

RIPPLE EFFECT



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Mission Statement

As one of 16 [NOAA Cooperative Institutes](#), CIGLR helps NOAA accomplish its goals for research and management of the Laurentian Great Lakes by leading exciting new [research](#) efforts, [training](#) the next generation of Great Lakes scientists, expanding NOAA research in the Great Lakes through our [Consortium](#), and [translating](#) research into actionable science to meet societal needs. The [Great Lakes Environmental Research Laboratory](#) (GLERL) is our primary NOAA sponsor and home of CIGLR research personnel.

Director's Letter

New Partners Join CIGLR

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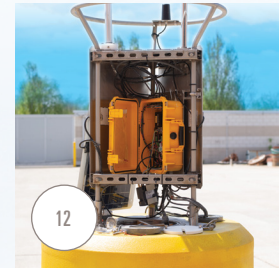
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FORECASTING GREAT LAKES Ice and LAKE-EFFECT Snow



Mitigating the Impact OF HARMFUL ALGAL BLOOMS IN THE GREAT LAKES

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- CIGLR um
- Cooperative Institute for Great Lakes Research

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Dear Friends and Colleagues,

It is my pleasure to introduce the inaugural issue of the Cooperative Institute for Great Lakes Research (CIGLR) annual



magazine. The name of the magazine — *Ripple Effect* — is a metaphor for how our actions as residents, visitors, and stewards of the Great Lakes have impacts far beyond our immediate reach. At CIGLR, our research, engagement, and career training activities are designed to resonate across the basin and into the future to achieve the shared vision of a safe and sustainable Great Lakes for generations to come.

Imagine the formation of a ripple on the water's surface. For me, this image begins with my family visiting the shores of Lake Michigan where my son Elliot likes to skip rocks across the water. As the rocks hit the water, ripples spread outward across the surface. When my daughter Chloe begins to throw rocks as well, her ripples occasionally synchronize with Elliot's as the waves come into phase. Synchronization causes the waves to multiply and grow.

As they grow, the waves travel further, creating a ripple effect that extends far beyond the initial points of contact.

The ripple effect is analogous to how CIGLR works to join individual research projects, educational efforts, and management programs to multiply and spread their impact throughout the Great Lakes as a whole. CIGLR is composed of twelve research universities, four non-governmental organizations, and three private business partners who span all five Great Lakes on both sides of the U.S.-Canada border. These institutions and organizations work together alongside the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL) to better understand, manage, and protect the Great Lakes for the good of all people who call them their home.

In this inaugural version of CIGLR's annual magazine, we share stories about research programs being led by CIGLR and its partners. While each project is important in its own right, it is the coordination of efforts across lakes and borders that allows us to maintain healthy ecosystems that people depend on, develop warning systems that help avoid environmental catastrophes, and generate science-based plans that prepare communities to be resilient to global change.

We also share stories about our public education and

stakeholder engagement programs, which are spreading across the Great Lakes. Last year, CIGLR connected with more than a million people through conferences, public outreach events, social media, newsletters, and our website. We co-designed research and monitoring programs with local and regional authorities to help protect drinking water for more than 3 million people. And, we developed better models to predict lake water levels, ice cover, and lake effect snow events — predictions that protect lives, and that support shipping and commerce in our vibrant blue economy.

Throughout the magazine, you will read stories about how CIGLR is working to ensure that our impacts grow through time as we train the next generation to take over research, education, and management of the Great Lakes. This past year we supported more than 50 students and postdoctoral fellows who are starting their careers by receiving hands-on research training. As you will see from our highlights of these individuals and their work, the future is in good hands.

I hope you enjoy the inaugural version of *Ripple Effect*. This collection of stories shows how we are working together to Keep the Great Lakes Great!

Sincerely,

A handwritten signature in black ink that reads "Bradley J. Cardinale".

Brad Cardinale, PhD, *Director*
Cooperative Institute of Great Lakes Research

New Partners

JOIN CIGLR TO KEEP THE GREAT LAKES GREAT

Four new partners have successfully competed to join the CIGLR Regional Consortium, further expanding our capacity and expertise to understand, predict, and ultimately solve the critical issues facing the Great Lakes and surrounding communities. With the addition of these new partner organizations, the CIGLR Regional Consortium consists of 12 universities, four NGOs, and three businesses who partner with the National Oceanic and Atmospheric Administration (NOAA) in research and development activities that support NOAA's mission in the Great Lakes.

The four new partners are: Cleveland Water Alliance, Lake Superior State University, Michigan Technological University, and Wayne State University. These institutions were selected for membership because each brings a critical new element to the CIGLR

Regional Consortium.

The Cleveland Water Alliance is a nonprofit organization dedicated to growing the region's water innovation system, or "blue economy," by coordinating a network of corporations, universities, research institutions, public agencies, and utilities. They bring strong connections to industry and innovation, and a demonstrated ability to facilitate the transfer of research-phase technologies to market-based solutions for water quality and economic development. "We are thrilled to collaborate with CIGLR to bolster connections between innovations in the research community with our blue economy industry partners. With the help of CIGLR, fostering and developing these partnerships can provide a key piece of the puzzle to keeping our lakes great while supporting our regional

economy," said Bryan Stubbs, who led the Cleveland Water Alliance proposal.

Located in Sault Ste. Marie at the nexus of three Great Lakes, Lake Superior State University is expanding its long tradition as leaders in Great Lakes fisheries management and aquatic science with the new Center for Freshwater Research and Education. Their addition fills a critical geographic void in the CIGLR Regional Consortium, brings needed fisheries management facilities and expertise, and connects the CIGLR university network with research-trained undergraduate students that will be well prepared for graduate studies on Great Lakes topics. Ashley Moerke, PhD, led the Lake Superior State University proposal. "We are excited to have been selected as a partner in the CIGLR Regional Consortium," said Moerke. "We see this partnership

as an opportunity for Lake Superior State University to enhance its research expertise through collaborations with other consortium partners, while simultaneously providing unparalleled training opportunities for our undergraduates interested in pursuing careers in fisheries and freshwater science."

Michigan Technological University's Great Lakes Research Center supports freshwater and ocean research with state-of-the-art laboratories, a fleet of surface and subsurface vessels, and other advanced technologies on the shores of Lake Superior. In addition to expertise in marine engineering and predictive modeling, Michigan Technological University adds valuable high-tech capabilities in remote sensing and autonomous vehicles to the Regional Consortium.

"I am excited about the new era of sustainable resource management that is being built right now — an era that is based on partnerships among great organizations who work together for the good of all who call the Great Lakes their home."

— Brad Cardinale, PhD, Director, CIGLR

"Michigan Tech is excited to join the outstanding group of partners which form CIGLR and to combine our efforts to further support NOAA's missions in the Great Lakes and coastal ocean. Through our main campus on the waterfront of central Lake Superior and the Michigan Tech Research Institute in Ann Arbor, we wholeheartedly welcome this opportunity to help solve the very tough problems facing the Great Lakes," said Guy Meadows, PhD, Director, Great Lakes Research Center.

Located in the City of Detroit, Wayne State University is an urban research university with exemplary programs for supporting underrepresented groups in science and engineering. Their expertise in invasive species, environmental health, environmental law and policy, and urban water and wastewater infrastructure brings a unique set of skills to the CIGLR Regional Consortium. The proposal from Wayne State University was led by Donna Kashian, PhD, and Carol Miller, PhD. "Wayne State looks forward to growing

our Great Lakes research program through a partnership with CIGLR and its partners, providing novel, collaborative research opportunities for our diverse faculty and student body. We are confident that this partnership will significantly expand the depth and reach of CIGLR and NOAA, while also expanding the Wayne State University Great Lakes profile," said Kashian.

CIGLR's Regional Consortium members partner with scientists at NOAA's Great Lakes Environmental Research Laboratory to tackle important

issues facing the Great Lakes. The CIGLR Regional Consortium adds geographic breadth, technical capabilities, and cutting-edge facilities to amplify the capacity of the Ann Arbor, Michigan-based government lab. "We welcome the new CIGLR partners and look forward to new opportunities for collaboration. As the consortium grows, so does NOAA's research capacity in the Great Lakes basin," said Debbie Lee, Director of the NOAA Great Lakes Environmental Research Laboratory.

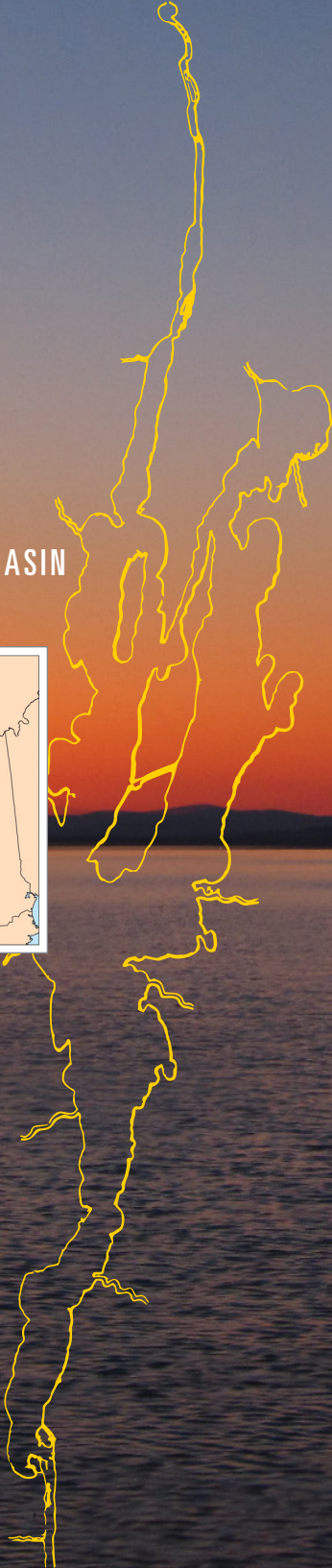
Cooperative Institute for Great Lakes Research
CIGLR
Great Lakes Science for Society

Partners:

- Central Michigan University
- Cleveland Water Alliance
- Cornell University
- Fondriest Environmental
- Grand Valley State University
- Great Lakes Environmental Center
- Lake Superior State University
- LimnoTech
- University of Michigan
- Michigan Environmental Council
- Michigan State University
- Michigan Technological University
- University of Minnesota Duluth
- National Wildlife Federation
- Nature Conservancy
- Ohio State University
- Wayne State University
- University of Windsor
- University of Wisconsin-Milwaukee

Forecasting Flood Events

FOR THE LAKE CHAMPLAIN-RICHELIEU RIVER BASIN





“Our goal is to use the information we gather to analyze the causes and impacts of flooding in the basin and to develop models to provide short-term (5-7 day) flood forecasts.”

— Dmitry Beletsky, PhD

A FLOOD-PRONE REGION will be more prepared for the destructive effects of floods, with help from the Cooperative Institute for Great Lakes Research (CIGLR) and the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL). In collaboration with the International Joint Commission, they are branching outside of the Great Lakes to study the effects of recurring floods in the Lake Champlain basin and develop a real-time flood forecast modeling system. Lake Champlain is a binational lake bordered by Vermont, New York, and Quebec. The lake connects naturally to the St. Lawrence River via Quebec’s Richelieu River and to the Great Lakes via the New York State Canal System.

Severe floods caused by intense rain events and spring snow melt have caused significant destruction of property and infrastructure in the Lake Champlain basin, which is characterized by steep mountains, narrow valleys, and a relatively wet climate.

“Our team began work with the International Joint Commission in response to an intense 2011 flood in the Lake

Champlain and Richelieu River basin,” said CIGLR research scientist Dmitry Beletsky, PhD. During the 2011 flood event, water levels increased in the basin due to a record snowfall followed by intense spring rains. Lake Champlain stayed at flood stage for more than 65 days, affecting more than 3,000 homes and causing over \$6 million in damage. Having led research in this region before, Beletsky is familiar

with the Lake Champlain basin and is helping the research team further develop a flood forecast model.

The scientists are designing models to inform operational flood forecasts for the National Weather Service by providing information on runoff, water levels, lake circulation, temperature, and waves. The system will also support other forecast needs

such as recreational activities, search and rescue efforts, and emergency management.

“It is important for the citizens of the Lake Champlain basin to be aware and informed of the water levels and flood risks in their area,” said Beletsky. “By developing a flood forecast model for this region, the residents will have more insight and preparation time for events like those of 2011.”

In future model phases, a demonstration of the flood forecast system will be made available by NOAA GLERL in real time on the web, allowing researchers to access the forecast system data for use in their own research initiatives.

Lake Erie Walleye

MANAGEMENT AND SUSTAINABILITY



“The opportunities that the CIGLR consortium provides for multi-disciplinary research are critical for management and conservation of the Great Lakes’ ecosystem and fishery resources”

— Aaron Fisk, PhD

WALLEYE are remarkable fish, thriving in all types of freshwater environments from cool, clear rivers to murky, warm lakes. Depending on the year, Lake Erie is home to more than 80 million adult walleye. After spring spawning, the adults migrate hundreds of miles to feed and restore their energy in preparation for next year’s spawn. Lake Erie’s walleye fishery represents one of the most valuable freshwater commercial and recreational fisheries in North America and plays an important ecological role as a top predator in the food web. Four U.S. states (Michigan, Ohio, Pennsylvania, New York) and one Canadian province (Ontario) share the management of this fishery. However, due to the lake-wide migrations of this species, sustainably coordinating the management of the walleye fishery is extremely challenging.

Aaron Fisk, PhD, a professor at the University of Windsor’s Great Lakes Institute for Environmental Research (GLIER), and CIGLR Postdoctoral Fellow Jordan Matley, PhD (GLIER), are leading research to understand how rapidly changing environmental conditions (algal blooms, temperature) and Ohio’s proposed construction of offshore windfarms will affect walleye movements and migrations. A second, equally important objective is to determine if current fishery guidelines adequately incorporate walleye habitat use. They are joined by scientists

from CIGLR, the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL), Great Lakes Acoustic Telemetry Observation System, Ohio DNR, USGS, LimnoTech, and Michigan State University. Having worked together since 2010, these organizations have tracked the movements of millions of Lake Erie walleye, generating the most comprehensive acoustic telemetry dataset in the world. “Although our research is ongoing, we have already made several key findings,” said Fisk. “Based on data from

over one thousand individuals and six years of tracking, we identified seasonal fluctuations in habitat selection across several walleye stocks that coincide with migrations.” For example, they have observed that shallow waters, less than 20 feet deep, were preferred habitat during the March and April spawning periods. During summer and fall, when walleye are migrating across the lake, waters greater than 40 feet deep were preferred. In the winter months, as the walleye returned to their spawning areas, they favored habitats between 20 and 40 feet deep.

“We identified lake-wide similarities in bottom-depth selection across walleye populations in Lake Erie, despite the fishes exhibiting different migration patterns,” said Fisk. “We also found that 20 percent of the tagged walleye passed within 12 miles of the coastal area designated for windfarm construction and remained in that area between two and seven days each month.”

This year the Lake Erie walleye research team will be using Slocum gliders to supplement their dataset. “Gliders are autonomous underwater vehicles (AUVs) that provide a suite of water column observations,” he said. “These instruments will help us better understand the influences of environmental factors such as harmful algal blooms, dissolved oxygen, and temperature on walleye movements and migrations.”

FORECASTING GREAT LAKES

Ice and LAKE-EFFECT Snow





“A numerical model is just a combination of math, but can save ships from getting stuck in the ice and can save people from getting stuck in the snow.”

— Ayumi Fujisaki-Manome, PhD

WINTER WEATHER in the Great Lakes region is responsible for dozens of injuries and deaths every year, as well as economic impacts from disruptions to commercial shipping, winter recreation, and road and air traffic. Due to their massive size, the lakes store and move substantial amounts of heat and water, making the weather and regional climate here unique and difficult to predict. Better understanding of major winter weather processes such as lake ice and snow is crucial to providing accurate forecasts for these sometimes hazardous events.

Assistant Research Scientist Ayumi Fujisaki-Manome, PhD, leads the Great Lakes cryosphere (Earth’s frozen water areas) research program at CIGLR that works to improve predictions of hazardous weather, ice, and lake-effect snow events throughout the Great Lakes region. “Currently, the team is focused on improving models to understand these phenomena,” said Fujisaki-Manome. “We are collaborating with several different agencies, universities and the National Oceanic and Atmospheric Administration (NOAA) who bring their expertise and knowledge to our research program.”

The Great Lakes ice team focuses on the amount and variation of ice coverage from

year to year, and its effect on weather, lake currents, and water temperature.

Over the past year, the ice team has tested and verified two mathematical models that describe ice motion, freezing and melting, and lake currents. The models simulate ice extent over the lakes and reveal several important winter lake processes, including factors influencing the timing of ice-out in Lake Erie and the effect of ice cover on under-ice lake currents. Their models showed weak lake currents under high ice over, which likely provide favorable conditions for winter-spring spawning fish species and their eggs.

“By collaborating with scientists from the NOAA Great Lakes Environmental Research

Laboratory and the Great Lakes Evaporation Network, our team enabled the first-ever ice forecast prediction tool for the Great Lakes Operational Forecast System, which the NOAA National Ocean Service is now operationalizing to improve ship navigation and Coast Guard search and rescue missions,” said Fujisaki-Manome.


Improving the accuracy of lake-effect snow forecasts has been another major focus for the cryosphere research team. The research team has assessed various operational models for simulating the driving forces of lake-effect snow — heat and evaporation. They applied new methods to the analysis of a devastating lake-effect snowstorm that

left at least thirteen people dead in the metropolitan area of Buffalo, New York, in 2014. Although the National Weather Service predicted this storm, the weather forecast models failed to simulate the extreme intensity and location of the storm. By comparing modeled and observed atmospheric moisture and evaporation loss from Lake Erie, they revealed for the first time how heat transfer between Lake Erie and the air fueled the storm.

“Funding from the NOAA Office of Weather and Air Quality has helped our team improve lake-effect snow forecasts by applying a ‘loose coupling’ technique between the ice-lake model (FVCOM-CICE) and NOAA’s High Resolution Rapid Refresh weather model,” she said. “This modeling technique was tested at NOAA’s Hydrometeorology Testbed with hopes for future implementation in operations at NOAA to provide more accurate lake-effect snow forecasts.”

ADVISORY FORECAST GUIDES FERTILIZER APPLICATION TO

Improve Water Quality



“By working together with the agricultural community, university researchers, and NGOs, we aim to improve Lake Erie’s water quality while supporting agricultural production.”

— Jay Martin, PhD

APPLYING FERTILIZER just before a heavy rainfall increases the risk that nutrients intended to enrich the soil will end up in the water instead, where they can cause serious problems. The water quality impacts of nutrient runoff have been observed in the western basin of Lake Erie, which receives nutrient-laden water from a watershed dominated by agriculture (60-80 percent) and several large cities like Detroit, Toledo, and Monroe. Once in Lake Erie, the excess nutrients, along with the warm and shallow waters of Lake Erie, create the perfect environment for the development of harmful algal blooms (HABs) that plague the lake annually.

Through a collaborative effort, spearheaded by the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS), a decision support tool called the Runoff Risk Advisory Forecast (RRAF) has been developed to help guide the timing of fertilizer application based on real-time weather forecasts and soil moisture conditions. Jay Martin, PhD, Margaret Kalcic, PhD, and Asmita Murumkar, PhD, of The Ohio State University’s College of Food, Agricultural,

and Environmental Sciences (CFAES) are evaluating how water quality in the Maumee River and western Lake Erie may improve when farmers and fertilizer applicators use the RRAF tool.

“We are using watershed models to simulate different RRAF scenarios by altering the timing of fertilizer application,” said Murumkar, CFAES postdoctoral researcher. “This research will help quantify and predict potential impacts that different RRAF scenarios will have on water quality.”

Funding for this research is from the EPA Great Lakes Restoration Initiative, awarded to the NOAA NWS North Central River Forecast Center and administered by CIGLR. Murumkar is leading the development and analysis of the project’s modeling framework. Key partners in the study also include Chelsie Boles, PhD, and Todd Redder, PhD, from LimnoTech, Remegio Confessor, PhD, from Heidelberg University, and Dustin Goering from NOAA NWS.

Mitigating the Impact

OF HARMFUL ALGAL BLOOMS IN THE GREAT LAKES



“The management community is tasked with reducing phosphorus delivery to Lake Erie by 40 percent, yet we do not have evidence that this will result in an ‘acceptable’ level of HABs.”

— Thomas Johengen, PhD

HARMFUL ALGAL BLOOMS (HABs) are on the rise across the globe, including in the Great Lakes. A warming climate plus large nutrient inputs from human activities on the land are implicated in the increased severity of HABs, particularly in Lake Erie. These annually occurring blooms in the Great Lakes affect public health and various ecosystem services such as recreational activities. Controlling human exposure to microcystins, the most common toxin produced by the cyanobacterium *Microcystis*, is of particular concern for drinking water plants, which rely on the lakes for source water.

“One of the more difficult challenges for mitigating the impacts of HABs in the Great Lakes is that our traditional monitoring tools do not adequately characterize toxicity,” said CIGLR Research Scientist Thomas Johengen, PhD. “For many bloom-forming cyanobacteria, only a sub-population is genetically capable of producing toxins. Environmental cues seem to govern when and how much toxin they produce.”

“Both Ohio and Michigan have declared their portions of western Lake Erie as “impaired” under the Clean Water Act due to persistent HABs from July to September.”

“This is worrisome,” he explained, “since the Lake

Erie basin is the most densely populated of the Laurentian Great Lakes and its ecosystem services comprise the recreational, commercial, and drinking water resources for 11.6 million people.”

CIGLR has been working with the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL) to conduct research on HABs since 2008.

The primary goal of this research is to produce forecasts that predict HABs so that drinking water intake managers and public health officials can make decisions that protect the public from potential toxin exposure. Much like the weather, HABs forecasts

include both long-term seasonal forecasts and short-term 3-5 day forecasts.

Seasonal HAB forecasts are early season predictions of bloom severity based on estimates of how much phosphorus is expected to be delivered from the Maumee River to the western basin of Lake Erie. The short-term 3-5 day forecast is developed using a combination of satellite remote sensing and particle-tracking models to estimate bloom extent and intensity. These forecasts known as HAB Bulletins are operated and maintained by the NOAA National Center for Coastal Ocean Science.

The secondary goal of this research is to link land-

based activities to reduce phosphorus to reductions in the size, duration, and toxicity of HABs. “Understanding this relationship is critical. The Lake Erie community is working hard to reduce the phosphorus entering the lake by 40 percent and it is important to understand how nutrients already contained in the lake’s sediments are contributing to HABs events,” he said.

Monitoring is used to detect the presence and movement of nutrients and harmful algal blooms throughout the lake, including weekly ship-based sampling, observing buoys, and satellite remote sensing.

“Our western Lake Erie water quality monitoring buoys provide hourly estimates of nitrate and phosphate concentrations,” explained Johengen. “This gives us over 150 times more information than we can generate from weekly ship-based sampling.”



Picky Invasive Mussels

PROMOTE HARMFUL ALGAL BLOOMS IN LAKE ERIE



“The mussels also excrete nutrients during their feeding process. So that’s going to promote the growth of the *Microcystis*, which they’ve rejected.”

—Thomas Johengen, PhD

INVASIVE MUSSELS in

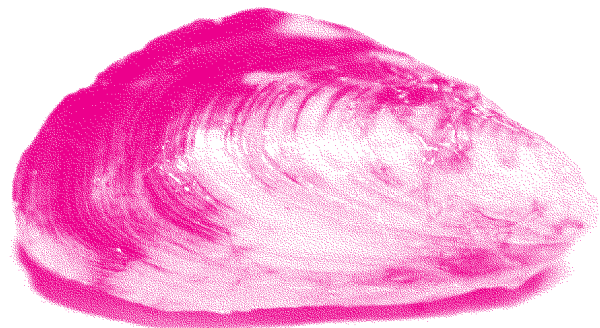
Lake Erie may be contributing to the lake’s harmful algal bloom (HAB) problem, according to scientists from Central Michigan University, University of Michigan, CIGLR, and the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL). After three decades of water quality improvements in Lake Erie, the recent proliferation of HABs has motivated research teams like ours to better understand the role that zebra and quagga

mussels play in the lake. Results from a recent series of laboratory experiments suggest that the plankton in Lake Erie provide invasive mussels with enough food that they can reject the not-so-appetizing and less nutritious HAB species *Microcystis*. From May to October 2018, the research team completed 10 trials of two-week laboratory experiments to measure mussel grazing on intact plankton assemblages from Lake Erie. In all 10 experiments, mussels fed heavily on small algae,

diatoms, and larger protists, while *Microcystis* and some colonial green algae were left uneaten. Given this, our team believes that sustained invasive mussel grazing, in addition to nutrient inputs from the land, can promote the occurrence of HABs in Lake Erie.



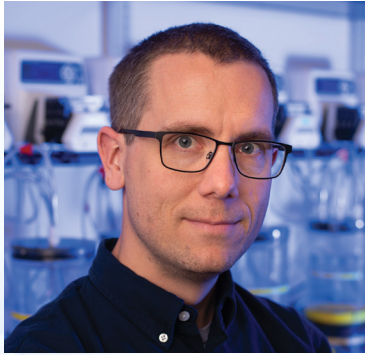
Hear from our scientists



HYPOXIA RESEARCH TURNS

Heavy Metal





“We use sediment core experiments like a physician might use a tissue biopsy — we carefully extract an intact sample from the bottom of the lake and bring it back to the laboratory where we use specialized techniques to understand the process at a mechanistic level.” — Casey Godwin, PhD

THE MOST DRAMATIC IMAGERY of environmental problems in Lake Erie comes from harmful algal blooms — bright green swirls and eddies against the typical blue background of the lake. Another symptom of nutrient runoff in Lake Erie occurs out of sight, at the bottom of the lake. Hypoxia, or low oxygen in the water, has occurred regularly in the summers since the 1960s. Hypoxia occasionally receives attention when it leads to localized fish kills (hence the term ‘dead zones’), but there is growing awareness that low-oxygen water is a problem for communities that rely on the lake for their drinking water.

Assistant Research Scientist Casey Godwin, PhD, is part of an interdisciplinary team at CIGLR and the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL) working to understand the risks that hypoxic water poses for water utilities. According to Godwin, “This layer of hypoxic water is typically located offshore, but our research shows how wind events can rapidly slide this layer of water across the bottom of the lake toward the shoreline, potentially bringing water quality problems toward water intakes.”

This work, funded by grants from NOAA’s Coastal Hypoxia Research Program and the Environmental Protection

Agency’s (EPA) Cooperative Science and Monitoring Initiative, was motivated by interactions with staff at public drinking water facilities, who reported that hypoxic water can be corrosive and sometimes have an elevated amount of the element manganese. Manganese is a naturally occurring heavy metal that is released from sediments during hypoxia. If not removed during treatment, manganese can cause water to become discolored — and potentially toxic to humans — when it occurs at high levels.

Stricter manganese standards for drinking water have been established by the World Health Organization and the EPA, creating an urgent need to understand how manganese

responds to hypoxia and how we can help treatment facilities anticipate when manganese removal processes may be needed.

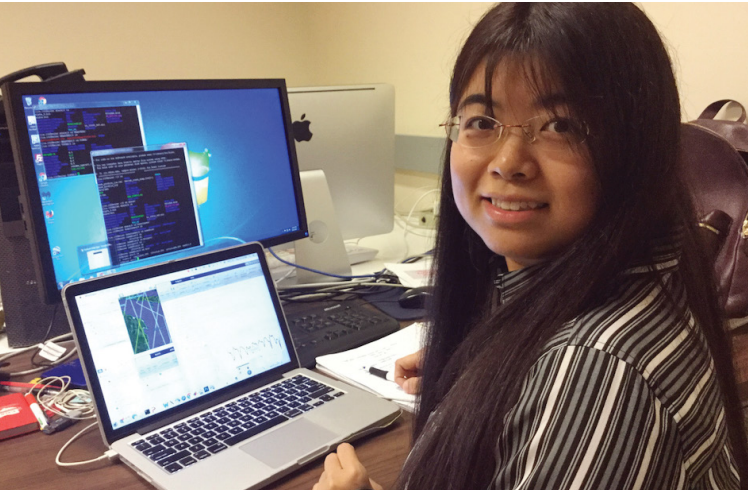
In 2018, experimental results suggested that Lake Erie sediments undergoing hypoxia released manganese much earlier and faster than expected. “The research team is working to identify conditions that lead to the accumulation and release of manganese from sediments into the water,” said Godwin.

This year, Godwin teamed up with Deric Learman, PhD, from Central Michigan University and CIGLR Summer Fellow Jessica Zehnpfennig. They performed additional sediment core experiments to ask whether the

effect of hypoxia on manganese becomes stronger over the course of the summer. They also tried to understand what happens to manganese once it is in the water and exposed to light and biological processes, like photosynthesis.

Godwin and colleagues are also collaborating with Great Lakes agencies including U.S. EPA, Ohio EPA, and Fisheries and Oceans Canada to intensively sample for manganese throughout the lake during 2019. Ultimately, the team will combine findings from laboratory experiments, measurements from in-lake sampling, data from instruments deployed in the lake, and sophisticated models of water movements in order to predict where and when manganese may be present in the lake.

Postdoc Fellows



OBSERVING GREAT LAKES WATER LEVEL Changes from Space

Yuanyuan Jia, PhD, is a CIGLR Postdoctoral Fellow at The Ohio State University working with C.K. Shum, PhD (OSU) and Philip Chu, PhD (NOAA GLERL). During her two-year fellowship, she is investigating the use of satellite data, specifically from radar altimetry, to complement the Great Lakes Observing System and improve the forecast reliability of the Great Lakes Operational Forecasting System. Her work will expand the use of near real-time satellite data and provide more detailed information on Great Lakes water levels, wave heights, and lake storage, ultimately supporting improved forecasts of these factors.

“Historical and current satellite data for the Great Lakes give scientists a window to the changes in water levels and other important environmental variables through time.”

— Yuanyuan Jia, PhD

How Many Fish are in the Great Lakes?

USING MICROSCOPIC ORGANISMS TO ESTIMATE FISH NUMBERS

Thomas M. Evans, PhD, and his advisor Lars Rudstam, PhD (Cornell University) are recipients of a 2018 CIGLR Postdoctoral Fellowship award. They have teamed up with James Watkins, PhD (Cornell), Doran Mason, PhD (NOAA GLERL), and Zachary Feiner, PhD (Wisconsin Department of Natural Resources) to investigate whether they can estimate the number of fish in each Great Lake by measuring the amount of smaller organisms present. Because larger animals, like fish, depend on smaller organisms like algae for their food, there can be a strong relationship between the density of organisms and their body size (also called size spectrum theory). “Currently we are developing size spectra for each lake,” said Evans. “Although our data are preliminary, we are pleased to see relationships appearing between organism abundance and biomass. If our approach is successful, we hope it will be useful for state and federal agencies to detect changes in the structure of the Great Lakes food webs.”





TOWARD FORECASTS OF Toxic Cyanobacterial Blooms IN LAKE ERIE

Cyanobacterial harmful algal blooms (HABs) threaten freshwater ecosystems and drinking water across the world. Annual HABs plague Lake Erie and are made of the cyanobacterium *Microcystis*, which produces a toxin that entered the Toledo, Ohio drinking water supply in 2014, leading to a “do not drink” warning. Currently, scientists use numerical models of Lake Erie to help predict where the HABs will be located. But since not all algal blooms are toxic, these models cannot predict the risk of toxin exposure. Drawing on genetic and environmental data collected from Lake Erie, CIGLR Postdoctoral Fellow Kevin Meyer, PhD, and Greg Dick, PhD (University of Michigan) with colleagues at LimnoTech, CIGLR, NOAA GLERL, The Ohio State University, and Bowling Green State University, are developing new models to better simulate the growth of toxic and non-toxic cyanobacteria, to improve bloom toxicity forecasts and evaluate management strategies. “We don’t just study the Great Lakes, we live here; and we’re trying to keep our lakes and communities healthy. If we can accurately forecast algal blooms and their toxicity, we can prevent the Toledo Water Crisis from happening again in our Great Lakes communities,” said Meyer.

Tracking Walleye IN LAKE ERIE

Walleye support one of the biggest fisheries in the Great Lakes and properly managing this multimillion-dollar industry is essential for both Canada and the United States. Supplementing a data collection started in 2010, Aaron Fisk, PhD, and colleagues at CIGLR, National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL), Great Lakes Acoustic Telemetry Observation System, Ohio DNR, USGS, LimnoTech, and Michigan State University continue to track the movements of walleye throughout Lake Erie. This research has generated millions of observations and has become the most comprehensive acoustic telemetry dataset in the world. Currently, CIGLR Postdoctoral Fellow Jordan Matley, PhD, (University of Windsor) and the Lake Erie walleye research team are using autonomous underwater vehicles (Slocum gliders) to supplement this dataset and better understand the influence of environmental factors such as harmful algal blooms, dissolved oxygen, and temperature on walleye movements and migrations.

“Because of the economic value of walleye and its ecological role as a top predator in the food web, effective management and research are imperative.”

— Jordan Matley, PhD



2018 Great Lakes Summer Fellows

In partnership with the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL), CIGLR has the pleasure of hosting a group of bright, upcoming scientists each year as part of our Great Lakes Summer Fellows Program. During the course of their 12-week fellowship, upper-level undergraduate and graduate students are exposed to a broad range of disciplines while working on a substantive research topic under the mentorship of a CIGLR or NOAA GLERL scientist. The 2018 Great Lakes Summer Fellows included:



Alex Johnson

Cleveland State University
Alex worked with Thomas Johengen, PhD (CIGLR) and Steve Ruberg (NOAA GLERL). He participated in field and laboratory research designed to monitor the timing, location, and toxicity of harmful algal blooms in western Lake Erie and Saginaw Bay, Lake Huron.



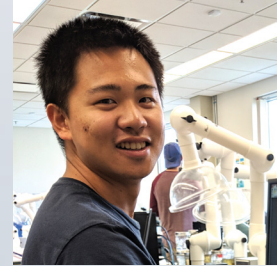
Ben Moran

Northeastern University
Ben worked with Hank Vanderploeg, PhD, and Craig Stow, PhD (NOAA GLERL) on a project to use statistics to understand the factors that influence daily vertical movements of zooplankton in the water column.



Cindy Lebrasse

North Carolina State University
Cindy worked with Qianqian Liu, PhD (CIGLR) and Eric Anderson, PhD (NOAA GLERL) to study how hydrodynamic drivers such as river inputs, winds, and water circulation shape the ecology of Muskegon Lake, thus aiding ongoing restoration efforts there.



Haoran Liu

University of Maryland
Haoran was mentored by Edward Rutherford, PhD, and Hank Vanderploeg, PhD (NOAA GLERL). He evaluated how different types of sampling gear affect density estimates of small organisms like opossum shrimp, spiny water flea, and larval fish.

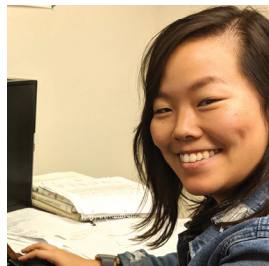




Jenny Tompkins

Allegheny College

Jenny worked with Tian Guo, PhD (CIGLR), Devin Gill, (CIGLR), Mark Rowe, PhD (CIGLR) and Victoria Campbell-Arvai, PhD (U-M) to expand her training in social science methods. She participated in data collection and management related to understanding voter preferences for voluntary or regulatory policy tools intended to reduce harmful algal blooms in western Lake Erie.



Jenny Rhee

University of Louisiana at Lafayette

Jenny worked with Joe Smith (CIGLR), Steve Ruberg (NOAA GLERL) and Philip Chu, PhD (NOAA GLERL) to create a data management system for archived data collected from a series of buoys and other instruments in the Great Lakes.



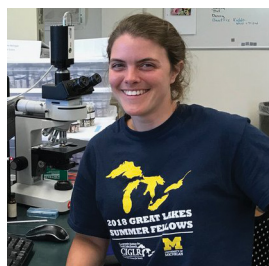
Meg Giitter

St. Mary's College of Maryland

Meg was mentored by Mark Rowe, PhD (CIGLR) and Craig Stow, PhD (NOAA GLERL). She used a large database of Lake Erie observations to develop statistical models that predict changes in conditions like hypoxia, algal biomass, and nutrient concentrations.

“Being a Great Lakes Summer Fellow has given me the opportunity to explore and contribute to diverse research aimed at keeping the human and biological communities safe and balanced in the Great Lakes Region I call home.”

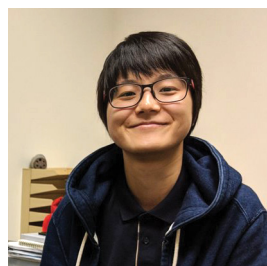
– Jennifer Tompkins



Sara Prendergast

University of Michigan

Sara worked with Edward Rutherford, PhD (NOAA GLERL) and Mark Rowe, PhD (CIGLR), investigating factors that influence changes in the alewife population in Lake Michigan.



Ting-Yi (Franky) Yang

Ohio State University

Franky worked with Jia Wang, PhD (NOAA GLERL), Haoguo Hu (CIGLR), James Kessler (CIGLR) and Philip Chu, PhD (GLERL) to analyze long-term and short-term trends in Great Lakes ice cover.

CONGRATULATIONS TO THE 2019 GREAT LAKES SUMMER FELLOWS COHORT

Clay Carufel

University of Minnesota-Duluth

Lauren Marshall

University of Toledo

Andrew Oppliger

The Ohio State University

Holly Roth

Northern Michigan University

Jacob Rudolph

North Carolina State University

Anna Schmidt

University of Wisconsin-Madison

Steven Smit

University of Michigan

Nolan Smith

William & Mary

Matthew Trumper

University of Minnesota-Twin Cities

Jessica Zehnpfennig

Central Michigan University



Hear about the program from the fellows themselves! Scan for fellows profile videos.

Summits, Rapid Response & ECO Funding



CIGLR Summit:

Improving Farmland Soil Health to Curb Harmful Algal Blooms

More than 20 scientists, policy experts, and agriculture representatives gathered at the University of Michigan to link farmland soil health to downstream water quality. Healthy soils are able to naturally retain nutrients, improve water filtration, and prevent erosion and runoff, providing economic benefits for farms and protecting water quality. Current tools for predicting the downstream benefits of agricultural land management practices may not adequately include soil health factors, making it difficult to promote these strategies to farmers, agribusiness, policymakers, and regulators. Led by the Michigan Environmental Council, this summit explored new watershed models that link soil health to reductions in harmful algal blooms.



CIGLR Summit:

Revisiting Approaches to Great Lakes Restoration and Protection

In light of new information on Great Lakes stresses and responses over the last decade, an in-depth exploration of the approaches used to address stresses in the region and identify the additional research needed to support restoration and protection efforts is essential. The National Wildlife Federation organized an expert workshop to explore better methods for approaching restoration and protection of the Great Lakes. The team identified several potential frameworks, based on an existing structure relating stresses, impacts, and management responses. A white paper summarizing the summit's results and recommendations will be released in the summer of 2019.



Rapid Response to Meteotsunamis:

Monitoring the Menace in the Great Lakes

The recent occurrences of meteotsunami events on Lake Michigan, including a 14 inch water level rise in only 40 minutes near Ludington, Michigan on April 13, 2018, demonstrated that the existing instruments to measure over-lake meteorology (wind speed, direction, and air pressure) and water levels are not adequate to observe or attempt to predict this phenomenon. Meteotsunamis are similar to earthquake-generated tsunamis, but are caused by meteorological events such as rapid changes in barometric pressure often associated with fast moving weather systems. With CIGLR Rapid Funds, LimnoTech is upgrading a network of air-pressure sensors around Lakes Michigan and Erie with the hope of detecting potentially-harmful meteotsunami waves. If their pilot project proves successful, the Great Lakes will be one step closer to a meteotsunami alert or warning statement by the National Weather Service, helping to protect and educate the roughly 30 million people living along Great Lakes coastlines.

2019 Winners

CIGLR AWARDS \$442,000 IN 2019 PARTNER PROGRAMS

Each year, CIGLR offers competitive programmatic funding for Consortium partners to build collaborations with NOAA. Through these partnerships, recipients provide early career training to graduate students and postdocs, delve into big Great Lakes issues in multidisciplinary summits, translate research to the public, and respond to emergencies and other time-sensitive needs in the Great Lakes. The recipients of the 2019 partner awards will advance important areas of Great Lakes research and form connections between our partners and NOAA. Thank you to all who applied and congratulations to the winners!



ECO Funding:

CIGLR Awards Environmental Journalism Scholarships

Five students from CIGLR Regional Consortium universities were awarded competitive scholarships to attend the nation's largest gathering of environmental reporters at the 28th Annual Society of Environmental Journalists (SEJ) Conference on October 3-7, 2018 in Flint, Michigan. The SEJ is an association of professional journalists dedicated to strengthening the quality, reach, and viability of journalism across all media to advance public understanding of environmental issues.

Hosted by the University of Michigan-Flint, highlights of the conference included sessions on honing the craft of environmental reporting and critical election-related issues, such as water rights and bridging the urban-rural divide. The scholarships included all costs to attend the conference and a one-year student membership to SEJ.

(Pictured left to right): Adam Reinhardt (University of Minnesota Duluth), Samantha Shriber (Central Michigan University), Talis Shelbourne (University of Wisconsin Milwaukee), Ed Makowski (University of Wisconsin Milwaukee), and Julia Montag (University of Michigan).

POSTDOCTORAL FELLOWSHIP AWARDS

- **Jay Martin, PhD, The Ohio State University:** Comparison of Model Flow Predictions to Edge of Field (EOF) Data: Determining the Ability of a Watershed Model (SWAT) and Forecast Tool (NOAA RRAF) to Predict Runoff from Agricultural Fields in Western Lake Erie Watersheds
- **Allison Steiner, PhD, University of Michigan:** Generation and Transport of Aerosolized Toxins from Harmful Algal Blooms in the Western Lake Erie Basin
- **Christiane Jablonowski, PhD, University of Michigan:** Improving Lake-Effect Snowfall Forecast Capability Using a Coupled High-Resolution Weather, Hydrodynamic-Ice Modeling System
- **C.K. Shum, PhD, The Ohio State University:** Support of an Improved Establishment and Maintenance of the International Great Lakes Datum

GRADUATE RESEARCH FELLOWSHIP AWARDS

- **Harvey Bootsma, PhD, University of Wisconsin-Milwaukee**
- **Peter Dijkstra, PhD, Central Michigan University:** Predicting Round Goby Establishment Using Environmental and Physiological Indicators
- **James Hood, PhD, The Ohio State University:** Evaluating the Role of Zooplankton in Internal Nutrient Cycling Dynamics in Western Lake Erie
- **Phanikumar Mantha, PhD, Michigan State University**
- **C.K. Shum, PhD, The Ohio State University:** Ice Thickness Retrieval Using Satellite Altimetry for Assimilative Lake Forecasting Studies

SUMMIT AND WORKING GROUP (SWG) AWARDS

Ted Ozersky, PhD, University of Minnesota-Duluth: Winter Limnology on the Great Lakes: Prospects and Research Needs.

ECO AWARDS

- **Dave Poulson, Eric Freedman, PhD, and Perry Parks, PhD, Michigan State University:** Funds used to support a student journalist to identify and produce stories for the *Great Lakes Echo* on CIGLR-affiliated research and activities.
- **Jill Crossman, PhD, and Aaron Fisk, PhD, University of Windsor:** Funds used to support a student to communicate and disseminate Realtime Aquatic Ecosystem Observation Network (RAEON) results, increase public awareness, and help highlight opportunities to collaborate using RAEON infrastructure.
- **Michael McKay, PhD, John Hartig, PhD, and Patricia Galvão-Ferreira, PhD, University of Windsor:** Funds used to support a student intern to join the State of the Strait (SOS) Conference Steering Committee, prepare indicator reports, and assist with transfer of the findings to inform future policy decisions.

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Michigan Environmental
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*Indicates research institute staff
transitions



Congratulations to Lindsay Fitzpatrick and Haoguo Hu!

It is with great enthusiasm that we congratulate Lindsay Fitzpatrick (*Hydrological Modeler*) and Haoguo Hu (*Ice Modeler*) on their new positions at CIGLR. Lindsay joins a new team of hydrological modelers working on a series of projects related to the development, testing, and deployment of hydrological models across the Great Lakes basin. Haoguo is beginning work on a new project to develop storm surge forecasts for western Alaska, which includes implementing, testing, and verifying a sea ice model for this region. CIGLR is fortunate to have Lindsay and Haoguo on our team and we look forward to their contributions to these new areas of research!

Rowe, Kessler, Glyshaw, and Palladino join the NOAA Great Lakes Environmental Research Laboratory

We congratulate Mark Rowe, PhD, Paul Glyshaw, James Kessler, and Danna Palladino on their new positions at the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL). Rowe recently joined NOAA



GLERL as a Physical Research Scientist, focusing on models that link Great Lakes biology and hydrodynamics to further support Great Lakes nutrient and fisheries management. Glyshaw has joined the lab as a Great Lakes Lower Food Web Ecologist focusing on the temporal and spatial patterns and interactions of these organisms. As NOAA GLERL's newest Physical Scientist, Kessler will work on model development and forecasting for hydrodynamics, lake ice and hydrology in the Great Lakes. Danna Palladino is NOAA GLERL's new Nutrient Ecologist working with the Environmental Sample Processor to perform harmful algal bloom sample analyses. CIGLR was fortunate to have Rowe, Kessler, Glyshaw and Palladino on our team and we look forward to the many years of continued collaboration!

CIGLR welcomes eight new members to our team!



Peter Alsip is an Ecological Modeling Data Analyst working with Mark Rowe, PhD (NOAA GLERL) and Thomas Johengen, PhD (CIGLR) on an experimental hypoxia forecast model for Lake Erie.



S. Rao Chaganti, PhD, recently joined CIGLR as an Assistant Research Scientist. His work focuses on the application of functional genomics to study influences of various stressors (e.g., nutrient availability, invasive species, climate change, pollution) on microbial processes, such as what triggers harmful algal bloom toxin production.



Paul Den Uyl is an Aquatic Ecology Research Technician working with Thomas Johengen, PhD (CIGLR), Hank Vanderploeg, PhD (NOAA GLERL) and Steve Ruberg, PhD (NOAA GLERL) to better understand the ecology of the harmful alga *Microcystis*. He is currently working with a new technology, the 3rd Generation Environmental Sampling Processor or 3G-ESP, to improve physical surveys of microbial communities in Lake Erie.



Casey Godwin, PhD, recently joined CIGLR as an Assistant Research Scientist. His current research focuses on the effects of nutrient abundance and forms on harmful algal blooms and the influence of hypoxia on

the biogeochemical cycling of nutrients and heavy metals in Lake Erie.



Yao Hu, PhD, is a Postdoctoral Research Fellow working with Dustin Goering (NWS NCRFC), Lindsay Fitzpatrick (CIGLR), Dmitry Beletsky, PhD (CIGLR) and Brent Lofgren, PhD (NOAA GLERL) to develop decision support tools for agricultural nutrient application timing using the National Weather Service National Water Model framework. The support tools aim to help agricultural producers maximize nutrient retention on the landscape, while simulating ecological impacts of nutrient transport from runoff events.



Qianqian Liu, PhD, is a Postdoctoral Research Fellow working with Eric Anderson, PhD (NOAA GLERL) on a project to develop a hydrodynamic model for 3-dimensional harmful algal bloom movement in Lake Erie. The model will be integrated into the HAB Tracker forecast model to provide more detailed daily information for public health officials, drinking water intake managers, and the public.

In the Media



Freya Rowland, PhD, is a Postdoctoral Research Fellow working with Craig Stow, PhD (NOAA GLERL) and Thomas Johengen, PhD (CIGLR) to build statistical models of harmful algal blooms to better understand and predict their toxicity and growth.



Dan Titze, PhD, is a Hydrodynamic-Wave Modeler working alongside Dmitry Beletsky, PhD (CIGLR) and the Lake Champlain project team on a hydrodynamic model and forecasting system for the lake.

HARMFUL ALGAL BLOOMS

- [Inside NOAA's tracking of Lake Erie's harmful algal bloom](#), WXYZ News
- [NOAA and partners test unmanned vehicle to detect harmful algal blooms in Lake Erie](#), NOAA Research
- [Fishing in greener waters: understanding the impact of harmful algal blooms on Lake Erie anglers](#), Michigan News
- [Study: toxic algae develops faster](#), Great Lakes Echo
- [Some cyanobacteria survive the winter in western Lake Erie](#), Michigan Radio
- [Lake Erie algal blooms 'seeded' internally by overwintering cells in lake-bottom sediments](#), Michigan News
- [Monitoring algal blooms in the Great Lakes Basin](#), Great Lakes Echo

GOVERNMENT SHUTDOWN IMPACTS

- [Partial government shutdown: Impact on U-M research](#), Michigan News
- [Six things to know about the federal government shutdown in Michigan](#), Bridge
- [Federal shutdown hits UM-affiliated environmental studies](#), Crains Detroit
- [How the government shutdown leaves the Great Lakes in limbo](#), WDET 101.9 fm
- [How the government shutdown impacts the Great Lakes](#), WWMT
- [Between government shutdowns? Great Lakes researchers struggle to carry on](#), Great Lakes Echo

METEOTSUNAMIS

- [Scientists launch project to warn of potentially dangerous 'meteotsunami' waves in Great Lakes](#), WDIV ClickOnDetroit
- [Scientists creating meteotsunami warning system for the Great Lakes](#), Michigan Radio

GREAT LAKES ICE & SNOW

- [Researchers to sharpen Great Lakes ice alerts](#), Great Lakes Echo
- [Forecasting tool for cold-weather shipping a good project](#), Mining Journal
- [Improved lake-effect snow forecasts through experimental coupling of weather prediction with lake hydrodynamics](#), NOAA ESRL

CONSORTIUM PARTNERS

- [New partners join U-M-based CIGLR to keep the Great Lakes great](#), Michigan News
- [Michigan Tech joins Great Lakes research collaborative](#), Michigan Tech News
- [Wayne State partners with CIGLR to keep the Great Lakes great](#), Wayne State CLAS News
- [LSSU joins CIGLR in new strategic partnership](#), LSSU News
- [Universities, nonprofit group join Great Lakes partnership](#), Detroit News



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Peer-Reviewed Publications

- Anderson, E.J., A. Fujisaki-Manome, J. Kessler, G.A. Lang, P.Y. Chu, J.G.W. Kelley, Y. Chen and J. Wang. 2018. Ice Forecasting in the Next-Generation Great Lakes Operational Forecast System. *Journal of Marine Science and Engineering*. 6(4):123. (DOI:10.3390/jmse6040123).
- Bartlett, S.L., S.L. Brunner, J.V. Klump, E.M. Houghton and T.R.J. Miller. 2018. Spatial analysis of toxic or otherwise bioactive cyanobacterial peptides in Green Bay, Lake Michigan. *Journal of Great Lakes Research*. 44(5):924-933. (DOI:10.1016/j.jglr.2018.08.016).
- Biddanda, B.A., A.D. Weinke, S.T. Kendall, L.C. Gereaux, T.M. Holcomb, M.J. Snider, D.K. Dila, S.A. Long, C. VandenBerg, K. Knapp, D.J. Koopmans, K. Thompson, J.H. Vail, M.E. Ogdahl, Q. Liu, T.J. Johengen, E.J. Anderson and S.A. Ruberg. 2018. Chronicles of Hypoxia: Timeseries buoy observations reveal annually recurring seasonal basin-wide bottom water hypoxia in Muskegon Lake Area of Concern – a Great Lakes estuary. *Journal of Great Lakes Research*. 44(2):219-229. (DOI:10.1016/j.jglr.2017.12.008).
- Bosse, K.R., M.J. Sayers, R.A. Shuchman, G.L. Fahnenstiel, S.A. Ruberg, D.L. Fanslow, D.G. Stuart, T.H. Johengen and A.M. Burtner. 2019. Spatial-Temporal Variability of in situ Cyanobacteria Vertical Structure in Western Lake Erie. *Journal of Great Lakes Research*. (DOI:10.1016/j.jglr.2019.02.003).
- Charusombat, U., A. Fujisaki-Manome, A.D. Gronewold, B.M. Lofgren, E.J. Anderson, P.D. Blanken, C. Spence, J.D. Lenters, C. Xiao, L.E. Fitzpatrick and G. Cutrel. 2018. Evaluating and improving modeled turbulent heat fluxes across the North American Great Lakes. *Hydrology and Earth System Sciences*. 22(10):5559-5578. (DOI:10.5194/hess-22-5559-2018).
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- Hietala, D.C., C.M. Godwin, B.J. Cardinale and P.E. Savage. 2019. The independent and coupled effects of feedstock characteristics and reaction conditions on biocrude production by hydrothermal liquefaction. *Applied Energy*. 235:714-728. (DOI:10.1016/j.apenergy.2018.10.120).
- Kitchens, C.K., T.H. Johengen and T.W. Davis. 2018. Establishing spatial and temporal patterns in *Microcystis* sediment seed stock viability and their relationship to subsequent bloom development in Western Lake Erie. *PLOS One*. 13(11):1-18. (DOI:10.1371/journal.pone.0206821).
- Klump, J.V., J. Bratton, K. Fermanich, P. Forsythe, H.J. Harris, R.W. Howe and J.L. Kaster. 2018. Green Bay, Lake Michigan: A proving ground for Great Lakes restoration. *Journal of Great Lakes Research*. 44(5):825-828. (DOI:10.1016/j.jglr.2018.08.002).
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- Kramer, B.J., T.W. Davis, K.A. Meyer, B.H. Rosen, J.A. Goleski, G.J. Dick, G. Oh and C.J. Gobler. 2018. Nitrogen limitation, toxin synthesis potential, and toxicity of cyanobacterial populations in Lake Okeechobee and the St. Lucie River Estuary, Florida, during the 2016 state of emergency event. *PLOS One*. 13(5):1-26. (DOI:10.1371/journal.pone.0196278).
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