulbils), starch and starch allocation. Results to date indicate that June/July are the best time for management in the Great Lakes to maximize herbicide contact with leaves and prevent bulbil formation. Flowering rush principal investigators: Nathan Harms, PhD and Bradley Sartain, PhD.*


*Figure 2. Research continues to focus on hydrilla management in the U.S. Major areas of investigation include further understanding of reproductive biology patterns (turions and tubers), field verification of novel chemical control tools and techniques, genetic lineage of populations found in the U.S., strategies for control in high water exchange environments, and deleterious effects of hydrilla on aquatic ecosystems. In addition to these efforts, which focus on existing monecious and dioecious hydrilla genotypes, a new effort has been initiated to explore the biology and management of a novel hydrilla genotype (Clade C) recently found in the Connecticut River. (a) dye study being conducted in a flowing system at Merritt's Mill Pond near Lake Seminole; (b): Connecticut River hydrilla. Hydrilla principal investigator Benjamin P. Sperry, PhD.*

# **Don't Forget** Your Camera

Ian Pfingsten

## Out on the lake

As the season changes and spring sets in, some of us camp, hike, or fish, if not all three. This is the time we find ourselves outside enjoying the warming air and leafing branches as we cast a reel in hopes of a bite. While relaxing on your boat headed to your prime fishing hole, you notice something growing in the water. It looks like a plant you did not see the last time you were at this lake, but you think it might not be worth much attention, and you continue with your day of fishing. Later, as you float into your favorite bass cove, you see the plant again, but this time it is much harder to ignore; the same plant is covering the entire cove from the sediment to the water's surface. As you become more concerned, you start to wonder, what is this plant? How did it get to this lake? Who do I tell about it?

## Resource availability

Several publicly accessible resources for answering these questions exist online that specialize in species that are non-native to the U.S., which means those species have been moved by humans into the U.S. where they are less likely to encounter natural pests or predators. We are most concerned when non-native species are labeled invasive, meaning they are detrimental to the environment, the economy, and human health outside of their native range. If you need to identify an organism, but you lack a field guide or the knowledge to identify it yourself, then submitting a photo to a national distribution database is another option. If the organism is aquatic, there is the U.S. Geological Survey's (USGS) Nonindigenous Aquatic Species (NAS) Database (nas.er.usgs.gov), which staffs taxonomic experts able to identify public sighting reports. Other databases exist for terrestrial and some aquatic invasive organisms which utilize experts, state-officials, and community members for identifications. Many of these databases have phone apps for mobile reporting and the USGS NAS database has a mobile-friendly reporting website (nas.er.usgs.gov/SightingReport.aspx [use this QR code to access the form]). The NAS database also allows anonymous reporting, while the other databases require user accounts. Once the database curators receive and review your sighting report, and the organism fits the criteria for public display on the database website, then you can view your sighting record on a distribution map with other occurrences in your area (Figure 1).

These databases offer an answer to what organism you find, but what about how the organism arrived in its new location? What if you are interested in more information about the organism's life history, distribution, introduction pathways, chemical, mechanical, and biological control options, and its impacts to human health, the environment, or the economy? The same national databases provide distribution maps and informational pages on many of these topics. Specifically, the USGS NAS database provides peer-reviewed profiles containing most of this information on

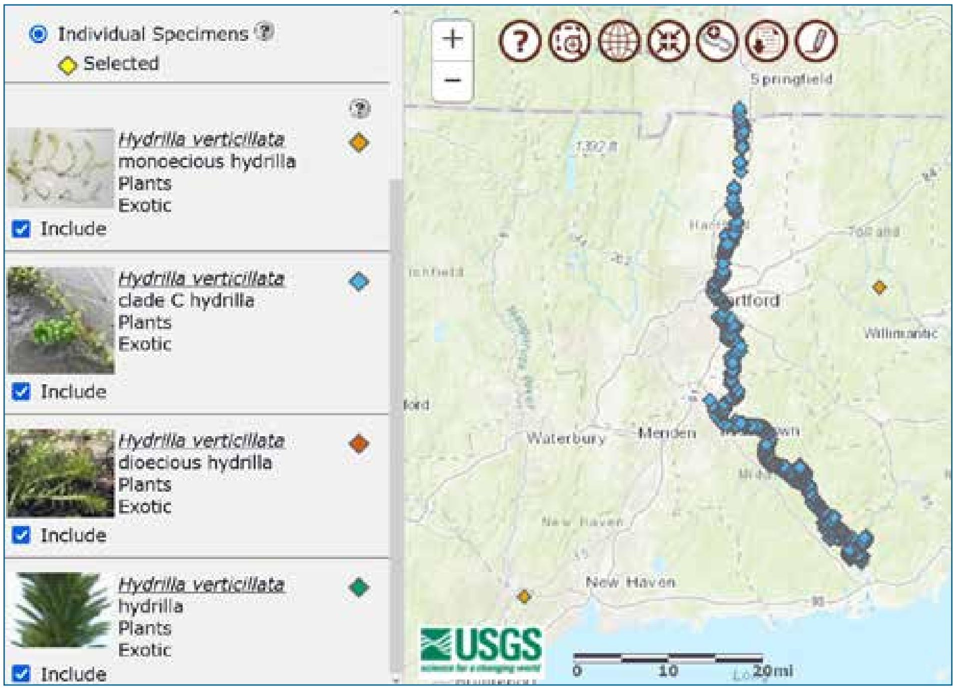


*Figure 1. Distribution map of* Hydrilla verticillata *in Connecticut. Different colored diamonds indicate* H. verticillata *sightings by biotype or clade.*

aquatic non-native species including citations to references found in the searchable NAS reference database. For example, each species profile in the NAS database has or plans to have in the future a section on known species impacts that summarizes the available literature for a variety of environmental, economic, or human health impacts such as habitat alteration, increased toxicity and disease prevalence, and effects on recreation, infrastructure, and water quality. Many detrimental impacts caused by invasive species are not studied or are assumed detrimental based on anecdotal accounts. By collecting published studies on invasive aquatic species impacts, users can quickly and easily locate available evidence for impacts. Combined with the distribution maps of those aquatic species, users of the NAS database can locate where these impacts are likely to occur.

**Responsible stewardship**

While researchers and invasive species coordinators are obvious audiences for these occurrence databases, they also provide public access to the information. This means access to public reporting of sightings and access to species distributions and relevant background knowledge of those species. It also means access to new occurrences of non-native species that may be of interest to the public. The occurrence databases provide new reports of non-native species through alert e-mails to individuals upon request. The NAS database alerts the public of aquatic non-native species that are new to the United States or new to individual states, counties, or watersheds. These alerts inform the public of areas potentially at-risk of further species spread, which can help early detection and rapid response efforts to mitigate detrimental impacts (and why reporting these sightings to the national databases is likewise important). When you report the organism to occurrence databases you are also answering the question earlier about who to contact with your sighting, because these databases share information with each other and with invasive species coordinators who can respond to the introduction.

The combined efforts of the public sending reports of invasive species and the stakeholders involved with managing those invasive species encourages responsible stewardship of non-native plants and animals and the resources most likely affected by those organisms. Outreach to the public is one way to empower those with interest in making decisions that affect themselves and their community. Access to resources for identifying invasive organisms, knowledge of their impacts and how to prevent their further spread, and when and where these organisms are recently found can help to empower responsible stewardship. The USGS continues to work with stakeholders and our national and regional data providers to share this information with the public through a variety of accessible media and tools.

**Future tools**

What do these accessible tools look like? Last fall, Hurricanes Ian and Nicole swept through Florida and decimated coastal towns like Fort Myers. The floods from intense storm surge and rainfall impacted communities and caused widespread damage to the economy and environment. One of those impacts that the NAS database has highlighted since 2017 was the potential movement of aquatic organisms through flood waters caused by these major storms. After Hurricane Harvey devastated southeast Texas in 2017, NAS released its first rendition of the Flood and Storm Tracker (FaST) map showing the watersheds that contained non-native aquatic species prior to a flood event and those watersheds that likely became hydrologically connected due to flooding, providing a potential corridor for aquatic species movement (Figure 2). These interactive maps are hosted on the NAS database and created in two steps: an initial version that provides timely FaST maps via USGS stream gages and National Oceanic and Atmospheric Administration (NOAA) storm surge models to quickly estimate downstream and coastal flood risk and species movement, and a final version of FaST maps that uses USGS stream gages and high-water mark data and NOAA tide sensors to provide evidence of connections between watersheds that occurred through flooding. Having knowledge of where a species is likely to spread by flooding informs the public and stakeholders of where to expect a new invasion of a potentially impactful plant or animal. We plan to improve FaST maps with new water monitoring efforts provided by USGS, NOAA, and the National Aeronautics and Space Administration (NASA).

Sometimes seeing an organism is difficult to near impossible given the time of year or its biology. Sometimes all you are left with is a trace of genetic material from the organism's skin or feces to know if it could be present. This genetic material that is no longer part of the organism is called environmental DNA, or eDNA, and it can be collected and compared to unique strands of DNA that identify the organism. To avoid confusion among the variety of collection and analytical techniques when reporting eDNA detections, the USGS has developed minimum quality standards for displaying eDNA data on the NAS website and maps (Ferrante et al. 2022). This year, NAS plans to begin accepting eDNA reports from those using USGS national standards with the aim of displaying eDNA reports on NAS distribution maps and e-mail alerts to encourage timely and appropriate response by invasive species agencies. Using the best available science on eDNA detections limits reporting of false positive detections that could lead to wasted time and resources in response efforts.

More public products are being developed by USGS to assist in early detection efforts of potentially invasive species introductions. New threats to our environments, economies, and human health are being assessed through collaborations between universities and other federal agencies. One product in development is a nationwide risk assessment of organisms imported into the U.S. This is known as horizon scanning, and the goal is to provide stakeholders with a list of organisms in the trade ranked by their invasive potential in the U.S. We have already finished a national horizon scan for vertebrates imported into the U.S., and we are conducting new horizon scans for invertebrates and plants also in the U.S. trade. A follow-up effort is also underway to determine the hotspots, or potential locations, of invasion by these organisms in the trade into the U.S. by considering suitable habitat conditions that are likely to promote establishment and spread where

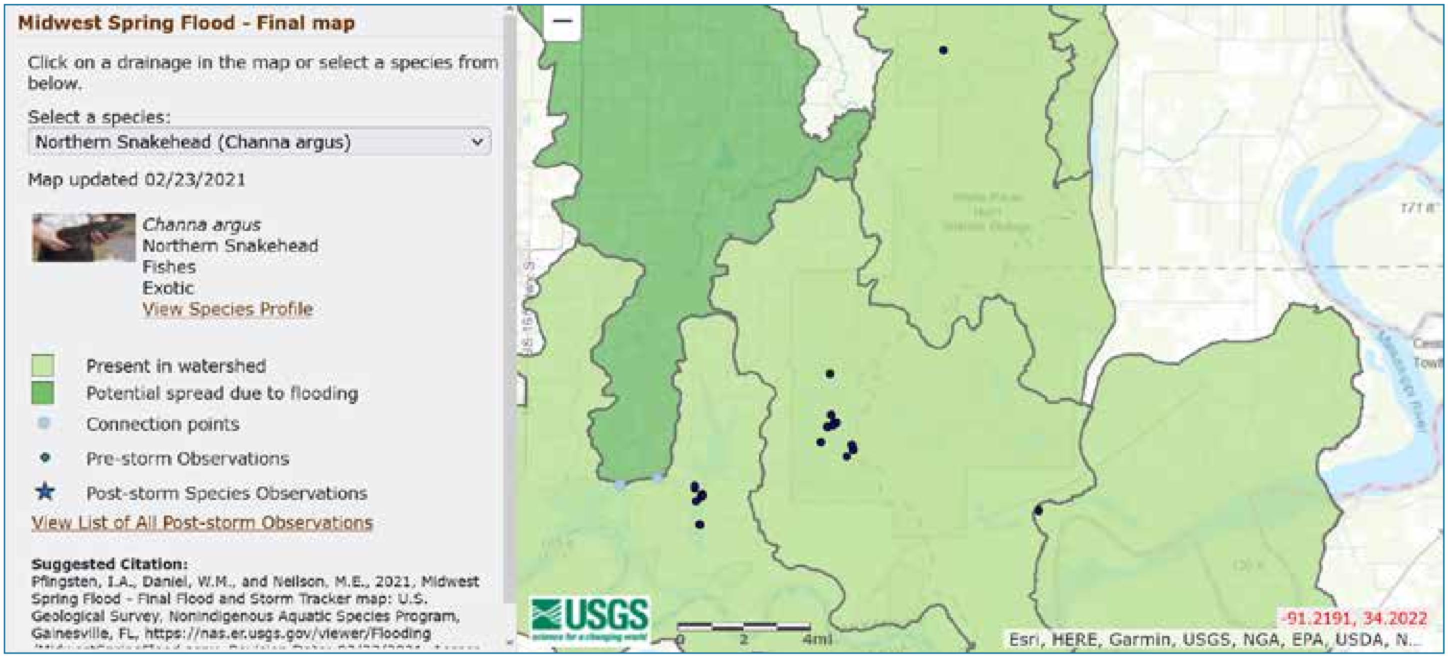


*Figure 2. Example Flood and Storm Tracker map of* Channa argus *(Northern Snakehead) after the Midwest spring flood event in 2019. Light green areas indicate watersheds where* C. argus *is present, and dark green areas indicate watersheds where there is potential for introduction of* C. argus *via flood waters. Locations of* C. argus *sightings are indicated with dark blue dots, and flood connections across watersheds are indicated with light blue dots.*

those conditions are found. In a similar project involving the northeast U.S., we are working with stakeholders to determine the invasive potential of aquatic plants and animals due to climate change, where the focus is on the suitability of habitat conditions in the next fifty years and the likelihood of aquatic organisms spreading from the western and southern U.S. Another NAS product related to human and animal health risks is underway to provide locations of disease-promoting, aquatic organisms, such as the location of submerged aquatic vegetation with high levels of a cyanotoxin that causes brain lesions in birds and reptiles. The goal is for each of these products to be accompanied by a visual component such as a risk map on the NAS database website.

## Return to the lake

Planning another trip out to your favorite fishing spot, you check the weather report and your tackle box. You start to recollect the time when you had all the gear and knowledge you needed, given you had enough bait and patience. The reality sets in that there are additional considerations to enjoyably recreate. From the fishhook waterfleas clinging to your fishing line to the hydrilla tangled on your propellor, these invasive organisms can impact your time on the lake or send you in search of a new pristine fishing hole. Yet, you have access to resources in your smartphone to research, identify, and report the new invasive species found in your lake. With the tools available on the NAS database and other invasive species reporting services, you can provide crucial information needed to reduce the harmful impacts these species may cause in our waters.

You can contact NAS database staff with questions or data requests at: ipfingsten@usgs.gov, 352-264-3517

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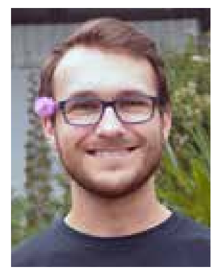

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# **Starry Stonewort:** An Aggressive Invasive Freshwater Macroalga

Brian K. Ginn and Tyler J. Harrow-Lyle

## Introduction

Starry stonewort (*Nitellopsis obtusa*) is a Eurasian macroalga that was first recorded in the 1970s in the St. Lawrence River near Montreal, Quebec, Canada. This aggressive invasive species has since become widespread in the Laurentian Great Lakes Region, particularly in many inland lakes that are used for recreational activities. Rapidly growing during summer, starry stonewort can outcompete most native macrophyte species, and even other aggressive invaders such as Eurasian watermilfoil (*Myriophyllum spicatum*). Because of its ecological and morphological similarities to native charophytes, such as muskgrass (*Chara* spp.), and other stonewort / brittleworts (e.g., *Nitella* spp., *Tolypella* spp.), starry stonewort is difficult to identify and is poorly reported, which has likely enabled it to spread through the Great Lakes Region.

Starry stonewort was featured in a previous *LakeLine* article by Pullman and Crawford (2010); however, much has changed in the years since. Research has been undertaken into the ecology and management of this invasive species, and there are now targeted efforts toward reporting, tracking, and preventing the spread of starry stonewort. Here we present our experiences with understanding the ecology and predicting the spread of this invasive species in south-central Ontario, Canada, which are no doubt similar to other experiences and management efforts across the invaded range.

## Experiences in Ontario

Currently, in south-central Ontario, Canada, starry stonewort has been mostly found along the Trent-Severn Waterway (TSW) (Figure 1a), a canal system connecting Lake Ontario to Georgian Bay in Lake Huron. Completed in the 1920s as a transportation corridor, but now mainly used by recreational boaters, this canal system has enabled the spread of many invasive species between lakes including zebra and quagga mussels (*Dreissena* spp.), Eurasian watermilfoil, round goby (*Neogobius melanostomus*), and spiny waterflea (*Bythotrephes longimanus*).

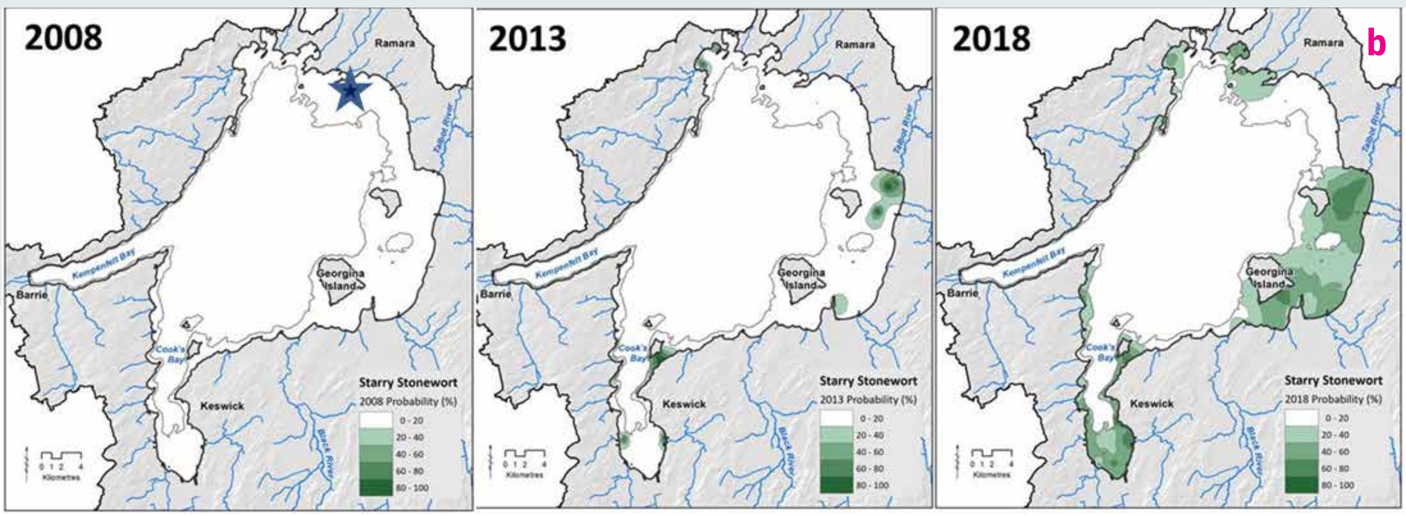
The first reports of starry stonewort in Ontario were a “weedy chara” reported in 2009 at a Presqu’ile Bay marina near Brighton, on Lake Ontario, at the eastern terminus of the TSW. In Lake Simcoe, bulbils were recovered in a benthos sample in 2009 and in 2010 a marina experienced a large increase of a “tangled weedy plant” following application of the herbicide diquat, used to control Eurasian watermilfoil. In the years since, the Lake Simcoe Region Conservation Authority’s aquatic plant monitoring program tracked the expansion of starry stonewort across Lake Simcoe (Figure 1b, Ginn et al. 2021). From our initial record in 2009, starry stonewort increased to 33 percent of total lakewide aquatic plant biomass in 2013 and 67 percent in 2018.

In 2015, starry stonewort was identified by the Scugog Lake Stewards in Lake Scugog, a large, but shallow reservoir that is a major headwater of the TSW. For decades, the aquatic plant community was dominated by Eurasian watermilfoil for most of the growing season, however, a severe population collapse of Eurasian watermilfoil was documented (Harrow-Lyle and Kirkwood 2022) following starry stonewort establishment. The rapid increase in the amount of starry stonewort in these and other locations highlights the aggressive nature of this invader, particularly at the expense of Eurasian watermilfoil, another invasive considered to be equally aggressive in some locations.

Similar to other aquatic macrophytes, starry stonewort populations have proven to be dynamic over the monitoring period. In 2019, starry stonewort was 68 percent of the aquatic plant biomass (Figure 2) in Cook’s Bay, a shallow (maximum depth 15 m) nutrient-enriched embayment at the south end of Lake Simcoe where it was first recorded in 2011. During the 2020 aquatic plant survey in Lake Simcoe, a large (~79 percent) decrease in starry stonewort was recorded, with similar phenomena anecdotally reported in Lake Scugog and in some smaller adjacent lakes along the TSW.

The cause of this population decrease, which continued into 2021, is currently being investigated. Harrow-Lyle and Kirkwood (2022) have previously determined that lake depth and cation (calcium, potassium, sodium, and magnesium) concentrations are important drivers of starry stonewort distribution. However, since there were no significant differences in environmental variables in either Lake Scugog or Lake Simcoe in 2020-21 relative to previous years, the cause of the recent declines are likely related to unique regional conditions that occurred during this time period. In 2022, the amount of starry stonewort increased in Lake Simcoe, an increase that occurred alongside the existing aquatic plant biomass, instead of outcompeting other species as in the past (Figure 3). Similarly, the biomass of starry stonewort increased in the shallow (average depth of 1.4 m) western basin of Lake Scugog. In contrast, the eastern basin of Lake Scugog (average depth of 7.6 m), had very little starry stonewort biomass in comparison to other years, and was almost exclusively composed of native stoneworts.


Figure 1. (a, at left) map of south-central Ontario showing the location of the Trent-Severn Waterway (blue line), (b, below) map of Lake Simcoe showing expansion of starry stonewort from 2008-2018, star denotes site of first bulbil recovery (b is re-drawn and modified from Ginn et al. 2021).



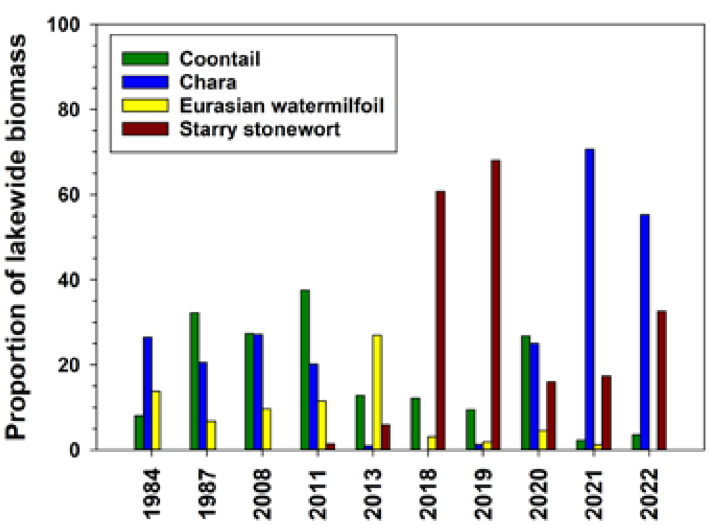




Figure 2. Proportion total aquatic plants that was starry stonewort in Cook's Bay, Lake Simcoe, 1984-2022.

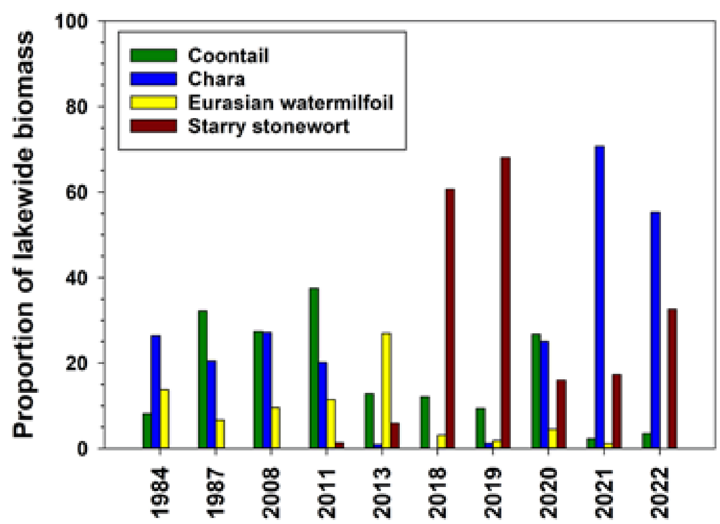



Figure 3. Proportion of aquatic plant community in the four most common species in Cook's Bay, Lake Simcoe 1984-2022.

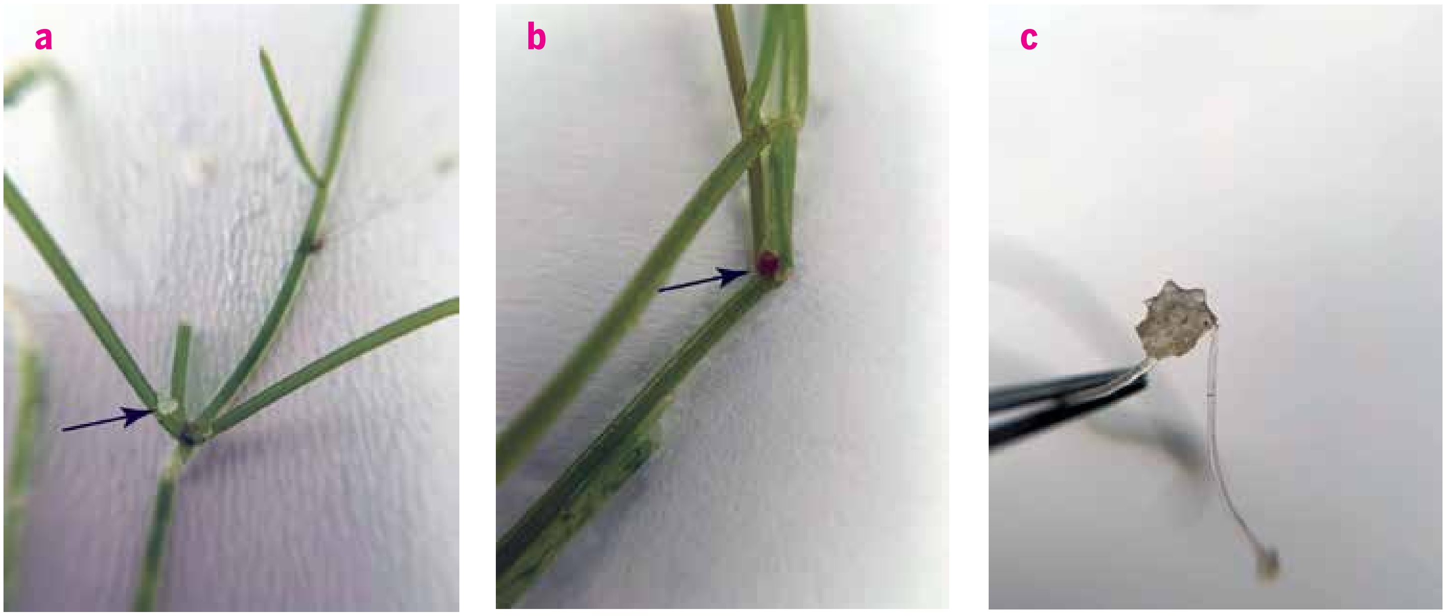



*Figure 4. Reproduction structures recorded from starry stonewort in Lake Simcoe and Lake Scugog: (a) female oogonia, (b) male antheridia, and (c) bulbil attached to rhizoid.*

In addition to the rebound of starry stonewort in 2022, we recorded the first instances of female reproductive structures (oogonia; Figure 4a) on starry stonewort in Lake Simcoe and Lake Scugog (Harrow-Lyle et al. 2023). Up until then, only male individuals of starry stonewort, identified by the presence of orange spherical gametangia (Figure 4b) had been reported in North America, and reproduction was thought to be through vegetative means, such as fragmentation and bulbils (Figure 4c). The explanation for this sudden occurrence of female individuals is interesting and more research is required. Likely scenarios include an environmental trigger such as changing climate conditions and longer growing seasons, or possibly as a response to the population decline during the two previous years.

## Future expansion in Ontario

Although there have been many reports by the public that starry stonewort has invaded numerous lakes across south-central Ontario, the actual range distribution has not been fully established partly due to the prevalence of misidentification. Furthermore, in Ontario, there is a geological transition zone known as "The Land Between," representing a transition between limestone and granite-dominated parent bedrock (Figure 5, Harrow-Lyle and Kirkwood [in review]. The geology of the landscape is the main driver for a gradient of water hardness, most commonly measured as calcium carbonate ($CaCO_3$), which is important to starry stonewort and other stoneworts that benefit from bicarbonate as a carbon source for growth. Widespread monitoring for all components of aquatic habitat that could be conducive to starry stonewort invasion is not routinely undertaken in Ontario; however, essential parameters such as water hardness and calcium concentration are collected for a subset of lakes.

To date, starry stonewort appears to be relegated to shallow lake environments across south-central Ontario. Even so, Pullman and Crawford (2010) have documented that when all available habitat is colonized, starry stonewort will move to deeper habitats. Starry stonewort, and stoneworts in general, have been documented to grow at depths of 75 m, thus it is plausible that using depth as a habitat-defining characteristic may not be appropriate. Furthermore, stoneworts have a low light compensation point, therefore identifying conducive habitats based on water clarity may also not be appropriate. Until the full extent of chemical, physical, and biotic factors involved in starry stonewort invasion are elucidated, we think water hardness ($CaCO_3$) or calcium concentrations remain an important habitat constraint that should be considered.

By evaluating calcium concentrations available from the Ontario Lake Partner Program, we identified 170 lakes across Ontario with calcium concentrations that are conducive for present and future starry stonewort colonization (Figure 5; Harrow-Lyle and Kirkwood [in review]). Ultimately, the invasion of starry stonewort across Ontario lakes appears to be much more constrained than in bordering US states in the Great Lakes Basin, where the underlying parent material is dominated by limestone. Conducting further research is necessary to generate refined invasion risk assessments, which incorporate additional habitat characteristics (e.g., manganese and potassium concentrations, and site hydrodynamics) that support starry stonewort invasion across North America.

## Management

Starry stonewort has the reputation in the Great Lakes Region for being very difficult to manage or eradicate. In Ontario, we have noticed that herbicides, such as diquat, seemingly have no effect on this invader and may actually increase starry stonewort biomass by killing competing species (such as Eurasian watermilfoil). In a canal estates community and several private marinas on Lake Simcoe, diquat has been applied annually to control Eurasian watermilfoil for aesthetic reasons and to allow boat traffic. Although Eurasian watermilfoil has been mostly eliminated at these sites, there has been a large increase in the

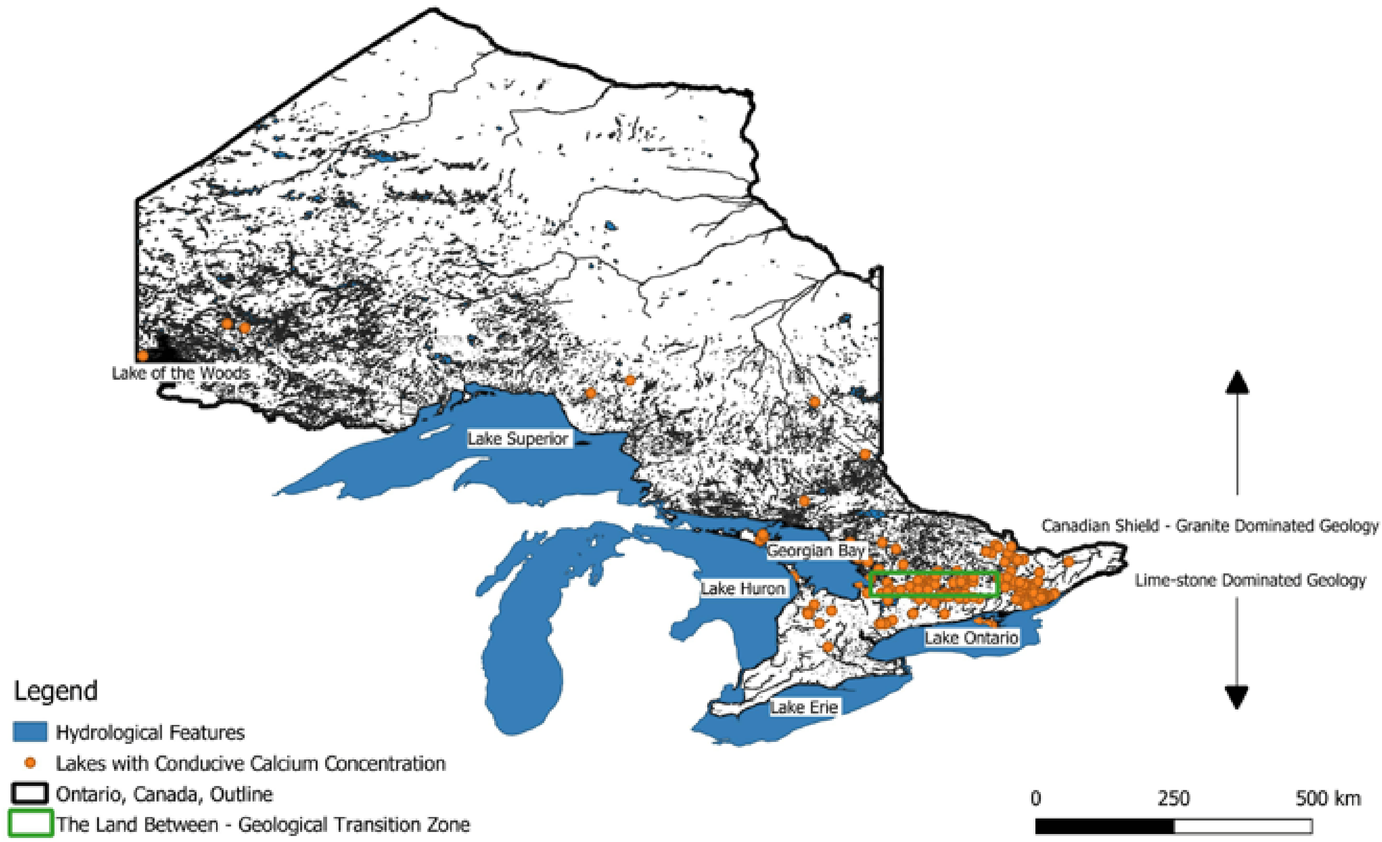



*Figure 5. Ontario lakes with calcium concentrations conducive for starry stonewort survival and future invasion.*

amount of starry stonewort to the point where backhoes and digging equipment are required to remove truckloads of biomass to keep waterways open.

Not widely used in Ontario, copper-based herbicides / algaecides have been tested in the USA with limited success. These algaecides seem to be effective at killing the top portion of a starry stonewort mass, but the lower part can often survive and overgrow the dead area above it. Copper algaecides offer some reduction in biomass when combined with mechanical harvesting. However, they seem to be ineffective at inhibiting bulbil viability in the sediments and thus treatments need to be repeated for several growing seasons (Glisson et al. 2018; Pokrzywinski et al. 2020). There has been some success with hand removal or hand pulling and diver-assisted suction harvesting (i.e., DASH) of starry stonewort, although these methods seem most effective in the early stages of the invasion where patches are small and relatively easy to access (Figure 6a). Mechanical harvesting of aquatic plants has been carried out in a limited capacity on Lake Simcoe, usually in response to aesthetic complaints from shoreline property owners, and has almost exclusively targeted Eurasian watermilfoil.

Strategic use of mechanical harvesters and hand tools (rakes and gas-powered pole saws) has been used at Friday Harbour, a marina condominium community on Lake Simcoe, in order to control Eurasian watermilfoil and starry stonewort. A mechanical harvester (Figure 6b) is used to trim Eurasian watermilfoil to a depth of one meter below the water surface. The remaining plant material attached to the bottom, and shorter growing native pondweeds, then serves as a shade to limit light reaching the substrate and prevent growth by starry stonewort. Hand tools are used along docks and piers to reach areas that cannot be accessed by the mechanical harvester. All harvested plant material is removed from the marina to reduce regeneration from cuttings. Although starry stonewort has been reported in this marina community, it has so far remained at a very low biomass compared to other locations on Lake Simcoe and other marinas that rely solely on diquat applications as a control strategy. The disadvantages of this harvester and hand tool method are the capital cost of the mechanical harvester and the amount of labour involved, particularly during the peak summer growing season for aquatic plants.

Despite these management efforts, fragmentation and the persistence of bulbils make any management option a multi-year initiative. Additionally, even though hand removal as a treatment seems like a gentle alternative to mechanical harvesting or herbicide application, Ontario legislation limits the cropping of aquatic plant beds in order to protect this vital fish habitat. However, the quality of fish habitat comes into question when starry stonewort is the dominant macrophyte. By outcompeting and overgrowing native aquatic plant species (Figure 6c), starry stonewort also alters the structure of shallow water habitats. In an aquatic plant community dominated by native species, and to some degree even Eurasian watermilfoil, the underwater habitat resembles a forest (Figure 7a) with many shelter spaces and nursery areas for warmwater species (e.g., perch and bass,


*Figure 6. Aquatic plants management strategies for starry stonewort: (a) hand-pulling at boat slip, (b) mechanical harvester in marina, (c) starry stonewort overgrowing native muskgrass.*

bait fish, and ambush predators such as northern pike, walleye, and muskellunge). Starry stonewort restructures this habitat space into a tangled mass of macroalgae (Figure 7b) that greatly limits available habitat space, displaces small fish into open water, and can force ambush predators to alter their hunting behavior to a more energetically costly pursuit strategy. In addition, our research on Lake Simcoe and Lake Scugog has shown that masses of starry stonewort reduce dissolved oxygen, which may further decrease fish habitat quality. In a native plant community, dissolved oxygen values average 9 mg/L, compared to hypoxic conditions (2 mg/L) within starry stonewort masses. Furthermore, these low dissolved oxygen values can facilitate internal loading of dissolved phosphorus from sediments, which can stimulate more algal and macroalgal growth as well as impede nutrient reduction strategies.

## Conclusions

Starry stonewort is an aggressive invasive species that is widespread in the Great Lakes Region and continues to spread to new areas each year. Lakes with sufficient nutrient and cation concentrations, as well as boat traffic, seem to be most at risk for colonization and establishment. Currently, management and eradication options for this species are limited, however research is on-going to find a sustainable method for biomass control. Difficulty in identifying starry stonewort, and its similarity to native species makes tracking the spread challenging, however concerted identification training and reporting events are making the public more aware and involved. Our experiences in Ontario are similar to other areas, particularly Upstate New York, Michigan, and Minnesota. Using a coordinated effort, sharing information and research, and educating recreational lake users will, hopefully, lead to solutions in managing starry stonewort and other invasive species.

## Acknowledgements

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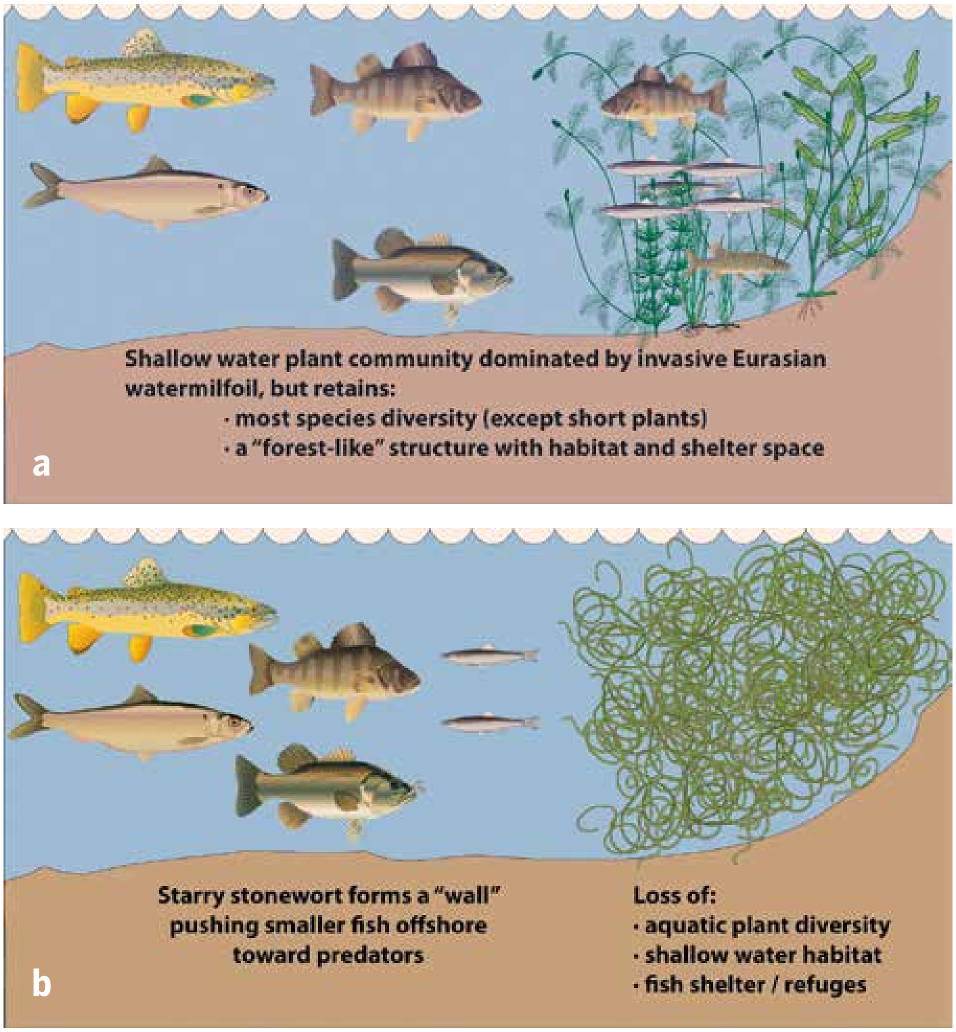


*Figure 7. Structure of shallow water fish habitat: (a) dominance by native plants and / or Eurasian watermilfoil, and (b) dominance by starry stonewort.*

as well as the Huron Wendat and Metis Nation of Ontario – Region 7, whose lands and waters we traversed in our research and monitoring. We thank D. Leeder of Hutchinson Environmental Services Ltd. and Friday Harbour Resorts for sharing insights into their aquatic plant management program; A. Kirkwood, M. Moos, and P. Strong for their thoughtful suggestions; and D. Campbell for Figure 1.

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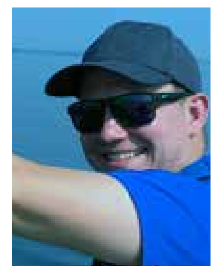

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# Strategies for Improving Participation in a Statewide Volunteer Monitoring Program for AIS

Angela De Palma-Dow and Jo A. Latimore

## Introduction

Many invasive species prevention, monitoring, and management programs prioritize public involvement because of the role humans play in spreading invasive species and the impacts they have on public enjoyment and value of ecosystems. For example, the program we explore here is a volunteer monitoring program for aquatic invasive species (AIS) in lakes that takes a community science approach to early detection and monitoring.

Typically, plant identification, methods, and tools for monitoring are taught at mostly in-person workshops, trainings, or education and outreach events. During the COVID-19 pandemic, many volunteer-centric programs were reduced, modified, or temporarily cancelled, especially while state or local resources shifted to support public health sectors. Statewide and regional volunteer-led monitoring programs are no exception, and many were disrupted during the pandemic. Now that the pandemic is in decline, managers restarting or revitalizing community science volunteer programs might be looking for ideas to jumpstart participation or refreshers to improve methods and strategies for successfully engaging volunteers. Here we describe the lessons we learned while working to improve participation in a state-wide community science invasive plant volunteer monitoring program, before COVID, that may provide some valuable insights to those programs restarting or getting off the ground.

Community science is a powerful tool for conservation, education, and ecological management. Ecological community science programs connect the lay person to a resource of interest, making these community members more connected to their environment and therefore more invested in the policies that regulate and influence these ecosystems. In fact, when community members participate in community science projects and efforts, they tend to share their learned ideas and values with others, expanding the significance of community science itself.

Well-designed AIS monitoring programs provide large scale bio-monitoring and high-quality data that can be used by state natural resource agencies, researchers and the public. Consistent monitoring of aquatic systems for invasive species facilitates early detection and eradication before invasions become unmanageable. Community members who live near or regularly visit an aquatic system can serve as the first line of defense against new AIS introductions. In terms of the number of aquatic systems monitored, as well as the frequency of monitoring, volunteer AIS monitoring represents a valuable asset especially considering the efforts of natural resource management agencies, which are limited by available funding and personnel resources.

## History of Michigan's Cooperative Lakes Monitoring Program and the Exotic Aquatic Plant Watch

The Michigan Clean Water Corps (MiCorps) volunteer monitoring program is a partnership-based program involving state, academic, and regional organizations and local volunteers. Within MiCorps, the Cooperative Lakes Monitoring Program (CLMP) has been providing technical assistance, training, and other support to lake volunteers since 1974, making it the second-oldest lake monitoring program in the U.S. Hundreds of volunteers monitor 250-300 lakes through MiCorps each year. CLMP volunteers can choose from a variety of limnological parameters to monitor throughout the ice-free season, including water clarity (Secchi disk depth), total phosphorus (TP), chlorophyll-*a*, dissolved oxygen and temperature, shoreline habitat quality, and aquatic plants. One purpose of the CLMP is to provide volunteers a standardized approach for monitoring the ecological status and trends in their lakes, with the support of CLMP staff biologists, so that the data generated are reliable and comparable through time and across the state.

The Exotic Aquatic Plant Watch (EAPW) is one of the newer components of the CLMP. This program provides valuable aquatic invasive species (AIS) data to community members, local decision-makers, and state managers. Michigan has approximately 11,000 lakes five acres or larger, and state agency funding and personnel constraints make it hard for them to consistently monitor for AIS. The engagement of volunteers in AIS monitoring using the pre-existing CLMP community monitoring network provided a feasible solution for establishing an early-detection and long-term monitoring network for AIS.

The purpose of the EAPW is to provide volunteers with a simplified protocol for detecting and monitoring invasive aquatic plants, increasing the probability of early detection while simultaneously providing education and outreach about the role of aquatic plants in lake ecosystems. The EAPW focuses on five species: Eurasian watermilfoil (*Myriophyllum spicatum*), curly-leaf pondweed (*Potamogeton crispus*), hydrilla (*Hydrilla verticillata*), starry stonewort (*Nitellopsis obtusa*), and European frog-bit (*Hydrocharis morsus-ranae*). Only hydrilla is not currently established in Michigan.

### Volunteer methods for EAPW monitoring

Before completing a survey, volunteers attend a required training session that covers the sampling protocol, plant identification, and the reporting process, followed by hands-on plant identification practice using dried and fresh specimens. In addition, volunteers learn to submit unknown plant samples to program staff for identification by placing plant samples between moist paper towels, placed in zip-top plastic baggies and sent through the mail. Plant sample photos are now permanent EAPW requirements as mobile phone camera technologies are more widespread and dependable.

When designing the EAPW methodology (www.MiCorps.net) , we attempted to keep the protocol volunteer-friendly by intentionally focusing on a limited number of species, allowing low-tech alternatives options for recording and submitting data (i.e., allowing data to be submitted on paper rather than directly into the online MiCorps database) and making ourselves available to provide support.

During COVID, many educational efforts refrained from providing outreach and guidance face-to-face, and instead, many digital methods were developed to reflect the same information and could be easily accessed from a mobile phone or computer.

### Challenges to enrollment and reporting

Although public interest in the EAPW has been great since it was launched in 2011, evidenced by high attendance at annual training sessions, volunteer enrollment and report completion rates were initially low. For example, in 2011, of all lakes enrolled in the CLMP, only 11 percent (23 of 211) chose to join the EAPW program. Of those that did join, less than half (43 percent) reported any results at the end of the monitoring season.

These trends led us to ask some important questions:

*What motivates volunteers to enroll in this program?*
*What might discourage enrollment?*
*Why do many enrolled lakes not report any results?*
*What tools or strategies were helpful in increasing enrollment and reporting?*

We used four approaches to answer our questions, including:

- Conducting a national program review by interviewing managers and coordinators of other statewide AIS volunteer monitoring programs to identify how they addressed challenges similar to ours.
- Conducting lake visits with volunteers during four field seasons (2013-2016) to identify technical challenges and gather volunteer feedback.
- Tracking participation, enrollment, and reporting trends and participant feedback to better guide improvements and implement strategies.
- Developing and evaluating new tools and strategies to help increase participation and reporting

### AIS program review

In general, volunteer retention strategies in community science programs are well-researched and documented, but specifics pertaining to volunteer involvement in aquatic invasive plant monitoring programs are less known as evidenced by the limited number of comparable programs we were able to identify. At the time of our review, we were only able to identify 11 AIS monitoring state or regional programs in the U.S. that contained some component of AIS monitoring.

Program directors we interviewed identified keys to successful volunteer participation, including acknowledging volunteers' efforts, increasing online usability (e.g., ease of use when uploading and downloading data), and relying on multiple training events in locations around their state to minimize volunteers' need to travel long distances to attend. Of course, during the pandemic, traveling to in-person training events was no longer a viable option, and long-distance learning and remote trainings were established as the default. Many programs that existed through the pandemic probably now have a library of online training tools that can help to supplement and support the in-person requirements needed for volunteers to participate in community science programs.

### Lake visits

We conducted lake visits over four monitoring seasons (n=41, 2013-2016). A typical lake visit would start with a review of the major points covered during classroom training, including the overall goal of the program, with a strong emphasis on identifying and mapping only the four species on the EAPW (rather than a comprehensive plant inventory). During the visit we would provide guidance on the best places to survey such as boat ramps, public parks and beaches, and inlets and outlets that are high-risk locations for AIS introductions. We worked with the volunteers to identify any challenges they faced while completing the EAPW protocol (Figures 1 and 2). We observed the processes of plant surveys, plant identification, and reporting, and directly asked the volunteers about their concerns. We usually did not complete the entire lake survey during a lake visit. The intent was to identify the challenges volunteers encounter when executing the survey, identifying the AIS plants in their lake, and recording and uploading their data reports.

During the pandemic, some strategies were developed that remain useful today, including an online "mid-season check-in" event, to address questions and concerns and to provide tips and tricks to conducting surveys without in-person guidance. This tool is continued practice in the program today, for the entire CLMP not just the AIS monitoring portion.

We discovered four main challenges facing EAPW volunteers during our lake visits. First, many volunteers were unsure how to select sampling locations in their lake. Second, we learned that when surveys were completed and no AIS were found, many volunteers did not realize that they should submit this "negative data." Absence of AIS is important information, but without a report, these negative results were not included in EAPW database and we were led to assume that volunteers had not completed the survey. Third, many volunteers lacked confidence in their ability to accurately identify plants. Many were also unsure how to obtain help in confirming the identity of a possible AIS, although some

*Figure 1. Volunteers in Gull Lake, MI, learning how to distinguish between native aquatic plants and invasive plants from CLMP EAPW Staff* (Photo: Angela De Palma-Dow).

*Figure 2. Volunteers learning how to enter data into EAPW datasheets in Lake Pleasant, Washtenaw County, MI* (Photo: L. Nordeen).

volunteers were comfortable following program instructions to send specimen samples in the mail for staff verification. Finally, some volunteers reported feeling overwhelmed by their task, and pressured to complete the survey alone with little support from others in their lake community.

Reporting rates for those lakes receiving a staff lake visit were higher each year than both the non-visited and overall reporting rate for that year (visited lake reporting range: 70-100 percent; overall range: 63-79 percent; non-visited range: 10-58 percent). These differences were significant when using a Chi-square test of independence to compare reporting rates between visited and non-visited lakes ($X^2 = 33.3$, $p<0.001$, df=4).

## Clarifying program value and expectations

Based on the results of our investigations, we implemented several changes to the EAPW to increase enrollment and reporting by volunteers (Table 1). Uncertainty about program specifics that was likely limiting volunteer enrollment and success was addressed through the redesign and distribution of educational and promotional materials. These materials included an updated full-color program brochure and two newsletter articles that were distributed in hard copy and online, targeting the entire MiCorps CLMP community. The brochure and articles specifically emphasized (1) the importance of the program for protecting Michigan lakes, (2) the importance of regular monitoring for new invasions even where a lake management plan exists or a lake management company has been retained, (3) the time commitment needed to conduct a thorough EAPW survey, and (4) supporting resources for plant identification. All of these materials are available on the MiCorps website in the EAPW document section at: https://micorps.net/lake-monitoring/clmp-documents/.

## Tools to boost volunteer capabilities and confidence

To improve volunteer confidence in plant identification, we provided a new waterproof field guide to selected invasive aquatic plants in Michigan. This guide, provided to all enrolled volunteers, contains large, colorful photos of 11 specific invasive species of concern, including the four EAPW focus species, as well as USDA location information and QR codes for quick, digital access for more information.

We also created and distributed a heavy-duty, waterproof, laminated photography card to make it easier for volunteers to submit field photos of plants for identification help (Figure 3, a and b).

**Table 1.** Summary of identified barriers to participation in EAPW program.

| Barrier | Action(s) Implemented |
|---|---|
| 1. While volunteers were aware of the program's existence, they were unclear about its important and necessary role in providing useful data and the realistic amount of time and effort it takes to complete. | i. Distribution of program brochure to educate volunteers about need to be active citizens when surveying for AIS.<br>ii. Published newsletters and blog post on MiCorps web forums about the importance of collecting AIS data in lakes. |
| 2. Volunteers expressed uncertainty and low confidence in correctly identifying plants when executing the EAPW | i. Maintained hands-on ID activities during annual training events<br>ii. Creation and distribution of a Michigan-specific water-resistant, pocket-sized AIS plant field guide. |
| 3. Volunteers were uncertain how to ask for help with plant identification | i. Encourage digital photographs and electronic correspondence of those photos with program staff<br>ii. Creation and distribution of a laminated water-proof "scale-sheet" with pro tips about taking plant photos for ID and where to send them for fast confirmation response. |
| 4. Volunteers felt unsure where to start survey and general uncertainty in following survey protocol | i. Improved clarity and step-by-step methods for survey protocol during annual training events.<br>ii. Back side of laminated water-proof "scale-sheet" included abbreviated program protocols about where in the lake to prioritize sampling efforts. |
| 5. Volunteers did not think they needed to submit reports when they did not find an AIS in their lake. | i. Update of survey data sheet with required section containing check box when no AIS were detected.<br>ii. Emphasized the importance of submitting non-detect report. |
| 6. Feelings of being overwhelmed with EAPW tasks or not having enough support from other lake residents / community to complete surveys and submit reports. | i. Created and implemented teamwork training modules during annual training events<br>ii. Create and distribute "team work tips" factsheet to help volunteers identify what kinds of help they needed and where/how to ask for that help. |
| 7. Need for more emphasis on award or acknowledgement system to successful lake and volunteers. | i. Encouraged veteran volunteers to write blog posts to share their experiences with EAPW.<br>ii. Encouragement and registration of volunteers to present their lake's story at year-end conferences |
| 8. More user-friendly web platform for training and protocol review / refreshers. | i. Increased advertisement and training of available online resources such as data sheets, updated methods documents, step-by-step mapping tutorials, and videos of example surveys.<br>ii. Production and advertisement of 10-minute online EAPW training video published on YouTube and the program website. |
| 9. Regional training and support was lacking. | i. Additional training opportunities to be offered in other parts of the state. For example, to date all EAPW annual training events have only been offered in the Lower Peninsula. Starting in 2017, trainings offered in the Upper Peninsula will provide volunteers in the far northern areas of the state an opportunity to get staff-led instruction and training.<br>ii. Encouragement and instruction for volunteers to contact experienced, nearby EAPW volunteers or their local Cooperative Invasive Species Management Area (CISMA) for additional assistance. |
| 10. Monitor enrollment, completion and reporting trends. | i. In order to identify if efforts are resulting in positive improvements in the program, yearly reports and analysis on enrollment and reporting rates between 2013 -2016 summer seasons were conducted to identify what aspects of the program were or were not improving so further action could be continues, eliminated, or improved. |

Sources of barrier identification included pre-season questionnaires (n=36), staff lake visits (n=41), interviews with AIS monitoring program directors from other states (n=9), and casual conversation and discussions at annual conferences and training events.

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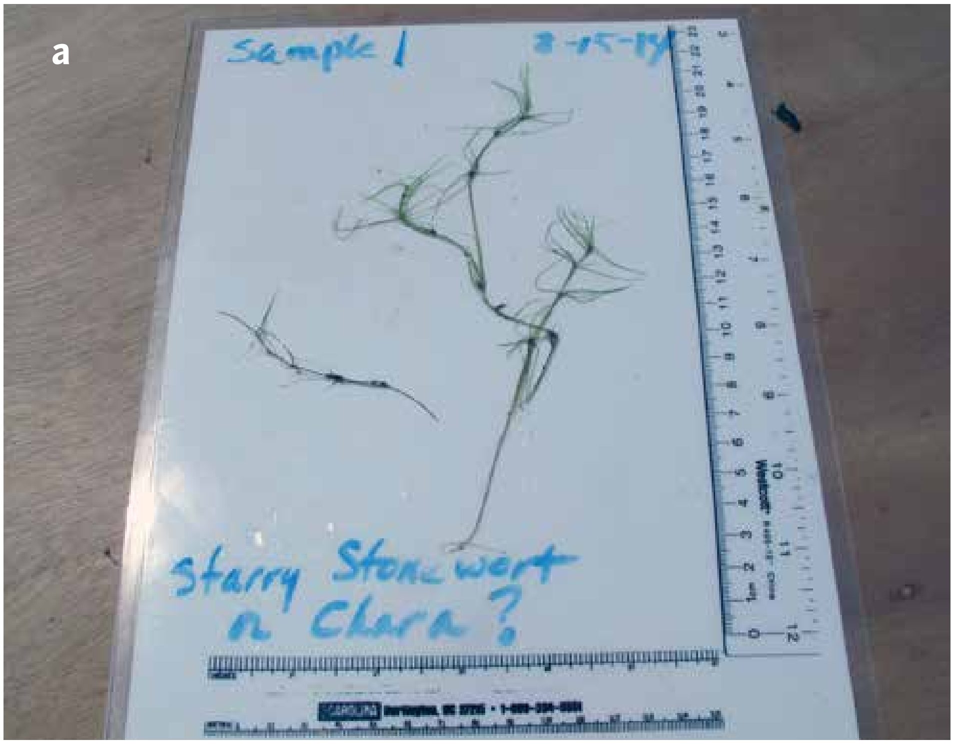


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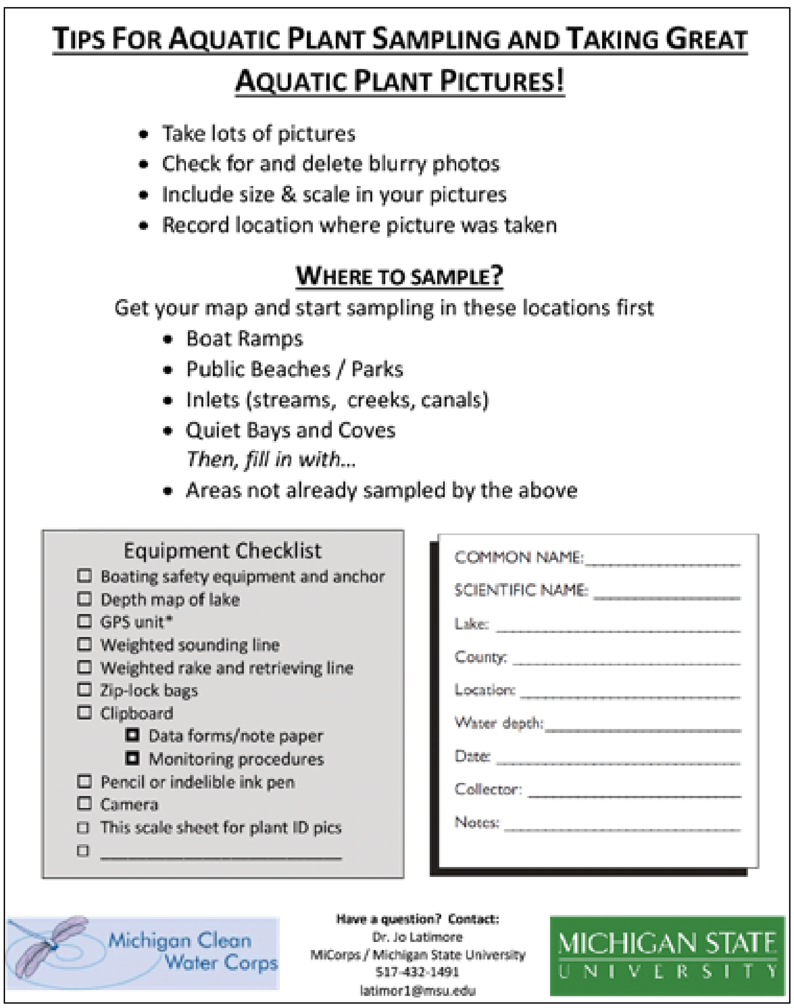

## TIPS FOR AQUATIC PLANT SAMPLING AND TAKING GREAT AQUATIC PLANT PICTURES!

- Take lots of pictures
- Check for and delete blurry photos
- Include size & scale in your pictures
- Record location where picture was taken

### WHERE TO SAMPLE?

Get your map and start sampling in these locations first

- Boat Ramps
- Public Beaches / Parks
- Inlets (streams, creeks, canals)
- Quiet Bays and Coves

*Then, fill in with…*

- Areas not already sampled by the above

Equipment Checklist

- ☐ Boating safety equipment and anchor
- ☐ Depth map of lake
- ☐ GPS unit*
- ☐ Weighted sounding line
- ☐ Weighted rake and retrieving line
- ☐ Zip-lock bags
- ☐ Clipboard
  - ☐ Data forms/note paper
  - ☐ Monitoring procedures
- ☐ Pencil or indelible ink pen
- ☐ Camera
- ☐ This scale sheet for plant ID pics
- ☐ ____________________

COMMON NAME: ____________
SCIENTIFIC NAME: ____________
Lake: ____________
County: ____________
Location: ____________
Water depth: ____________
Date: ____________
Collector: ____________
Notes: ____________

Michigan Clean Water Corps

Have a question? Contact:
Dr. Jo Latimore
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*Figure 3. (a): Submitted plant sample from EAPW volunteer on program-provided scale sheet, and (b): reverse side of scale sheet with steps to taking good digital photo tips and suggestions on where to sample for invasive plants.*

Photo validation tools and electronic submission can ensure accurate identification of species and quality control because validation of the observation is recorded and because photos can be easily and quickly sent electronically to CLMP staff for confirmation, volunteer confidence in their identification skills is enhanced, and this positive feedback encourages improved monitoring.

To ensure the reporting of negative data, we promoted the idea that "the absence of data is data" and added a specific learning objective to EAPW training along with a prominent instruction and check box on the datasheet to encourage volunteers to take a positive action (i.e., checking a box) in the event no invasive plants were found. We also clarified protocols to include a report requirement, regardless of plant survey results.

## Not going it alone

Volunteers' concern about the difficulty of completing plant surveys alone was substantial, and in response we focused on promoting a teamwork approach to lake volunteering. In addition to creating a more fun and welcoming experience for participants, the importance of increasing the teamwork training and opportunities for the EAPW volunteers is two-fold: to ensure both immediate (survey completion) and long-term (community understanding and engagement) goals of the program. To support a team approach to the EAPW, we developed a "Teamwork Tips!" (https://micorps.net/wp-content/uploads/2017/12/CLMP-ExAqPlant-Teamwork.pdf) handout that we provided to all CLMP volunteers, which formed the basis of a teamwork training module in 2015 and 2016. These tips are still provided to enrolled lakes and considered valuable by participants.

The goal of the teamwork training module was to provide guidance and resources on: (1) how to convince others that monitoring for AIS is important, (2) finding and recruiting local short-term or long-term help and, (3) demonstrating how fun and easy participation in the EAPW can be. The teamwork training and handout also included testimonials and advice from successful EAPW volunteers, which provided an opportunity to simultaneously acknowledge successful

EAPW volunteers as well as promote communal encouragement and guidance to newer or struggling volunteers. This strategy is probably the hardest to resurrect in a post-COVID volunteer science world, as working with a small or large group of people in a small space, such as a classroom or on a boat, can still be concerning for some due to risk of exposure. However, more and more people are willing to get outside and conduct monitoring, and the lack of partnerships, comradery, and assistance is a big motivator for participating and completing surveys, especially on larger water bodies.

### Investigating participation trends

During 2011-2016, enrollment and reporting rates increased compared to 2011, with 76 unique lakes enrolled in the EAPW. In 2011, before any significant changes were incorporated into the program, there were 23 enrolled lakes and 43 percent submitted complete reports. After some tools and strategies were implemented, there was some improved participation and reporting. For example, 2014 saw the highest enrollment (32 lakes) and 20 lakes (63 percent) submitted reports (Figure 4). For reporting, 2015 was the most productive year with 23 out of 29 enrolled lakes (79 percent) submitting reports. While not every lake re-enrolls in this program every year, new lakes were enrolling in the program, as demonstrated by the accumulation of total unique lakes over time (Figure 5).

Based on 96 responses from volunteer evaluations, awareness of the EAPW program, was slightly higher than in 2013 (87 percent in 2013, 93 percent in 2017). Volunteer confidence in their ability to identify AIS plants accurately increased by 8 percent between 2013 and 2017. Time commitment continued to be a concern for some volunteers, no change really from 13 percent in 2013, compared with 14 percent in 2017. However, respondents did indicate that alternatives to EAPW, such as paying an aquatic plant professional or participating in an advanced plant monitoring program offered through the CLMP, was a bigger influence for not enrolling in the EAPW in 2017 compared to 2013 (26 percent in 2013, 46 percent 2017). When asked if a site visit would encourage their enrollment in the program, only 14 percent of respondents indicated that "Yes, absolutely!" it would, 43 percent responded "Maybe," and 43 percent indicated that it would not impact their decision to enroll (n=96).

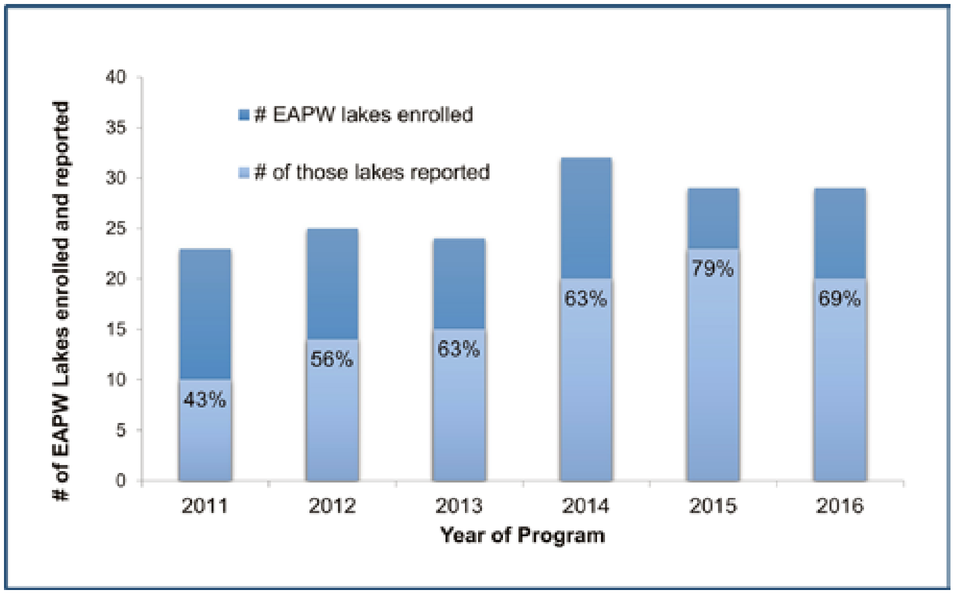


*Figure 4. EAPW enrollment and reporting from 2011-2016, percentages within the light blue bars represent the percent of enrolled lakes that submitted reports at the end of that season.*

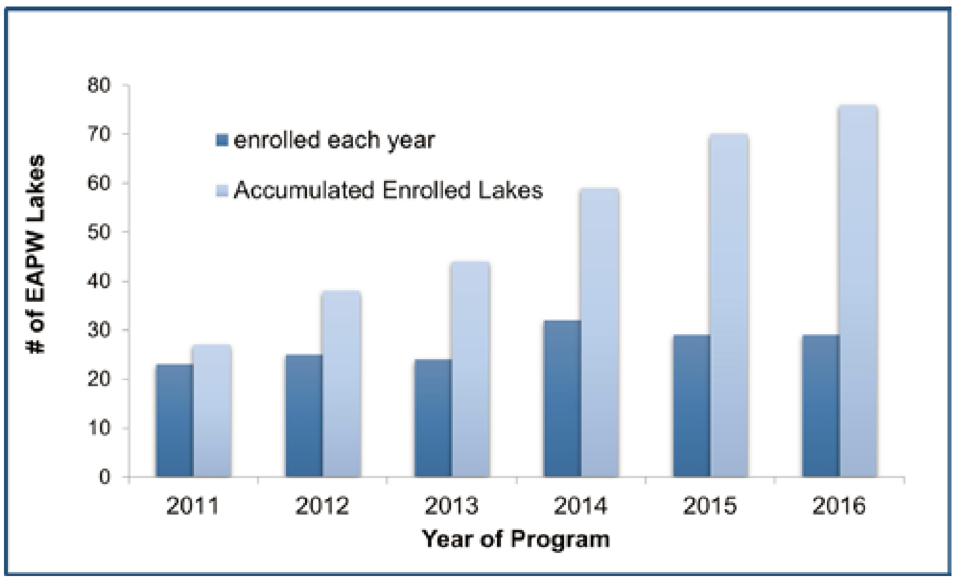


*Figure 5. Lakes enrolled in EAPW from 2011-2016 with blue bars representing enrollment numbers for each year and light blue bars representing accumulated enrollment (i.e., total enrollment to date).*

### Outcomes and results

The new species identification guides and photography cards were used by EAPW volunteers, and are popular handouts at training events. We distributed a simple online questionnaire to volunteers who were provided the new guide to invasive aquatic plants of Michigan. Responses indicated that 78 percent (n=12) of volunteers using the guide felt higher confidence in their ability to accurately identify invasive aquatic plants. While we did not collect quantitative data about use of the laminated photography cards, we observed that approximately 25-30 percent of reports submit photographs using the cards and we receive 3-5 plant identification questions each year where the plant is displayed using the photography card. We regularly observe volunteers using the photography cards during lake visits, and volunteers have reported keeping the cards and identification guides in their boats so they are easily accessible and ready to use. More interestingly, the reports received from participants where no AIS species have been detected have increased (Figure 6) with the most species being detected in 2016 (20 AIS detected) and the most reports of no AIS detections occurring in 2015 (12 reports of no AIS detections). These results suggest two things, (1) the program is expanding to areas where AIS are not yet a large threat or presence on lakes and, (2) participants are submitting reports even if they do not find AIS, indicating that our efforts to increase awareness that the "presence of no data, is data" is successful.

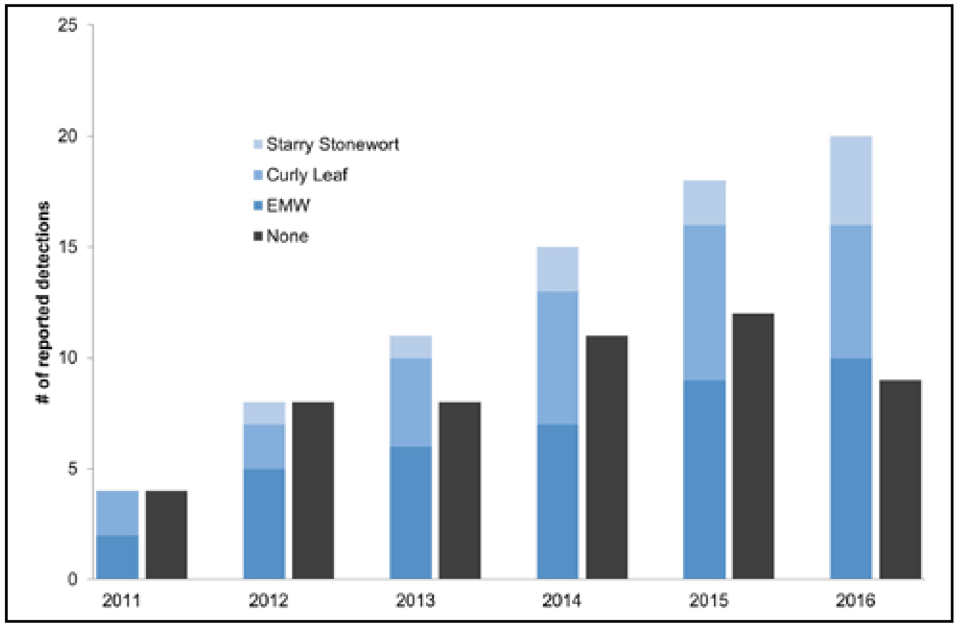


*Figure 6. Number of invasive species detections by monitors, alongside number of reports from lakes.*

## Lessons Learned

The EAPW program is supporting an important effort to get more concerned community members trained and out monitoring their lakes for invasive species. The more informed people that are out on lakes searching for AIS, the higher the probability that an invasive species will be seen, identified, and reported along the proper channels Compared to a researcher or government technician conducting a one-time plant survey, the exposure a volunteer has to their lake resource is greater, leading to greater chance of spotting AIS. The ability to access and collect this local knowledge through community collected data is extremely valuable for effective management and would not be possible otherwise. The future of AIS detection literally relies on community members and the volunteers, such as those participating in the EAPW, that are on the forefront.


## Acknowledgements

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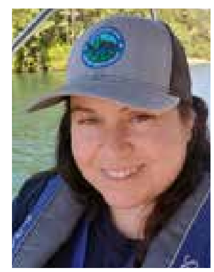


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# Natural and Social Science Work Better Together **for Managing AIS**

Tim Campbell and Bret Shaw

When talking about people in a natural resource management context, many of us have likely heard a variation of the joke "That's why I study (insert physical or biological thing that can be studied). That thing is easy. People are hard!" As with every good joke, part of the humor comes from the vein of truth in the statement. When you know what a fish needs to find food, not become food, or to reproduce, you can start to guess where they are going to be (even if they're still hard to catch). The impact of a new physical or chemical element to a lake can be predicted thanks to the wealth of data that exist on lake ecosystems. When we introduce a lake management program or tweak an existing one, we have an idea of what is going to happen because of past experiences with similar programs.

But people? People are hard to predict. They can make decisions that can harm the ecological health of their lake even though they care for their lake. They may say one thing and do another. They think they're good environmental stewards even though some of their behaviors suggest otherwise. They may tell you what they think you want to hear as opposed to what they believe or do. People can hold conflicting values and views. What motivates one person to do something doesn't motivate others. All of these things, and many other quirks of human behavior, can make working with people difficult. Yet, it's necessary to understand people and work with them because many of us aren't exclusively responsible for whatever natural science we were trained in. We work with communities of people who care for and use lakes and reservoirs, and we need their support and behavioral compliance to improve and protect these waters.

While all aspects of lake and reservoir management benefit from a social component, aquatic invasive species (AIS) management– which for the purposes of this article includes all aspects of working with AIS, including but not limited to outreach, prevention, and control – is a clear example where it is impossible to make meaningful progress without also addressing human behavior. Human behaviors move invasive species, so only by working with people can we reduce their spread. The application of social science approaches can help us understand the attitudes and behaviors of people intentionally and unintentionally moving invasive species and how to develop interventions to reduce the number of invasive species in transport. Without the human and social science component, invasive species management would be limited to addressing ever worsening and new impacts of invasion.

Luckily, there are rigorous social science methods that help us understand and influence the behaviors of people to prevent the spread of aquatic invasive species. These methods can help us understand how people think and behave, while providing insights on what messages are most effective in encouraging people to perform AIS prevention behaviors. These methods are also important for program evaluation and can be used to both identify opportunities for program improvement while also providing data on the effectiveness of our AIS-prevention programs. If you haven't thought much about how social science approaches could improve your AIS management program, we encourage you to follow along as we highlight some social science projects that have helped improve aquatic invasive species management across the country. Specifically, we highlight how these approaches can help us better understand our target audiences, help us craft better messages to communicate with our audiences, and how these approaches can remove barriers to people performing invasive species prevention behaviors.

### Understanding your target audiences

There are several approaches that can be used to understand a target audience. Surveying a randomly selected sample of a larger population can provide information that is representative of the population as a whole. This can be an efficient way to collect quantitative data to help understand the broader knowledge, behaviors, and beliefs of that group. Targeted interviews and focus groups with an audience can generate qualitative data that bring new insights to light and can help uncover additional details that are difficult to get through a quantitative survey alone. Informal conversations with people can even be useful if care is taken to not overinterpret what was learned. All these approaches, used in combination or on their own, can help AIS managers learn more about their target audiences and have been used to improve AIS management.

In Wisconsin, qualitative approaches have been used to better understand the specific beliefs of water users. For example, focus groups were used to talk with boaters more about their behaviors relating to draining water from their boats. Through these conversations, AIS staff learned that boaters generally knew the rules about draining water prior to leaving the landing, but for anglers, if fish were in the livewell, they believed that water was needed to transport their fish and it didn't occur to them to drain it. Interviews with waterfront property owners have been used to understand detailed beliefs about aquatic plant management, which often can be a contentious topic. Interviews with waterfront property owners uncovered that there was a disconnect between what managers and waterfront property owners believe to be a management action. Managers considered monitoring a management action while waterfront property owners did not mention monitoring a population as an action they would take in response to finding a new AIS. It's easy to see how this difference in beliefs could cause discontent and improved communication on how monitoring can help manage AIS could overcome this.

Quantitative efforts are also used to set baseline information for how many people are performing prevention behaviors and how they feel about AIS issues. The data can be used to identify gaps in prevention behaviors that can inform new outreach programs. If the surveys are repeated, they can be used to evaluate outreach programs that were implemented between the survey periods. Wisconsin has regularly surveyed registered boaters in the state to set benchmarks for how often they report performing AIS prevention behaviors and how knowledgeable they are about AIS. This information has also been used to segment recreational boaters into different audiences, such as boaters that don't travel and boaters that travel frequently, or that have different levels of knowledge and different trusted information sources. Prevention messages and sources can then be tailored to the boaters that have the riskiest boating behaviors.

## Crafting better messages

Social science doesn't just help us broadly define and understand audiences. It can be used to develop better messaging that helps our audiences feel and act in desirable ways. Using the survey methods discussed earlier, researchers can test different models of human behavior with different messaging to better understand which models and concepts from those models best explain a target audience's reactions and their intention to implement AIS prevention behaviors. Understanding which aspects of those constructs best motivate people can then allow us to create messages that operate on those beliefs or feelings. Perhaps feelings of self-efficacy – I can perform the action – help people perform certain AIS prevention steps. If that is the case, we can lean heavily on messages that emphasize what people need to do and that the prevention steps are things they can do. Another common construct that is influential is response efficacy, or that the suggested actions will make a difference in protecting the waters they use. Many people feel as if the spread of AIS is inevitable and our actions don't matter, so they don't perform prevention behaviors. Our messaging can help overcome those feelings by including information on how prevention behaviors can make a difference.

Social science can be used more explicitly to test messages that might improve outreach. To test the impacts of and reactions to different types of messages, the specific text of an outreach campaign can be changed while the visual aids remain the same, allowing researchers to directly compare messages. Work done by researchers at the University of Arkansas at Monticello and Texas A&M University suggests that regulation-framed messages were most effective for increasing boater intention to perform AIS prevention behaviors. Key messaging strategies can be operationalized into specific text and visual aids and then placed in a setting where people are likely to respond to the message with actions – like at a boat ramp. Message testing can also take place in a digital setting. Facebook has been used to test different messages and how they impact people's desire to click on a link to learn more about invasive species information. In this instance, the research found that an informational, scientific message frame can achieve the same communication outcomes as commonly used nativist or militaristic frames (e.g., "alien species aren't welcome" or "the war against invasive species"), which are associated with ethical questions and can have unintended consequences that may ultimately undermine ecologically sound lake and reservoir management (Figure 1). For example, there are some preliminary data to suggest that fear campaigns targeted at transient boaters can have "spillover" effects such that lakeshore property owners can overreact to a new


*Figure 1. Message testing approaches allow researchers to compare the effectiveness of different messaging approaches. In this example, invasive species social media posts with (a) a militaristic frame did not outperform (b) a science and fact-based frame. This suggests that we can achieve communication goals without the potential ethical concerns or unintended consequences of militaristic messaging* (photo: Brooke Alexander).

AIS with aggressive treatments that may harm native plants or animals when more methodical and ecologically informed options may be available as an initial course of action. Using social science to help us understand how messages are impacting people can tell us what to change about an outreach program to get the desired impact.

## Addressing barriers to behavior change

For most of us, the ultimate goal for our AIS-prevention outreach efforts is to help water users adopt behaviors that prevent the spread of AIS, and there are a number of examples that have translated social science research into effective outreach programs. A lot of this has been done in the context of community-based social marketing (CBSM), which is a form of social marketing that emphasizes direct contact with community members and the removal of barriers to action. It embraces the psychology of behavior change and staying focused on behavioral outcomes vs other forms of education that focus on filling knowledge gaps. Both Stop Aquatic Hitchhikers! (https://stopaquatichitchhikers.org/) and Habitattitude (https://www.habitattitude.net/), which are national AIS prevention campaigns, are based on CBSM principles and encourage people to perform AIS prevention behaviors. In a more recent example, the Minnesota DNR has used a CBSM approach as part of a small grants pilot program for county-level AIS programs and local groups to implement programs that remove barriers to AIS prevention activities. This program has funded projects that target specific AIS prevention behaviors including encouraging waterfront property owners to dry docks, lifts, and equipment for 21 or more days before installing them to a new body of water and working with anglers to properly dispose of unwanted bait in the trash. Each of these small projects included an evaluative component that allowed for the larger Minnesota AIS program to learn from each of these local projects. Efforts like this can apply the lessons learned from social science research with the help of local partners.

Another example can be drawn from the previously mentioned example of Wisconsin boaters and their disconnect with the requirement to drain water from livewells and their need to transport harvested fish. Out of this misunderstanding came the Drain Campaign, which was developed to educate boaters specifically on this behavior. The outreach efforts included an ice pack as a giveaway (Figure 2), which served as a reminder to boaters to drain livewells and provided the ice they needed to keep their fish fresh until they returned home. A follow-up statewide survey completed in 2018 indicated a slight improvement in these behaviors, indicating the program had a positive effect.

A relatively easy to implement opportunity for lake and reservoir managers may be placement of boat cleaning tools at landings. Many surveys of recreational boaters indicate that the lack of tools to clean their boats at water access points is a common reason why they do not perform AIS-prevention behaviors. Providing these tools, whether they be tools purchased from a hardware store or an all-in-one cleaning station solution, can remove that barrier to action.

In all these instances, the key to getting people to perform the desired action was to remove barriers that made it easier for them to do the right thing.

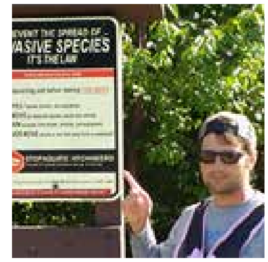

*Figure 2. To help boaters and anglers engage in AIS prevention behaviors, it can be helpful to provide reminders to action and to remove barriers to any desired behaviors. Branded towels and ice packs that are handed out by watercraft inspectors in Wisconsin remind boaters and anglers on behaviors they need to engage in while providing the tools they need to complete the actions. Towels can help dry watercraft and gear, while the ice pack can be used to keep fresh during transport. Both behaviors help reduce AIS transport risk* (photo: Ellen Voss).

## Doing more social science for AIS management

We hope you are now motivated to try more social science approaches to inform your lake management outreach programs. Below are a few ideas that can help anyone incorporate more of these approaches within their work:

- *Have social scientists or people familiar with social science working on teams.* They can help make connections to where these approaches can help. These people may be researchers or extension staff at a university, natural resource managers with this background, or simply someone with an interest in the subject that is looking at a problem through that lens. Having someone on your team with some social science experience can provide valuable insights to pursue this work and can help make connections that get this work done.

- *Direct funding to this work.* While social science work might not require field work or capital expenses like a lot of natural resource management projects, it does still cost something. It often costs money to compensate participants or find a sample of people to survey. Even “free” information from willing participants still requires time or financial resources in the sense that someone needs to collect the data, process it, and report the results. Investing in this kind of work will help you realize more applicable and useful results. It’s important to budget for social science to understand your audience and evaluate your outreach just like you would fund other aspects of an AIS management program.
- *Consider social science a tool for evaluation.* Even if you might not be interested in some of the theoretical information that social science approaches can provide, many of these approaches are needed to understand the impacts of management programs since these programs involve people. We all can benefit from knowing if our programs are having the intended effects within communities and using social science approaches help us understand whether our outreach programs are working and where they can be improved.
- *Apply an actionable science lens to these projects to help ensure results are applicable to AIS-prevention and management programs.* One question we’ve heard at the end of research projects about natural resource management is “How am I supposed to use this information?” Somewhere in the process of conceiving of the study and analyzing and communicating the research findings, the original need of the natural resource manager was lost. Ensuring that throughout the process someone is continually thinking about how this work can be used and how it can improve the management of AIS will help us all complete more applicable social science projects.



**Tim Campbell** is the aquatic invasive species program manager for the University of Wisconsin Sea Grant Institute and the National AIS Liaison for the NOAA Sea Grant Program. He supports AIS prevention outreach, communications, and program evaluation, and works to apply university and Sea Grant resources to AIS issues.

**Bret Shaw** is Environmental Communication Specialist for the Division of Extension and a Professor in the Department of Life Sciences Communication at the University of Wisconsin-Madison. He focuses on planning and evaluating social marketing campaigns dealing with natural resource management issues such as water quality, land use and other environmental conservation topics.

# Regional Panels Join Forces to Prevent Spread of AIS: **The Strength in Numbers**

Cathy McGlynn and Ceci Weibert

Every year, hundreds of boaters, anglers, swimmers, and property owners enjoy recreational activities on the water. Our freshwater lakes and rivers provide ample opportunities for everyone to enjoy time on a boat, head out fishing, or even snorkel and SCUBA dive. However, while enjoying our freshwater resources, water users are at risk of unintentionally moving aquatic invasive species, or AIS, between bodies of water.

Numerous AIS are confirmed in the Great Lakes, St. Lawrence River, Lake Champlain, Mohawk River, Hudson River, Connecticut River, and other inland waterbodies throughout the Great Lakes and Northeast. Plants, including *Hydrilla verticillata* (hydrilla), Eurasian watermilfoil (*Myriophyllum spicatum*), and starry stonewort (*Nitellopsis obtusa*); fish such as the round goby (*Neogobius melanostomus*); and invertebrates like the bloody red shrimp (*Hemimysis anomala*), spiny waterflea (*Bythotrephes longimanus*), and fishhook waterflea (*Cercopagus pengoi*) are just some of the species that have been introduced into these aquatic systems and cause negative impacts to these ecosystems. These species are known to prey upon native species, outcompete native species, alter ecosystem function, limit recreation, generate economic costs and, in some cases, impact human health. These species and other AIS can expand their ranges via transportation by motorboats to new locations. Educating boaters about the threat of AIS and how they can avoid transporting AIS across the region is incredibly important.

The AIS Landing Blitz directly addresses this objective, focusing on interactions with the public and building strong community relationships to empower recreational water users to take steps to clean their boats and gear to mitigate the risk of AIS spread every time they visit a water access point. With careful and intentional messaging about this risk, water users can become knowledgeable about the risks of AIS, ways to reduce that risk, and may even serve as ambassadors for our shared freshwater resources by extending that education to their friends and families (Figure 1).

## 2019-2021

The AIS Landing Blitz is a binational, multi-agency, cross-regional project that was initially led by Great Lakes states and provinces independently of each other. These Landing Blitz events prioritize education of boaters and other water users by sending staff and volunteers out to public boat ramps to meet people where they are, and constructively engage them in educational opportunities. The structure of these events is unique in that the emphasis is on getting staff *out* of the office and focusing their time on talking with people. These educational opportunities mean that water users can put a face to an organizational label; these are real people representative the agency that they work for, rather than a faceless organization. Giving agency staff and the public an opportunity to interact one-on-one not only provides more valuable educational experiences, but also contributes to building and maintaining important community relationships.

The event was first coordinated at a regional scale by the Great Lakes Panel on Aquatic Nuisance Species [Great Lakes Panel on Aquatic Nuisance Species – Great Lakes Commission (glc.org)] in 2019, and received funding by the USEPA


*Figure 1. NYS watercraft inspection steward in action* (NYSDEC).

Great Lakes Restoration Initiative Interjurisdictional Grant Program in 2021 (https://www.glc.org/work/blitz) to further expand those efforts. The Great Lakes Panel is one of the regional panels created by the Federal Aquatic Nuisance Species Task Force (https://www.fws.gov/program/aquatic-nuisance-species-task-force) and was first established by Congress in 1990 to "to protect the waters of the United States by creating a coordinated, unified network that raises awareness and takes action to prevent and manage aquatic nuisance species."

Partners from the Great Lakes states and Canadian provinces (Figure 2) (Illinois, Indiana, Michigan, Minnesota, New York, Ontario, Ohio, Pennsylvania, Québec, and Wisconsin) agreed to have active boat stewards along the lakes during a ten-day period covering both Canada Day (July 1) and Independence Day (July 4). These on-the-ground efforts were combined with an increase in social media, press, and television coverage through the coordinated social media templates developed for consistent messaging. Boat stewards who interact with the public are a very effective means of promoting behavior change among boaters, helping them adopt the habit of cleaning, draining, and drying their watercraft.

Clean.Drain.Dry (Figure 3) is the catch phrase for the U.S. Fish and Wildlife Service (USFWS) Stop Aquatic Hitchhikers! Program (https://stopaquatichitchhikers.org/). These constitute the basic steps that all boaters need to take when moving from one waterbody to the next or from one launch to another in a larger waterbody (e.g., Lake Ontario, Lake Erie, Lake Champlain, Cayuga Lake):

**CLEAN** off visible aquatic plants, animals, and mud from all equipment before leaving water access.

- Rinse equipment and boat hulls (with high pressure, hot water when possible)
- Rinse interior compartments of boats with low pressure, hot water (120°F)
- Flush motor with hot water (120°F) for 2 minutes (or according to owner's manual)

**DRAIN** motor, bilge, live well, and other water containing devices before leaving water access.

**DRY** everything for at least five days OR wipe with a towel before reuse.

**For ANGLERS, the additional step of DISPOSE is recommended:**

**DISPOSE** of unwanted bait, worms, and fish parts in the trash. When keeping live bait, drain bait container and replace with spring or dechlorinated tap water. Never dump live fish or other organisms from one water body into another.


*Source:* stopaquatichitchhikers.org.

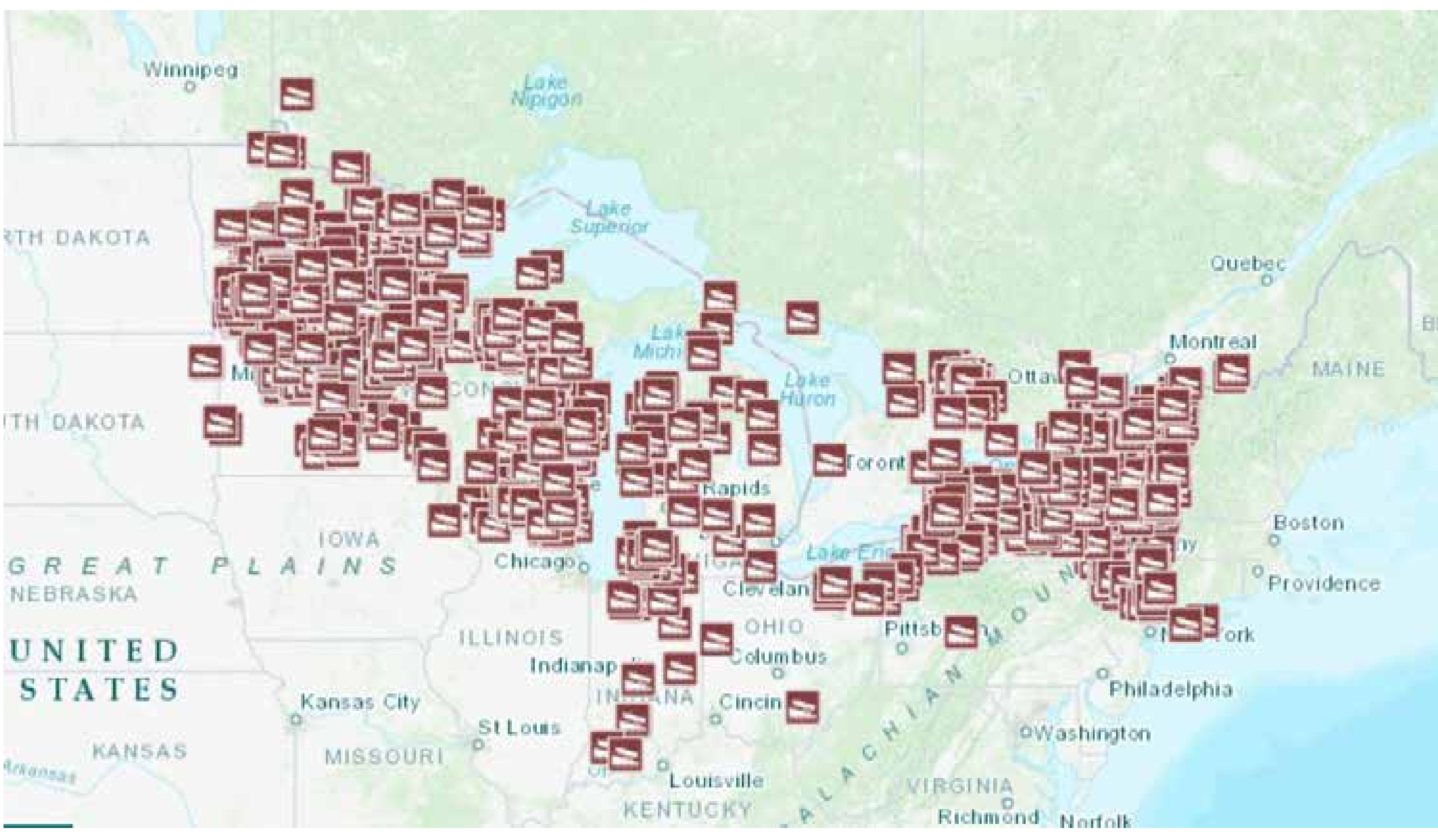



*Figure 2. Map of Great Lakes AIS Landing Blitz coverage in 2022* (NYSDEC).

*Figure 3. Boater removing plants from equipment after leaving water* (Illinois-Indiana Sea Grant; (NYSDEC).

These are the recommendations provided by all stewards in combination with a walk-through inspection as stewards point out locations where aquatic invasive species may get caught on trailers or around the prop. They also review the importance of draining water containing compartments to avoid transport of microscopic AIS. AIS interceptions are a key activity here.

During Landing Blitz events, stewards have intercepted spiny waterflea and fishhook waterflea, zebra mussels, quagga mussels, Asian clam, Eurasian watermilfoil, curly leaf pond weed, Brazilian elodea, and hydrilla on boats during the period of the Landing Blitz. Preventing the spread of hydrilla in particular is a priority as this species is considered the world's worst aquatic weed and is a Federally Listed Noxious Weed and prohibited by many states (hydrilla (Hydrilla verticillata) – Species Profile (usgs.gov)).

In some cases, steward programs have collected data on where boaters have been before launching that day which allows us to figure out how boats move across the landscape and which waterbodies could be potential sources of infestations or at risk of introductions (assuming a record of AIS in many waterbodies in those states exist). In addition, if species found on boats at a location don't match the confirmed species for that waterbody that information would help prioritize that pond, lake, or river for aquatic surveys. For example, on occasion boat stewards in the Buffalo, NY, area have intercepted hydrilla near locations that were confirmed to have infestations (some Niagara River marinas).

Along with recording the number of interceptions (and species intercepted) we also document the number of steward locations, interactions, and inspections for each state. The value of the program can easily be seen in the increase in the number of people educated from 115,000 in 2019 to 173,000 in 2022.

Note there are data for 2020 – the height of the pandemic. As a testament to the commitment of our partners we managed to (safely) reach 128,000 people and conduct 110,000 inspections at more than 1,000 boat launches. Our reach in the Great Lakes region has been steadily increasing from the program's inception and we still have room to grow.

As the program gains momentum, we continue to make changes to reach more boaters and to support the development and/or maintenance of boat steward programs. In 2022, the Great Lakes Commission, via the U.S. Fish and Wildlife Service and the Great Lakes Restoration Initiative, offered more $65,000 in small grants to 11 local organizations in the Great Lakes Region to host their own Landing Blitz events. The purpose of the small grants program was to expand community relationships between local organizations and state natural resource agencies, while also providing support for Landing Blitz events in the parts of the Great Lakes region that have historically had less staff capacity and a smaller number of event locations. Recipients in 2022 include the Saginaw Chippewa Indian Tribe of Michigan, Benzie Conservation District (MI), Lapeer Conservation District (MI), Upper Peninsula Resource and Conservation Development Council (MI), Cleveland Metroparks (OH), Fox-Wolf Watershed Alliance (WI), Glacierland Resource and Conservation Development Council (WI), Great Lakes Community Conservation Corps (IL), Kosciusko Water and Woodland Invasive Partnership (IN), Keuka Lake Association (NY), and Seneca Lake Pure Waters Association (NY). Grant recipients held 87 events at 39 locations, educating more than 11,000 people about AIS and demonstrating boat cleaning and inspection methods.

Social media, television, radio, and video help us to reach many people who recreate in the Great Lakes region and raise awareness about the economic and ecological costs of AIS. As the program has grown so has its digital reach, from 130,500 people in 2019 to 272,000 people in 2022. A series of social media templates were developed around the five most important messages for the event: How to properly Clean, Drain, Dry gear/boats (motorized and non-motorized), a review of different cleaning methods, and common AIS associated with boating, how to identify/report them, and their impacts. This coordinated social media approach included the use of hashtags and provided sample posts along with key messages to use when writing social media posts.

In 2022, the Great Lakes AIS Landing Blitz utilized geofencing at a regional scale to spread the word about the event. Geofencing is a digital marketing strategy that uses location services on smart phones to identify visitors at boat launches and serve targeted ads to those visitors about the Landing Blitz. These ads are designed to both inform visitors about the events (e.g., locations, partners, etc.) and to educate them on the key messages of the event (e.g., Clean, Drain, Dry). This strategy had previously been used in Pennsylvania with great success, and this regional rollout was no different. Seventy-five locations around the Great Lakes were targeted for geofencing, resulting in 389,000 impressions, or views of the ads.

We are working hard to create a culture that supports the protection of our precious water resources from AIS. In fact, in 2022 the Northeast Aquatic Nuisance Species Panel (NEANS: [www.northeastans.org](www.northeastans.org)) joined the effort – the Northeast states and neighboring Canadian provinces: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont, New Brunswick, Nova Scotia, Prince Edward Island, and Québec (Aquatic Invasive Species Landing Blitz – Northeast Aquatic Nuisance Species Panel (northeastans.org)). NEANS Panel stewards provided coverage at 463 locations. Social media and press reached more than 55,000 water recreationists.

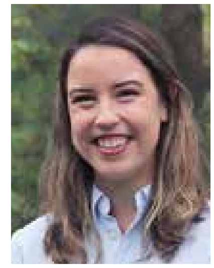
## 2023 and beyond

The Great Lakes and Northeast Panels will continue to expand our education and outreach and increase the support we provide for local and regional organizations hosting boat stewards. By working together, the Great Lakes and Northeast Panels have had an opportunity to learn from each other and build successful events rather quickly, getting events off the ground on a much shorter timeline than would be required if events were coordinated independently of each other.

In 2023, the Great Lakes Commission plans to distribute $85,000 in a continuation of this small grants program and hopes to continue the success of 2022 while expanding the geographic reach of the program.

In the future, we hope that more of the six regional aquatic nuisance species panels (Regional Panels | U.S. Fish & Wildlife Service [fws.gov]) will host their own Landing Blitz events. Education and outreach promoting AIS spread prevention is a long-term investment with many returns. AIS introductions will be prevented, infestations will be contained, and generations of aquatic recreationists will become water stewards. We hope that you will join us in preventing the spread of AIS.

**Cathy McGlynn** is the Aquatic Invasive Species Coordinator for NYSDEC. Her job is to help implement the NYS AIS Management Plan. She oversees the statewide watercraft inspection steward program and several large scale hydrilla control projects. Cathy received her Ph.D. from the Department of Ecology and Evolution at SUNY Stony Brook.



**Ceci Weibert** is the project manager for the Great Lakes Commission's aquatic invasive species program. In this role, she serves as coordinator of the Great Lakes Panel on Aquatic Nuisance Species as well as lead for the Blue Accounting AIS issue, and manages a variety of interjurisdictional invasive species projects. Prior to coming to the Commission, Ceci worked for the Michigan Department of Natural Resources and Department of Agriculture and Rural Development conducting risk assessments for aquatic invasive plant species. She holds a master's degree in coastal zone management as well as a bachelor's degree in marine affairs and policy from the University of Miami in Florida. Go Canes!

# Better-Informed
# Invasive and Native Macrophyte Management

Jesse Smith

## *Using information from the past, present, and potential future to guide management decisions*

### Introduction

Many lake managers know all too well that the opinions of a lake community towards aquatic plants, invasive or not, tend to vary widely. While anglers may prefer dense beds of macrophytes in their lake to provide cover for the fish they target, these same dense growths can be a massive source of frustration to boaters. Many lake-users also loathe touching "seaweed" when swimming off their dock, and some may prefer to see no aquatic plants in their lake whatsoever. Lake managers of course know that in most, if not all cases, a lake owner's desire for a crystal-clear lake with zero algae, zero plants, and huge fish is usually not the most feasible goal, especially in eutrophic waterbodies like those present in parts of the northeast. If the nutrients are present, something or other will try to use them, and in the absence of vascular plants, algae and potentially cyanobacteria will usually become the dominant primary producers. What, then, should be done about large, legitimately problematic growths of invasive plants that impede the use of a lake and threaten native species (Figure 1)? The solution, of course, will be different for every lake, and lake managers pull from a wide range of management methods to handle different situations.

*Figure 1. Dense beds of brittle naiad* (Najas minor) *dominates shallow areas in a New York Lake.*

Many of the lake management programs in the northeast are beginning to strive to emphasize the importance of acting proactively in order to address growth of harmful algae blooms. While reactive management, such as the chemical treatment of a cyanobacteria bloom, is necessary at times, there have been efforts to encourage the development of long-term plans that work to identify the conditions that allow blooms to occur and to act prior to the start of a bloom. It stands that management of invasive aquatic macrophytes can be approached in a similar manner. The more information that is available about a lake's vegetation community and current management activities, the more well-informed a long-term management plan can be created. Relevant information includes not only current, modern-day conditions, but also historical data. Furthermore, a long-term management plan can help prepare for several years in the future by drawing from known conditions in the lake and surrounding area and by fostering an increased interest in the lake community.

### Drawing from the past

I have received the comment from lake users before: "My family has been on this lake for 40+ years and we have never seen this plant in here before." This brings about several questions. Whether an invasive plant or a native one, was it introduced to the lake recently, or was/has it been present for some time and gone unnoticed? If it was introduced, by what pathways might it have entered the lake? If the species is suspected to have been present for many years, when does it begin to occur in historical records? What conditions might now be present that allow the plant to grow to more noticeable densities?

Whether assessing the macrophyte community as a whole or combatting one or two invasive plants specifically, the assessment of historical data can provide a surprising amount of information and potentially shed light on some of these questions, as well as others.

Lakes that have many years of documented assessments performed by limnologists will strongly benefit here, especially regarding more recent history. In such instances, lake scientists may create a long-term database of measurements and observations collected each season. These can be used to explore trends in water quality, plant observations, weather conditions, and other parameters, providing a sense as to what baseline conditions may be and allowing managers to assess the effects of extreme events.

While intensive macrophyte surveys may not always be performed on an annual basis, compiling and comparing the results of each survey can allow managers to create the timeline of an invasion and apparent impacts on native plants or correlate changes in macrophyte density with weather, water quality measurements, or other factors. As an example, invasive macrophyte species such as curlyleaf pondweed (*Potamogeton crispus*), water chestnut (*Trapa natans*), or hydrilla (*Hydrilla verticillata*) largely reproduce from seeds or over-wintering vegetative structures (turions or tubers, Figure 2). Do the historical data suggest that the invasive is relatively new, and that the seedbank can be largely diminished after a few years of aggressive treatment? Or has the species existed in the lake for a decade or more and produced a large propagule-bank? The latter may call for a different long-term management plan than the former.

Even if formal assessments of a lake's plant community are not regularly conducted on a lake, historical information may still be obtainable, at times from surprising sources. Simple plant observation data, when compiled, can display interesting trends in a lake's

*Figure 2. Invasive* Hydrilla verticillata *tubers and turions collected as part of a management program in central New Jersey.*

macrophyte community. Observation records can be particularly useful in obtaining an estimation for when approximately an invasive species has entered the lake. The United States Geological Survey's Nonindigenous Aquatic Species (NAS) database maintains observational records of aquatic invasive plants, providing historical data for their invasion in the United States.

Another form of observational macrophyte data that is particularly useful for this is herbarium records. Herbaria are repositories of pressed plant specimens collected by botanists and often stored in controlled conditions by universities or other institutions, some of which can be as much as a century old. Scans and records of these specimens are often available online, including databases containing herbarium records from multiple institutions.

It should be noted that the availability of historical plant records will vary largely between waterbodies. Small private lake communities that have typically only stayed within one or two families or reservoirs that have only recently been impounded are less likely to have available data. Furthermore, historical data should be checked for identification accuracy as best as feasible. This is where herbarium records are helpful, in that the plant itself can be examined and the identification double-checked. Last, both the names of waterbodies and scientific names of macrophytes are subject to change over time or may be referred to under multiple different names, depending on the source.

## Assessing and addressing the present

While historical information can tell a lake manager and the lake community a lot about what has grown in the lake in the past, many members of a lake community will likely be more interested in knowing what is growing in the lake right now and what needs to be done about it. In order to make well-informed management decisions, a survey of a lake's macrophytes should be conducted, especially if one has never been conducted in the past or has not been conducted in several years.

In the northeast, lakes that receive herbicidal treatments or other forms of macrophyte management usually receive some form of macrophyte survey. This may be as simple as conducting a visual survey from a boat or can involve a more intensive survey that explores the entirety of the littoral zone (Figure 3). While they are often more expensive and labor-intensive, a full-scale macrophyte survey performed by professional lake scientists will often provide the lake community with the most detailed information, including all plant species present, where in the lake each species is located, and the approximate densities at which they are growing, among other things. Madsen and Wersal (2017) detail several methodologies for aquatic macrophyte surveys; the method best used for a particular lake may depend on factors such as the size of the littoral zone, the species present, overall budget, and goals of the lake community. The professional lake scientist can recommend a plant survey methodology best suited for the lake community's needs.

In some lakes I work with in the northeast, macrophyte surveys are performed more than once over the course of the season. This regime can provide

*Figure 3. Aquatic macrophytes sampled as part of a rake-toss survey in an Adirondack Park Lake.*

potential areas of concern. As the identification of aquatic plants can sometimes be difficult, lake users should collect samples and/or good photographs in order to confirm the species of the problematic plant with their lake manager.

Observations by lake users can be critical when it comes to invasives such as water chestnut, which can be easy controlled by hand-pulling if addressed early enough in the invasion. A lake management service can assist a lake community in developing a volunteer monitoring program for this purpose that involves the mapping of plants located and tracking the number of plants pulled each year.

As mentioned briefly already, reactive management – addressing the problem when it occurs – is certainly not always ideal when compared to a long-term plan, but nonetheless it is sometimes necessary. It is an unfortunate fact that, in most cases, once an invasive species is starting to cause problems to the average lake user, it is likely past the point of simple eradication, and focus must at this point instead be placed on limiting the spread of the species within the lake or on maintaining areas suitable for boating or swimming (Harvey and Mazzotti 2014). In many cases in the northeast, this typically involves the seasonal application of herbicides, although some lake communities may opt for mechanical harvesting (Figure 4), diver-assisted suction harvesting (DASH), the use of triploid grass carp (*Ctenopharyngodon idella*), or other proven methods. Each methodology has its strengths and weaknesses, and each lake may benefit most from a different management method. As a long-term macrophyte management plan is developed, the use of these and other methodologies can be more strategically conducted or changed if necessary.

lake managers with information pertaining to how the macrophyte community behaves over the course of a year and can be used to track the effectiveness of current management implementations. Often, surveys that occur more than once a year do not employ as rigorous a methodology as an intensive full lake macrophyte survey might but are focused on specific areas or concern or the detection of problematic species.

While a professional lake management service can't necessarily be at a single lake every single week, members of the lake community can be. In monitoring a lake's aquatic plants, the lake user community can often bring attention to concerns that may not be otherwise identified in as timely a manner. Observations from lake users can't fully replace a thorough survey conducted by professionals, but lake users can identify the beginnings of a problematic growth or the presence of a previously undetected invasive species, alerting managers to

*Figure 4. Dense invasive water chestnut* (Trapa natans) *plants are mechanically removed from a pond in the New York metropolitan area.*

### Preparing for the future

While lake managers find themselves busy with the management of invasive and nuisance plant populations currently present in a lake, it pays to also be aware of potential new invaders and the pathways by which they may enter the waterbody. In many cases, the simplest and most cost-effective form of invasive species management is the prevention of these species entering the lake at all. Many programs, such as those used by the Adirondack Watershed Institute, check boats entering and leaving a lake to prevent movement of invasives between waterbodies (Kelting et al. 2021). Some private lake communities may take this a step further and only allow the launching of boats that are strictly used only in their respective lake, and only after a thorough cleaning protocol.

As invasive species may enter a lake through pathways other than boaters, a lake community may benefit from also learning about newer invasive species that may be occurring in their area. How are these species known to spread? Do the water quality, chemical, and physical aspects of the lake put it at greater risk for the establishment of species that do enter? Attention should be paid to other waterbodies in the lake's watershed, as plants from these locations may spread downstream to the lake in question. Keeping open lines of communication with neighboring lake communities can strongly assist with the tracking of new potential invasives.

Waterbodies downstream of the lake may also be considered, especially if they are known to harbor a new invasive species not yet present in the lake. Are boats often used in this downstream waterbody before entering the lake being managed? Is there the potential for waterfowl and other animals to spread the invasive species upstream? While some of these pathways are not easily prevented, identifying them may allow a lake community to prepare for a potential introduction.

As previously mentioned, lake users in the community can assist with the potential identification and potential removal of a new invasive. This requires, however, that the lake user community be interested and informed as to what species are presently in their lake and what invasives to look out for. Realistically, not everyone will inherently take interest in the macrophytes growing within their lake, but fostering an interest in the lake's macrophyte populations and other ecological aspects in the lake user community can lead to an overall better community stewardship of the lake. This can be accomplished through educational programs such as plant identification workshops or the encouragement of lake owners to submit observations of life found in their lake.

The wildlife identification smartphone app iNaturalist has seen some popularity among professional and novice ecologists alike and may provide functionality to lake managers looking to encourage interest in the lake community towards the macrophytes and other organisms living in their lake. Projects can be created via the app to log submissions of specific taxa or from a specified area, and community members and managers can assist each other in species identification. These projects can also be used by a professional lake manager to keep an eye on what species lake owners are seeing, allowing for further rapid identification of species of concern.

I've heard it said before around the lake management circle – a lake is not a swimming pool; it is more like a garden. A lake community that understands this may be better prepared to deal with a new invasive or nuisance densities of already established plants. While the "swimming pool" mentality may suggest that aquatic macrophytes should be completely eradicated from one's lake, the "garden" mentality may foster a management style that encourages the growth of a healthy, diverse population of macrophytes that serve ecological functions while not rendering the lake unusable to community members. By viewing a lake's macrophytes from an ecological perspective, lake communities may make better informed decisions in the management and curation of their "garden".

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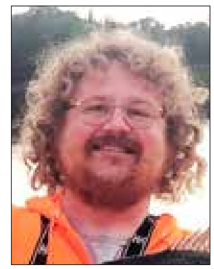


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Amber M. White

# Student Corner

## Lakeside Lessons: Insight from three years of aquatic herbicide treatments

I spent the summers from 2019 to 2022 traversing the state of Wisconsin to study aquatic herbicide treatments as part of my graduate studies at the University of Wisconsin-Madison. All treatments were targeting the invasive Eurasian watermilfoil, one of the most managed aquatic plants in Wisconsin, due to aggressive growth patterns that make it nearly impossible to paddle, fish, or swim. As a scientist, I am interested in how chemicals move through aquatic environments and how laboratory experiments compare to what happens in the environment. Aquatic herbicide treatments are ideal to study this question because of the intentional and controlled application of the chemical to a lake.

### Are herbicide treatments good or bad?

Throughout my studies, I learned a lot about the chemical treatments themselves as well as the lake users. Intrigued by my abundance of coolers but lack of fishing equipment, everyone was curious why I was on the lake, and most importantly, whether herbicide treatments are good or bad. While I can't broadly say whether a treatment is good or bad, I can share some insight on the process and chemistry to help resource managers make decisions for their lakes. First, liquid herbicide products will drift away from the treatment area and likely mix completely throughout the lake. While herbicides can be very effective, knowing baseline lake characteristics support successful treatment design. However, preventing the introduction of any invasive species is critical to maintaining long-term ecosystem health.

### Logistics of herbicide treatments

When an herbicide is applied to a lake, it is usually applied over a target area with a high plant density. This process can take several hours as applicators crisscross the target areas on the lake and requires ideal weather conditions, such as low wind and no rain, to limit the drifting away from the treatment area. Drift away from the treatment area can either help or hinder the success of the application.

While the initial application is intended to inundate the invasive plants with high concentrations, some herbicides like those containing 2,4-dichlorophenoxyacetic acid (2,4-D) or fluridone, work best when applied as low dose, whole-lake treatments. This means the herbicide is present in the lake at a low concentration for an extended period of time – at least two weeks for 2,4-D and several months for fluridone (Nault et al. 2017). This is not the case for florpyrauxifen-benzyl (FPB). This herbicide touts an exposure time of less than a day at concentrations significantly lower than 2,4-D. However, rapid drift away of FPB from treatment area can influence the effectiveness of the treatment.

In my studies, I observed these herbicides mix completely and achieve lake wide concentration (i.e., the entire waterbody is the same concentration) within 24 hours of treatment and initial detection of the herbicide outside of the treatment area just hours after treatment (White et al. 2022). Thus, knowing rapid (within hours) chemical drift will occur with liquid products is critical to remember when designing a chemical treatment and it requires consideration of specific waterbody features, such as treatment area size versus lake size and plant distribution/density within the lake, to achieve required concentration and exposure time.

### Know the waterbody

There are important lake characteristics that can be monitored prior to treatment as part of regular lake monitoring programs. Knowing lake stratification timing and depth is important to scheduling the initial herbicide application and applying the correct amount of herbicide. We also observed that discharge through streams could account for 20-30 percent of chemical loss in a lake, which is important when choosing a longer exposure herbicide like 2,4-D or fluridone products (White et al. 2022).

For herbicides that can stick to sediments, like FPB, or that can be degraded by sediment bacteria, like 2,4-D, knowing the sediment characteristics can be useful. Collecting bathymetry data and measuring organic matter content of the sediment can inform treatment design to reduce chemical loss to sediments.

Water chemistry parameters, such as pH, can change the rate at which an herbicide breaks down. For example, FPB can break down more quickly in high pH systems (pH 8+) compared to more acidic or neutral systems (pH 6-8) (SePRO 2017).

Last, knowing whether your targeted plant population has developed a tolerance to a certain herbicide is important to promoting successful treatments in the present and future. For Eurasian watermilfoil specifically, knowing whether the targeted plant population is mostly invasive or mostly hybrid watermilfoil is important for selecting an herbicide that will be effective on both strains (Nault et al. 2017). Conversely, documenting the population of native plants and knowing their sensitivity to individual herbicides can support treatment of nuisance plants while limiting impacts to the native plant population (Mikulyuk et al. 2020). The collection of baseline water quality and ecological data is instrumental to designing effective and efficient treatments that optimize costs and minimize negative outcomes.

Finally, efforts to reduce new introductions of previously treated/eradicated or novel invasive species can reduce or prevent the costs of treatment. This can include prevention and early detection activities. Our lakes are a valuable resource that provide numerous social and ecological functions for our communities. Invasive species management practices can be costly and disruptive whether it is chemical or not. Proper cleaning and disinfection of boats and equipment when moving between waterbodies might be annoying at the end of a successful day of boating, but a little prevention can go a long way for protecting our precious aquatic resources.

*Author's note:*

This article is written by Dr. Amber White, but the research was carried out by a team at the University of Wisconsin-Madison including Sydney Van Frost, Josie Jauquet, Angela Magness, Dr. Trina McMahon, and Dr. Christy Remucal, as well as Michelle Nault at the Wisconsin DNR.

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**Amber White** recently graduated with her PhD in environmental chemistry from UW-Madison and is now working as a chemist with a biodegradation focus at 3M Company in Minnesota. She specializes in conducting studies to characterize chemical fate and transport in the environment and is passionate about bridging the gap between laboratory studies and true environmental fate. Amber also holds a master's degree in water resources from the University of Minnesota-Duluth and bachelor's degree in biology and environmental science from Loyola University Chicago. Amber can be reached at ambermwhite16@gmail.com.

## UPCOMING IN *LAKELINE*

**SUMMER 2023: Harmful Algal Blooms** – Every other summer we like to focus on Harmful Algal Blooms (HABs), and include a range of articles highlighting new data, activities, monitoring techniques, and reporting strategies, among other topics. If you are working on something now related to HABs, consider writing up your work for the summer 2023 issue of *LakeLine*.

**Articles for summer 2023 are due June 15, 2023, for publication in July 2023.**

**FALL 2023: Shoreline Stabilization** – The fall issue will focus on topics related to shoreline stabilization. Topics related to impacts of shoreline erosion on water quality and aquatic life, methods for shoreline restoration and stabilization, case studies on restoration projects, and other topics related to shoreline stabilization are welcome.

**Articles for fall 2023 are due by September 15, 2023. The issue will be published in October 2023.**

Please contact Amy Smagula, LakeLine Editor, with any questions, or to propose an article for one of the above-listed themes. Do you have a topic that doesn't match a theme? That's okay, we can include the article in any of these issues, or use it to build a themed issue. Amy can be reached at lakeline@nalms.org.


YOU could be the winner of the 2023 NALMS Annual Photo Contest!
Two winning images will be selected, a Member's Choice winner selected by Symposium attendees and an Editors' Choice winner selected by the *LakeLine* editor and production editor for the entry that will make the best *LakeLine* cover. Prizes will be awarded to the contest winners, and your favorite lake or reservoir photo could grace a cover of *LakeLine*!
Entries will be judged during the 2023 NALMS Symposium in Erie, PA.
You must be a NALMS member to submit an entry. Only electronic submissions will be accepted. Photos should be of sufficient resolution to print from (at least 300 dpi at 8.5" x 11").
Maximum of one submission per person. Please include a brief caption for the photo.
Entries must be received by September 30, 2023.
Send your entry to:
Amy Smagula, *LakeLine* Editor
LakeLine@nalms.org

## LAKES APPRECIATION MONTH

# POSTER CONTEST


***Three posters will win a $300 cash prize!***
*$250 to the artist's school or organization / $50 to the artist*

July has been Lakes Appreciation Month for the past 25 years! This spring, students of all ages are encouraged to submit posters reflecting how important lakes are to all of us!
Submitted artwork will be a big part of NALMS' celebrations through July across North America.

***Show us your love for lakes - send us your artwork!***
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### Instructions:

All grades K -12 welcome to participate!

Send an electronic version of your poster artwork to **lakesappreciation@nalms.org**

Each entry must include student name, grade, school, and contact information

Prizes will be awarded to the top entry in each grade division

Full instructions available at *https://www.nalms.org/lakes-appreciation-month/poster-contest/*

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# How Small Stream Monitoring and a Benthic Algae DNA Metabarcoding Study has Informed **TMDL Development in a SW Ohio Watershed**

Christopher Nietch, Paul Gledhill, Nathan Smucker, Matthew T. Heberling, Erik Pilgrim, Richard Mitchell, Amina Pollard, and Lester Yuan

## Background

Establishing the the concentration of nutrients (namely nitrogen and phosphorus) where impacts to aquatic life begin to occur is difficult. This article describes how historical small stream monitoring and a study using DNA metabarcoding of algae growing attached to stream bottoms informed this issue in a watershed in Southwestern Ohio. USEPA Office of Research and Development (ORD) worked with USEPA Office of Water (OW) to advance the application of DNA metabarcoding methods in establishing nutrient reduction goals. ORD partnered with Ohio EPA's Total Maximum Daily Load (TMDL) development expert (co-author Gledhill) to help write a Loading Analysis Plan (LAP) that was published by the Ohio EPA in 2021. The LAP is a critical component of the state's required TMDL development process. The TMDL is a pollution budgeting tool that serves as a restoration plan for addressing a waterbody impairment.

## Central science question and goals

Studying the nutrient target setting and implementation issue has been a focus of ORD's research in the East Fork of the Little Miami River (EFLMR) watershed. The EFLMR is a case study system established in 2006 with the goal of studying watershed nutrient management and the linkages to harmful algae blooms (HABs) and other impacts to aquatic life (Figure 1). The case study conducts routine monitoring (weekly) and watershed modeling that supports nutrient reduction planning and implementation efforts. This work has benefited from an established partnership that includes local and state professionals working in the watershed. One of the major goals of the partnership was to support Ohio's statewide TMDL efforts by using the EFLMR as a demonstration watershed.

The EFLMR is a 1300 km² mixed use watershed consisting of 19 HUC12 subwatersheds (HUC stands for "hydrologic unit code;" HUCs are geographic referencing units for the nation's watersheds). The upper portion, the UEFW, is dominated by row-crop agriculture while the lower watershed, the LEFW, is largely mixed urban and forested area (Figure 1). Harsha Lake, which separates the upper and lower watersheds, is a U.S. Army Corps of

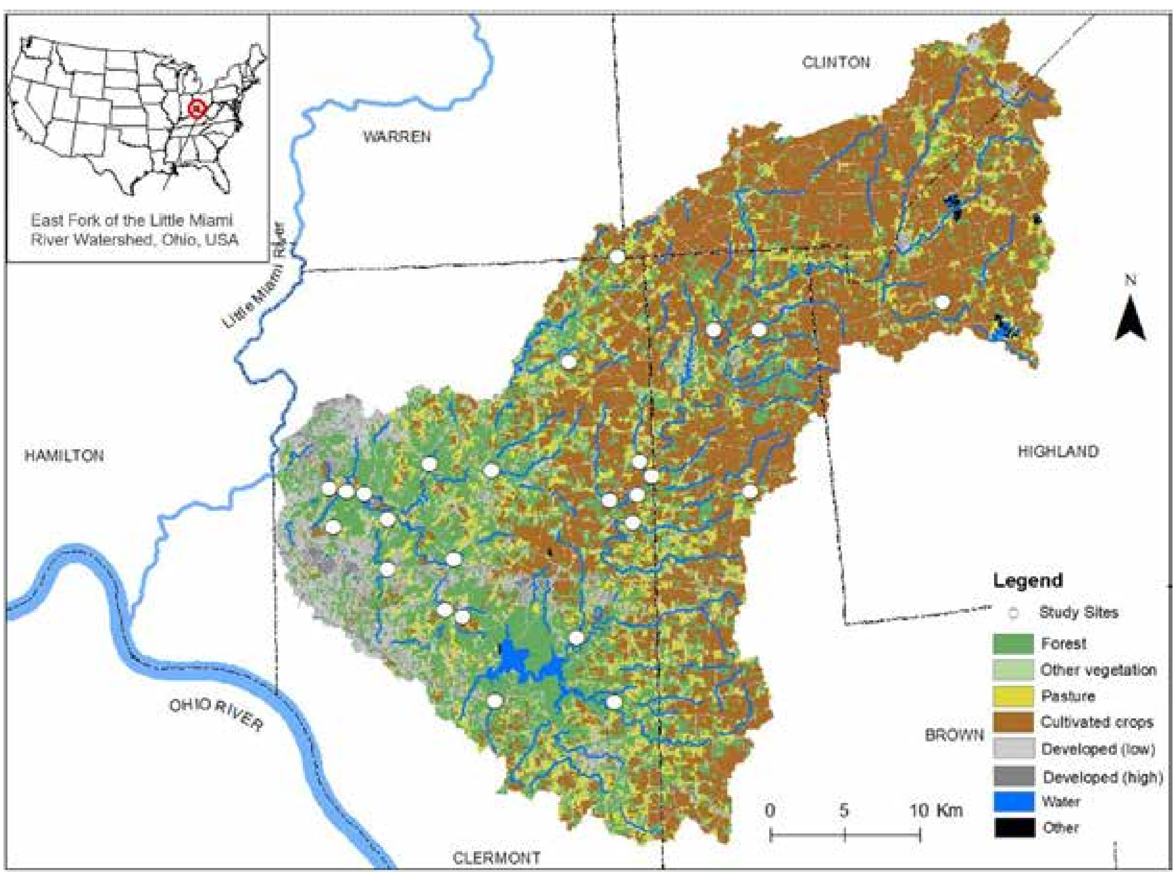


*Figure 1. Land use, drainage network, stream sites map of the EFLMR.*

Engineers reservoir built in 1978, serves as a major source for drinking water, and provides recreation for the surrounding region, but harmful algae blooms (HABs) have been occuring in this in the lake since 2009 (Smucker et al. 2021).

The Ohio EPA surveys large watersheds like the EFLMR on a rotational basis to comply with requirements for water quality assessment under sections 303(d) and 305(b) of the Clean Water Act (USEPA 2013). Assessments based on fish and macroinvertebrate communities are used in Ohio to determine whether the designated use for aquatic life is supported. If found not to be supported, the cause of the water quality impairment needs to be determined and a restoration plan, in this case a TMDL, developed. Before the reduction requirements can be determined for the TMDL, numeric targets must be set, which here are concentrations of nitrogen and phosphorus.

Ohio established a new framework for its TMDL program in 2017 (LSC 2017). It lists five steps leading up to the official TMDL (OhioEPA 2020). In 2012, the EFLMR was surveyed for CWA section 303(d) reporting and it was established that 52 percent of the 88 stream and river sites assessed did not support aquatic life designated uses (OhioEPA 2014). This survey's report constitutes Step 2 of Ohio's TMDL process. Since the state endeavors to write its TMDLs on a HUC12 subwatershed basis, if a HUC12 contains an impaired stream it requires a TMDL. Fifteen of the 19 HUC12s in the EFLMR contained at least one stream assessment site that did not support its aquatic life use.

Ohio has also listed under CWA section 303(d) the assessment unit containing Harsha Lake as impaired with regards to its public drinking water supply use. This impairment is due to HABs and is based on Ohio's algal toxin thresholds. An ORD analysis of reservoirs, including Harsha Lake, helped establish that excess nutrients were a key contributor to the harmful algae problem (Smucker et al. 2021). All the waters that feed the lake must be considered when addressing the nutrients causing these HABs. Therefore, 12 HUC12s (11 full ones and one partial one) require TMDLs.

The state considers TMDLs needed for stream aquatic life use impairments as "near-field" TMDLs, because these systems have smaller drainage areas, the would-be source are nearer to the impairment. TMDLs associated with systems like Harsha Lake address the impairment of the public drinking water use and receive loads from a larger drainage area. These types of TMDLs are referred to as "far-field" TMDLs. Ten of the HUC12 subwatersheds overlap in that they require a nutrient TMDL to address both near-field and far-field issues.

A major component of Step 2 of the state's TMDL process is establishing the sources of the impairment and causal mechanisms. Bob Miltner, a biologist with Ohio EPA, conducted an analysis of the 2012 survey data and proposed a "cautionary" model that linked fish index of biotic integrity and macroinvertebrate assemblage scores to a feedback mechanism linking low flow, low dissolved oxygen, and nutrient enrichment, with the statistical results pointing to organic nitrogen (N) as a potentially more important driver of impairment than phosphorus (P) (OhioEPA 2014). The finding that organic N was the most likely stressor raised questions relating to the exact mechanism of the impact from an ecological perspective. Enter the USEPA's monitoring and modeling research program in the EFLMR.

## Supporting research

A major research goal of the EFLMR case study is to conduct stream monitoring to obtain data for performance evaluation of the watershed model and tracking the effectiveness of nutrient reduction practices through time. To meet this goal, stream monitoring sites needed to be located to capture nutrient conditions specific to dominant land uses and soil types in the system. This forced a focus on low-order, small-sized streams, which are not typically included in routine state monitoring programs (Figure 2). In larger streams, with larger drainage areas, land use types and soils can't be isolated. This monitoring design was important to identify "background" nutrient concentrations for streams needed for the TMDL development process.

ORD had established nutrient background conditions, operationally defined as the median of the distribution of nutrient concentrations in streams draining relatively undisturbed, forested sites, whose soils were reflective of the dominant classes in the system. ORD proposed using the 75$^{th}$ percentile of these streams' distributions as the targets to help move forward on specific research objectives – 77 µg/l for total phosphorus


*Figure 2. Picture of one of ORD's small stream monitoring sites in the EFLMR.*

(TP) and 707 µg/l for total nitrogen (TN). These target concentrations provided initial information to support the development of the state's LAP, Step 3 of Ohio's TMDL process. After careful consideration of this reference site approach, the state decided to adopt these targets for the far-field, drinking water use TMDL for the lake. However, further investigation into the effects of nutrients on stream organisms was desired to develop the targets for the near-field TMDLs to address the impact to aquatic life.

Owing to the difficulty linking mechanisms of nutrient stress to traditional measures of aquatic life use in streams, ORD designed a novel DNA metabarcoding study focused on characterizing the stream benthic algal community. Algae are of particular interest because they are highly responsive to nutrients and they are critical components of stream ecosystems that affect other organisms through changes in the food web and habitat. Important aspects of the study design included analyzing the existing nutrient data that were available for EFLMR streams to select sites that captured the broad range of nutrient concentrations in the watershed (25 sites shown in white in Figure 1).

Streams were visited weekly over one growing season. Benthic algae were collected from rocks during each sampling event, DNA was extracted, and primers targeting the diatom rbcL chloroplast gene were amplified with polymerase chain reaction (PCR) to characterize the diatom communities across both space and time (Smucker et al. 2020). Diatoms are a type of unicellular algae found in nearly all aquatic environments and they have a long history of research supporting their possible use as indicators of environmental conditions. Metabarcoding and bioinformatics identify the unique gene sequence reads in a sample and these were treated as "operational taxonomic units" (OTUs), which is a concept similar to species but is not a formal taxonomic grouping. Collectively, these OTUs comprise the diatom assemblage in a sample collected from a stream site.

Next, an approach was developed for analyzing the metabarcoding data. Three statistical methods were used to identify possible concentrations along the nutrient gradient at which large changes in the diatom assemblage occurred (Figure 3). The concentrations demarking large shifts in the structure of the diatom assemblage are referred to as change points, and they corresponded well with those established from the small-stream reference condition approach. These change points corresponded closely to the reference condition approach targets and Ohio EPA decided to use them in combination as one set of targets for phosphorus and nitrogen concentrations. This was the second critical piece of information from ORD Research that supported the LAP development.

The change point analysis aggregated the diatom assemblage information to site level means, but two additional exploratory data analyses focused on identifying how changes in nutrient

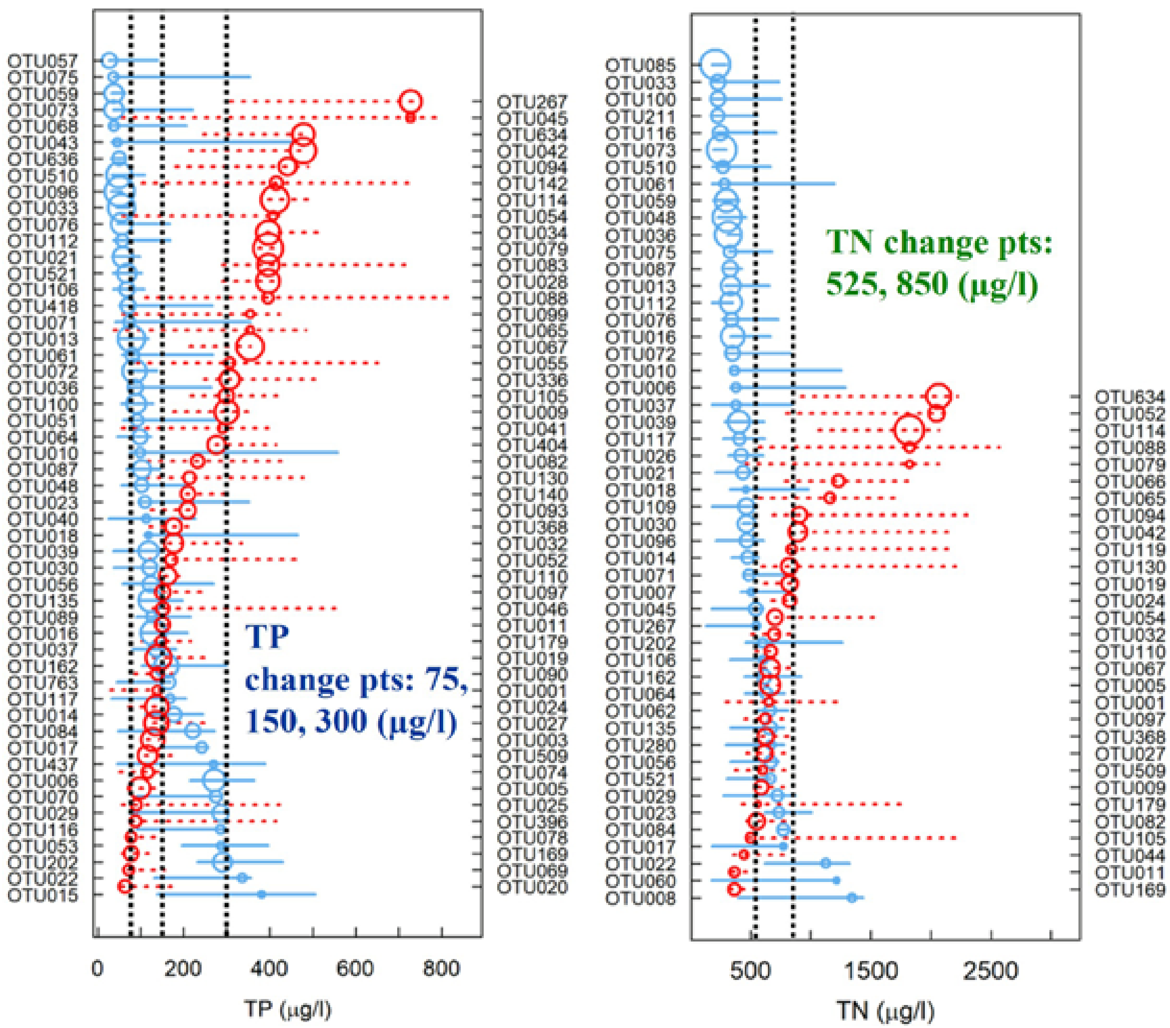


*Figure 3. Graph adapted from Smucker et al. (2020). Possible nutrient targets (vertical dotted lines) based on considering all responses from Threshold Indicator Taxa Analysis (TITAN), boosted regression trees, and gradient forest analyses. Data are taxa change points those indicating low (blue) and high (red) TP or TN concentrations from TITAN.*

concentrations and diatom assemblages over time might affect results and interpretations. Taken together these follow-on analyses supported the relative importance of phosphorus as a community driver and suggested that high frequency benthic algae sampling may not be necessary to capture significant relationships between nutrients and diatoms (Yuan et al. 2022 and Smucker et al. 2022, respectively). These conclusions proved to be a third critical piece supporting the subsequent TMDL development after the LAP was published.

### Impact and future research

ORD and Ohio EPA partnered to write the sections of the LAP entitled "Linking impairment to TMDL pollutants," which is a critical component of the "Proposed Actions" to address the near- and far-field impairments of designated uses (OhioEPA 2021; https://epa.ohio.gov/static/Portals/35/tmdl/LAPs/Little percent20Miami/EFLMR_LAP.pdf. The diatom nutrient change points provided in Smucker et al. (2020) were used to bolster the rationale for setting specific targets for both P and N for the streams needing near-field TMDLs in the system by providing a direct link between nutrient concentrations and support for aquatic life use. The state justified the targets proposed by ORD as necessary for preserving low nutrient diatoms. Because diatoms are primary representatives of the base of stream food webs, loss of low-nutrient diatoms can cascade to higher trophic levels. The follow-on analyses helped the state decide to focus on P for setting proposed point source effluent limits. The LAP formally sets the nutrient targets for the subsequent TMDL calculations in the next step of the process.

Now the plan for the partnership is to use ORD's application of the Soil Water Assessment Tool (SWAT) model in the EFLMR (Karcher et al. 2013) to describe nutrient export for the TMDL calculations and develop nutrient reduction scenarios to meet the near and far-field targets. The SWAT output will be configured in terms of load duration curves using the exiting, background, and targeted nutrient concentrations. The model validated daily loads aggregated to an annual scale will be distributed among source-specific allocations and nutrient reduction requirements. This modeling analysis will be conducted for all the HUC12s and partial ones in the system needing a TMDL, and may serve as a valuable approach for use in other watersheds requiring TMDLs in the state.

Finally, the lessons learned from ORD's monitoring, modeling, and metabarcoding work in the EFLMR are beginning to be applied in other systems, with the intent of further demonstrating their utility toward establishing direct linkages between nutrient concentrations and aquatic life in streams. To this end, ORD is continuing to partner with Ohio and now is collaborating with Indiana on the processing of samples through the benthic algae metabarcoding workflow collected during the state's 303(d) surveys in East Fork of the White River Watershed, IN, and the Wabash, OH, in 2022. Stay tuned.


### Acknowledgments

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**Christopher (Chris) Nietch** is a research ecologist with USEPA's Office of Research Development. He received a doctorate in biological and marine sciences from the University of South Carolina. He has been working on water quality issues related to nutrient pollution for 20 years, directs research at the USEPA's Experimental Stream Facility, and oversees a large watershed partnership with goals of making nutrient reduction efforts more effective at system scale and to prevent harmful algae blooms.

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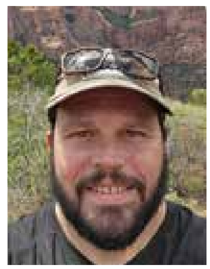

**Richard Mitchell** is a biologist with EPA's Office of Wetland Oceans and Watersheds. He is a team member of the National Aquatic Resource Surveys (NARS) and has led the National Rivers and Stream Assessment (NRSA) for over five years. In additional to leading NRSA, he has been involved in various efforts to develop biological indicators for use in NARS, and more general for the bioassessment community.

**Amina Pollard** is a limnologist and coordinates research for the Office of Water at the U.S. EPA. Her research has advanced our understanding of how environmental change and the structure of landscapes influence freshwater communities and ecosystems. She serves on the Association for the Sciences of Limnology and Oceanography (ASLO) board of directors (2018-2024), and is a scientific advisor to Canada's Lake Pulse research program.

**Lester Yuan** has worked at the U.S. Environmental Protection Agency for 20 years and in the most recent 10 years has focused on nutrient issues in the Office of Water. He received a doctorate in mechanical engineering from Stanford University studying the physics of fluid flow.

# Tracking Climate Impacts on **Vulnerable High Elevation Environments**

Heather Shaw and Paige Thurston

High elevation ecosystems in mountainous regions – often referred to as alpine and subalpine ecosystems – are more vulnerable to climate change than lower elevation ecosystems. Consequently, they are expected to experience climate impacts more rapidly (Minder and Letcher 2017).

Research suggests that small changes in climate can drive large shifts in alpine freshwater systems (Preston et al. 2016). Shorter winters, earlier freshet, and an increase in precipitation as rain versus snow will continue to have an impact on the health and function of alpine ecosystems, and subsequently, the human and biological communities that share these watersheds.

While high and low elevation areas differ in hydrology, biology, and ecosystem pressures, water security efforts require a holistic and integrated view of watersheds. High elevation areas are highly influential on downstream hydrology in the Columbia Basin as they contain the majority of headwaters. Moreover, high elevation areas may even become climate refugia for lower elevation species in the future.

There is an urgency to start collecting data as many high elevation areas in Canada have not been actively monitored. A comprehensive and science-based understanding of these sensitive ecosystems is needed to help fill important data gaps, inform water management and decision making, and support climate change adaptation. It is with this lens that Living Lakes Canada has developed its High Elevation Monitoring Program (HE Monitoring Program).

The HE Monitoring Program aims to collect baseline data and provide insight into how high elevation ecosystems are currently functioning. While some projections about future climate impacts can be made with baseline data, the continuous collection of alpine-specific data over a longer period will increase the accuracy and specificity of these projections.

In 2022, the HE Monitoring Program was piloted in two areas in the West Kootenay region of the Canadian Columbia Basin. A High Elevation Framework (HEF) was developed through considerable consultation with partner hydrologists and biologists, and the Living Lakes Canada's Advisory Board. The HEF outlines the methodologies and protocols required to collect meaningful scientific data in alpine areas. The success of the pilot year has led to an expansion of this project in 2023 (Figure 1).

*Figure 1. Heather Shaw completing a bathymetric map survey on Upper Joker Lake from her inflatable Alpacka raft in August 2022.*

## High elevation monitoring program design

The Canadian Columbia Basin can be divided into ten Hydrologic Regions (HRs). Living Lakes Canada is working to implement a unified and nested monitoring network (known as the Columbia Basin Water Monitoring Framework, or CBWMF) across all ten HRs. As a component of the CBWMF, the HE Monitoring Program feeds into the broader monitoring network.

The data collected through the HE Monitoring Program and the CBWMF are made publicly accessible through the Columbia Basin Water Hub database. The "Water Hub" is a central repository where decision makers, researchers, students, professionals, and the public can access a wide variety of data and information about water in the Canadian Columbia Basin.

The HE Monitoring Program works collaboratively with the CBWMF to identify monitoring sites that will contribute valuable information to the broader project. Water monitoring sites are localized features within a monitoring area, such as a lake and the associated inflow and outflow streams. Where possible, a variety of monitoring sites within an area are selected to capture variability.

In Kokanee Glacier Provincial Park, monitoring sites include lakes that are snow-fed, glacier-fed, and differ in elevation, aspect, depth, and biogeoclimatic (BEC) zones. Collecting data from sites that differ in ecosystem features will generate a broader understanding of climate impacts on the various types of high elevation ecosystems. At each site, biological, physical, and chemical parameters are measured and analyzed, and photo plots are established to track changes at a landscape level. Through the HE Citizen Science Project, an inventory of flora and fauna information is gathered using iNaturalist (https://livinglakescanada.ca/project/high-elevation-monitoring-program/).

Other parameters not directly measured through the HE Monitoring Program, that are key components in understanding high elevation ecosystem health, include: climate, streamflow, snowpack, and glacier mass balance. The HE Monitoring Program tracks climate variability and streamflow parameters through climate and hydrometric stations installed by the CBWMF and in combination with existing climate stations operated by various ministries and other organizations. Snowpack parameters are shared by partnering backcountry lodge owners, and glacier mass balance is collected and published by the World Glacier Monitoring Service.

The HE Monitoring Program data are collected according to the appropriate standards and recognized protocols to ensure that they can be used for analysis, research, and decision-making support. Quality assurance and control are ensured by logging the calibration of equipment, following standardized water sampling protocols, field blanks, and data auditing.

## 2022 pilot implementation

The 2022 pilot areas included four lakes and two streams. The first area, Kokanee Glacier Provincial Park (KGP), is situated northeast of Nelson, B.C. Selected bodies of water in KGP were identified as a priority by the Integrated Lake Monitoring Framework for British Columbia (Zirnhelt et al. 2018). The park holds historical and cultural significance for Indigenous Peoples and the community of Nelson, and offers recreational activities such as mountaineering, skiing, fishing, and hiking. The second area is located north of Valhalla Provincial Park in the Selkirk Mountains.

Sapphire Lake, Lemon Creek, Tanal Lake, and Upper Joker Lake were selected as monitoring sites within the KGP area, and Shannon Lake and Huss Creek were selected as monitoring locations in the Valhalla/Selkirk area. Bathymetric, temperature, and lake level data were collected at Sapphire, Tanal, and Upper Joker Lake and bathymetric data on Shannon Lake was initiated. Biomonitoring was completed on the lower portion of Lemon Creek and the upper reaches of Huss Creek.

The expansion of the HE Monitoring Program will include the addition of temperature and light loggers, depth profiles, and water samples at each lake site. The program will also establish upper and lower biomonitoring locations at each stream site.

The following methods and results will focus on the data collected at Sapphire, Tanal, and Upper Joker Lake as part of the 2022 pilot implementation. Preliminary data on Shannon Lake, Huss Creek, and Lemon Creek will be available on the Water Hub this upcoming summer (Figure 2).

## Methods used in lake data collection

Upper Sapphire Lake is located in the southwest regions of KGP at an elevation of 2,263 m above sea level. The lake is a deep blue sapphire colour as the name suggests and lies within the Interior Mountain-heather Alpine (IMA) biogeoclimatic zone (Government of British Columbia 2022). The lake is predominantly fed by snowmelt and marks the headwaters of Lemon Creek, a large fish-bearing tributary of the Slocan River.

In mid-August 2022, a level logger was installed off the lake's east shore and bathymetric map surveying was initiated. The level logger continuously tracked changes in lake level and temperature at 15-minute intervals from August 15th to October 7th, 2022. Bathymetric surveying was used to create a contoured map of the lake bottom and determine the locations where light and temperature sensors will be installed. Depth profiles will be completed in 2023 and onwards. This methodology applies to all the lakes monitored through the HE Monitoring Program. Site locations were also identified to complete the stream monitoring component of the HEF for 2023.

Tanal Lake sits approximately 500 m below Upper Sapphire Lake at 1,797 m. The dominant surrounding area is characterized by the Engelmann Spruce Subalpine Fir – wet cold (ESSFwc4) biogeoclimatic zone (Government of British Columbia 2022). The lake is predominantly fed by snowmelt and marks the headwaters of Enterprise Creek, another large tributary to Slocan Lake. The monitoring activities carried out at Tanal Lake for the 2022 monitoring season were consistent with those at Upper Sapphire Lake.

Joker Lakes are the only two lakes in KGP that are fed by Kokanee Glacier. Upper Joker Lake is a darker emerald colour, which is a stark contrast to the bright turquoise colour of Lower Joker Lake only 50 m away. The colour difference is due to the glacial stream from

*Figure 2. An image of Upper Sapphire Lake in Kokanee Glacier Provincial Park.*

Kokanee Glacier feeding mainly into Lower Joker, and only a small portion of the melt entering Upper Joker. Glacial streams carry significant amounts of glacial flour. These white particles reflect blue-green wavelengths and create the bright turquoise colour seen by the naked eye.

In August 2022, a lake level on the east side of Upper Joker Lake was installed as well as a string of temperature and light sensors spaced in 1-m intervals from the lake surface to the lake bottom. The sensors continuously tracked changes in light and temperature from August 11th to September 27th. Due to the technical nature of accessing Upper Joker Lake, monitoring sites will be moved to a more accessible area near Talus Lodge, B.C., in 2023. Two lakes near the lodge share similar characteristics to Upper and Lower Joker Lakes.

## Preliminary results

This section outlines the results of the preliminary lake level and temperature data for the HE Monitoring Program pilot collected from Sapphire, Tanal, and Upper Joker Lake. We correlated the data with past 24-hour precipitation and temperature data from the nearby Redfish Creek climate station.

Sapphire Lake expressed the lowest water temperatures ranging from approximately 7º to 11ºC (46.6º to 51ºF). The highest water temperatures for all lakes occurred in August with the lowest temperatures observed in late September to early October.

The largest fluctuations in lake level are correlated with a decrease in water temperature, air temperature, and a precipitation event (Figure 3). The change in water level recorded by the level logger from August to September/October was approximately 10 cm at Sapphire Lake, 12 cm at Tanal Lake, and 20 cm at Upper Joker Lakes (Figure 1).

The graphs in Figure 3 express the relationship between lake level, water temperature, air temperature, and precipitation. While it's too early to identify a baseline condition for these lakes, the study can deduce that there is a strong relationship between the mentioned variables, lake level (quantity), and water temperature (quality). These variables are expected to change year to year due to climate variability. However, long-term monitoring will identify climate trends and large shifts in these variables that are predicted to have a negative impact on these lakes.

## Expanded monitoring through collaboration

After a successful pilot implementation, Living Lakes Canada looks forward to expanding the HE Monitoring Program throughout the Canadian Columbia Basin. In 2023, the HE Monitoring Program will see the addition of four lake and ten stream sites.

Living Lakes Canada will continue to collaborate with the Alpine Club of Canada and the Backcountry Lodge of British Columbia Association to carry out monitoring efforts in 2023.

Preliminary data from the pilot project will be available on the Columbia Basin Water Hub in the summer of 2023. In the short term, the data collected help us to

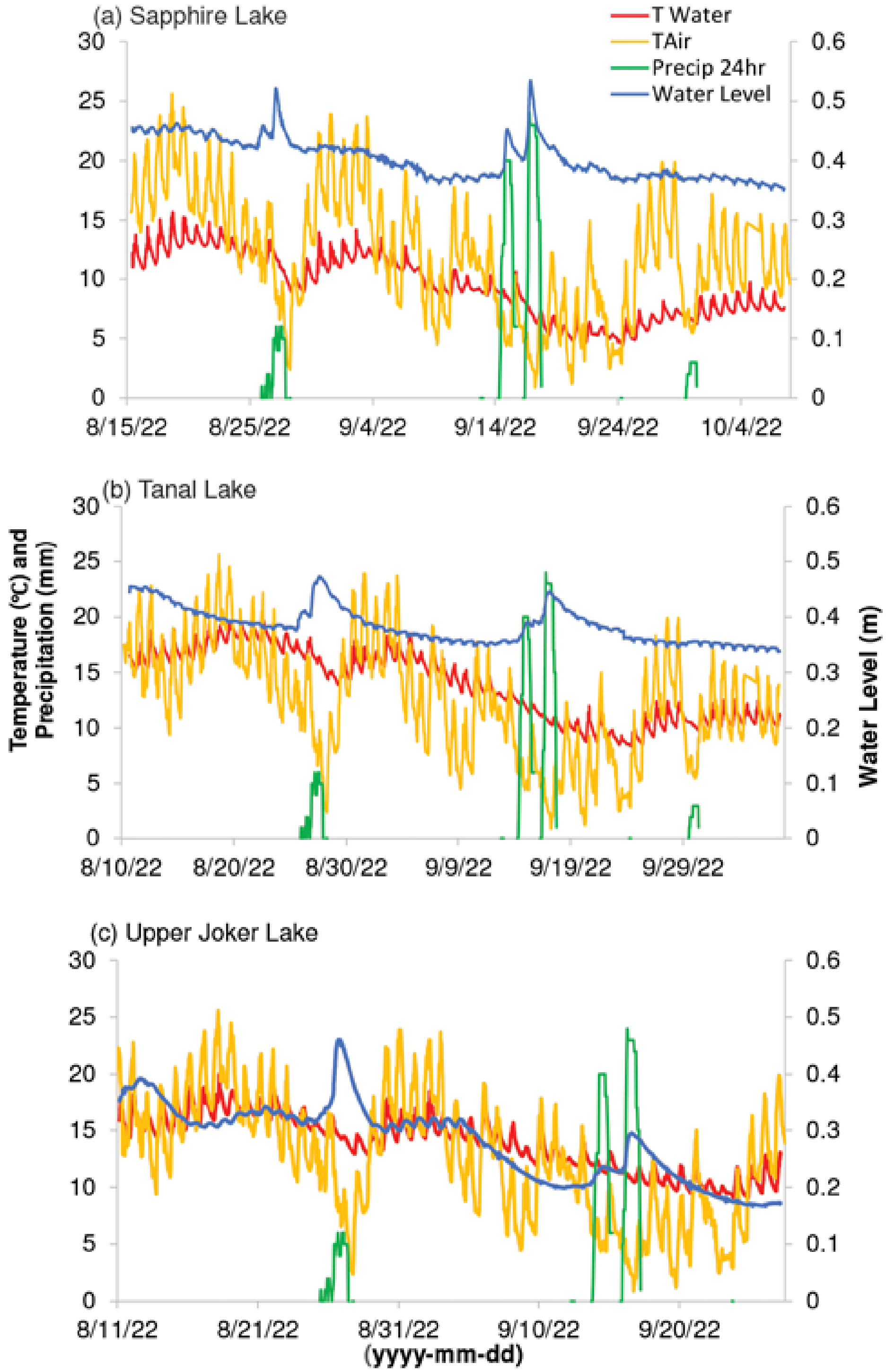


*Figure 3. Values in lake level and water temperature (T water) for three high elevation lakes within the Canadian Columbia Basin, correlated with air temperature (T air), and past 24-hour precipitation data from the Redfish Creek, B.C., climate station from August-October 2022.*

understand the current state of these lakes and to identify strategies for climate change adaptation and watershed security. Regional modeling will improve as more data are acquired year to year.

Given the hydrological, biological, and cultural importance of these mountainous ecosystems and their particular vulnerability to climate impacts, there is exceptional value in a continuous, long-term study. Such a study will provide the data required to more accurately model climate trends and changes, which in turn can inform climate adaptation planning.

The HE Monitoring Program, in conjunction with the CBWMF program, will support these efforts towards water security.

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**Heather Shaw** works with Living Lakes Canada as the High Elevation Monitoring Program Manager. In this role, Heather oversees monitoring objectives on select high elevation sites throughout the Canadian Columbia Basin and is working to expand the program throughout B.C. Heather is a graduate of the Selkirk College Recreation, Fish & Wildlife program and holds a degree in natural resource science from the Thompson Rivers University.

**Paige Thurston** works with Living Lakes Canada as the Columbia Basin Water Monitoring Framework Program Manager. In this role, Paige leads the implementation of a coordinated water and climate monitoring network for the Canadian Columbia Basin region. Paige is a graduate of the Forest Technology program at Selkirk College, holds a degree in environmental science from Royal Roads University and is currently pursuing a master of natural resources through the University of Idaho.

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Rev. 1/19


# "Lakespert" – It's Not the Plant's Fault

Steve Lundt, CLM

When it comes to aquatic invasive species (AIS), I think we focus too much on the individual species, the actual infestation, and damage control, and not enough on the root cause – people making decisions. People's actions, most of the time accidentally, lead to moving these species where they don't belong. I constantly remind myself that it is not the species' fault. The Brazilian elodea did not decide to travel up from South America. The common carp didn't swim to the U.S. in the 1830s. The sticky zebra mussel was doing just fine in the Caspian Sea. People's decisions and actions moved these species, and now we have words like invasive, non-native, nuisance, introduced, and invaders to help explain what we have done wrong.

*Figure 1. Three invasives piggy-backing their way into a new treatment pond system just for a pretty photo shoot. The choices we make can have major consequences down the road.*

Here is a great example. A series of three one-acre treatment ponds were constructed to polish wastewater effluent before being released into a river. Just before the grand opening of the facility, administrative staff decided to heavily, and I mean heavily, plant decorative aquatic plants in and around the treatment ponds for opening-day photos (Figure 1). Six months later, I discover three AIS plants, parrotfeather, Eurasian watermilfoil, and Brazilian elodea (first discovery for Colorado), growing in the ponds (Figure 2a-c). At least three of the 250+ aquatic plant pots that a landscaping contractor installed had hitchhikers. Each species was found growing out of a pot. Poorly managed aquascaping practices and administrative decisions clearly created this AIS problem.

The last five years have been spent on eradication efforts ($85,000 on herbicides and at least another $50,000 on staff time), monitoring, and being frustrated with these plants. About 90 percent of the effort has been focused on the species and reactionary efforts. Little effort has been spent on figuring out how people created this problem, and how we can prevent this from reoccurring. We did raid the landscaping nursery but found no evidence of AIS or wrongdoing. The aquatic plant and aquascaping industry need to make better decisions on how aquatic plants are cultivated, transported, sold, and installed in our waterbodies. Administrative staff need to be aware of the unintended consequences and need to include water quality-oriented experts when making water-related decisions – even for a photo shoot.

An ounce of prevention is worth a pound of cure. Let's make better decisions up front to avoid AIS problems and stop blaming the species.

**Steve Lundt**, Certified Lake Manager, has monitored and worked to improve water quality at Barr Lake (Denver, Colorado) for the past 19 years. Steve is active with the Colorado Lake & Reservoir Management Association and is a past Region 8 director for NALMS and an active member since 1998.


*Figure 2. Invasive plants found in the ponds include (a) hydrilla; (b) parrotfeather; and (c) Brazilian elodea.*