R.B. Annis Water Resources Institute

2021 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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Dr. Alan Steinman, The Allen and Helen Hunting Director

"WHEREOF WHAT'S PAST IS PROLOGUE…" -- OR IS IT?

Shall we follow the likes of Antonio and Sebastian, who presumed that their prior actions foretold their future destinies, in Shakespeare's *The Tempest*? The relevance of this question should come as no surprise as humanity, finally, begins to seriously examine and address the impacts of climate change. As someone who has given numerous public presentations on the topic over the past 20 years, I have received my fair share of negative audience feedback, ranging from "being part of an international scientific consortium that is spouting falsehoods just to obtain federal funding" to "single-handedly trying to ruin the American economy." My efforts to assure one individual that there truly is no conspiracy among global thermometer manufacturers to artificially raise temperature readings not only fell on deaf ears but resulted in a strongly worded commandment to go visit the Creation Museum in Kentucky to get my facts straight.

Why this soapbox? Because our changing climate is starting to have demonstrable impacts to our Great Lakes and inland waters. And we can no longer count on past climate behavior to predict what the future will look like. Climate modelers call this phenomenon "non-stationarity." Past precipitation and temperature trends must be viewed very cautiously as indicators of future conditions. Extreme events, such as unprecedented storm intensities, record high or low water levels, intense heat waves, or perhaps events that we simply have not yet considered, are all possible, if not probable. But we do know some things. We know that warming waters will impact the ecology of organisms that are adapted to colder or cooler waters. We know that warming waters will result in more harmful algal blooms. We know that more intense rain events will wash more pathogens and nutrients into our waterways. And we know that we need good science to inform decision makers as to how best deal with our changing world.

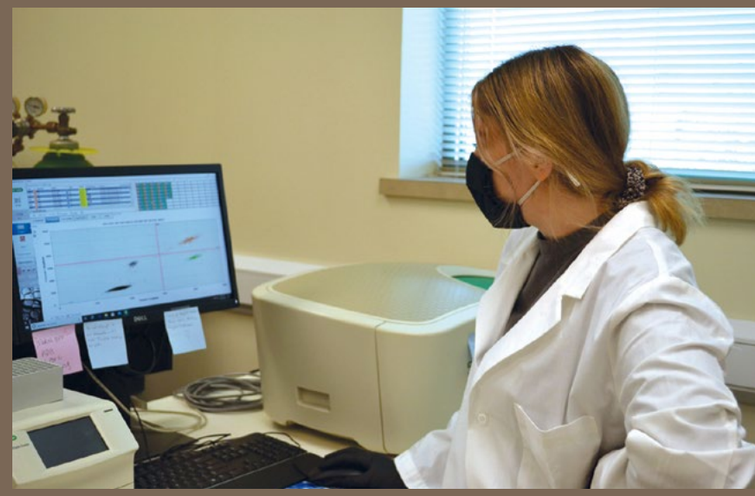
Although this year was challenging to everyone, including those of us at AWRI, we continued to tackle the environmental problems facing this region and beyond, painfully aware that the window for action is becoming narrower. The articles contained in this 2021 Year in Review reflect our focus on solving these problems, and our ability to be versatile, creative, and adaptable—as we can no longer approach problems using the thinking and technology of the past, with all due respect to the Bard.

Thank you, as always, for your interest and support. Please don't hesitate to contact me if you have questions.

Alan Steinman
Allen I. and Helen J. Hunting Director, AWRI

$1.7M GRANT FOR WASTEWATER VIRUS MONITORING

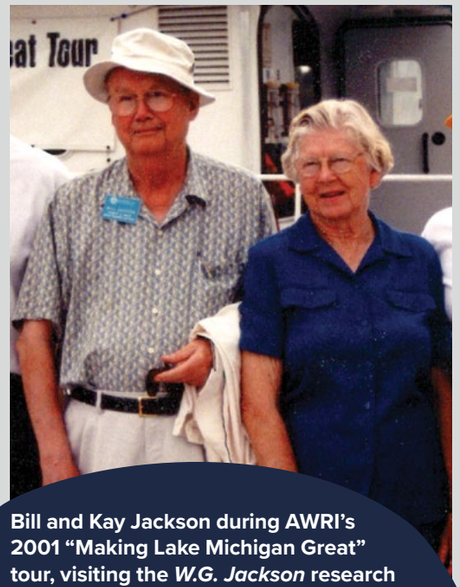
AWRI began a two-year project with Muskegon and Ottawa Counties to monitor the SARS-CoV-2 virus in wastewater, obtaining a $1.7m grant from the Michigan Department of Health and Human Services (MDHHS) to collect and analyze weekly wastewater samples from Spring Lake, Grand Haven, Muskegon, Allendale, and the GVSU Campus. Droplet digital PCR (ddPCR) is used to measure viral RNA and track variants. The COVID-19 virus is excreted in wastewater a week before symptoms are observed so this type of testing can provide important data on the community spread of the pandemic and the emergence of variants. Drs. Richard Rediske and Charlyn Partridge lead the project and AWRI staff Alexis Porter, Renée Tardani, and Brian Scull are analyzing samples. Results are reported to local health departments and partners within 72 hours of collection. AWRI is part of a 23-lab network providing wastewater testing support to MDHHS in monitoring the COVID-19 pandemic in Michigan.



Research assistant Alexis Porter conducts ddPCR testing on wastewater samples for COVID-19 delta variant.

Kay Jackson Summer Internship Fund

The estate of Kathleen (Kay) Jackson and her husband Dr. William (Bill) Jackson has provided funds to AWRI for the creation of a new summer undergraduate internship. The Jacksons were long-time supporters of AWRI and foundational to its long-term success.



Bill and Kay Jackson during AWRI's 2001 "Making Lake Michigan Great" tour, visiting the *W.G. Jackson* research vessel named in Bill's honor.

DIRECTOR STEINMAN IN THE NEWS

Al Steinman (right) appeared on "Good Morning America" with Ginger Zee on Earth Day 2021.

Dr. Al Steinman was named to a two-year appointment to the National Academy of Sciences committee to oversee Florida Everglades restoration, which culminates in the publication of a book that synthesizes Everglades restoration progress. Prior to his directorship at AWRI, Al was Director of the Lake Okeechobee Restoration Program at the South Florida Water Management District. Al also was honored this year by being voted into the 2021 class of Fellows of the Society for Freshwater Science.

Education Programs Set Sail

After a year and a half pandemic hiatus, AWRI's vessel education programs returned to the water in fall 2021. Our floating laboratories once again connected people in West Michigan with local water resources through hands-on, experiential learning about water chemistry, lake food webs, and human impacts on water quality.

This vessel season was unlike any other in the more than 30 years our program has been afloat due to COVID-19 protocols in place to keep staff and participants safe. Hundreds of students from twenty schools experienced aquatic science on board the *W.G. Jackson* and *D.J. Angus*. Four GVSU courses also made trips on both vessels.

The *D.J. Angus* set sail with a fully renovated lab this season. Almost single handedly, Fleet Captain Tony Fiore completely gutted and refurbished the inside of the vessel. He replaced all windows; upgraded plumbing and lighting; and installed new flooring, cabinets, and countertops.

Fleet Captain Tony Fiore piloting the *D.J. Angus*. Photo Credit: Christina Catanese.

STAFF MEMBER DEPARTURES

Dr. Janet Vail (left), Michele Smith and Shirley McIntire (top center), Molly Lane (top right), and Emily Kindervater and Maggie Oudsema (bottom right).

Several long-time staff members left AWRI in 2021. Shirley McIntire and Michele Smith were science instructors on the *W.G. Jackson* for 15 years. Maggie Oudsema started as an undergraduate intern and technical call-in for the education program and Biddanda Lab, then later became a research assistant in the Steinman Lab, for a total of 14 years. Emily Kindervater was a graduate student and then research assistant in the Steinman Lab for four years. Molly Lane was a graduate student and then research assistant in the Rediske Lab for two years. We especially would like to honor Dr. Janet Vail, who led AWRI's vessel-based education and outreach program for 31 years! Dr. Vail has received state and national recognition throughout her career for outreach and curriculum development and was awarded research scientist emerita status by GVSU. We thank all of these women for their years of service at AWRI and wish them the best in their new jobs or retirement.

AWRI Welcomes Christina Catanese!

Christina Catanese joined AWRI this summer as the new Education Specialist. She oversees AWRI's environmental education and outreach programs, including vessel-based and K-12 classroom education programs. After studying hydrogeology at the University of Pennsylvania, she gained over a decade of science communication and teaching experience in informal science education settings, from nature centers to the EPA's regional office in Philadelphia. Most recently, Christina has served in nonprofit leadership roles and drawn from her science foundation and creative side to integrate the arts into environmental education programs.

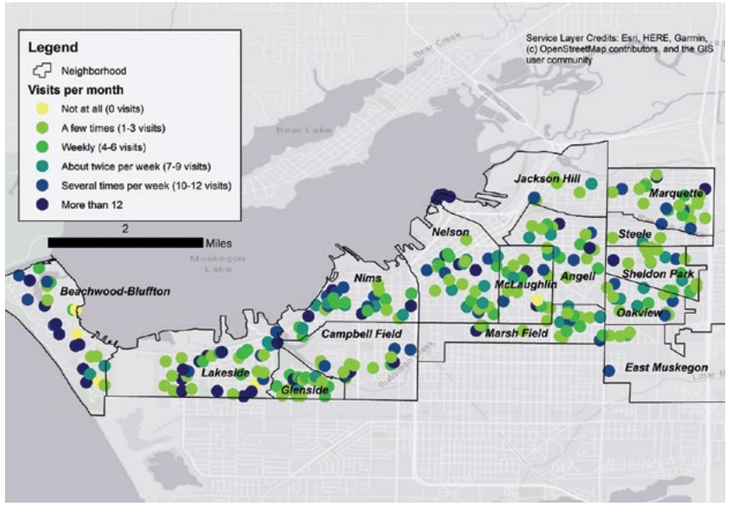
Christina Catanese at the bow of the *W.G. Jackson* with plankton and benthic samples collected during an educational cruise.

PROJECT WET UPDATES

Amanda Syers has joined Janet Vail as the Co-Coordinator for Michigan Project WET (Water Education Today). Both Amanda and Janet were trained in the North American Association for Environmental Education (NAAEE) Guidelines for Excellence and now incorporate the Guidelines into Project WET workshops and presentations.

The My Muskegon Lake Survey: Connecting Residents to Muskegon Lake

How do Muskegon residents engage in recreational opportunities at Muskegon Lake? What barriers do they face? How do they value public spaces on the lake, and perceive its environmental quality? GVSU faculty Amanda Buday (Sociology), Dani Devasto (Writing), and Sean Woznicki (AWRI) developed a mail survey that was sent to 1,600 Muskegon households this summer. The survey results will help inform the community in developing lakeshore access that reflects the needs of all residents as lake restoration continues.



Responses to one of many questions in the survey – "How often do residents visit Muskegon Lake monthly?" Figure Credit: Sean Woznicki.

IN MEMORIAM: CHERI GERHART

Cheri Gerhart passed away on September 30, 2021. She had worked as a science instructor on the *D.J. Angus* since 2012. Before joining AWRI in her retirement, Cheri taught natural science at schools in Rockford, IL, Flint, MI, and Muskegon, MI; she received the Subaru National Science Teacher Award in 2001. She will be missed.

SHARKS IN MICHIGAN LAKES?

Graduate student Ellen Foley (left) and undergraduate Jacquie Molloseau (right) conducting research at Church Lake. Photo Credits: Travis Ellens and Mike Hassett.

Of course not, but increased use of road salt as a deicer has resulted in freshwater ecosystems becoming saltier. One such ecosystem is Church Lake in Grand Rapids, where salt accumulates due to runoff from the East Beltline Highway, resulting in high chloride concentrations. This prevents the lake from the normal turnover that occurs each spring and fall, trapping extremely high phosphorus (P) concentrations at the lake bottom. Steinman Lab graduate student Ellen Foley is monitoring chloride and P concentrations in Church Lake water and sediments to create a roadmap for restoration management. Ellen was assisted by GVSU undergraduate Jacquie Molloseau, who measured chloride retention in Church Lake tributary sediments and its impact on other nutrients and metals. This research is supported by the Church Lake Homeowner's Association, Michigan Chapter of the North American Lake Management Society, Michigan Lakes and Streams Association, Michigan Space Grant Consortium, and the Allen and Helen Hunting Research and Innovation Fund.

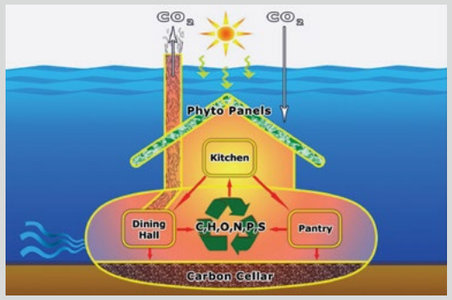
Changes in Lake Hypoxia

The annual formation and dynamics of low-oxygen bottom waters (hypoxia) in Muskegon Lake are linked to environmental and anthropogenic factors. Analysis of data from the long-term, high frequency Muskegon Lake Observatory (www.gvsu.edu/buoy) reveals high inter-annual variability, with a decreasing trend throughout the last decade. However, years in which stronger thermal stratification prevailed had more persistent and severe hypoxia – suggesting in a future world experiencing greater warming, we may see more severe hypoxia events.

Technical call-ins Ian Stone (left) and Anthony Weinke (right) prepare the Muskegon Lake Observatory buoy for launch in spring 2021. Photo Credit: Bopi Biddanda.

HOUSEKEEPING MATTERS

The Biddanda Lab's new peer-reviewed article in the journal *Life* asks: Who's cooking, who's cleaning, and who's got the remote control within the waters blanketing the Earth? It argues that although they are tiny, the numerically dominant and physiologically active microbes are the crucial "homemakers" of the watery household, keeping our planet habitable.



Underwater household: Simplified schematic diagram of microbial cooking, cleaning, and control in the aquatic ecosystem (From Biddanda et al. 2021, *Life*; www.mdpi.com/2075-1729/11/2/152/pdf).

Predicting the Habitat of an Invader

Starry stonewort, an invasive macroalga, is a threat to the Great Lakes region. Developing early detection plans for this species is a crucial tool we can use to slow their spread. Graduate student Emily Neuman, Dr. Sarah Hamsher, and Dr. Sean Woznicki used large-scale data analyses to determine the habitats for possible starry stonewort invasion across 17 states. The analyses used data from publicly available sources, such as LAke multi-scaled GeOSpatial and temporal database (LAGOS), bicarbonate concentrations, and climate variables from WorldClim, along with records from the William and Lynda Steere herbarium of the New York Botanical Garden (NY) and the Global Biodiversity Information Facility (GBIF). Emily determined that starry stonewort is most likely to occur in areas with increased development and has the potential to spread farther in the Midwest and northeastern United States, including into states currently free of documented starry stonewort populations.

Graduate student Emily Neuman prepares a starry stonewort herbarium specimen. Photo Credit: Sarah Hamsher.

GVSU-OURS summer scholar Kelsey Inman-Carter collecting a fragment of starry stonewort for epiphyte analyses. Photo Credit: Kendra Stanley-Mills/GVSU University Communications.

Diatoms, an algal group with glass cell walls, can live while attached to aquatic plants and macroalgae. Whether or not specific species of diatoms prefer to live on specific hosts is an ongoing debate. Undergraduate Kelsey Inman-Carter and Dr. Sarah Hamsher are using DNA sequence data to explore the diatom diversity growing on starry stonewort (an invasive macroalga) and *Chara contraria* (a closely related native macroalga), allowing them to compare hosts and differences/similarities between invasive and native species.

Starry Stonewort Wars – The Invasion Menace

Starry stonewort is an aquatic invasive species spreading in the Great Lakes region. Undergraduate summer intern Brooke Keck and Dr. Sarah Hamsher are monitoring this species in Pentwater and Muskegon Lakes to determine how fast this species is growing and relating its growth to light and temperature data.

AWRI intern Brooke Keck snorkeling to monitor starry stonewort. Photo Credit: Emily Neuman.

MAPPING INVASIVE WETLAND PLANTS FROM SPACE

Graduate student Jon Walt, undergraduate Michael Stefanou, and their advisor Dr. Sean Woznicki are mapping the extent of the common reed *(Phragmites australis)*, an invasive species that is spreading throughout Michigan wetlands. This species, similarly to invasive cattails *(Typha angustifolia)*, quickly forms monocultural stands that prevent a diverse and well-functioning ecosystem by limiting the growth of native species. Despite this, the invasive species are difficult to track and manage because of the sometimes remote and difficult-to-navigate terrain that they inhabit. Jon spent the summer confirming locations and creating maps of the extent of both species, and is connecting this data to spectral and radar satellite imagery to develop mapping algorithms. Jon is also developing models of suitable future habitats for both common reed and cattail in the context of climate change.

Jon Walt collects GPS coordinates of *Phragmites australis*, which can reach 15 feet in height. Photo Credit: Sean Woznicki.

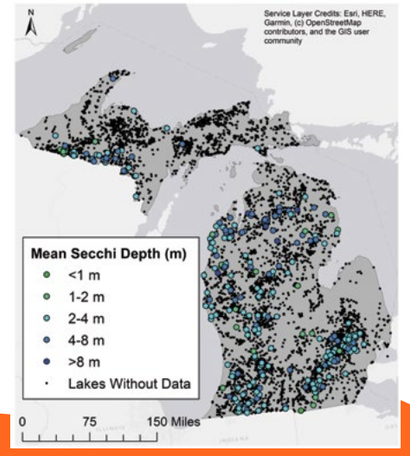
HWA Monitoring in Coastal Forests

Hemlock forests support critical habitat for aquatic ecosystem by shading streams, regulating streamflow, and decreasing runoff into surrounding water bodies. This is one reason why protecting hemlocks along Lake Michigan is a priority for management groups. Michigan's hemlocks are under threat from a tiny invasive insect, hemlock woolly adelgid (*Adelges tsugae*), otherwise known as HWA. Dr. Charlyn Partridge and graduate student Meg Sanders are working to develop environmental DNA (eDNA) methods, which use genetic material collected from the environment to monitor for the presence of HWA. This spring, they evaluated how well their eDNA traps captured adelgids and how the number of adelgids captured correspond with distance to infested hemlock trees. Preliminary analyses indicated that eDNA traps are highly efficient, and the number of adelgids captured may help pinpoint infested hemlock stands within an area. This technology could help optimize HWA eradication efforts in Michigan, thereby saving time and money.

Students change out slides on a hemlock woolly adelgid trap. Photo Credit: Renee Tardani.

A Clear View of Michigan's Inland Lakes

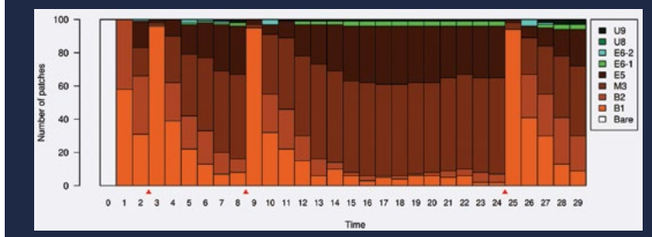
Undergraduate Michael Stefanou is working with Dr. Sean Woznicki to estimate the water clarity of Michigan's inland lakes using the NASA/USGS Landsat 8 Earth observation satellite. This will fill a critical data gap for thousands of lakes that are not part of regular water quality monitoring programs.



There are over 6,500 inland lakes in the state >10 acres by area. Only 314 lakes have publicly available clarity data since 2013, when Landsat 8 was launched. Figure Credit: Michael Stefanou.

EFFECTS OF HIGH-FLOW EVENTS ON STREAM EPILITHIC ALGAL COMMUNITIES

Algae growing on the surface of streambed stones are called epilithon. The community structure of these algae (e.g., number of species and their relative abundances) is a good indicator of water quality. However, high-flow events scour a significant proportion of epilithic algae from the streambed and partially sever the connection between water quality and community structure. Algal communities develop again after each high-flow event, reestablishing the connection between water quality and community structure, but this process takes time. Drs. Jim McNair and Dean DeNicola (Slippery Rock University, PA) have developed a model that predicts the time required for epilithic algal communities to redevelop into good indicators of water quality after a high-flow event.

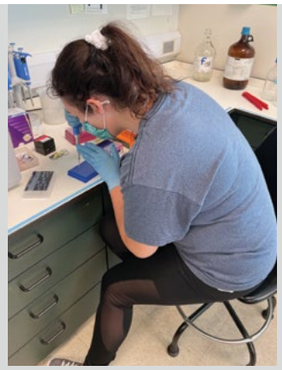


Example of predicted dynamics. Patches (vertical axis) are stones in a stream. The community structure at each observation time is characterized by the number of patches with different algal compositions (stacked columns and colors). Red triangles indicate high-flow events in time (horizontal axis). These events cause pronounced changes in community structure, followed by a gradual succession that becomes negligible after 5-6 time periods. Figure Credit: Jim McNair.

WILD RICE GENETICS

Undergraduate students Carlin Moore and Elliot Fair are using multiple sequencing methods to understand the genetic relationship of two native species of wild rice, *Zizania aquatica* and *Z. palustris*. Wild rice is a culturally important food to the Anishinaabe people and the Gun Lake Tribe is collaborating on this research.

Elliot Fair (left) measuring wild rice. Carlin Moore (right) running a gel after a wild rice DNA extraction. Photo Credits: Charlyn Partridge.



MST in Local Watersheds

The Rediske Lab completed a three-year project with the Ottawa Conservation District (OCD) to determine the source of high *E. coli* levels in the Deer Creek and Bass River watersheds. AWRI sampled sites in 2019 and OCD initiated a program to repair failing septic systems and reduce agricultural runoff. *E. coli* levels decreased after restoration programs were completed; however, human bacteria markers were still present in 70% of the samples.

AWRI graduate student John Hart and Master of Public Health program intern Aurelia Peña collect samples from Deer Creek for measurement of *E. coli* and the human marker HF183.

AWRI AT WORK

1 Rediske Lab COVID-19 wastewater pilot team: Molly Lane, Alexis Porter, Brian Scull, and Rick Rediske.

2 Anna Watson measuring salinity in Montague, MI.

3 Maggie Brenneman gears up to analyze COVID-19 wastewater samples.

4 Grad student Katy Sheets, research assistant Travis Ellens, and intern Jacquie Molloseau collect a sediment core.

5 Intern Taylor Suttorp measuring Muskegon Lake water quality.

6 Grad students Ellen Foley and Paris Velasquez sampling Lake Macatawa.

7 Grad student Matthew Silverhart and a snapping turtle smile for the camera.

8 Intern Katelyn Anderson measures *E. coli* in Lake Michigan.

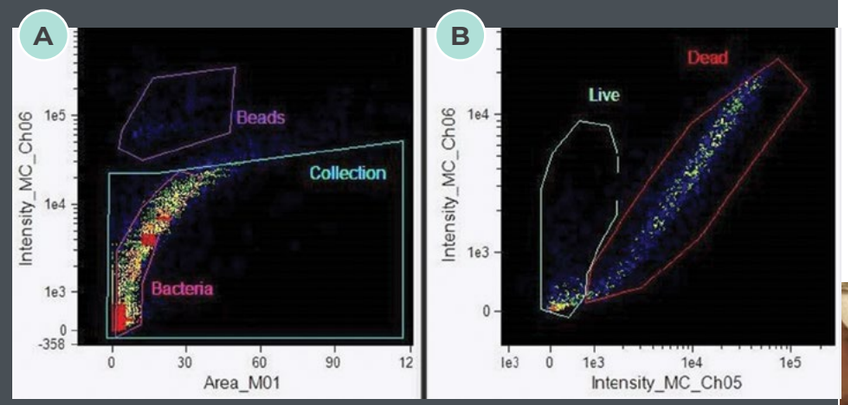
9 Educational and vessel crew onboard the *D.J. Angus*: Christina Catanese, Pete Hewett, Jamie Cross, Paula Capizzi, Diane Veneklasen, and Tony Fiore.

10 Technical call-in Tori Vander Stelt and a longnose gar.

11 Technical call-in Ian Stone and grad student Nate Dugener cruising on Muskegon Lake.

IMAGE FLOW CYTOMETRY (IFCM) ASSESSMENT FOR *E. coli*

The Food and Drug Administration (FDA) dictates specific Colilert and qPCR testing methods for *Escherichia coli*, but there is interest in developing faster and comparable tests. Dr. Kevin Strychar and undergraduate student intern Katelyn Anderson tested the use of Imaging Flow Cytometry (IFCM) to rapidly characterize *E. coli* while sampling 13 Lake Michigan beaches, 13 inland lakes, and three creeks in Muskegon County weekly during summer 2021. Their study showed that IFCM can detect general populations of *E. coli* rapidly within a few minutes, requiring less than two hours from delivering samples to the lab until obtaining test results. Using genetic markers, IFCM can distinguish live and dead bacteria and separate *E. coli* from other bacteria within a field sample including avian, bovine, and canine sources.

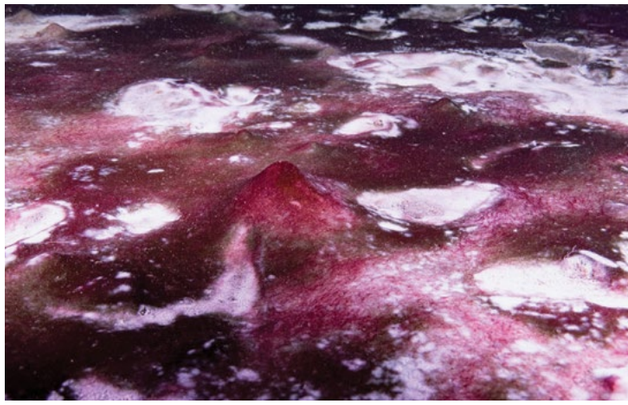


Water sample from Lake Michigan Beach, characterizing (A) bacteria cells vs. beads (used for comparison) and (B) live and dead cells analyzed by image flow cytometry. Figure Credit: Katelyn Anderson.

The 1-mm Journey

Animal migrations mark the largest daily movement of biomass on Earth today, but who performed the first daily migration? Modern-day benthic microbial mats that resemble life on early Earth, such as those at the bottom of Lake Huron's low-oxygen, high-sulfur submerged sinkholes, may have the answers. Here, the lakebed is dominated by motile filaments of purple photosynthetic cyanobacteria, and clear chemosynthetic sulfur-oxidizing bacteria. Time-lapse images revealed daily vertical migration between these two communities – turning the mat surface completely purple after dawn and nearly entirely white after dusk. Micrometer-scale micro profile measurements revealed corresponding daily vertical movements of oxygen, hydrogen sulfide, and pH. Such synchronized daily migrations – although only 1 mm (~0.04 inches) long – might have been the largest daily mass movement of life during the early phases of the Earth's history (2.5-0.5 billion years ago), and played a critical role in optimizing photosynthesis and oxygenation during our biosphere's 2-3 billion years of early childhood.

(Left to Right) Ian Stone, Janie Cook, Sarah Hamsher, and Bopi Biddanda study sinkhole mats under simulated day-night conditions in the laboratory.



A Living Canvas: Colorful patches of photosynthetic (purple) and chemosynthetic (white) microbes flourish in Middle Island Sinkhole, Lake Huron. Photo Credit: Phil Hartmeyer, NOAA-TBNMS.

Invasive *T. coccinea* is commonly called the "sunflower coral" because of its red and bright yellow colorings. Photo Credit: Dan Beltz.

Climate Change May Select for Heartier Invasive Corals

Tubastraea coccinea (TC) is an Indo-Pacific regional coral that's invasive in the Gulf of Mexico. To determine if invasive TC populations are more stress-resistant than native TC, Dr. Kevin Strychar and collaborators at Marshall University and Louisiana Universities Marine Consortium measured tissue loss when exposing corals to heat stress. Overall, 50% tissue loss happened faster in natives than in invaders. Hence, invasive TC appears more robust and may emerge as a new dominant coral, displacing native populations as a consequence of climate warming.

IMMUNE EXPRESSION IN CORAL AND LOCAL ADAPTATION

A collaboration between Mote Marine Lab (FL) and the Strychar Lab examining offshore vs. inshore *Porites* sp. coral near Florida revealed an adaptive response to environment-dependent biotic stress. These results are important and open-up other avenues of research since only higher vertebrates possess adaptive immunity.

Coral aquaria research mesocosms at Mote Marine Laboratory, FL. Photo Credit: Kevin Strychar.

OPTIMAL qPCR-BASED BACTERIAL THRESHOLDS FOR BEACH-CLOSING DECISIONS

Michigan water quality standards require monitoring recreational beaches to assess contamination by fecal bacteria. These standards specify that culture-based methods be used to estimate bacterial concentrations, but these require 18–24 hours to produce results. Michigan is evaluating a genetic method (qPCR) that requires only 3–4 hours. AWRI scientists have developed a statistical technique for determining the qPCR-based bacterial threshold for making beach-closing decisions that best agree with decisions based on the culture-based threshold.

MLO Buoy Year 11

The Muskegon Lake Observatory was successfully deployed (with help from NOAA-GLERL) and operated for the 11th consecutive year. The buoy has provided high-resolution time-series weather and water quality data enabling detailed analyses of societally important issues, such as harmful algal blooms, hypoxia, and episodic and extreme weather events www.gvsu.edu/buoy.

The Muskegon Lake Observatory floats for the 11th year on Muskegon Lake. Photo Credit: Bopi Biddanda.

Au Sable River Trout Surveys

The Au Sable River has long been a destination for trout fishing enthusiasts and is the birthplace of Trout Unlimited. Today, the Au Sable attracts anglers from around the globe. Recent declines in the North Branch Au Sable trout population have anglers and managers concerned. To better understand current conditions in the North Branch, graduate student Paul Dingman and Dr. Mark Luttenton have estimated the abundance of aquatic invertebrates to determine if trout populations are limited by food. Data suggest that food may not be limiting and that submerged logs support far more invertebrates per square meter than any other substrate type. Luttenton, with assistance from local volunteers, has also been tracking trout populations in the North Branch. Juvenile trout numbers are much lower than in 2000-2001, suggesting that low reproductive success may partly account for the current status of trout populations.

Brook trout (*Salvelinus fontinalis*) captured during North Branch Au Sable River population surveys. Photo Credit: Mark Luttenton.

ENVIRONMENTAL GRADIENT ALONG EASTERN LAKE MICHIGAN

Megan Mader drives a jonboat on Mona Lake. Photo Credit: Carl Ruetz.

Drowned river mouths are lake-like ecosystems that connect rivers to Lake Michigan. Graduate student Megan Mader, working with Dr. Carl Ruetz, sampled water quality to test the hypothesis of a latitudinal gradient in environmental conditions among drowned river mouths. Natural variability in climate and soils in Michigan's Lower Peninsula creates a gradient in environmental conditions that is confounded with the human activities that are suited to those conditions. Megan's research supported the hypothesis of a latitudinal gradient with more eutrophic (higher nutrients and algae biomass) in the south and more oligotrophic (lower nutrients and algae biomass) conditions in the north, which corresponded with human activities on the landscape. This research highlights the spatial aspect of environmental differences among drowned river mouths, as well as the broad-scale human activities (agriculture and development) that drive the spatial pattern.

Ecological Surveys of Boardman River

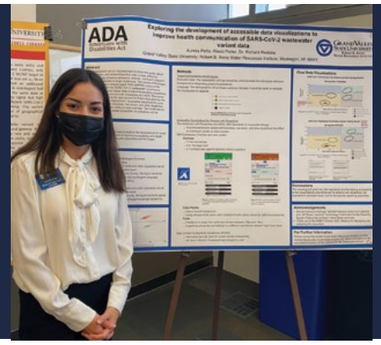
Arctic grayling is a native species that was once abundant in Michigan rivers but was extirpated by human activities. Nick Vander Stelt, a graduate student working with Dr. Carl Ruetz, is conducting habitat and fish surveys in tributaries of the Boardman River in collaboration with the Little River Band of Ottawa and Chippewa Indians. Nick's research will help managers identify the optimal sites for the statewide effort to reintroduce arctic grayling to Michigan.

Graduate student Nick Vander Stelt holding a tiger trout encountered during backpack electrofishing.

MICROPLASTIC INGESTIONS

Microplastics are found all throughout the world's aquatic environments. Once microplastic enters an aquatic environment, a microbial biofilm forms on its surface. If these microplastics are ingested by other aquatic organisms, such as fish, this can potentially alter their natural gut microbial community, which can lead to negative health implications. Graduate student Maggie Petersen in the Partridge Lab is exploring this topic to understand how microplastic pollution impacts aquatic wildlife in the Great Lakes.

Fathead minnows used for the microplastic ingestion study. Photo Credit: Maggie Petersen.



MPH Interns

GVSU Master of Public Health program interns Aurelia Peña (pictured left) and Hava Topolski completed their practicum and research project courses working at AWRI. Aurelia's work on making ADA-friendly graphics for COVID-19 wastewater data was presented at a Michigan PCR Network Meeting.

Fish Surveys Support Habitat Improvements in Little Cedar Creek

Undersized or perched culverts at road-stream crossings can fragment fish populations by impeding fish movement. The Ruetz Lab is conducting fish surveys at two such sites in Little Cedar Creek in Muskegon County that are being targeted for improvements to enhance fish passage.

Graduate student Matthew Silverhart holds a creek chub during an electrofishing survey of Little Cedar Creek. Photo Credit: Gale Nobes.

Carl Ruetz uses a backpack electrofisher to sample fish in Little Cedar Creek. Photo Credit: Gale Nobes.

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- Dave Fisher, Engineer WGJ
- Mitch Gingras, Deckhand DJA/WGJ
- Tim Halloran, Deckhand WGJ
- Roger Haynor, Lead Captain DJA
- Eric Hecox, Lead Captain WGJ and Relief Captain DJA
- Pete Hewett, Engineer DJA
- Brad Nieboer, Marine Electrician
- Tim Smith, Deckhand WGJ

Ecological Research, Environmental Chemistry:
Richard Rediske, Professor
- Molly Lane, Adjunct Research Assistant
- Aurelia Peña, Graduate Student (Public Health)
- Alexis Porter, Adjunct Research Assistant
- Brian Scull, Laboratory Supervisor
- Hava Topolski, Graduate Student (Public Health)

Ecological Research, Environmental Biology:
Bopaiah Biddanda, Professor
- Mikaela Berg, Undergraduate Student
- Ian Stone, Technical Call-in
- Anthony Weinke, Technical Call-in

Sarah Hamsher, Assistant Professor

Mark Luttenton, Professor of Biology

Jim McNair, Associate Professor

Charlyn Partridge, Assistant Professor
- Kathryn Geller, Undergraduate Student
- Syndell Parks, Technical Call-in
- Renée Tardani, Technical Call-in

Carl Ruetz III, Professor
- Travis Ellens, Adjunct Research Assistant
- Ashley Golightly, Technical Call-in
- Victoria Vander Stelt, Technical Call-in

Alan Steinman, Professor
- Aaron Dunnuck, Adjunct Research Assistant
- Michael Hassett, Scientific Technician
- Emily Kindervater, Adjunct Research Assistant
- Rachel Orzechowski, Adjunct Research Assistant
- Maggie Oudsema, Research Assistant
- Kurt Thompson, Research Associate

Kevin Strychar, Professor

AWRI Science Advisory Board:
Dr. Harvey Bootsma, University of Wisconsin – Madison
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
- Emily Neuman

Luttenton, major advisor
- Bert Carey
- Paul Dingman
- Billy Mulligan

Partridge, major advisor
- Maggie Petersen
- Megan Sanders

Rediske, major advisor
- John Hart

Ruetz, major advisor
- Travis Ellens
- Ashley Fleser
- Jason Lorenz
- Megan Mader
- Matthew Silverhart
- Nick Vander Stelt

Steinman, major advisor
- Ellen Foley
- Katy Sheets
- Paris Velasquez

Strychar, major advisor
- Cassidy Gilmore
- Jennifer Kovac
- Casey Varriale

Woznicki, major advisor
- Jonathan Walt

INTERNSHIPS & SCHOLARSHIPS

AWRI provides opportunities for students to pursue their interests in our environment. The following students received internships during 2021.

Herbert VanderMey (summer) Intern:
Brooke Keck (Sarah Hamsher)

Robert B. Annis Foundation (summer) Interns:
Maggie Brenneman (Rick Rediske)
Janelle Cook (Bopi Biddanda)
Brendan May (Carl Ruetz)
Carlin Moore (Charlyn Partridge)
Anna Watson (Janet Vail)

AWRI Interns (summer):
Katelyn Anderson (Kevin Strychar)
Michael Stefanou (Sean Woznicki)

AWRI Interns (fall and winter):
Katelyn Anderson (Kevin Strychar)
Carlin Moore (Charlyn Partridge)

Bill and Diana Wipperfurth (fall) Scholarship:
Maggie Brenneman (Rick Rediske)

Ron Ward Scholarship:
Kyler Cope
Hope Fischer
Sophia Raab
Ethan Vink
Zane Walters

Student Summer Scholar (S3):
Kelsey Inman-Carter (Sarah Hamsher)

Allen and Helen Hunting Interns (summer):
Jacquelyn Molloseau (Al Steinman)
Taylor Suttorp (Al Steinman)

Pierce Cedar Creek (summer) Intern:
Elliot Fair (Charlyn Partridge)

Photo Credit: Christina Catanese

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.

Biddanda, B.A., A. Weinke, **I. Stone***, S. Kendall, P. Hartmeyer, W. Lusardi, S. Gandulla, J. Bright, and S. Ruberg. 2021. Extant earthly microbial mats and microbialites as models for exploration of life in extraterrestrial mat worlds. Life (special issue on Microbial Life in the Solar System) 11(9): 883. doi: 10.3390/life11090883

Biddanda, B., D. Dila, **A. Weinke**, **J. Mancuso****, M. Villar-Argaiz, J.M. Medina-Sánchez, J.M. González-Olalla, and P. Carrillo. 2021. Housekeeping in the hydrosphere: Microbial cooking, cleaning, and control under stress. Life 11(2): 152. doi: 10.3390/life11020152

DeNicola, D., **J.N. McNair**, and J. Suh. 2021. A stochastic model of epilithic algal succession and patch dynamics in streams. Ecosphere 12(7): e03566. doi: 10.1002/ecs2.3566

Hamsher, S.E., J.P. Kociolek, S.A. Spaulding, and A.I. Saleh. 2021. Taxonomy and nomenclature of some members within the Obtusae section of *Nitzschia* Hassall (Bacillariophyceae) including descriptions of two new species. Fottea 21(2): 247-258. doi: 10.5507/fot.2021.010

Haslun, J.A., B. Hauff-Salas, **K.B. Strychar**, J.M. Cervino, and N.E. Ostrom. 2021. Variation in immune-related gene expression provides evidence of local adaptation in *Porites astreoides* (Lamarck, 1816) between inshore and offshore meta-populations inhabiting the Lower Florida Reef Tract, USA. Water 13(15): 2107. doi: 10.3390/w13152107

Hopkins, K.G., A.S. Bhaskar, **S.A. Woznicki**, and R.M. Fanelli. 2020. Changes in event-based streamflow magnitude and timing after suburban development with infiltration-based stormwater management. Hydrological Processes 34(2): 387-403. doi: 10.1002/hyp.13593

Iavorivska, L.***, T.L. Veith, R. Cibin, H.E. Preisendanz, and **A.D. Steinman**. In Press. Mitigating lake eutrophication through stakeholder-driven hydrologic modeling of agricultural conservation practices: A case study of Lake Macatawa, Michigan. Journal of Great Lakes Research.

Klatt, J.M. A. Chennu, B.K. Arbic, **B.A. Biddanda**, and G.J. Dick. 2021. Possible link between Earth's rotation rate and oxygenation. Nature Geoscience 14: 564-570. doi: 10.1038/s41561-021-00784-3

Kleindl, P.** and **A.D. Steinman**. 2021. Contrasting trajectories in macrophyte community development after shoreline restoration: Water level obscures trends. Aquatic Botany 169: 103327. doi: 10.1016/j.aquabot.2020.103327

Lane, M.J.**, R.R. Rediske, **J.N. McNair**, S. Briggs, G. Rhodes, E. Dreelin, T. Sivy, M. Flood, B. Scull, D. Szlag, B. Southwell, N.M. Isaacs, and S. Pike. 2020. A comparison of *E. coli* concentration estimates quantified by the EPA and a Michigan laboratory network using EPA Draft Method C. Journal of Microbiological Methods 179: 106086. doi: 10.1016/j.mimet.2020.106086

Mancuso, J.L.**, **A.D. Weinke**, **I.P. Stone***, **S.E. Hamsher**, M. Villar-Argaiz, and **B.A. Biddanda**. 2021. Cold and wet: Diatoms dominate the phytoplankton community during a year of anomalous weather in a Great Lakes estuary. Journal of Great Lakes Research 47(5): 1305-1315. doi: 10.1016/j.jglr.2021.07.003

Mancuso, J.L.**, **A.D. Weinke**, **I.P. Stone***, **S.E. Hamsher**, M.M. Woller-Skar, E.B. Snyder, and **B.A. Biddanda**. 2021. Bloom and bust: Historical trends of harmful algal blooms in Muskegon Lake, Michigan, a Great Lakes estuary. Freshwater Science 40(3): 463-477. doi: 10.1086/716236

Mock, A.J.**, **C.R. Ruetz**, **J.N. McNair**, D. Mays, and A. Martell. 2021. Evaluating remote site incubators in Michigan streams: Implications for Arctic Grayling reintroduction. North American Journal of Fisheries Management 41(2): 434-445. doi: 10.1002/nafm.10534

Myers, D.T.L.***, **R.R. Rediske**, **J.N. McNair**, A.D. Parker, and E.W. Ogilvie. 2021. Relating environmental variables with aquatic community structure in an agricultural/urban coldwater stream. Ecological Processes 10: 37. doi: 10.1186/s13717-021-00312-6

Scott, J.W., K.G. Gunderson, L.A. Green, **R.R. Rediske**, and **A.D. Steinman**. 2021. Perfluoroalkylated substances (PFAS) associated with microplastics in a lake environment. Toxics 9(5): 106. doi: 10.3390/toxics9050106

Shabani, A., **S.A. Woznicki**, M. Mehaffey, J. Butcher, T.A. Wool, and P. Whung. 2021. A coupled hydrodynamic (HEC-RAS 2D) and water quality model (WASP) for simulating flood-induced soil, sediment, and contaminant transport. Journal of Flood Risk Management: e12747. doi: 10.1111/jfr3.12747

Squires, A. and **K.B. Strychar**. In Press. The important role of sea-whip coral (*Leptogorgia* sp.) as a habitat of temperate near-shore fish of Gulf of Mexico jetties. International Journal of Biology.

Steinman, A.D. and **E. Kindervater**. 2020. Ecosystem restoration in the Everglades and Great Lakes ecosystems: Past, present, and future preventive management. Inland Waters. doi: 10.1080/20442041.2020.1804272

Thompson C.L., M. Alberti, S. Barve, F.U. Battistuzzi, J.L. Drake, G.C. Goncalves, L. Govaert, **C. Partridge**, and Y. Yang. 2021. Back to the future: Reintegrating biology to understand how past eco-evolutionary change can predict future outcomes. Integrative and Comparative Biology: icab068. doi: 10.1093/icb/icab068

Non-Peer Reviewed:

Biddanda, B. and S. Kendall. 8/17/2021. Hidden life of giant microbialites in Laguna Bacalar, Yucatan Peninsula, Mexico. Postcards from the Field, Eos, American Geophysical Union. https://americangeophysicalunion.tumblr.com/tagged/postcards+from+the+field

Biddanda, B., A. Weinke, I. Stone*, S. Kendall, P. Hartmeyer, S. Gandulla, J.C. Bright, and S. Ruberg. 2021. Microbial mats: Extraterrestrial life models. Encyclopedia. https://encyclopedia.pub/15065

Biddanda, B., A. Weinke, J. Mancuso**, D. Dila, M. Villar-Argaiz, J. Medina-Sanchez, J. Gonzalez-Olalla, and P. Carrillo. 2021. Small things considered: How very tiny housekeepers run our very big hydrosphere. Interchange, Connections for the STEM Classroom, March 2021. https://www.gvsu.edu/rmsc/interchange/2021-march-connections-1644.htm

Cook, J.*, **C. Catanese**, and **B. Biddanda**. 2021. A just and delightful tantrum: Sophia's call for climate action. Interchange, Connections for the STEM Classroom, September 2021. https://www.gvsu.edu/rmsc/interchange/2021-september-connection-1-a-just-and-delightful-1669.htm

Hartmeyer, P., S. Gandulla, **I. Stone***, **A. Weinke**, and **B. Biddanda**. 2021. A glimpse of the otherworldly "lakescape" at the bottom of the Middle Island Sinkhole in Lake Huron. Eos, American Geophysical Union 102 (3): 49. https://eos.org/wp-content/uploads/2021/02/EOS_MAR21.pdf

Steinman, A.D., D.G. Uzarski, D. Lusch, C. Miller, P. Doran, T. Zimnicki, L. Fry, P. Chu, J. Allan, J. Asher, J. Bratton, D. Carpenter, D. Dempsey, C. Drummond, M. Erickson, J. Esch, A. Garwood, R. Haefner, A. Harrison, L. Lemke, J. Nicholas, W. Ogilvie, B. O'Leary, P. Sachs, P. Seelbach, T. Seidel, A. Suchy, and J. Yellich. 2021. Groundwater in crisis? Addressing groundwater challenges in Michigan as a template for the Great Lakes. A white paper. Cooperative Institute for Great Lakes Research, University of Michigan, Ann Arbor, MI.

Stone, I.*, **A. Weinke, N. Dugener****, **J. Cook***, and **B. Biddanda**. 2021. Anchor truth to power: The battle for Earth. Interchange, Connections for the STEM Classroom, September 2021. https://www.gvsu.edu/rmsc/interchange/2021-september-connection-2-the-new-climate-war-1670.htm

2021 Master of Science Theses

Kovach, J. H. (Mentor: Strychar) - Use of imaging flow cytometry to assess the hematology of eastern massasauga rattlesnakes (*Sistrurus catenatus*)

Lorenz, J. (Advisor: Ruetz) - Evaluation of lake sturgeon (*Acipenser fulvescens*) spawning success on an artificial reef constructed in the Kalamazoo River, Michigan

Mader, M. (Advisor: Ruetz) - Effects of shoreline development and land cover on water quality and fish communities along a latitudinal gradient in eastern Lake Michigan

Neuman, E. (Advisor: Hamsher) - Invasion on a local and regional scale: The growth of starry stonewort (*Nitellopsis obtusa*), an aquatic invasive species, in two Michigan lakes, and its predicted spread in the Midwest and Northeast United States

Photo Credit: Tori Vander Stelt

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Giving Opportunities

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.

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