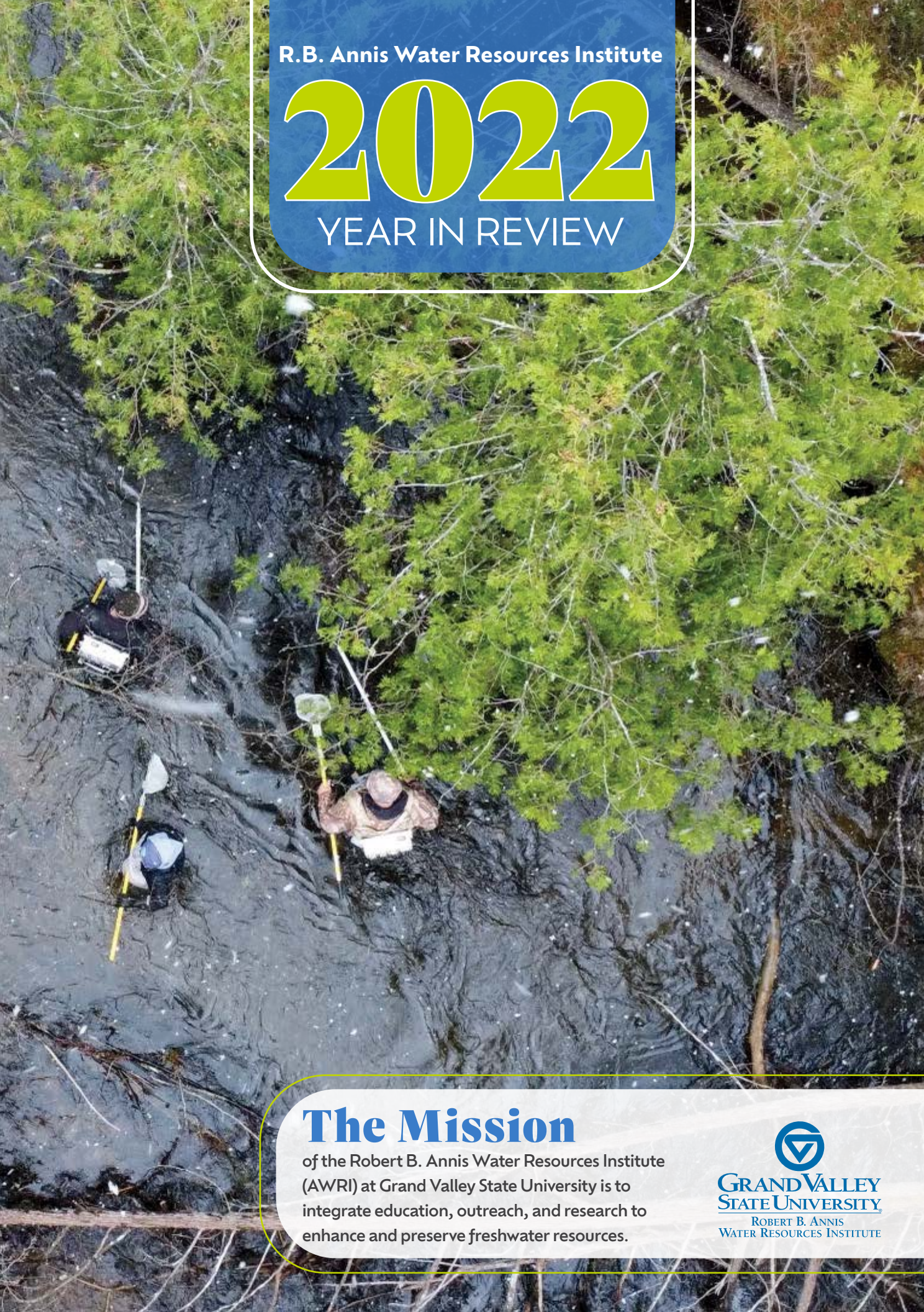

R.B. Annis Water Resources Institute

2022

YEAR IN REVIEW

The Mission

of the Robert B. Annis Water Resources Institute (AWRI) at Grand Valley State University is to integrate education, outreach, and research to enhance and preserve freshwater resources.

Grand Valley State University
Robert B. Annis Water Resources Institute

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DIRECTOR'S COMMENTS

When I started at GVSU in 1989, enrollment was around 10,000 students and what is now the Robert B. Annis Water Resources Institute had only just been established. Ron Ward, AWRI's first Director, was starting to lead the Institute full-time, and I was hired to assume most of Ron's teaching load. The thought that I have been at GVSU for over half of the school's history and almost the entire time that AWRI has been in existence is a little sobering, but also, deeply rewarding. Now, as Al Steinman moves into his new role, I am delighted to have the opportunity to serve as Interim Director.

Grand Valley's history of educating individuals about water resources started in 1964 when Donald J. Angus donated the motor launch, the *Angus*, to GVSU to be used as a "floating classroom". Since then, AWRI has launched two vessels, the *D.J. Angus* (1986) and the *W.G. Jackson* (1996), and those programs have reached 184,000 people in 4 states. Additionally, AWRI provides undergraduate and graduate students the opportunity to be engaged in real-world research and high-impact educational experiences. Since 2001, AWRI faculty have mentored 300 undergraduate students and 120 graduate students on research projects, with many students presenting their work at professional conferences or publishing in a scientific journal. The contribution that AWRI makes to the educational mission of GVSU while advancing the understanding of our water resources is exceptional.

In 2001, AWRI started a new chapter when Al Steinman was hired to serve as Director. Under Al's directorship, AWRI has emerged as a highly respected research group. During COVID alone, AWRI faculty/staff authored or co-authored 40 peer-reviewed articles and book chapters, gave 84 presentations, 44 of which were with or by students, and the faculty were awarded nearly $2,950,000 in grants and contracts. Even more impressive is the fact that much of the AWRI research has been used to make management decisions that aimed at improving the quality of our water resources.

Even with this short accounting of accomplishments, it's obvious that AWRI has had a lasting impact on our understanding of aquatic ecosystems, the health of our region's water resources, and the education of the next generation of scientists. The success that AWRI has realized over the years has come through the hard work of students, faculty, and staff alike. I am confident that we will continue building AWRI's legacy by promoting a vibrant and creative environment that will support our research and educational mission, and ultimately contribute to sustaining our water resources.

Mark Luttenton

Interim Director, AWRI

Professor of Biology

AWRI Hosts Joint Aquatic Science Meeting

AWRI Director Mark Luttenton and Al Steinman co-chaired a meeting of the Consortium of Aquatic Science Societies, a group of nine different societies with varying scientific interests that combine for a larger meeting once every several years. Over 2,400 scientists, students, and vendors from 57 countries traveled to Grand Rapids, Michigan for a week in May to attend the conference. Almost 1,000 more attendees joined online via the meeting's virtual platform. AWRI and GVSU faculty, staff, and students attended and gave poster and oral presentations of their research, attended workshops, and networked with other scientists spanning across academia, the private sector, and various local, state, federal, and tribal agencies. AWRI also hosted two cruises onboard the *W.G. Jackson* of Muskegon Lake and the Lake Michigan shoreline, first for a group of African women scientists and a second as a post-conference field trip.

A group of African women scientists joined AWRI vessel staff for a cruise on the *W.G. Jackson*, supported by the African Center for Aquatic Research and Education (ACARE). Photo Credit: Janet Vail.

PARTRIDGE JOINS MLSA BOARD

Charlyn Partridge in her lab with a genetic analyzer.

Dr. Charlyn Partridge was invited to join the Board of Directors of the Michigan Lakes and Streams Association. This exciting opportunity allows her to work more closely with statewide lake associations and private citizens to solve some of the most pressing environmental concerns facing our freshwater resources.

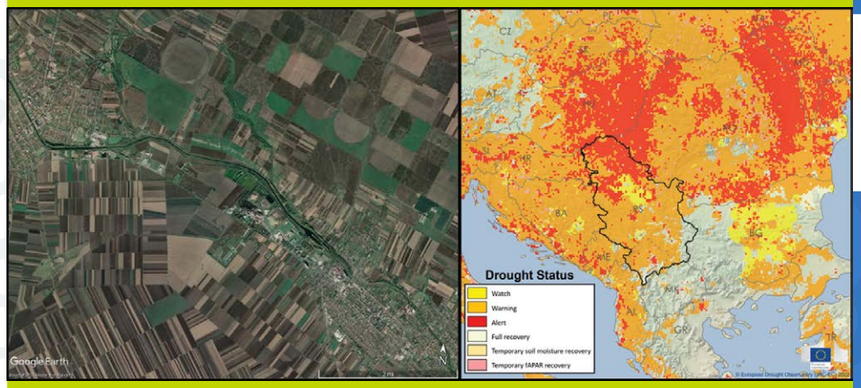
Biddanda Wins Award

Bopi Biddanda on field work at the Middle Island Sinkhole, Lake Huron.

AWRI's Dr. Bopi Biddanda was awarded the Distinguished Contribution to Discipline award by GVSU in 2022. Bopi was recognized for his contributions to advancing the field of Aquatic Microbial Ecology and Carbon Biogeochemistry. As the award commendation states: "Biddanda is an internationally recognized expert in the field of Microbial Ecology and Carbon Biogeochemistry, particularly in the Great Lakes. Biddanda's activities, attitude, and productivity have brought distinction and recognition to GVSU." Congratulations, Bopi!

IRRIGATION IN A HOTTER, DRIER DANUBE

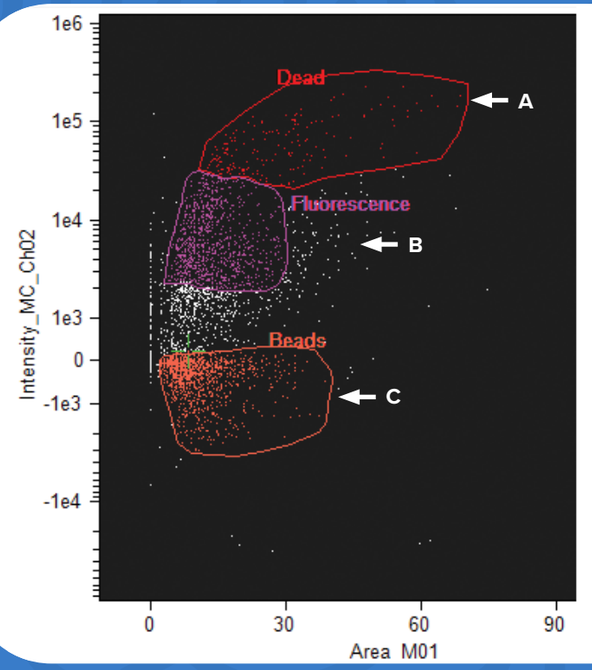
Dr. Sean Woznicki received a NASA grant to study how climate change, agricultural markets, and water availability alter the agricultural landscape in the Serbian Danube River Basin. Serbian farms are typically less than 30 acres, roughly 10 times smaller than the average Michigan farm. The landscape is a shifting mosaic of corn, soy, wheat, and sunflower crops year after year. As Serbia faces increasingly dry summers, farmers must decide whether to invest in irrigation, plant drought-tolerant crops, or carry on as normal. This leads to potential exploitation of ever scarcer water resources. Dr. Woznicki and colleagues at Michigan State University, Michigan Technological University, University of Oklahoma, and the BioSense Institute in Serbia are combining satellite remote sensing of agricultural change, computational watershed modeling, and economic analysis to understand how farmers, and their imprint on the landscape, will respond to a warmer and drier future. While this analysis is regional, the lessons learned will be applicable globally.



(Left) Typical agricultural landscape in Serbia, with small fields and expanding irrigation. Image Credit: Maxar Technologies 2022 and Google Earth. (Right) Serbia's agricultural regions experienced drought alerts for much of the 2022 growing season. Image Credit: European Drought Observatory 2022.

Re-Using Organic Wastewater and Environmental Impacts

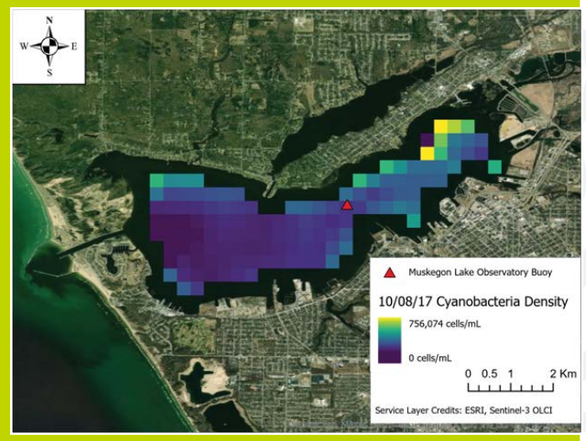
Working with local agricultural producers, industry food processors, conservation districts, and state legislators, Dr. Kevin Strychar is studying agricultural safety and the use of natural organic fertilizers and irrigation water as a mechanism to reduce or eliminate dependence on synthetic fertilizers. Materials assessed include nutrients (e.g. nitrates), heavy metals (e.g. arsenic), and bacteria of concern (*Escherichia coli*) using novel methodologies called imaging flow cytometry (IFCM). The goal is to develop a rapid method to detect and potentially eliminate any pathogens infecting food-consumer sources and human health.



Simultaneous detection of (A) dead and (B) live *E. coli* using IFCM. Cells shown in "C" are beads used to help characterize size, shape, and concentration of cells of interest. Figure Credit: Kevin Strychar.

Sensing HABs from Space

Undergraduate student Jillian Greene is working with Dr. Sean Woznicki and Dr. Bopi Biddanda to remotely sense cyanobacterial Harmful Algal Bloom (cHAB) densities in Muskegon Lake. By applying an algorithm to Sentinel-3 satellite imagery, cHAB densities can be quantified from historic and present-day images. The remotely sensed cHAB data is compared to the Muskegon Lake Observatory Buoy's high resolution HAB measurements. Remote sensing of cHABs can provide critical water quality data to lakes that do not have regular monitoring programs.



Cyanobacteria in Muskegon Lake, MI on October 8, 2017 calculated with Sentinel-3 imagery. Image Credit: Jillian Greene.

AND THE SURVEY SAYS...

Muskegon residents' satisfaction with various public access features at Muskegon Lake, on a scale of 1 (very unsatisfied) to 10 (very satisfied). Image Credit: Amanda Buday, Dani DeVasto, and Sean Woznicki.

GVSU faculty Amanda Buday (Sociology), Dani DeVasto (Writing), and Sean Woznicki (AWRI) developed a mail survey to understand Muskegon residents' perception of Muskegon Lake's environmental quality and their engagement in and barriers to recreation opportunities there. Surveyed residents were satisfied with some features at Muskegon Lake, particularly the Lakeshore Trail, although there were many suggestions to improve what the lake offers to the public.

BEACH MONITORING FOR PUBLIC HEALTH

(L to R) Renée Tardani, Emma Piasecki, Katelyn Anderson, Alexis Porter, and Amelia Heminger collecting samples and monitoring beach conditions at Meinert Park.

AWRI staff and interns monitored Lake Michigan beaches in Muskegon County throughout the summer to determine whether water is safe for swimming, or if authorities may want to issue warnings or close beaches. Data is reported to Public Health Muskegon County and can be found online at www.egle.state.mi.us/beach.

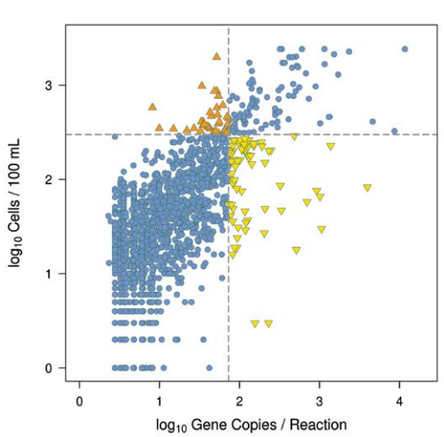
IFCM for *E. coli* Beach Monitoring

In Michigan, total reported cases of *Escherichia coli* (*E. coli*) appear to be increasing along beaches used by both local and visiting tourists. Molecular methods such as quantitative polymerase chain reaction (qPCR) offer a great opportunity to identify specific strains of *E. coli.* However, a newer method, called imaging flow cytometry (IFCM) combined with molecular tags offers another opportunity to improve the management of beach usage and avoid public health risks.

Graduate student Katelyn Anderson poses next to the imaging flow cytometer.

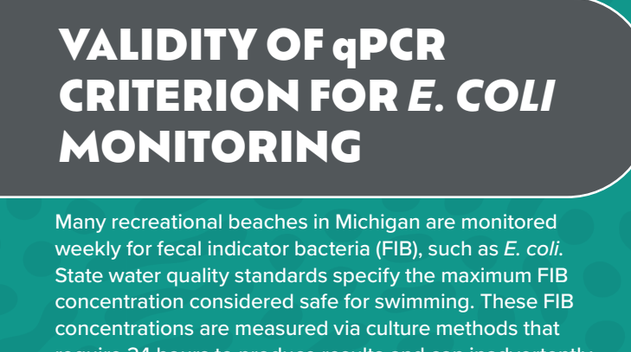
VALIDITY OF qPCR CRITERION FOR *E. COLI* MONITORING

Many recreational beaches in Michigan are monitored weekly for fecal indicator bacteria (FIB), such as *E. coli*. State water quality standards specify the maximum FIB concentration considered safe for swimming. These FIB concentrations are measured via culture methods that require 24 hours to produce results and can inadvertently allow a full day of swimming at beaches that were unsafe when sampled. Michigan has proposed a new qPCR beach safety criterion for determining FIB concentrations that produces results in only 3-4 hours, making same-day safety decisions possible. AWRI assessed the validity of the proposed criterion using beach monitoring data from 2016-2020 comprising paired culture and qPCR-based concentrations. Beach safety decisions for the two methods agree in 91–95% of cases. Importantly, the proposed criterion correctly detects unsafe conditions in over 70% of cases where culture-based results available the next day show the beach had been unsafe.



Beach monitoring data for FIB concentrations at 127 Michigan beaches in 2019 and 2020, showing paired culture-based concentrations (vertical axis) and qPCR-based concentrations (horizontal axis). Horizontal dashed line is Michigan's culture-based safety standard; vertical dashed line is the proposed qPCR-based criterion. 95% of qPCR-based decisions agree with corresponding culture-based decisions, and 98% of beaches identified as safe by qPCR are also safe by the culture-based method. Figure Credit: Jim McNair.

Restoration Progress or Regress in the Everglades?



Al Steinman (orange shirt, back row) poses with other CISRERP members.

Dr. Al Steinman has continued his work on the National Academy of Sciences' *Committee on Independent Scientific Review of Everglades Restoration Progress* (CISRERP) for the US Congress. His service has included site visits to the Everglades, numerous Zoom meetings, and considerable research and writing. Steinman's contributions have been on the new regulation schedule for Lake Okeechobee, the phosphorus-reduction performance of the Stormwater Treatment Areas, and impacts of climate change on the inland water systems. The book is slated for publication in late 2022.

FROM LAKE TO LAKE: A VISIT BY SENATOR PETERS

Al Steinman (left) and U.S. Senator Gary Peters (right) onboard the *W.G. Jackson*. Photo Credit: Kendra Stanley-Mills, GVSU.

U.S. Senator Gary Peters visited AWRI in late August as part of his motorcycle tour through Michigan. Senator Peters highlighted his strong support of the Great Lakes Restoration Initiative, which has provided the funding to restore Muskegon Lake, among other Great Lakes Areas of Concern. Peters sailed on AWRI's research vessel, the *W.G. Jackson*, where Dr. Al Steinman explained the restoration activities on Muskegon Lake, and how this has helped revitalize the area.

Grad Research Supports Re-Establishing Arctic Grayling in Michigan

Nick Vander Stelt, a graduate student working with Dr. Carl Ruetz, conducted fish and habitat surveys in tributaries of the Boardman River in collaboration with the Little River Band of Ottawa and Chippewa Indians. His research will help fishery managers identify which streams should be targeted for the reintroduction of Arctic grayling – a native species that was once abundant in Michigan's northern Lower Peninsulas but was extirpated by human activities in the early 1900s. Although the actual stocking of Arctic grayling in Michigan streams is still several years away, fisheries managers will need to prioritize streams for reintroduction given the finite number of fish that will be available for stocking efforts. To be successful, streams where Arctic grayling are likely to thrive should be the focus of reintroduction efforts. Nick's research identified many high-quality, coldwater streams in the Boardman River watershed that may be candidates for reintroduction.

Nick Vander Stelt holds a brown trout captured during an electrofishing survey. Photo Credit: Tori Vander Stelt.

Nick Vander Stelt measures a brown trout captured during an electrofishing survey. Photo Credit: Brett Fessel, Grand Traverse Band.

New Research on Yellow Perch in Eastern Lake Michigan

Yellow perch is a native species in Lake Michigan that is well below peak abundance. A new study, led by Dr. Carl Ruetz, will identify the proportion of yellow perch harvest in several drowned river mouth lakes that consists of migrants from Lake Michigan using a combination of isotopic and genetic analyses. This research is a collaboration with Purdue University and Michigan Department of Natural Resources. Ultimately, the goal is to better understand and manage yellow perch populations in Lake Michigan. This research is funded by the Great Lake Fishery Trust.

Student researchers sample yellow perch with boat electrofishing from a drowned river mouth lake. Photo Credit: Tyler Hoyt.

A yellow perch captured during an electrofishing survey of a drowned river mouth lake. Photo Credit: Tyler Hoyt.

IMPROVING FISH PASSAGE

The Ruetz Lab continued its second year of conducting fish and habitat surveys in West Michigan streams to support habitat improvement efforts. This year's efforts were focused on improving fish passage in Stony Creek and tributaries of the White River.

GVSU students and staff sample fish in Stony Creek with backpack electrofishers. Photo Credit: Carl Ruetz.

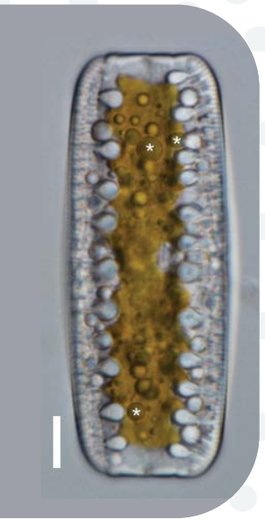
GVSU students and staff sample fish in Stony Creek with backpack electrofishers downstream from culverts that increase water velocity at Marshville Dam Road. Photo Credit: Carl Ruetz.

Technician Grayson Kosak measures water velocity in Swinton Creek, a tributary of the White River. Photo Credit: Carl Ruetz.

THE HOLE STORY

(L to R) Ian Stone, Anthony Weinke, and Davis Fray measuring water parameters and sampling microbial mats at a spring outlet near the shoreline of Lake Huron. Photo Credit: Bopi Biddanda.

Dr. Sarah Hamsher and her graduate student Davis Fray, with Dr. Bopi Biddanda and technicians Ian Stone and Anthony Weinke, are continuing to study the fascinating microbial communities inhabiting the sinkholes of Lake Huron. These sites are fed by low-oxygen, high-sulfur groundwater, creating conditions comparable to those found in ancient seas. Microbes including cyanobacteria and diatoms form mats over the sediment here, working together to take advantage of the extreme water conditions using various metabolism strategies. Davis' molecular investigation of these mat communities is providing a new level of detail of their taxonomic composition, including the discovery of new species. Additionally, Davis is using culture experiments to unravel the interactions between members of the mat community, revealing how they are maintained over time. Learning more about the composition and activities of these communities could provide insights on the microbial inhabitants of ancient seas that were responsible for oxygenating Earth's atmosphere.



THE EVOLUTION OF ENDOSYMBIONTS

Rhopalodiales are a group of diatoms (microscopic algae with glass cell walls) that have obligate cyanobacterial endosymbionts (cells that live within cells like nesting dolls). These endosymbionts fix atmospheric nitrogen for the diatoms, allowing the diatoms to grow in low nitrogen environments, a competitive advantage. However, the Rhopalodiales have lower reported diversity than other similar groups of diatoms. Dr. Sarah Hamsher and colleagues are exploring this perceived paradox and the evolution of this unique relationship.

Light microscope image of a live Epithemia cell with cyanobacterial endosymbionts (asterisks). The scale bar represents 10 microns. Photo Credit: Sarah Hamsher.

Seeing Green

AWRI again hosted a three-day Plankton Algae Course, which was sponsored by EGLE with Dr. Rick Rediske as the main instructor. Water treatment personnel from throughout Michigan were in attendance.

Adult learners working together to identify algae species. Photo Credit: Janet Vail.

Exploring an Analog of Earth's Ancient Seas

An overhead drone-view of Great Sulphur Spring and the raft used to explore its depths. Photo Credit: Davis Fray.

Springs venting low-oxygen, high-sulfur groundwater have similar water chemistry to ancient seas, making them interesting study sites. Davis Fray (graduate student), Collin Toth (undergraduate student), Ian Stone (technician), Dr. Bopi Biddanda, and Dr. Sarah Hamsher explored the interior of Great Sulphur Spring in Erie, Michigan and discovered fascinating microbial mat communities living at the bottom of this spring-fed sinkhole.

Vessel Program Surfs Wave of Change

The 2022 Outreach and Education season commenced with an adventurous start, as construction on a drawbridge in Grand Haven, Michigan delayed the beginning of the spring vessel season for the *W.G. Jackson* and resulted in a temporary docking location change for the *D.J. Angus*. However, the staff of both vessels met the challenge head on, and soon began what would become a successful year of trips!

In 2022, the program happily returned to near pre-pandemic numbers of participants and a bustling cruise schedule. New staff to the program this year include four new science instructors, several new engineers and deckhands, and two new captains. Eric Hecox was promoted as the new AWRI fleet captain. Also new for the 2022 season was fully outdoor "classroom" programming for students visiting AWRI. Engaging outdoor activities were used to allow students to interact with their "place" using place-based education pedagogy and incorporated Michigan K-12 Science Standards for education.

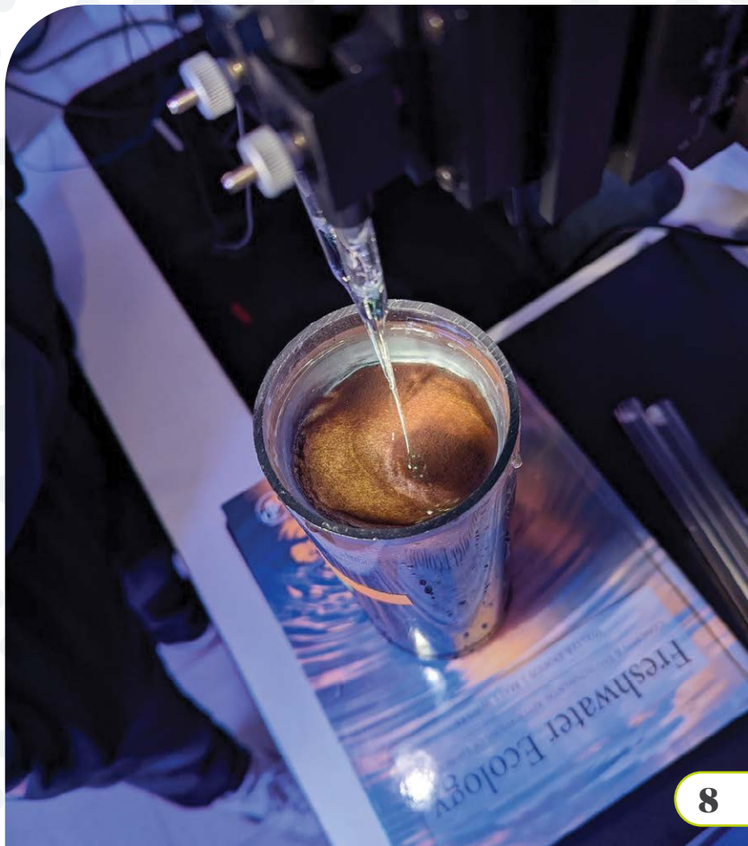
Students measuring water quality on the *D.J. Angus*. Photo Credit: School News Network/ Dianne Carroll Burdick.

Science instructor Doug Haywick teaching students. Photo Credit: School News Network/ Dianne Carroll Burdick.

DAILY TANGO IN MATWORLD

Microbial mats found in submerged sinkholes of Lake Huron resemble life on early Earth. Here, sunlight-loving purple cyanobacteria and sulfide-loving white sulfur-oxidizing bacteria, take turns migrating to the surface during day and night, respectively. Oxygen and hydrogen sulfide measured at sub-millimeter depth intervals revealed that cyanobacteria rise daily to harvest sunlight for photosynthesis and sulfur-oxidizing bacteria rise nightly to utilize hydrogen sulfide for chemosynthesis – providing insights into how the early sunny and smelly biosphere functioned.

Micro-profiling of microbial mats using diver collected intact mat-sediment cores under simulated day-night conditions in the laboratory. Photo Credit: Janelle Cook.



AWRI AT WORK

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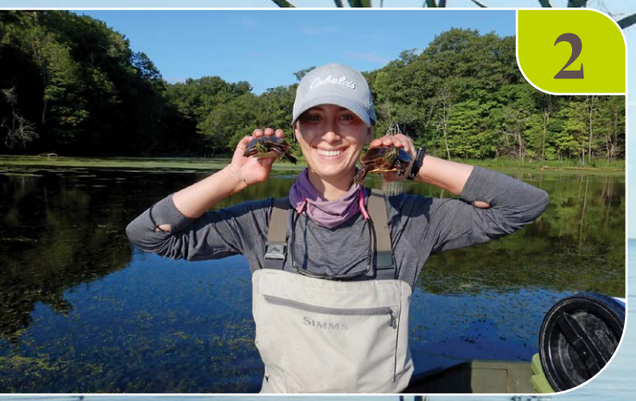

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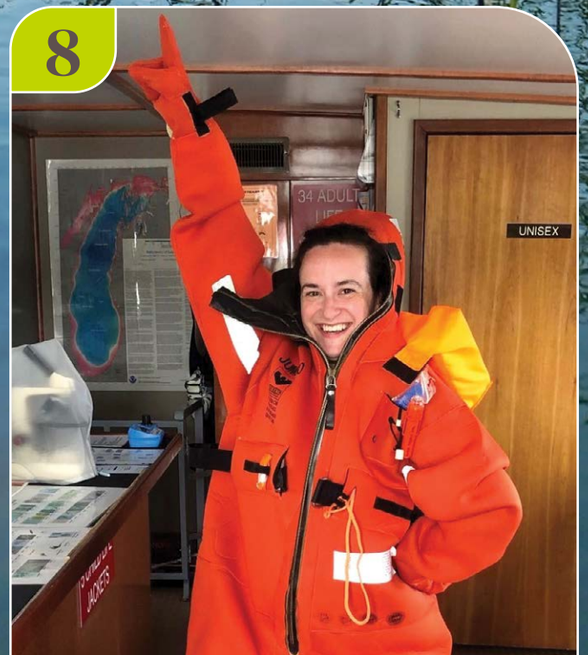

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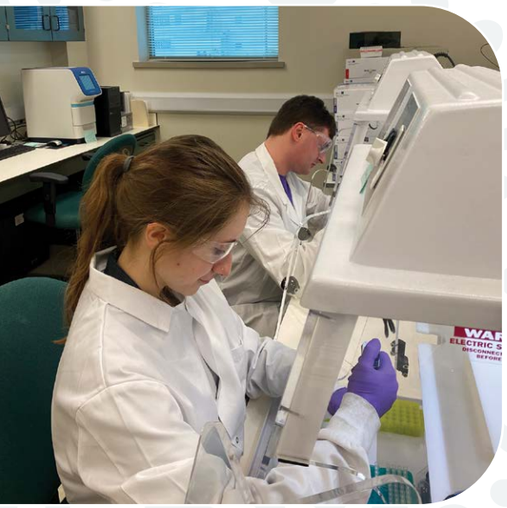
1. Graduate student Ellen Foley samples a snowbank.
2. Technical call-in Sunny Charpentier holding two painted turtles (*Chrysemys picta*).
3. Tyler Hoyt, Nick Vander Stelt, Davis Fray, and Grayson Kosak take a fishing break in downtown Muskegon.
4. Partridge Lab undergraduate Kathryn Geller deploys her 3D printed eDNA traps.
5. Summer interns Margaret Evele and Alexis Deephouse collecting mussels.
6. Research assistant Travis Ellens and intern Jacquelyn Molloseau measuring water quality on Lake Macatawa.
7. Al Steinman on his last day as AWRI Director.
8. Education specialist Christina Catanese in an immersion survival suit.
9. AWRI students, staff, and faculty presenters at the 2022 Michigan Lakes and Streams Association conference.
10. Ruetz Lab undergraduate Jacob Yingling exhibits his perch research at GVSU's first Chalk Art Symposium.
11. Technical call-in Colin Assenmacher holding a longnose gar (*Lepisosteus osseus*).
12. Biddanda Lab members Ian Stone, Janie Cook, Jillian Green, and Nate Dugener taking a boat ride to the Muskegon Lake Observatory Buoy.

Research assistant Alexis Porter conducts ddPCR testing of wastewater samples. Photo Credit: Brian Scull.

AWRI Completes Year of Wastewater Monitoring

AWRI completed the first year in a two-year project to monitor the SARS-CoV-2 virus in wastewater samples from Muskegon and Ottawa Counties. The Rediske Lab obtained a $1.7M grant from the Michigan Department of Health and Human Services (MDHHS) to collect and analyze weekly wastewater samples from Spring Lake, Grand Haven, Muskegon, Allendale, and the GVSU Campus. AWRI used ddPCR (droplet digital polymerase chain reaction) technology to measure viral RNA and track the presence of the Delta and Omicron variants. Drs. Richard Rediske and Charlyn Partridge are leading the project and AWRI staff Alexis Porter, Renée Tardani, and Brian Scull are conducting the testing with the assistance of undergraduate intern Emma Piasecki and GVSU-MPH graduate student Tyler Chlystek. The results are reported to the MDHHS, Center for Disease Control and Prevention, local health departments, wastewater utilities, and the GVSU Virus Action Team. AWRI was able to track the rise of the Omicron and the effectiveness of GVSU's vaccine mandate.



USING MOLECULAR SOURCE TRACKING TO ID PROBLEMS IN WATERSHEDS

The Rediske Lab started a three-year project with the Ottawa Conservation District in the Crockery Creek and Sand Creek watersheds and a one-year project with the Two Rivers Coalition on the Black River and Paw Paw River watersheds using Molecular Source Tracking to determine the origins of high *E. coli* levels. AWRI will focus on determining the source of bacterial pollution by testing environmental DNA markers for human, cow, and ruminant fecal pollution.

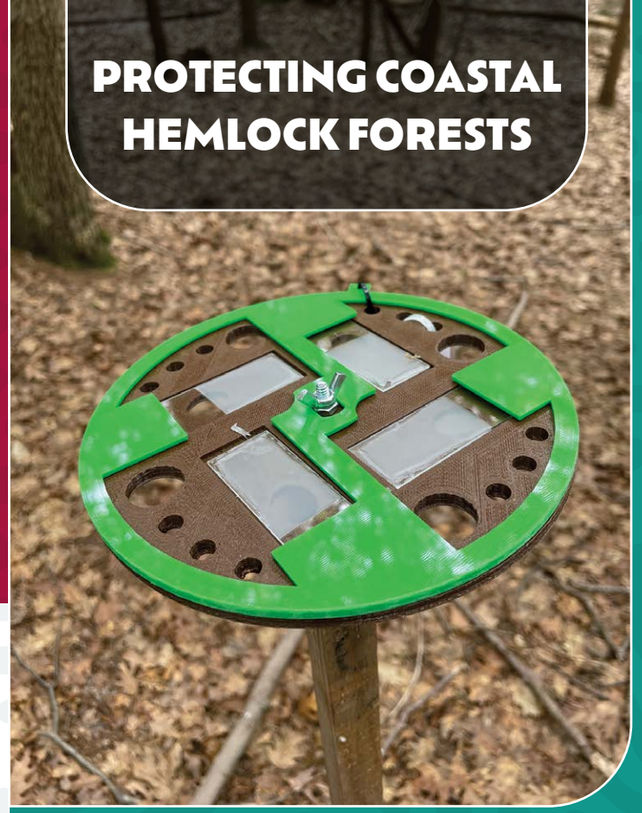
AWRI staff member Renée Tardani and graduate student John Hart prepare sample plates for ddPCR testing of human and animal markers. Photo Credit: Alexis Porter.

Wild Rice Genetics

Partridge Lab undergraduate students Elliot Fair and Carlin Moore are continuing to work with the Gun Lake Tribe to assess the population genetics of wild rice (manoomin) across Michigan. They are also evaluating how fungal disease and rice worm infestations vary across wild rice populations and how abiotic factors may be driving this variation.

Elliot Fair measuring wild rice height. Photo Credit: Charlyn Partridge.

Carlin Moore removing wild rice DNA gel bands for sequencing. Photo Credit: Charlyn Partridge.



HWA eDNA trap designed and 3D printed by Partridge Lab undergraduate Kathryn Geller. Photo Credit: Charlyn Partridge.

HWA eDNA trap deployed in Huron-Manistee National Forest. Photo Credit: Charlyn Partridge.

Eastern hemlock is a keystone species that provides erosion control, water filtration, wildlife habitat, and regulates stream temperatures. In Michigan, coastal hemlock forests are under threat from a tiny invasive pest, hemlock woolly adelgid (HWA). HWA is an invasive, sucking insect that feeds on the nutrients contained in hemlock trees. Without treatment, this can result in the death of a hemlock tree within four to seven years. In the eastern United States, HWA has devastated hemlock-dominated forests and drastically shifted the community composition of these ecosystems. The current invasion of HWA in Michigan was first detected in 2016 and, since that time, it has spread to five counties. With a grant from the Michigan Invasive Species Grant Program, the Partridge Lab is using environmental DNA (eDNA) to help monitor for HWA in high-risk areas. In addition, the lab is also exploring how the presence of HWA may drive community composition changes within these ecosystems.

The Bebot drone removing plastics from Pere Marquette Beach in Muskegon. Photo Credit: WZZM 13.

BEBOT AND PIXIE KEEP IT CLEAN

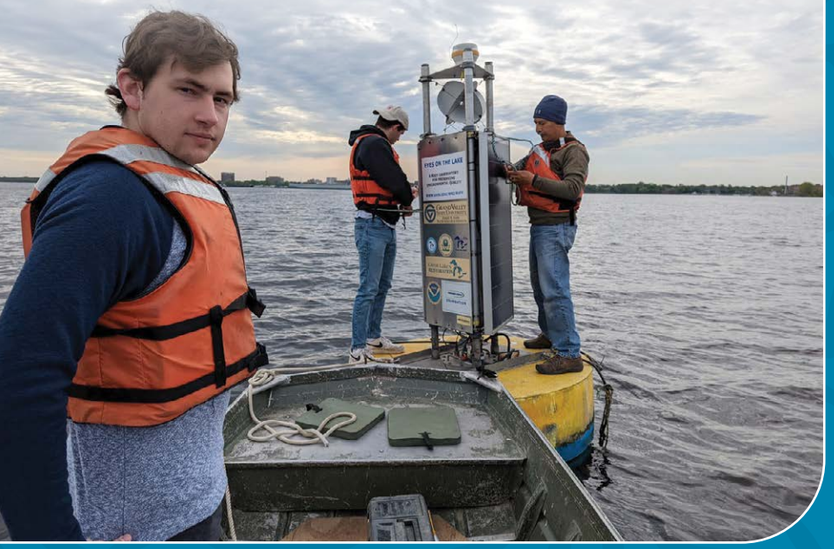
AWRI, Meijer, and the Council of the Great Lakes Region are teaming up to remove microplastics at their source while educating the community about the impacts of plastics as part of the Great Lakes Plastic Cleanup. In the center of it all is the Bebot and Pixie drones, which are designed to remove debris from beaches and waterways. Watch for them in Summer 2023!

Microplastics and Microbiomes

Microplastics are found everywhere in terrestrial and aquatic environments. When microplastics are ingested by aquatic wildlife, data evaluating health implications for individuals ingesting these pollutants are variable. Partridge Lab graduate student Maggie Petersen evaluated how microplastic ingestion impacts the health and natural gut microbial community of fathead minnows. Maggie found that microplastic ingestion significantly impacted growth rates in male fathead minnows, but there was no effect on the natural gut microbial community for these individuals.

Male fathead minnows used in microplastic ingestion study. Photo Credit: Charlyn Partridge.

Running Out of Oxygen

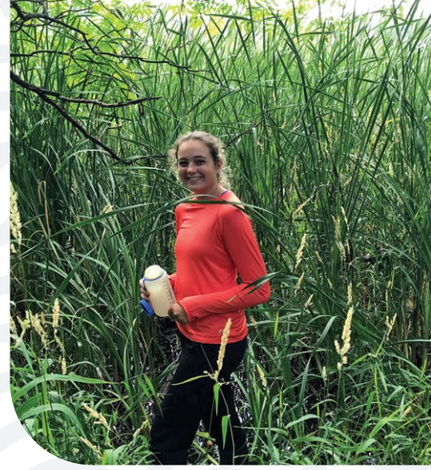


(L to R) Nate Dugener, Ian Stone, and Bopi Biddanda service the Muskegon Lake Observatory buoy. Photo Credit: Janelle Cook.

Annual formation and breakdown of low-oxygen (hypoxic) bottom waters in Muskegon Lake is linked to warming of surface waters and excessive loading of nutrients. Graduate student Nate Dugener analyzed 12 years of data from the Muskegon Lake Observatory buoy (gvsu.edu/buoy) revealing high inter-year variability in hypoxia. A hypoxic severity index was developed to identify years that experienced more severe hypoxia than others. 2012 and 2021 were the most severely hypoxic years whereas 2015 and 2019 were the mildest hypoxic years. Years that were warmer and rainy in the spring and early summer resulted in more severe hypoxia, and vice versa. Thus, the environmental state before hypoxia begins plays a regulatory role in determining its severity in any given year. Severe hypoxia in a warm and wet 2021 released sediment-bound phosphorus as a side effect, leading to a historically late harmful algal bloom in surface waters that lasted into November.

SALT NEVER SLEEPS

The Steinman Lab has been studying Church Lake's salt and nutrient issues for almost three years. Located in Grand Rapids, Michigan directly adjacent to the East Beltline Highway, this lake has received so much salt runoff from de-icer applications that the salt gradient prevents the lake from fully mixing. Studies by graduate student Ellen Foley, who recently defended her master's thesis, as well as by undergraduate interns Jacquie Molloseau and Allison Passejna, have shown that phosphorus concentrations have continued to accumulate in the bottom waters to alarmingly high levels, and that sediments in the inflowing tributary and the nearby floodplain can continue to release salt to the lake throughout the year. In addition, the two lakes downstream of Church (Middleboro and Westboro) also are experiencing salt issues, suggesting that a salt plume is moving via groundwater throughout this region. Dr. Steinman and the Lab have offered possible solutions to tackle the salt and phosphorus issues, which are currently being assessed by the local homeowners.



Undergraduate interns Jacquelyn Molloseau (left) and Allison Passenja (right). Photo Credits: Mike Hassett.

MLO YEAR 12

The Muskegon Lake Observatory floats for the 12th year on Muskegon Lake. Photo Credit: Bopi Biddanda.

The Muskegon Lake Observatory was successfully deployed and operated for the 12th consecutive year. The buoy provides open-access high-resolution time-series, weather and water quality data enabling detailed analyses of ecologically and societally important issues like harmful algal blooms, hypoxia, and episodic and extreme weather events www.gvsu.edu/buoy.

Great Lakes Estuaries

Tony Weinke is returning from a maintenance run to the Muskegon Lake Observatory buoy that gathers weather and water quality time-series data on Muskegon Lake – a model Great Lakes Estuary. Photo Credit: Bopi Biddanda.

Commonly, Great Lakes Estuaries form drowned river mouth lakes that are hot-spots of primary productivity, anthropogenic problems, and socio-economic-ecologic potential. An essay in the 2022 summer issue of *Lakes Letter* published by the International Association for Great Lakes Research details the economic, social, and ecological importance of Great Lakes estuaries.

FISH HABITAT CHANGES FOR HIGGINS LAKE?

Organic rich sediments in Higgins Lake results in reduced dissolved oxygen concentrations. Photo Credit: Mark Luttenton.

Higgins Lake has long had a reputation as a popular "fishing" lake. The lake supports both warm water and coldwater species such as lake trout. Historically, coldwater fish habitat extended from about 35 feet to the bottom of the lake. In recent years, Dr. Mark Luttenton has found that warmer summer surface temperatures and decreasing dissolved oxygen levels near the bottom of the lake has reduced the amount of coldwater fish habitat.

Luttenton Lab alumnus Paul Dingman '21 collecting invertebrates from the North Branch Au Sable River. Photo Credit: Mark Luttenton.

Au Sable Macroinvertebrates

If you like to canoe, then you know to avoid logs in rivers. But if you are an aquatic insect, logs and other wood are invaluable. Graduate student alumnus Paul Dingman working with Dr. Mark Luttenton surveyed aquatic insect communities on every substrate type in the North Branch Au Sable River. Paul's data strongly supports the conclusion that one square meter of submerged log supports more aquatic insects than any other type of substrate.

AWRI Faculty & Staff

Mark Luttenton, Interim Director (8/2022 – current)
Alan Steinman, Allen and Helen Hunting Director and Professor (stepped down 8/2022, currently faculty)
Carl Ruetz, Interim Assistant Director (for Steinman)

Staff/Administrative:
Tonya Brown, AWRI Assistant
Heidi Feldpausch, Office Coordinator
Roxana Taylor, Secretary

Facilities/Maintenance:
Len Wittlieff, Maintenance

Information Services Center:
Sean Woznicki, Assistant Professor

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Christina Catanese, Education Specialist
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- Jamie Cross, Lead Instructor WGJ
- Doug Haywick, Science Instructor
- Dave Helder, Science Instructor
- Ann Hesselsweet, Science Instructor
- Steve Jablonski, Science Instructor
- Tom Jackson, Science Instructor
- Bob Myers, Science Instructor
- Amanda Syers, Science Education Specialist
- Janet Vail, Research Scientist Emerita
- Diane Veneklasen, Science Instructor

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- Bill Breznau, Sr., Engineer WGJ
- Emily Cegelis, Deckhand
- Dave Fisher, Engineer WGJ
- Ossian Foley, Captain DJA/WGJ
- Tim Halloran, Deckhand WGJ
- Pete Hewett, Engineer DJA
- Brad Nieboer, Marine Electrician
- Ed Perrault, Captain DJA/WGJ
- William Young, Deckhand

Ecological Research, Environmental Chemistry:
Richard Rediske, Professor
- Tyler Chlystek, Graduate Student (Public Health)
- Alexis Porter, Adjunct Research Assistant
- Brian Scull, Laboratory Supervisor
- Renée Tardani, Adjunct Research Assistant

Ecological Research, Environmental Biology:
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- Janelle Cook, Technical Call-in
- Ian Stone, Technical Call-in
- Anthony Weinke, Technical Call-in

Sarah Hamsher, Assistant Professor
Mark Luttenton, Professor of Biology
- Alexis Neff, Graduate Student (Biology)

Jim McNair, Associate Professor
Charlyn Partridge, Associate Professor
- Kathryn Geller, Undergraduate Student
- Colleen McClure, Undergraduate Student
- Syndell Parks, Technical Call-in

Carl Ruetz III, Professor
- Colin Assenmacher, Technical Call-in
- Sunny Charpentier, Technical Call-in
- Grayson Kosak, Technical Call-in
- Brendan May, Technical Call-in

Alan Steinman, Professor
- Aaron Dunnuck, Adjunct Research Assistant
- Travis Ellens, Adjunct Research Assistant
- Cate Garretson, High School Volunteer
- Michael Hassett, Scientific Technician
- Rachel Orzechowski, Adjunct Research Assistant
- Kurt Thompson, Technical Call-in

Kevin Strychar, Professor

AWRI Science Advisory Board:
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Dr. Carol Johnston, South Dakota State University
Dr. Gary Lamberti, University of Notre Dame, Chair
Dr. Jennifer Haverkamp, University of Michigan

Graduate Students:
Biddanda, major advisor
- Nate Dugener

Hamsher, major advisor
- Davis Fray

Luttenton, major advisor
- Anna Briem
- Rob Larson

Partridge, major advisor
- Keely Dunham
- Maggie Petersen

Rediske, major advisor
- John Hart

Ruetz, major advisor
- Travis Ellens
- Ashley Fleser
- Tyler Hoyt
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- Nick Vander Stelt

Steinman, major advisor
- Ellen Foley
- Kate Lucas
- Paris Velasquez

Strychar, major advisor
- Katelyn Anderson
- Cassidy Gilmore
- Casey Varriale

Woznicki, major advisor
- Jonathan Walt

Internships and Scholarships

AWRI provides opportunities for students to pursue their interests in our environment. The following students received internships during 2022.

Herbert VanderMey Intern (summer):
- Alexis Deephouse (Ashley Elgin, NOAA-GLERL)
- Amelia Heminger (Rick Rediske)

Robert B. Annis Foundation Interns (summer):
- Elliot Fair (Charlyn Partridge)
- Jillian Greene (Bopi Biddanda/Sean Woznicki)
- Audrey Whitaker (Christina Catanese/Rick Rediske)

AWRI Interns (summer):
- Brianne Siple (Carl Ruetz)

Bill and Diana Wipperfurth Scholarship (fall):
- Brianne Siple (Carl Ruetz)

Allen and Helen Hunting Interns (summer):
- Jacquelyn Molloseau (Alan Steinman)
- Allison Passejna (Alan Steinman)

M-STEP Center for Undergraduate Scholarly Engagement:
Jacob Yingling (Carl Ruetz)

NOAA Intern (summer):
- Margaret Evele (Ashley Elgin, NOAA-GLERL)

NSF Intern (summer):
- Collin Toth (Sarah Hamsher)

OURS Intern (summer):
- Carlin Moore (Charlyn Partridge)
- Cianna Quattrin (Charlyn Partridge)

SEWER grant Intern (summer):
- Emma Piasecki (Rick Rediske)

Peer-Reviewed Publications

AWRI staff in bold
Undergraduate Students*
Graduate Students**
Post-doctoral Fellows***

Antonelli, P.L., S.F. Rutz, and **K.B. Strychar**. 2021. Heat stress on scleractinian corals: Its symbionts in evolution. Nonlinear Studies, 28(1):189-196.

Bergstrom, R.D., L.B. Johnson, R.W. Sterner, G.S. Bullerjahn, J.T, Fergen, J.D. Lenters, P.E. Norris, and **A.D. Steinman**. In Press. Building a research network to better understand climate governance in the Great Lakes. Journal of Great Lakes Research. https://doi.org/10.1016/j.jglr.2022.02.010

Biddanda, B., S. Kendall, **A. Weinke**, **I. Stone**, **N. Dugener****, S. Ruberg, J. Leidig, E. Smith, M. Berg, and G. Wolffe. 2021. Muskegon Lake Observatory buoy data: Muskegon Lake, Michigan: 2011-2019 ver 1. *Environmental Data Initiative*. 12-21-2021. https://doi.org/10.6073/pasta/d1ef6101a1870a0b0bd54d3914dc13dc

Biddanda, B., M. Villar-Argaiz, and J. M. Medina-Sánchez. 2022. Protecting the mountain water towers of Spain's Sierra Nevada. Eos, 103, September 16, 2022. https://eos.org/opinions/protecting-the-mountain-water-towers-of-spains-sierra-nevada

Biddanda, B., **A. Weinke**, and **I. Stone**. In Press. Extant mat world analog microbes synchronize migration to a diurnal tempo. Journal of Great Lakes Research.

Cheng, C., **A.D. Steinman**, K. Zhang, Q. Lin, Q. Xue, X. Wang, and L. Xie. 2022. Risk assessment and identification of factors influencing the historical concentrations of microcystin in Lake Taihu, China. Journal of Environmental Sciences, 127:1-14. https://doi.org/10.1016/j.jes.2022.03.043

Diller, S.N., A.M. Harrison, K.P. Kowalski, V.J. Brady, J.J.H. Ciborowski, M.J. Cooper, J.D. Dumke, J.P. Gathman, **C.R. Ruetz III**, D.G. Uzarski, D.A. Wilcox, and J.S. Schaeffer. 2022. Influences of seasonality and habitat quality on Great Lakes coastal wetland fish community composition and diets. Wetland Ecology and Management, 30:439-460. https://doi.org/10.1007/s11273-022-09862-8

Fergen, J.T., R.D. Bergstrom, M.R. Twiss, L. Johnson, **A.D. Steinman**, and V. Gagnon. In Press. Updated census in the Laurentian Great Lakes Watershed: A framework for determining the relationship between population and this aquatic resource. Journal of Great Lakes Research. https://doi.org/10.1016/j.jglr.2022.03.004

Gentine, J.A., W.M. Conard, K.E. O'Reilly, M.J. Cooper, G.E. Fiorino, A.M. Harrison, M. Hein, A.H. Moerke, **C.R. Ruetz III**, D.G. Uzarski, and G.A. Lamberti. 2022. Environmental predictors of phytoplankton chlorophyll-a in Great Lakes coastal wetlands. Journal of Great Lakes Research, 48(4):927-934. https://doi.org/10.1016/j.jglr.2022.04.015

Grim, S.L., A.A. Voorhies, **B.A. Biddanda**, S. Jain, S.C. Nold, R. Green, and G.J. Dick. 2021. Omics-inferred partition and expression of diverse biogeochemical functions in a low-O_2 cyanobacterial mat community. mSystems 6(6):e01042-21. https://doi.org/10.1128/mSystems.01042-21

Harman, T.E.**, D.J. Barshis, B. Hauff Salas, **S.E. Hamsher**, and **K.B. Strychar**. 2022. Indications of symbiotic state influencing melanin-synthesis immune response in the facultative coral, *Astrangia poculata*. Diseases of Aquatic Organisms, 151:63-74. https://doi.org/10.3354/dao03695

Harman, T.E.**, B. Hauff-Salas, J.A. Haslun, J.M. Cervino, and **K.B. Strychar**. 2022. Decreased photosynthetic efficiency in response to site translocation and elevated temperature is mitigated with LPS exposure in *Porites astreoides* symbionts. Water, 14(3):366 (Special Issue "Climate Change Studies of Coral Reefs"). https://doi.org/10.3390/w14030366

Hassett, M.C. and **A.D. Steinman**. 2022. Wetland restoration through excavation: Sediment removal results in dramatic water quality improvement. Land, 11(9):1559. https://doi.org/10.3390/land11091559

Hopkins, K.G., **S.A. Woznicki**, B.M. Williams, C.C. Stillwell, E. Naibert, M.J. Metes, D.K. Jones, D.M. Hogan, N.C. Hall, R.M. Fanelli, and A.S. Bhaskar. 2022. Lessons learned from 20 y of monitoring suburban development with distributed stormwater management in Clarksburg, Maryland, USA. Freshwater Science, 41(3):459-476. https://doi.org/10.1086/719360

Iavorivska, L.**, T.L. Veith, R. Cibin, H.E. Preisendanz, and **A.D. Steinman**. 2021. Mitigating lake eutrophication through stakeholder-driven hydrologic modeling of agricultural conservation practices: A case study of Lake Macatawa, Michigan. Journal of Great Lakes Research, 47(6):1710-1725. https://doi.org/10.1016/j.jglr.2021.10.001

Jamison, M.N., **J.J. Hart****, and D.C. Szlag. In Press. Improving the identification of fecal contamination in recreational water through standardization and normalization of Microbial Source Tracking. ACS ES&T Water. https://doi.org/10.1021/acsestwater.2c00185

Kindervater, E., **M. Oudsema**, **M.C. Hassett**, **C.G. Partridge**, and **A.D. Steinman**. 2022. Assessment of the effectiveness of muck-digesting bacterial pellets. Lake and Reservoir Management, 38(2):150-164. https://doi.org/10.1080/10402381.2022.2029635

McNair, J.N., **M.J. Lane**, **J.J. Hart****, **A.M. Porter**, S. Briggs, B. Southwell, T. Sivy, D.C. Szlag, **B.T. Scull**, S. Pike, E. Dreeling, C. Vernier, B. Carter, J. Sharp, P. Nowlin, and **R.R. Rediske**. 2022. Validity assessment of Michigan's proposed qPCR threshold value for rapid water-quality monitoring of *E. coli* contamination. Water Research, 226:119235. https://doi.org/10.1016/j.watres.2022.119235

Orzechowski, R.M.* and **A.D. Steinman**. 2022. Assessment of shoreline restoration using macroinvertebrates in a Great Lakes Area of Concern. Environmental Monitoring and Assessment. 194:260. https://doi.org/10.1007/s10661-022-09899-5

Sivaganesan M., J.R. Willis, M. Karim, A. Babatola, D. Catoe, A.B. Boehm, M. Wilder, H. Green, A. Lobos, V.J. Harwood, S. Hertel, R. Klepikow, M.F. Howard, P. Laksanalamai, A. Roundtree, M. Mattioli, S. Eytcheson, M. Molina, **M. Lane**, **R. R. Rediske**, A. Ronan, N. D'Souza, J.B. Rose, A. Shrestha, C. Hoar, A.I. Silverman, W. Faulkner, K. Wickman, J.G. Kralj, S.L. Servetas, M.E. Hunter, S.A. Jackson, and O.C. Shanks. 2022. Interlaboratory performance and quantitative PCR data acceptance metrics for NIST SRM® 2917. Water Research, 225:119162. https://doi.org/10.1016/j.water.2022.119162

Squiers, A., and **K.B. Strychar**. 2021. The role of sea-whip coral (*Leptogorgia* sp.) as habitat of temperate near-shore fish of Gulf of Mexico Jetties. International Journal of Biology, 13(2):17-36. https://doi.org/10.5539/ijb.v13n2p17

Steinman, A.D., **M. Hassett**, **M. Oudsema**, and C.J. Penn. 2022. Reduction of phosphorus using electric arc furnace slag filters in the Macatawa Watershed (Michigan). Frontiers in Environmental Science, 10:863137. https://doi.org/10.3389/fenvs.2022.863137

Steinman, A.D., D.G. Uzarski, D.P. Lusch, C. Miller, P. Doran, T. Zimnicki, P. Chu, J. Allan, J. Asher, J. Bratton, D. Carpenter, D. Dempsey, C. Drummond, J. Esch, A. Garwood, A. Harrison, L.D. Lemke, J. Nicholas, W. Ogilvie, B. O'Leary, P. Sachs, P. Seelbach, T. Seidel, A. Suchy, and J. Yellich. 2022. Groundwater in Crisis? Addressing groundwater challenges in Michigan (USA) as a template for the Great Lakes. Sustainability, 14(5):3008. https://doi.org/10.3390/su14053008

Strychar K.B., B. Hauff-Salas, J.A. Haslun, J. DeBoer, K. Cryer, S. Keith, and S. Wooten. 2021. Stress resistance and adaptation of the aquatic invasive species *Tubastrea coccinea* (Lesson, 1829) to climate change and ocean acidification. Water, 13(24):3645. https://doi.org/10.3390/w13243645

Su, X., **A.D. Steinman**, Y. Zhang, H. Ling, and D. Wu. 2022. Significant temporal and spatial variability in nutrient concentrations in a Chinese eutrophic shallow lake and its major tributaries. Water, 14(2):217. https://doi.org/10.3390/w14020217

Tang, X., **A.D. Steinman**, Q. Xue, Y. Xu, and L. Xie. 2022. Simultaneous electrochemical removal of *Microcystis aeruginosa* and sulfamethoxazole and its ecologic impacts on *Vallisneria spiralis*. Science of the Total Environment, 815:152769. https://doi.org/10.1016/j.scitotenv.2021.152769

Tijjani, S.B., S. Giri, and **S.A. Woznicki**. 2022. Quantifying the potential impacts of climate change on irrigation demand, crop yields, and green water scarcity in the New Jersey Coastal Plain. Science of The Total Environment, 838(4):156538. https://doi.org/10.1016/j.scitotenv.2022.156538

Villar Argaiz, M., J.M. Medina-Sánchez, and **B.A. Biddanda**. 2022. National Parks in Spain are failing to protect wetlands. Letter to Editor. Frontiers in Ecology and the Environment, 20(8):450-451. https://doi.org/10.1002/fee.2559

Non-Peer Reviewed Publications

Antosch, L., K. Dreyfuss-Well, F. Ettawageshik, L. Frede, S. Galarneau, J. Hull, V. Klump, S. Mackey, B. Miller, K. Nelson, S. Orduño, L. Rubin, **A. Steinman**, J. Stollenwerk, and J. Williams. (Great Lakes Advisory Board). 2022. Recommendations: Great Lakes Advisory Board Final Report to EPA. April 6, 2022. https://www.glri.us/sites/default/files/glab_final_report_april_6_2022_0.pdf

Biddanda, B., T. Roetman, A. Yagiela, and D. Burlingame. 2022. Retrieving a Great Lakes Observing science buoy. Postcards from the Field, Eos, American Geophysical Union, 103(5):49. https://eos.org/wp-content/uploads/2022/06/May22.pdf

Biddanda, B., **I. Stone**, **A. Weinke**, **J. Cook**, **N. Dugener****, **D. Fray****, **Sarah Hamsher**, P. Hartmeyer, S. Gandulla, J. Bright, R. Green, T. Smith and S. Ruberg. 2022. Mat microbes dance to the sun's beat. Postcards from the Field, Eos, American Geophysical Union, 103(7):48. https://eos.org/wp-content/uploads/2022/06/Jul22.pdf

Medina-Sánchez, J. and **B. Biddanda**. 2022. Lake effect: Multitude of meltwater lakes on the Greenland Ice Sheet. Postcards from the Field, Eos, American Geophysical Union, 103(10):49. https://eos.org/wp-content/uploads/2022/09/Oct22.pdf

Steinman, A.D., C. Godwin, C. Stow, E. Rutherford, D. Uzarski, D. Kashian, H. Vanderploeg, J. Bratton, J. Chaffin, K. Kapuscinski, S.R. Chaganti, R. Errera, M. Rowe, K. O'Reilly, E.D. Reavie, D. Woolnough. 2022. Coordinated experiments across the Great Lakes Basin: Great Lakes Integrated Mesocosm Research (GLIMR). A White Paper for the Cooperative Institute for Great Lakes Research, University of Michigan, Ann Arbor, MI.

Steinman, A.D. and E. Kindervater. 2022. Do muck-digesting pellets work? The Michigan Riparian, 58:24-27.

Villar Argaiz, M., G. Garrido-Cañete, and **B. Biddanda**. 2022. Sierra Nevada's Laguna Caldera turns chocolate brown. Postcards from the Field, Eos, American Geophysical Union, 103(9):48. https://eos.org/wp-content/uploads/2022/08/Sept22.pdf

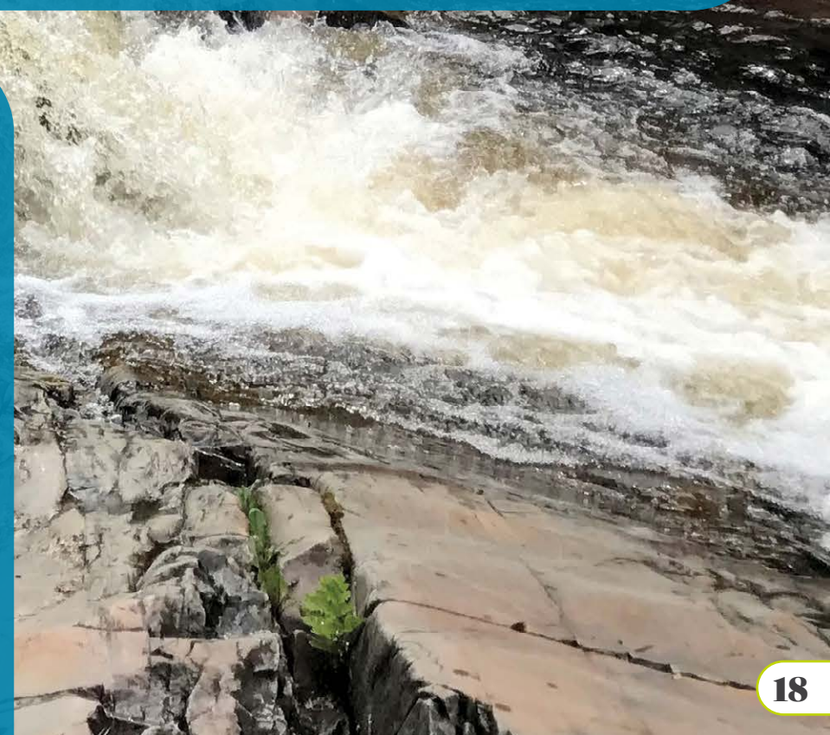
Weinke, A., **I. Stone**, **J. Greene***, **S. Woznicki**, **J. Cook**, **N. Dugener****, and **B. Biddanda**. 2022. Great Lakes Estuaries: Hotspots of productivity, problems, and potential. IAGLR Lakes Letter, Summer 2022, p. 9-10. https://iaglr.org/ll/2022-3-Summer_LL14.pdf

2022 Master of Science Theses

Petersen, M. (Advisor: **Partridge**) – Microplastics and Microbiomes: Impacts of weathered microplastic ingestion by Fathead Minnows (*Pimephales promelas*)

Sanders, M. (Advisor: **Partridge**) – Developing novel molecular detection techniques for hemlock woolly adelgid (*Adelges tsugae*)

Walt, J. (Advisor: **Woznicki**) – Mapping the spread of invasive species in Michigan wetlands using remote sensing



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to support the operations of the Annis Water Resources Institute are available at the Community Foundation for Muskegon County: www.muskegonfoundation.com or at the GVSU Office of Development,: www.gvsu.edu/giving.

In the future, if you would like to receive our Year in Review and newsletters electronically, please join our email list at: www.gvsu.edu/wri/review

IF YOU WOULD LIKE MORE INFORMATION ABOUT AWRI'S PROGRAMS, PLEASE CONTACT US.

Photo Credit: Brett Fessell, River Ecologist, Grand Traverse Band of Ottawa and Chippewa Indians.