COOPERATIVE INSTITUTE FOR GREAT LAKES RESEARCH 2020

# RIPPLE EFFECT

**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.

Produced by Michigan Creative, a unit of the University of Michigan Office of the Vice President for Communications. MC200290

# What's Inside




TRACKING THE RETURN OF THE **"Green Gunk"**

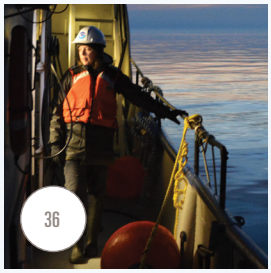



PHOTO CONTEST **Winners**

@CIGLR.UMich
@CIGLR_UM
@ciglr_um
Cooperative Institute for Great Lakes Research
CIGLR um
Cooperative Institute for Great Lakes Research

**ciglr.seas.umich.edu**

# Dear Friends and Colleagues,

We are facing so many new and unexpected challenges, both in our work and in our home lives. I hope that these changes have not been too burdensome, and that everyone is staying safe and healthy. I have been fortunate enough to work with an amazing and inspiring group of people who have made these difficult times more manageable. Every day, I am inspired by our scientists and staff who have found new ways to meaningfully contribute to the missions of CIGLR and NOAA. The quality and dedication of my colleagues gives me hope and optimism for a future beyond the limitations of the pandemic. I also hope that we all take pause to consider and support those who may have lost jobs or are struggling to care for their families. Because right now, we need to pull together and help whenever we see an opportunity to do so.

As you may have learned already, I was presented with yet another unexpected challenge. Recently, I was approached by the Dean of the University of Michigan's School for Environment and Sustainability about the need to provide new leadership for CIGLR. My decision was easy, because although it has only been a year since I stepped down as associate director at CIGLR, my work family needed me. After 29 years of working for CIGLR it truly does seem like family to me, and it is truly my honor to return to serve as acting director while we search for a permanent leader. During this period, I will also continue leading Michigan Sea Grant and conducting select research projects. My goal is to ensure a seamless transition for both our internal institute staff at NOAA GLERL and for all the ongoing activities with our external Consortium Partners. For those new Consortium Partners with whom I have not yet had the pleasure to interact, I look forward to working with you and helping to keep those partnerships thriving.

To this point, I want to express my sincere appreciation for everything that Dr. Brad Cardinale has done to promote expanded opportunities for new research and collaborations among all of our CIGLR Consortium members. Since undertaking the lead to win the recompletion for CIGLR in 2017, the organization has seen uninterrupted growth in the number of research projects, student fellowships, research staff and scientists, and the development of a strong network of 19 academic, business, and non-governmental partners. This growth translates into a significantly increased capacity to support NOAA, expanded leadership in helping drive science-based management of the Great Lakes, and a stronger commitment to diversity, equity and inclusion.

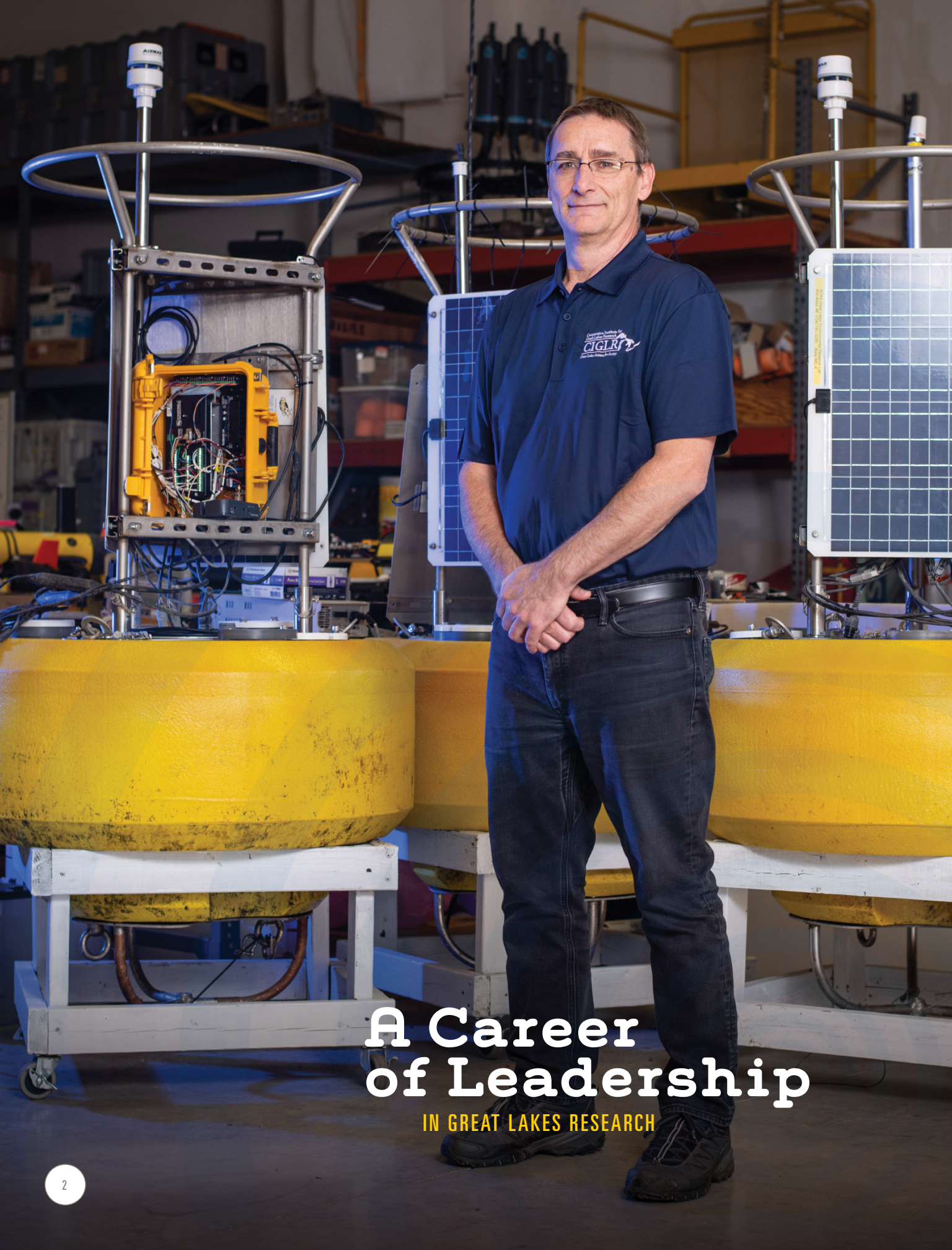
As you will read within this volume of the Ripple Effect, CIGLR is moving forward in a strong and positive direction. We are pleased to introduce you to our two new CIGLR Research Scientists: genomicist Rao Chaganti and biophysical modeler Michael Fraker, who will help us build upon some exciting new research initiatives in collaboration with NOAA.

In closing, I want to congratulate and thank all of our staff and all our partners, for the passion and dedication you bring to the job of helping to protect the resources and vitality of our beloved Great Lakes. What a privilege it is to work with you within the confines of such exemplary Great Lakes organizations, CIGLR and Michigan Sea Grant.

Sincerely,

Thomas H. Johengen

Thomas Johengen
*Acting Director,* CIGLR
*Director,* Michigan Sea Grant



# A Career of Leadership

## IN GREAT LAKES RESEARCH

**DR. THOMAS JOHENGEN** has been a research scientist with the Cooperative Institute for Great Lakes Research (CIGLR, formerly the Cooperative Institute for Limnology and Ecosystems Research (CILER)) at the University of Michigan since 1991. He has also served as the Cooperative Institute's Director (2000–2005), Associate Director (2009–2019), on numerous Great Lakes' advisory boards and panels, Michigan Sea Grant's Director (2019–present), and most recently became CIGLR's new Acting Director (August 2020–).

"I am thrilled to have the opportunity to help lead two impactful and well-respected Great Lakes organizations," says Johengen. "I look forward to working with our university researchers, our extension educators, and the broad range of public stakeholders connected with CIGLR and Michigan Sea Grant to promote the sustainable use of our Great Lakes resources, and to guide management actions in a way that benefits the quality of life for the citizens within the basin. The strength of these two organizations is that they focus research, education, and outreach efforts directly into the coastal communities to help address on-the-ground challenges related to ecosystem health, restoration, resiliency, and economic stability. I hope that I can build upon my years of Great Lakes research experience and use the tremendous partnerships afforded by CIGLR, Michigan Sea Grant, and NOAA to develop a common vision and commitment for enhancing our efforts to protect and promote the health and sustainability of our treasured Great Lakes."

Johengen holds degrees from Michigan State University (BS), Florida State University (MS), and the University of Michigan (PhD). His research has focused on a range of critical Great Lakes issues including harmful algal blooms, the impact of invasive species on lower food webs, ballast water management and the transfer of invasive species, and observing technologies.

"I have had the opportunity to be part of research projects that led to improved ballast water legislation to mitigate invasive species introductions, advanced our capacity to monitor Great Lakes water quality using emerging in situ technologies, and developed ecological forecasting models to protect public health from the adverse effects of harmful algal blooms and hypoxia," says Johengen. "While these beneficial societal outcomes are the underlying motivation of my research, it is of course the interactions with all my colleagues that have made the job a true privilege and delight. It has been an honor to work with so many dedicated and passionate professionals across the basin, all directed toward making a positive impact within the Great Lakes community."

Throughout his career, Johengen has led many exciting research projects and has mentored countless numbers of students, technicians, administrators, and scientists. His role as an advisor and Great Lakes science mentor has motivated, challenged, and afforded incredible experiences and opportunities to those lucky enough to work alongside him.

"Tom is an ideal leader of efforts to keep the Great Lakes great," says Dr. Jonathan Overpeck, Dean of the University of Michigan's School for Environment and Sustainability. "He knows the science, but also how that science is used to make sure the people and communities of the Great Lakes region thrive. This combination of perspectives gives Tom the ability to work with researchers and folks in society alike to create compelling vision, and make a real positive difference."

"I have always appreciated the fact that much of my research is directed at protecting the resources of the Great Lakes and serving public interests."

—Thomas Johengen, PhD

IMPROVING

# Alaska's

COASTAL HAZARD

# Forecasts

Learn more.

"The goal is to fill in the gaps of storm surge forecasting capability along Alaska's coast, which is collectively impacted by sea ice and waves."

— Ayumi Fujisaki-Manome, PhD

**COASTAL STORMS** threaten human safety in western Alaskan communities, where a combination of complex geography, highly energetic atmospheric and ocean circulation, wind, waves, and an extensive coastal floodplain leave them highly vulnerable to hazardous flooding. Western Alaska is limited in weather observations and replete of nearshore current and circulation information, leaving regional forecasters and the communities they serve severely limited in their ability to assess the impact risk of storm events. These problems have become even more vexing in light of continued diminishing ice conditions in the fall and winter months, when the most intense storm events occur.

Assistant Research Scientist Ayumi Fujisaki-Manome, PhD, leads CIGLR's ice and snow research program. She is working with a team of scientists from the Alaska Ocean Observing System, Axiom Data Science, CIGLR, NOAA, University of Notre Dame, and University of Texas-Austin to deliver improved storm surge, wave, and ice forecasting capacity to the NOAA National Centers for Environmental Protection (NCEP) and NOAA National Ocean Service (NOS). "Funding from the U.S. Integrated Ocean Observing System (IOOS) is supporting the development of an integrated modeling system for the coasts of Alaska," says Fujisaki-Manome. "The end product from this project is the coupled surge-wave-ice model for the western Alaska region, with the goal to provide forecast officers with model forecast guidance they can use to issue or not issue warnings and advisories."

Their advanced sea ice modeling system, based on the Los Alamos Sea Ice Model (CICE), will enable detailed representation of nearshore and offshore sea ice behavior such as landfast ice and increased surface roughness due to ridged ice, which impact surge and wave intensity. "Currently, the team of scientists at CIGLR and NOAA GLERL leads the advancement of a sea ice model component based on CICE," says Fujisaki-Manome.

Adequately depicting these processes is critical for accurate storm surge forecasting when the ocean is covered with ice. Thus far in the project, a standalone sea ice model has been successfully designed and verified using sensitivity studies and satellite measurements.

"Our team continues to couple sea ice modeling components with the other physical modeling components like ocean and wave models, using the NOAA Environmental Modeling System (NEMS) in collaboration with scientists at the University of Notre Dame, the University of Texas-Austin, and the NOAA National Centers for Environmental Prediction," says Fujisaki-Manome. "This project represents a major advancement in forecasting capacity to protect western Alaska communities and our lessons learned can be applied to ice-prone coastal regions elsewhere."

## MODELING LAKE MICHIGAN'S SUITABILITY FOR

# ASIAN CARP

**INVASIONS** of notorious non-native species like the sea lamprey and dreissenid mussels have transformed the Great Lakes ecosystem. As efforts to understand and minimize the damage of already entrenched invaders continue, the prevention of new invasions has become a strategic priority of invasive species management. Of the many species being monitored by scientists, perhaps none are more concerning than Asian carp.

Bighead and silver carp (collectively referred to as bigheaded carp) are the two plankton-feeding species of Asian carp that were imported to the United States in the 1970s as a means of controlling algal growth in reservoirs and sewage treatment lagoons. These species escaped into natural waterways, quickly spreading throughout the Mississippi River basin. Bigheaded carp have established dense populations in many rivers, including the Illinois River where they compose 63 percent of the total fish biomass. Bigheaded carp disrupt aquatic food webs by voraciously feeding on zooplankton and phytoplankton, which limits the food available to resident fishes. Bigheaded carp will also consume alternative foods, such as detritus and bacteria, when plankton becomes less available.

The close proximity of bigheaded carp to Lake Michigan has elevated concerns about the impact they could have on the Great Lakes food web, which supports a $7 billion recreational fishery. While their insatiable appetites, flexible diets, rapid growth, and reproduction rates make bigheaded carp a formidable invader, Lake Michigan is colder and has less plankton than the environments where they currently exist. Reductions in nutrient loads over the past 50 years and the proliferation of the invasive filter-feeding quagga mussels have transformed Lake Michigan into a plankton desert, which has prompted two questions: 1) Does Lake Michigan have enough food to support bighead and silver carp? 2) How do human-caused stressors such as climate change and nutrient pollution affect Lake Michigan's vulnerability to bigheaded carp?

To help answer these questions, a team of scientists from CIGLR, NOAA GLERL, the University of Michigan and Eureka Aquatic Research constructed a model that evaluates Lake Michigan's suitability for bigheaded carp growth. The work was part of CIGLR Ecological Modeling Data Analyst Peter Alsip's master's thesis at the University of Michigan School for Environment and Sustainability. The team's approach (known as a "growth rate potential model") measures habitat quality based on water temperature, prey abundance, and bigheaded carp's physiological requirements for growth. Previous studies indicated that bigheaded carp could only survive in Lake Michigan's plankton-dense areas, such as Green Bay, but these studies did not account for carp feeding flexibly on different food throughout the water column. The data produced by a 3D lake model allowed the team to build on previous research by evaluating subsurface habitats while also accounting for bigheaded carp's ability to feed on an alternative prey item, detritus, as well as phytoplankton and zooplankton.

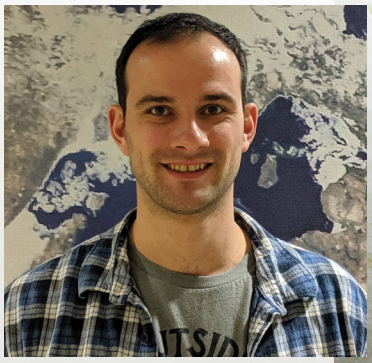
Their results were surprising. By accounting for diet flexibility and subsurface habitat in the model, the research team demonstrated that nearly all of Lake Michigan contains suitable habitat for bigheaded carp. Habitats with greatest potential to support bigheaded carp were located near river mouths and in Green Bay, which agrees with previous studies. However, their research also demonstrates that Lake Michigan's offshore areas are suitable for bigheaded carp. Although offshore areas offer a relatively low-quality habitat, making them less appealing for resident populations, they may provide migration corridors through which bigheaded carp could spread to more food-rich areas in the lake.

"Our research could provide a basis for understanding how bigheaded carp may respond to differing lake conditions."

— Peter Alsip

In the next phase of the study, Alsip and colleagues utilized this model to evaluate how anthropogenic, or human-caused, stressors such as climate change, nutrient pollution, and invasive mussel filtration individually and interactively affect bigheaded carp habitat suitability. Using simulated scenario datasets from the same lake model, the team was able to assess invasion risk for historical, present, and potential future lake conditions.

"We compared model data with recorded lake conditions representative of 2010 to those of the 1980s," says Alsip. "Lake Michigan experienced heavier phosphorus loads and no invasive mussels in the 1980s, which led to bigheaded carp gaining 8 to 40 percent more weight through the year." The research team also simulated a scenario with a warmer climate, which lengthened the growing season by increasing the fishes' foraging activity and limiting food competition with mussels due to prolonged summer stratification of the



water column. As suitable habitat increases in time and space, so does the risk of these fishes spreading throughout Lake Michigan and reaching food-rich habitats, such as Green Bay, that will support greater growth.

"Overall, our study demonstrates that Lake Michigan has become less suitable for bigheaded carp since the 1980s, primarily due to strategic phosphorus abatement," says Alsip. "However, the lake's vulnerability to these fishes will increase as climate change progresses or if nutrient pollution increases, despite the competitive feeding pressure from dreissenid mussels."

CIGLR RESEARCH CONTINUES TO SUPPORT NOAA'S MISSION; ADAPTS PHASED RETURN TO

# Critical Harmful Algal Bloom Fieldwork

"Our team is excited to begin the 2020 field season in a limited, safe capacity and deliver pertinent science for the Great Lakes community."

— Casey Godwin, PhD

**HARMFUL ALGAL BLOOM (HAB)** research is a major focus of CIGLR and the NOAA Great Lakes Environmental Research Laboratory (GLERL). Together, we produce a suite of experimental harmful algal bloom (HAB) monitoring products for Lake Erie each field year, in support of the operational HAB forecast issued by the NOAA National Ocean Service. In a typical field year, the team's HAB research would be well underway, with a full-complement of real-time buoys and Environmental Sample Processors (ESPs) deployed and collecting data, fly-over hyperspectral imagery, and weekly field monitoring campaigns in full swing.

Although much of this work has been delayed to protect our health and safety during COVID-19, NOAA has categorized our field monitoring work as mission-critical for support of the operational HAB forecast that serves stakeholders in western Lake Erie, including drinking water treatment plant managers. With a suite of approved safety protocols, CIGLR and NOAA GLERL have resumed limited field and laboratory operations to ensure that this critical Great Lakes research continues to serve the stakeholders that rely on our products and services.

But like all aspects of life and society, this HABs monitoring is significantly scaled back relative to past years. "When the state of Michigan emerged from the stay-at-home order, we headed into the summer HABs season and resumed this mission to provide up-to-date information on HAB toxin concentrations and other parameters to stakeholders," says Godwin. "The first monitoring mission, completed on June 16, was a success thanks to careful preparation and planning. Since then, we have continued to conduct our weekly campaigns albeit with fewer people and visiting fewer stations. This work requires a highly-trained team of staff and researchers, but this year the team is limited to the bare minimum number of individuals who are decked out in masks and protective equipment, spread out across different rooms, and only see each other at virtual meetings. Despite these important precautions and major changes to how we work, the team has done a great job preparing for the HAB season and accomplishing this critical work."

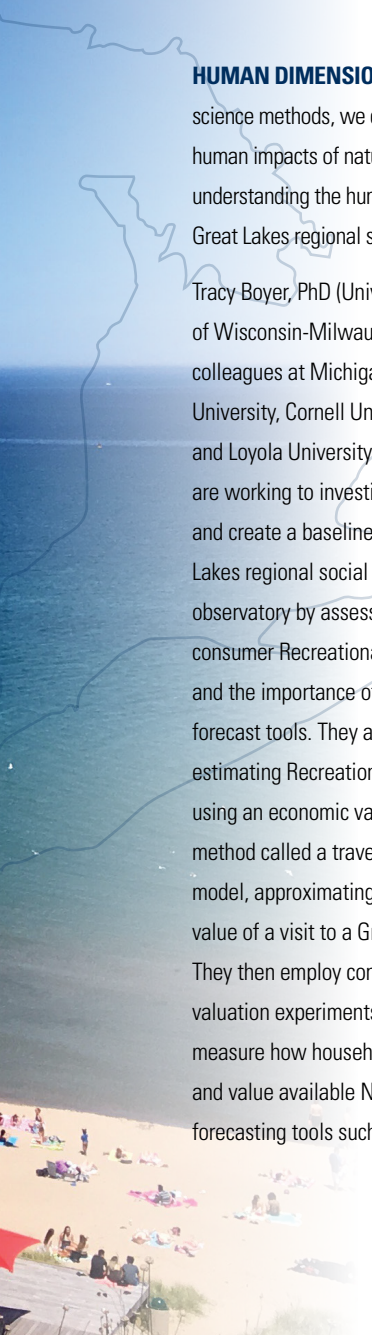
This important research has resumed just in time, as HABs tend to develop most quickly during July through September. "So far, the bloom is moderate relative to previous years but the research team remains vigilant," says Godwin. CIGLR and NOAA GLERL plan to continue weekly monitoring at locations in western Lake Erie through October and share data on toxin concentrations and HAB biomass with stakeholders.

WHAT IS THE VALUE OF

# Great Lakes Recreation?

"Our study looks at ways to put a value on the Great Lakes environment and their water resources, things that aren't typically given a market price."

— Tracy Boyer, PhD



**HUMAN DIMENSIONS RESEARCH** seeks to understand the relationships that people have with the natural environment. Using social science methods, we can evaluate the value of ecosystem services, desired natural resource management outcomes, and the potential human impacts of natural resources management decisions. Our growing social science program at CIGLR is making progress toward understanding the human dimensions of Great Lakes natural resources and sustainability. In one study, we are laying the groundwork for a Great Lakes regional social science observatory.

Tracy Boyer, PhD (University of Wisconsin-Milwaukee) and colleagues at Michigan State University, Cornell University, and Loyola University Chicago are working to investigate and create a baseline Great Lakes regional social science observatory by assessing consumer Recreational Value and the importance of NOAA forecast tools. They are estimating Recreational Value using an economic valuation method called a travel-cost model, approximating the value of a visit to a Great Lake. They then employ contingent valuation experiments to measure how households use and value available NOAA forecasting tools such as the Lake Erie Harmful Algal Bloom Tracker and the National Weather Service (NWS) Beach Hazard statements to modify behavior and travel.

In the fall of 2019, the observatory generated a unique dataset of over 10,000 individual surveys from residents of the eight U.S. Great Lakes states and Ontario, Canada. Currently, they are examining the surveys for the variety of recreational uses (e.g., angling, beach visitation, sightseeing) that each resident disclosed.

"Preliminary findings show that the Great Lakes are a significant regional attraction for recreation and the majority of those surveyed find value in the available forecasting systems from NOAA," says Boyer. "Seventy-six percent of respondents have visited a Great Lake at some point in their lives, and almost 54 percent of those who have visited have done so within the last year. And of those who visited in the last year, almost 75 percent took more than one trip (averaging two trips) to different and unique locations. Lake Michigan and the southern shoreline of Lake Erie were visited the most.

"Our study is unique as it considers travel for multiple recreational uses in the Great Lakes," says Boyer. "Collecting accurate data and survey responses over a large geographic region is uncommon and will be a unique contribution to the economic valuation literature. In the fall of 2020, we plan to conduct a repeat survey to examine how recreation differs with changing lake conditions. However, with the evolving COVID-19 pandemic, recreation is likely to change due to beach closures and perceived safety of visitation. Our team will monitor and evaluate the situation as it unfolds."

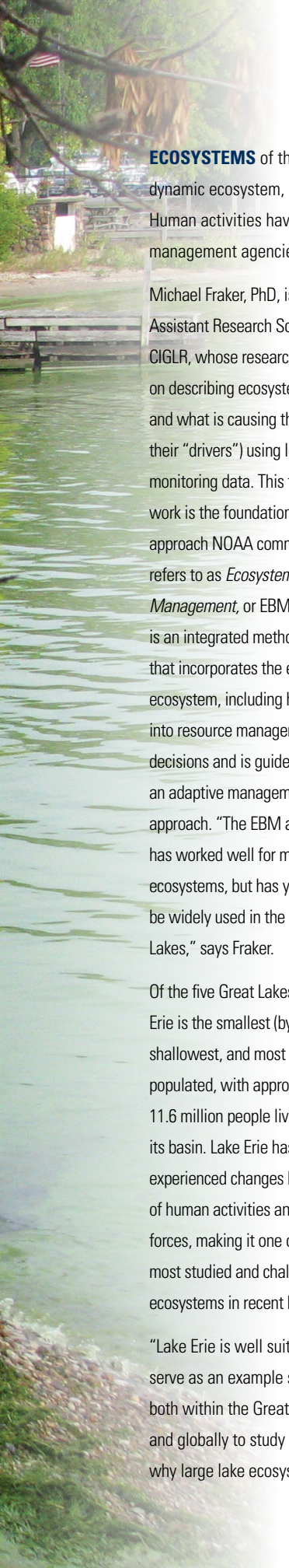
ASSESSING

# Environmental Changes

IN THE LAKE ERIE ECOSYSTEM

"Our research is the first step to observe what linkages and drivers are important for implementing ecosystem based management in the environment, starting with Lake Erie."

— Michael Fraker, PhD



**ECOSYSTEMS** of the Laurentian Great Lakes have been in a state of flux during the past century. Lake Erie has been an especially dynamic ecosystem, impacted by pollution, introduced species, increased nutrient inputs, climate change, and land-use change. Human activities have dramatically altered Lake Erie's natural conditions, presenting an ongoing challenge to conservationists and management agencies working to sustain the varied ecosystem services that the lake provides.

Michael Fraker, PhD, is an Assistant Research Scientist for CIGLR, whose research focuses on describing ecosystem trends and what is causing them (i.e., their "drivers") using long-term monitoring data. This type of work is the foundation for an approach NOAA commonly refers to as *Ecosystem Based Management*, or EBM. EBM is an integrated method that incorporates the entire ecosystem, including humans, into resource management decisions and is guided by an adaptive management approach. "The EBM approach has worked well for marine ecosystems, but has yet to be widely used in the Great Lakes," says Fraker.

Of the five Great Lakes, Lake Erie is the smallest (by volume), shallowest, and most densely populated, with approximately 11.6 million people living in its basin. Lake Erie has long experienced changes because of human activities and natural forces, making it one of the most studied and challenged ecosystems in recent history.

"Lake Erie is well suited to serve as an example system both within the Great Lakes and globally to study how and why large lake ecosystems have varied over time," says Fraker. "Our research team collected many of the long-term monitoring datasets for Lake Erie's western basin beginning in the late 1960s or earlier, including data on the biological, physical, and socioeconomic features of the lake. As we plot the data, we are looking for regime shifts within an ecosystem, what variables if any are correlated with these shifts, and what drivers are most important."

In ecology, regime shifts are large, abrupt, persistent changes in the structure and function of an ecosystem. Recently, many examples of regime shifts have been documented worldwide, especially in marine ecosystems, and understanding their mechanisms and consequences is of great importance for the sustainable use and management of natural resources.

"Our team is able to use the long-term datasets from Lake Erie to observe environmental and anthropogenic, or human-caused, drivers that play a fundamental role in causing unexpected and sudden shifts between the lake's ecosystem states," says Fraker. "Currently, our models indicate that nearly all ecosystem variables in our study respond to changes in agriculture and temperature. We also see how the location of organisms within the food web influences their response to alterations in their environment. For example, phytoplankton communities are affected by fluctuations in river discharge and the associated phosphorus levels, which in turn elicits a response by the zooplankton community that preys upon them. Higher up in the food web, fish and birds are not as strongly affected by those changes."

Prioritizing the different components and services of the Lake Erie environment through a holistic EBM approach balances the diverse and interconnected needs of society and the environment. Individual ecosystem components are intrinsically linked to each other and changes in one component might propagate through the system to influence the various other components.

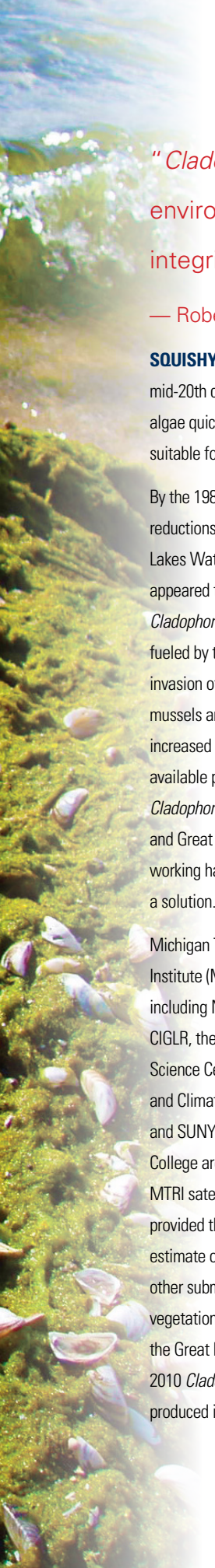
"Traditionally, when we talk about ecosystem management we are usually focused on a single species," says Fraker. "There can be ecosystem trade-offs associated with this kind of management. For example, if managers concentrate only on the Lake Erie walleye population, they might miss changes in ecosystem conditions that negatively impact other species of fish and birds."

As a result of this study, workshops are being planned in conjunction with the Great Lakes Fishery Commission, Ohio Department of Natural Resources, and NOAA to present the Lake Erie EBM research and strategize for the next steps of EBM in the Great Lakes.

"Through our research, we hope to advance the ability of agencies to use EBM approaches in the management of Lake Erie and, hopefully, the Great Lakes," says Fraker. "The data exist for a relatively wide and integrated assessment of the Lake Erie ecosystem and how it has responded to many of the same drivers that affect freshwater systems worldwide. We hope to use the numerous long-term monitoring datasets for Lake Michigan to start a similar study there in the near future."


TRACKING THE RETURN OF THE

# "Green Gunk"



"*Cladophora* is a nuisance that, when unchecked, may cause significant environmental degradation along the Great Lakes shoreline and compromise the integrity of its ecosystems."

— Robert Schuchman, PhD

**SQUISHY GREEN PILES** of *Cladophora* algae have been washing up on Great Lakes beaches for generations. It became a nuisance in the mid-20th century, when unregulated nutrient runoff resulted in never-before-seen *Cladophora* blooms. Washing up in mats, the stagnant algae quickly started to smell, desecrated the shoreline and beaches, clogged water intakes, and created warm, nutrient-rich environments suitable for microbes, some of which proved harmful to humans and wildlife.

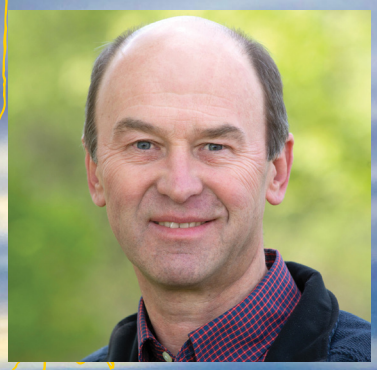
By the 1980s, phosphorus reductions required by the Great Lakes Water Quality Agreement appeared to mitigate the *Cladophora* problem. However, fueled by the relentless invasion of zebra and quagga mussels and their impacts of increased water clarity and available phosphorus, the *Cladophora* problem is back, and Great Lakes scientists are working harder than ever to find a solution.

Michigan Tech Research Institute (MTRI) and partners including NOAA GLERL, CIGLR, the USGS Great Lakes Science Center, Environment and Climate Change Canada, and SUNY Buffalo State College are updating a 2010 MTRI satellite map that provided the first reputable estimate of *Cladophora* and other submerged aquatic vegetation (SAV) throughout the Great Lakes Basin. "The 2010 *Cladophora* map was produced in cooperation with the EPA as part of the Great Lakes Restoration Initiative (GLRI) and has been used for a variety of applications including nutrient modeling, management decision-making, and predicting the outcome of possible new species invasions," says Robert Shuchman, PhD, MTRI Co-Director and Research Professor. "Now, our team is working to make meaningful updates to this map, both to capture the changes over the past decade and to take advantage of new advances in lake bottom mapping and satellite platforms that better estimate the volume of *Cladophora* produced by the Great Lakes every year."

In addition, the MTRI team — including co-principal investigator Michael Sayers, PhD, Amanda Grimm, Reid Sawtell, and Karl Bosse — are generating annual *Cladophora* maps for three "sentinel" locations in each Great Lake. These maps will provide resource managers further information on *Cladophora* growth hotspots and illustrate how the algae responds to different lake management tactics. "The Environmental Protection Agency (EPA) and MTRI established a new goal to map the spatial extent of SAV eight years after the initial assessment to ascertain change," says Shuchman. "In addition, MTRI refined the mapping algorithm so that benthic, or lake bottom, features could be routinely monitored.

"The newly generated satellite maps do not show a significant change in the proportion of the lake bottom colonized by *Cladophora* algae," Shuchman adds. "However, the maps do confirm increases in water clarity across the lower four Great Lakes." Due to the spread of invasive mussels in the mid-1990s in every Great Lake except Superior, which does not have enough calcium to support mussel shell formation, water clarity has allowed sunlight to penetrate deeper and promote growth of SAV such as *Cladophora*.

Clearer water allows algae to grow at greater depths while also allowing satellites to see through deeper water. Thus, both the percentage of the lake bottom that was mapped and the total area of *Cladophora* beds were higher in the updated 2018 map relative to 2010, by 22 percent and 15 percent, respectively. "We saw a lot of variation among the lakes," says Shuchman. "Water clarity increased the most for Lake Huron, where the area of visible lake bottom increased by 29 percent. As initially reported by Michigan Technological University researchers in 2017, Lakes Michigan and Huron are now even clearer than Lake Superior thanks to the mussels, plus the effects of reduced nutrient loads."



DEVELOPING A REALTIME

# Flood Forecast Modeling System

IN THE MOUNTAINOUS LAKE CHAMPLAIN BASIN

"The Lake Champlain flood forecast model works by dividing the lake into thousands of small sections, and solving a series of complex equations to predict how each section of the lake will respond to outside conditions."

— Dmitry Beletsky, PhD

**LAKE CHAMPLAIN** is an international body of water, spanning the border between the United States and Canada. It is located in a steep mountain valley, with the Adirondack Mountains of New York to the west and the Green Mountains of Vermont to the east. This mountainous setting, while picturesque, is an environment highly conducive to springtime flooding. As temperatures warm, rapid snowmelt from the mountains along with spring showers can lead to sudden rises in the lake's water levels.

Lake Champlain has experienced several such flood events over the past decade, causing destruction of property and infrastructure in the binational basin. The largest of these occurred in 2011, during which time the basin remained flooded for a period of more than two months. To better anticipate and prepare for flood events, researchers at CIGLR are working with NOAA GLERL and the International Joint Commission (IJC) to develop a state-of-the-art flood-forecasting model. The model is being developed in close collaboration with the NOAA National Weather Service (NWS), National Center for Atmospheric Research (NCAR), and emergency managers, who will use results from the Lake Champlain forecasting system to provide advance warning of floods to residents and other area stakeholders.

The model starts with a detailed 3D representation of Lake Champlain, and uses physics to predict how water will move through the lake in response to outside forces such as river inflows and local meteorology. "By feeding up-to-date weather and river forecasts into the model, we are able to predict how the lake will respond to future conditions, and produce 5-day forecasts of water levels, currents, and waves for the lake. These forecasts will improve our ability to plan and prepare for floods and, ultimately, reduce the severity of their impacts," said CIGLR Research Scientist Dmitry Beletsky, PhD.

The accuracy, or skill, of the Lake Champlain forecast model was tested by simulating events that have already occurred, such as the record flood of 2011. Results from these "hindcast" simulations showed strong agreement with historic measurements that were taken in the lake at the time of the floods. The proven ability of the model to realistically simulate past flood events gives the researchers a high degree of confidence that it is capable of forecasting future events.

The new flood forecasting model will be capable of resolving how flood conditions vary from location to location across Lake Champlain, which represents a major upgrade from existing tools used for forecasting in the basin. While we think of flooding as an influx of water, forces such as wind can significantly enhance the damage caused by flooding. Lake Champlain is only 14 miles wide from east to west, but is more than 100 miles long from north to south. When a strong wind blows over this long stretch of open water, it can "push" the water toward one end of the lake and also produce large waves on the surface. The ability to predict these wind-driven impacts in addition to high lake levels is critical for understanding not just when the lake may flood, but where impacts may be most severe.

"Results from the Lake Champlain forecasting system will be made available through an online tool that is updated in realtime," said CIGLR Hydrodynamic/Wave Modeler Daniel Titze, PhD. "This tool is currently in a research and testing phase, but will be made accessible to the public in the near future. Although the focus of the study is on flood forecasting, results from the model may benefit a variety of interests, such as boater safety, fishing, beachgoing, and scientific research. It is exciting and motivating to be working on research that has such a direct and immediate benefit to the public."

# Life's Building Blocks

## HOLD CLUES FOR GREAT LAKES SUSTAINABLE MANAGEMENT

"DNA is the code of life. Understanding how this code directs biological functions in harmful algae, under different environmental conditions, allows us to enhance the quality of drinkable and swimmable water."

— Subba Rao Chaganti, PhD

**'OMICS TECHNOLOGIES** are revolutionizing scientists' ability to monitor and understand the biological communities of aquatic environments. By using advanced methods to look at DNA, RNA, and proteins, 'omics research can help us understand ecological status, measure biodiversity, evaluate population distributions, estimate organism abundance, and determine food web function. These approaches can be faster, cheaper, and provide more information than traditional methods.

In early 2020, NOAA released a new 'Omics Strategy as one of four key science and technology focus areas to guide transformative advancements in the quality and timeliness of NOAA products and services. The goal of the NOAA 'Omics Strategy is to accelerate sustainable management of ocean and Great Lakes ecosystem resources for the benefit of people, communities, and economies.

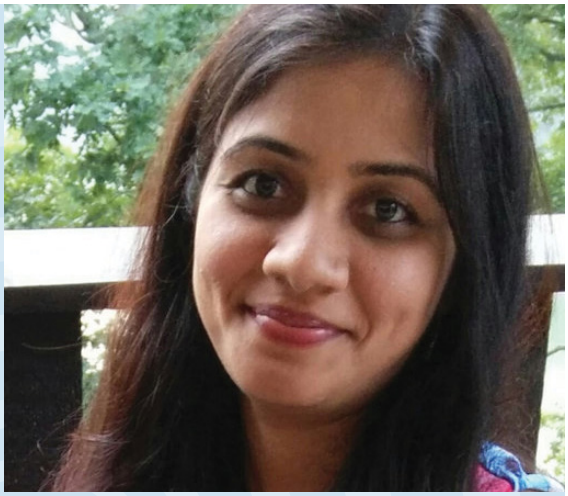
Assistant Research Scientist Subba Rao Chaganti, PhD, and colleagues at NOAA GLERL and the University of Michigan are leading NOAA's Great Lakes 'omics research program. Their research is designed to generate new insights on harmful algal blooms (HABs) and toxin production in Lake Erie.

"Our goal is to enhance the forecast of HABs by helping to predict changes in toxin concentrations and provide several days advance warning prior to high concentrations of toxins released in to the water," says Chaganti. "Developing the use of molecular tools for predicting short-term changes in HAB toxicity will complement the realtime data collection by NOAA GLERL and CIGLR. We are also working to advance our development and deployment of autonomous platforms that allow us to perform near-realtime HAB toxin analysis using 'omics technologies."

Early results show tremendous genetic diversity within the dominant bloom-forming cyanobacterium *Microcystis aeruginosa,* corresponding to variation in toxin production and interactions with invasive mussels. The toxin gene analysis has detected the presence of toxin-producing organisms even before toxins are produced, giving promise to the use of this technology for early warning systems. "The ability to differentiate toxin- vs. non-toxin-producing HABs and identify conditions that trigger toxin production will advance the development of HAB toxin forecasts," says Chaganti. "These data and research platforms will help guide water intake managers' decisions about water sampling frequency and will help us escape any potential repetition of instances like the 2014 Toledo water crisis."

In the second year of the project, the team is expanding their research to use environmental DNA (eDNA) to detect and monitor invasive species populations and their impacts on economically important fish species. They are investigating how invasive dreissenid mussel veligers, or planktonic larvae, affect the food web when they are used as a food source by planktonic predators, such as zooplankton and larval fish. "The results from our food web research will help us gain new insights into fish recruitment and fisheries sustainability in the post-mussel-invasion Great Lakes ecosystem," says Chaganti.

# Postdoc Fellows



## Flow Prediction at Field Scale:
### COMPARING MODEL ESTIMATES WITH OBSERVED CONDITIONS

Model predictions are widely used to evaluate and guide upstream management efforts to reduce nutrient runoff and improve downstream water quality. Watershed models are routinely calibrated only with downstream data, but seldom represent changes at smaller scales in upstream landscapes. Asmita Murumkar, PhD, and her advisor Jay Martin, PhD (Ohio State University) were recipients of a 2019 CIGLR Postdoctoral Fellowship award. They have teamed up with Margaret Kalcic, PhD (Ohio State University), Craig Stow, PhD (NOAA GLERL), Dustin Goering, PhD (NOAA National Weather Service), and Kevin King, PhD (USDA Agricultural Research Service) to evaluate the accuracy of hydrologic model upstream flow predictions in the western Lake Erie basin using observed edge-of-field data. "The results will guide recommendations and help improve model use as a management tool to reduce nutrient runoff from agricultural fields in the watershed," says Murumkar. "These agricultural landscapes in the Maumee River watershed have been identified as one of the leading sources of nutrient loadings that contribute to Lake Erie's harmful algal blooms."

## GENERATION AND TRANSPORT OF Aerosolized Toxins from HABs
### IN THE WESTERN LAKE ERIE BASIN

The intensity and frequency of harmful algal blooms (HABs) in western Lake Erie has increased in recent years, as have concerns about exposure to HAB toxins. While contact exposure to these toxins has been well studied, very little is known about exposure via airborne particles. 2019 CIGLR Postdoctoral Fellowship recipient Anahita Farahani, PhD, Allison Steiner, PhD, and Andrew Ault, PhD (University of Michigan) are using existing data from laboratory and field studies to model the potential range of aerosolized toxin exposure from HABs in the Great Lakes. "Our goal is to understand lake spray aerosol emission distribution, atmospheric lifetime, and surface deposition, and ultimately generate a range of exposure maps for aerosolized toxins that can impact regional human health," says Farahani.

EFFICIENT MAINTENANCE OF THE

## International Great Lakes Datum (IGLD)

USING NOVEL SATELLITE MEASUREMENTS

The International Great Lakes Datum (IGLD) is the reference system by which the Great Lakes and St. Lawrence River Basin water levels are measured. An accurate IGLD improves flood control, hydraulic energy operations, water resources management, navigation, and the Great Lakes Operational Forecasting System (GLOFS). Because of movements in the Earth's crust, the IGLD requires updating every 25 – 30 years. With their 2019 CIGLR Postdoctoral Fellowship award, Xiaobin Cai, PhD, and C.K. Shum, PhD (Ohio State University) with colleagues at NOAA National Geodetic Survey are demonstrating the feasibility of using novel lakewide water level measurements from satellites for efficient maintenance and establishment of a new 2020 IGLD and a potentially more accurate GLOFS. "Lake level corrections including hydraulic and land subsidence and uplift are vital to the IGLD maintenance; and, we've revealed the novel use of satellite altimetry as a means to efficiently measure lakewide water levels and potentially update or enhance the IGLD," says Cai.

## Improving Lake-Effect Snow Forecasts

David Wright, PhD, and his advisor Christiane Jablonowski, PhD (University of Michigan), were recipients of a 2019 CIGLR Postdoctoral Fellowship award. They are working with CIGLR Assistant Research Scientist Ayumi Fujisaki-Manome, PhD, along with NOAA GLERL scientists Philip Chu, PhD, Eric Anderson, PhD, and Brent Lofgren, PhD, to bring model simulations of lake-effect snowfall location and intensity closer to reality. They are creating a modeling framework that incorporates changing lake conditions over time, reflecting actual lake behavior. These improved simulations will help local weather forecasters better predict and communicate the potential impacts from lake-effect snowfall events in the Great Lakes region.

"Weather prediction models routinely struggle to predict lake-effect snowfall events for a few reasons," says Wright. "Snowfall bands can be so narrow that the models struggle to fully depict the exact placement and intensity of the bands."

— David Wright, PhD

# Graduate Research Fellows

## DO ZOOPLANKTON FUEL
## Harmful Algal Blooms
## IN LAKE ERIE?

Lyndsie Collis is a PhD student at Ohio State University and a 2019 CIGLR Graduate Research Fellow working with her advisor James Hood, PhD and colleagues Hank Vanderploeg, PhD (NOAA GLERL), and Hunter Carrick, PhD (Central Michigan University) to understand the drivers of harmful algal blooms (HABs) in Lake Erie. Nitrogen and phosphorus are two nutrients that fuel HAB growth. Although microscopic in size, zooplankton may be a potentially important source of nitrogen and phosphorus as they release these nutrients through egestion and excretion. In this study, the research team is focusing on zooplankton nutrient excretion through their carapace, or body cavity, into the water column. Collis's measurements of zooplankton-mediated nutrient release will help quantify the sources of nutrients in Lake Erie and better understand HAB dynamics for future mitigation efforts.

"The nutrients that fuel harmful algal blooms in Lake Erie likely come from many sources, including mussels, sediment release, and zooplankton. Our work is one piece of the puzzle to better understand the complex nutrient dynamics that control the timing, toxicity, and duration of harmful algal blooms."

— Lyndsie Collis

"Our goal is to better understand the movement of contaminant river plumes in Lake Michigan."

— Chelsea Weiskerger

# The Not-So-Calm After the Storm:

## MODELING STORM-ASSOCIATED RIVER PLUMES IN SOUTHERN LAKE MICHIGAN

Michigan State University doctoral student Chelsea Weiskerger and her advisor Phanikumar Mantha, PhD, are recipients of a 2019 CIGLR Graduate Research Fellowship. They are using numerical models to simulate the movement of contaminant plumes from rivers into southern Lake Michigan following heavy rainstorms. Their results show that the Lake Michigan shoreline is impacted for several days after a contaminant plume is released. When plumes are nearshore they tend to move with the wind, but over time the plumes start moving with the currents and disperse through the lake. Weiskerger and Mantha's work will improve decision making and prediction in areas of Lake Michigan impacted by contaminant plumes.

## WHAT HAPPENS TO
# Mussel Poop?

Invasive quagga mussels consume a large fraction of Lake Michigan's plankton, and a significant portion of what they consume is discharged as feces and pseudofeces. The long-term fate of these biodeposits has important implications for the nutrient and plankton dynamics in Lake Michigan. Rae-Ann MacLellan-Hurd, a 2019 CIGLR Graduate Research Fellow advised by Harvey Bootsma, PhD (University of Wisconsin-Milwaukee), and Hank Vanderploeg, PhD (NOAA GLERL), have found that bacteria on the lake bottom are important nutrient recyclers of Lake Michigan biodeposits. Their research showed that bacteria serve as a phosphorus sink by using mussel biodeposit nutrients for growth over short time scales. Over longer time scales, these bacteria act as a phosphorus source as they are recycled through the water column. These results could point to a future increase in Lake Michigan water column phosphorus concentrations as the quagga mussel populations stabilize.

"This fellowship exposed me to regional Great Lakes science and guided my graduate research to address a larger ecosystem perspective."

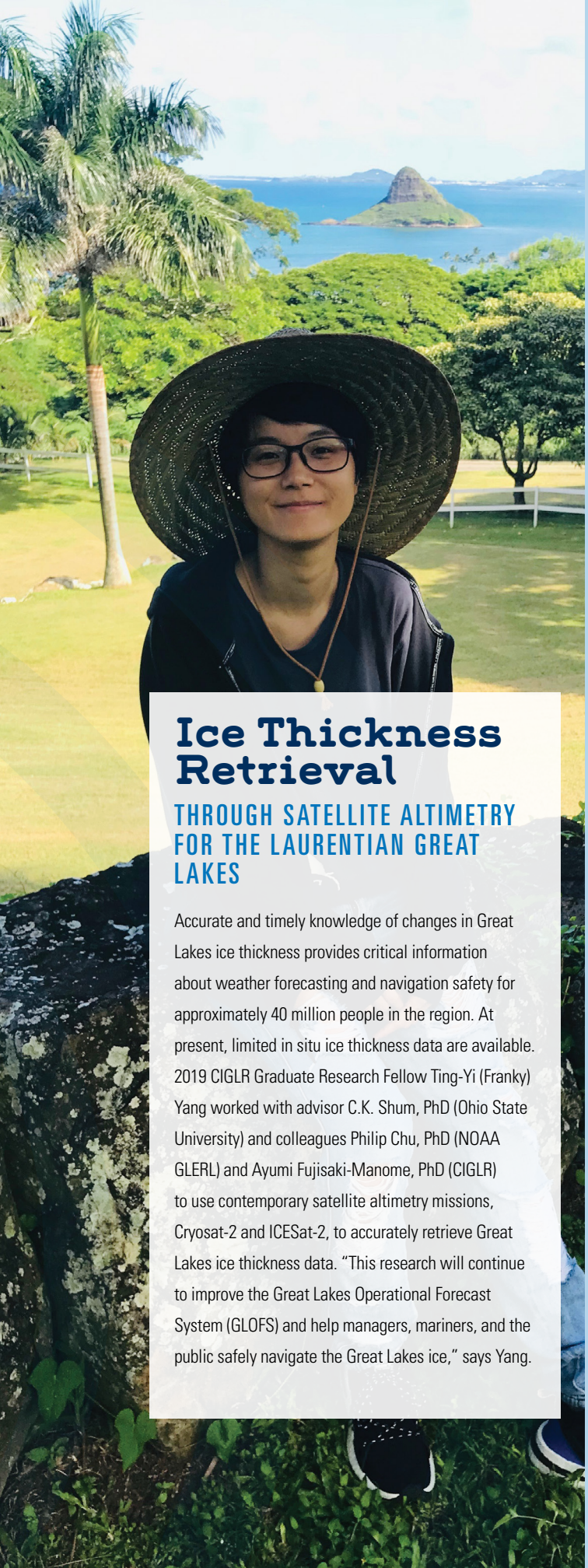
*— Rae-Ann MacLellan-Hurd*

# Health Checkup
## FOR WETLAND FISH

2019 CIGLR Graduate Research Fellow Renee Renauer and Peter Dijkstra, PhD (Central Michigan University) with colleagues from the CMU-led Coastal Wetland Monitoring Program worked to extensively monitor fish health throughout Great Lakes wetlands. They examined how wetland productivity influences oxidative stress levels, a bio-indicator of health, in invasive (round goby) and native (brown bullhead catfish, yellow perch) fish species. Highly productive habitats can experience increases in dissolved oxygen and pH fluctuation, which could make them resistant to round goby invasion. The team's observations indicate that wetland productivity did not affect fish oxidative stress levels; however, round gobies had significantly higher total antioxidants compared to brown bullhead and yellow perch, reaffirming their hardiness and intense competition for resources. Coastal wetland managers can utilize this information to prioritize sites for native species protection or formulate strategies to mitigate the impact of invasive round gobies.

"The collaboration, support, and resources from CIGLR and its consortium was invaluable, creating an amazing fieldwork and research experience."

*— Renee Renauer*



# Ice Thickness Retrieval

## THROUGH SATELLITE ALTIMETRY FOR THE LAURENTIAN GREAT LAKES

Accurate and timely knowledge of changes in Great Lakes ice thickness provides critical information about weather forecasting and navigation safety for approximately 40 million people in the region. At present, limited in situ ice thickness data are available. 2019 CIGLR Graduate Research Fellow Ting-Yi (Franky) Yang worked with advisor C.K. Shum, PhD (Ohio State University) and colleagues Philip Chu, PhD (NOAA GLERL) and Ayumi Fujisaki-Manome, PhD (CIGLR) to use contemporary satellite altimetry missions, Cryosat-2 and ICESat-2, to accurately retrieve Great Lakes ice thickness data. "This research will continue to improve the Great Lakes Operational Forecast System (GLOFS) and help managers, mariners, and the public safely navigate the Great Lakes ice," says Yang.


## NOAA GREAT LAKES COASTWATCH HOSTS INAUGURAL SATELLITE REMOTE SENSING COURSE

The inaugural NOAA Great Lakes CoastWatch Satellite Remote Sensing Data Training Course was held November 5th–7th, 2019 at NOAA's Great Lakes Environmental Laboratory (GLERL) in Ann Arbor, Michigan. There were 26 participants including faculty and graduate students from six universities, NOAA federal scientists and contractors, NOAA Cooperative Institute researchers, and scientists from private industry and local government. "Overall, the first CoastWatch Great Lakes training class was very successful. Through unique exercises, lectures, and hands-on practice, trainees learned how to search and utilize CoastWatch satellite data related to their research," says Songzhi Liu, CIGLR Programmer/Analyst and research assistant for Great Lakes CoastWatch.

# 2019 Great Lakes Summer Fellows

In partnership with NOAA 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 2019 Great Lakes Summer Fellows comprised:

**Clay Carufel**

*University of Minnesota Duluth*

Clay was mentored by Drs. Ayumi Fujisaki-Manome (CIGLR), Jia Wang (NOAA GLERL), and Philip Chu (NOAA GLERL). He analyzed simulation results from sea ice, wave, and storm surge models from the western Alaska coastal region to provide storm surge forecast guidance.

**Lauren Marshall**

*University of Toledo*

Lauren worked with Lacey Mason (NOAA GLERL), Russ Miller (CIGLR), and Dr. Philip Chu (NOAA GLERL) to process environmental data collected by autonomous underwater vehicles (AUVs) in the Great Lakes. She helped to visualize the data so that it can be used to engage the public and stakeholders.

**Andrew Oppliger**

*Ohio State University*

Andrew worked with NOAA GLERL scientists Drs. Ed Rutherford, Doran Mason, and Hank Vanderploeg to study how density, availability, and energetic content of *Dreissena* mussel veligers affect diet and growth of larval fish (yellow perch, alewife).

**Holly Roth**

*University of Colorado*

Holly was mentored by Dr. Dmitry Beletsky (CIGLR). She investigated the accuracy of over-lake meteorological forcing and its potential impact on surface heat balance and lake temperature predictions.

# CONGRATULATIONS TO THE 2020 GREAT LAKES SUMMER FELLOWS COHORT

**Chanse Ford**
*Michigan State University*

**Brenna Friday**
*Wayne State University*

**Kaylin Jones**
*University of Michigan*

**Lorrayne Miralha**
*Arizona State University*

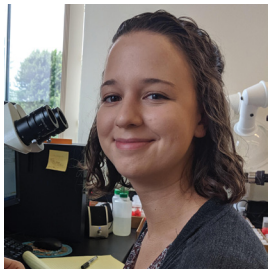
**Andrew Reiser**
*University of Illinois at Urbana-Champaign*

**Kaitlyn Rivers**
*Oberlin College*

**Anisha Shrestha**
*Grand Valley State University*

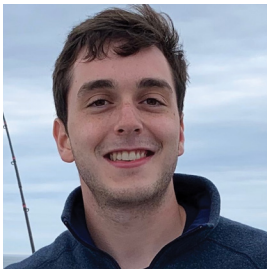
**Kaelan Weiss**
*University of Minnesota Duluth*

**Jacob Rudolph**
*North Carolina State University*
Jacob worked with Drs. Qianqian Liu (CIGLR), Eric Anderson (NOAA GLERL), and Mark Rowe (NOAA GLERL) on a project that evaluated the accuracy of the 2017 and 2018 western Lake Erie harmful algal bloom (HAB) forecasts, and investigated how using different satellites affects the accuracy of the western Lake Erie HAB tracker.



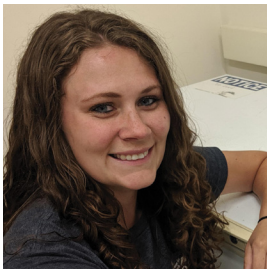
**Anna Schmidt**
*University of Wisconsin – Madison*
Anna was mentored by Drs. Doran Mason (NOAA GLERL), Ed Rutherford (NOAA GLERL), and Lars Rudstam (Cornell University). She studied *Mysis* biomass and vertical distribution in Lake Michigan.

**Steven Smit**
*University of Michigan*
Steven worked with Drs. Charlyn Partridge (Grand Valley State University AWRI) and Ashley Elgin (NOAA GLERL) to investigate invasive round goby reproductive strategies across a range of habitat conditions.



**Nolan Smith**
*College of William and Mary*
Nolan worked with Drs. Jill Crossman (University of Windsor), Aaron Fisk (University of Windsor), Mark Rowe (NOAA GLERL), and Tom Johengen (CIGLR, Michigan Sea Grant). His project evaluated the variation of environmental data collected by the Realtime Aquatic Ecosystem Observation Network (RAEON) in western Lake Erie.

**Matthew Trumper**
*University of Minnesota Twin Cities*
Matthew was mentored by NOAA GLERL scientists James Kessler and Dr. Jia Wang to build statistical models that predict Great Lakes ice cover and hypoxia in Lake Erie.



**Jessica Zehnpfennig**
*Central Michigan University*
Jessica worked with Drs. Casey Godwin (CIGLR) and Deric Learman (Central Michigan University) to study the fate of the heavy metal manganese during hypoxic events in Lake Erie.

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

# Summits, Rapid Response & ECO Funding

**Rapid Response to Flooding:**

## Protecting Great Lakes Coasts during High Water

With a CIGLR Rapid Fund award, University of Windsor investigators Aaron Fisk, PhD, and Trevor Pitcher, PhD, deployed four realtime water level sensors along the Detroit River to provide decision support information to city officials in LaSalle, Ontario. In July 2019, strong winds pushed already high Detroit River water above the stormwater system in Lasalle, resulting in significant flooding, street closures, and infrastructure threats. The flood occurred without warning, as the community and region did not have the technology to monitor changes in wind speed, wave height, or water levels along the Detroit River. The University of Windsor team acted quickly to install water level sensors, in consultation with city officials who provided guidance on sensor placement. They established a website that provided data at intervals of less than five minutes, for use by city officials and researchers. This project demonstrated the value of realtime monitors to LaSalle city administrators, along with the need for additional sensors to provide the data required for developing flood prediction models for predicting floods.

Left to right: Researchers Trevor Pitcher, Katelynn Johnson, and Aaron Fisk prepare high-tech buoys to deploy in the Detroit River channel between Canada's LaSalle and Fighting Island. Photo: University of Windsor.

**ECO Funding:**

## Ecosystem Health Reporting

A CIGLR ECO Award supported a University of Windsor Faculty of Law graduate student to participate in the development and reporting of ecosystem health indicators for the Detroit River and western basin of Lake Erie. Kevin Berk worked with subject-matter experts on several indicators, including: Human Population Growth and Distribution in the Windsor Census Metropolitan Area; Indigenous Treaty Obligations in the Western Lake Erie-Detroit River Ecosystem; and Climate Change Policy in Canada. The indicator reports were part of the 2019 State of the Strait Conference. Berk also participated on the conference steering committee and attended the conference as part of his CIGLR ECO activities.

State of the Strait Conference indicator development team. Left to right: Michael Siu (University of Windsor), Patricia Galvão Ferreira (University of Windsor), Gwen Gell (University of Michigan), Mike McKay (University of Windsor), Antonia Hristova (University of Windsor), Collin Knauss (University of Michigan), Kevin Berk (University of Windsor), and John Hartig (University of Windsor).

**ECO Funding:**

## Environmental Journalism

A CIGLR ECO Award provided support for a graduate student at Michigan State University's Knight Center for Environmental Journalism to tell more stories about the work done by CIGLR and our partners. Andrew Blok wrote 12 news articles in the Great Lakes Echo on a wide range of topics including threats to research budgets, regional impacts of climate change, invasive species control, and paddleboarders raising research dollars by crossing Lake Erie.

**CIGLR Summit:**

## Winter Limnology on the Great Lakes

More than 25 academic institutions and government research agencies from the United States and Canada gathered at the University of Michigan to better understand what happens in the Great Lakes during winter. Evidence from the Great Lakes and elsewhere shows that winter is not a "dead season," and that events and conditions in winter affect the rest of the annual cycle in aquatic systems. Yet winter has remained grossly understudied in seasonally frozen lakes, including the Great Lakes. The extent of the winter knowledge gap and the rapid change in winter conditions in recent years make it vital to improve our collective understanding of winter processes through research. Led by Ted Ozersky, PhD, of the University of Minnesota Duluth, this summit was the first multi-institutional meeting to establish research priorities specifically related to winter limnology in the Great Lakes. A publication summarizing the summit's results and recommendations is in preparation.

Left to right: Steering committee members Hank Vanderploeg (NOAA GLERL), Ashley Elgin (NOAA GLERL), Ted Ozersky (University of Minnesota Duluth), Andrew Bramburger (University of Minnesota Duluth), and Jia Wang (NOAA GLERL).

# 2020 Winners

### CIGLR AWARDS $433,000 IN 2020 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 region. The recipients of the 2020 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!

### POSTDOCTORAL FELLOWSHIP AWARDS

- **Gregory Dick, PhD, University of Michigan**
- **Carol Miller, PhD, Wayne State University:** Biodiversity and Ecosystem Services of Water Mites from the Laurentian Great Lakes
- **Donald Uzarski, PhD, Central Michigan University:** Assessing Influence of Extreme Water Levels on Coastal Wetland Extent and Function Across the Laurentian Great Lakes
- **Patrick Doran, PhD, The Nature Conservancy**
- **Bryan Stubbs, Cleveland Water Alliance**

### GRADUATE RESEARCH FELLOWSHIP AWARDS

- **Richard Norton, PhD, University of Michigan:** An Exploration of Quantification Methods Involving Measures of Fiscal Impact, Social Equity, and Environmental Health
- **Ted Ozersky, PhD, University of Minnesota Duluth**
- **C.K. Shum, PhD, Ohio State University:** Lake Mass Changes Using Satellite Altimetry and Gravimetry for Lake Forecasting Studies
- **Scott Steinschneider, PhD, Cornell University:** The Potential of Subseasonal-to-Seasonal Forecasts to Improve Multi-Objective Water Level Management on Lake Ontario
- **Christopher Weisener, PhD, University of Windsor**

### SUMMIT AND WORKING GROUP (SWG) AWARDS

- **Michael Murray, PhD, National Wildlife Federation:** State of the Great Lakes Reporting and the *Prescription* White Paper
- **Alan Steinman, PhD, Grand Valley State University:** Addressing Groundwater Challenges in Michigan as a Template for the Great Lakes
- **Volodymyr Tarabara, PhD, Michigan State University:** Oil Spills Under Ice – Challenges and Solutions

### RAPID AWARDS

- **John Lenters, PhD, Michigan Technological University:** Wave Buoys to Protect Public Safety in Lake Superior During COVID-19

# Staff & Governance

## ADMINISTRATION

Thomas Johengen
*Acting Director*
**Associate Director*

*Bradley Cardinale
*Director*

Mary Ogdahl
*Program Manager*

Ayumi Fujisaki-Manome
*Modeling & Forecasting Theme Lead*

Casey Godwin
*Ecosystem Dynamics Theme Lead*

Russ Miller
*Observing Systems Theme Lead*

Devin Gill
*Stakeholder Engagement Specialist*

Aubrey Lashaway
*Communications Specialist*

Michele Wensman
*Outreach Specialist*

## RESEARCH INSTITUTE

### *Research Scientists*

Dmitry Beletsky
*Research Scientist*

S. Rao Chaganti
*Assistant Research Scientist*

Michael Fraker
*Assistant Research Scientist*

Ayumi Fujisaki-Manome
*Assistant Research Scientist*

Casey Godwin
*Assistant Research Scientist*

Thomas Johengen
*Research Scientist*

### *Research Staff*

Peter Alsip
*Ecological Modeling Data Analyst*

Hanna Anderson
*Research Assistant*

*Mikayla Baer
*Graduate Student Research Assistant*

Raisa Beletsky
*Research Associate*

*Nicholas Boucher
*Research Assistant*

*Sarah Brannon
*Research Assistant*

*Emily Brines
*Research Assistant*

Ashley Burtner
*Research Lab Specialist Associate*

Andrew Camilleri
*Benthic Ecology Research Technician*

Glenn Carter
*Benthic Ecology Research Technician*

Paul Den Uyl
*Aquatic Ecology Research Technician*

*Katherine Ferran
*Research Assistant*

Lindsay Fitzpatrick
*Hydrological Modeler*

*Deanna Fyffe
*Aquatic Ecology Research Technician*

Nathan Hawley
*Research Assistant*

Hayden Henderson
*Observing Systems Engineer*

Haoguo Hu
*Ice Modeler*

Holly Kelchner
*Aquatic Ecology Research Analyst*

Clayton Kingdon
*Modeling Data Analyst*

Christine Kitchens
*Aquatic Ecology Research Technician*

Katherine Laramie
*Graduate Student Research Assistant*

Songzhi Liu
*General Programmer/ Analyst Lead*

*El Lower
*GLANSIS Research Associate*

Kelly McCabe
*Biogeochemistry Laboratory Analyst*

*Michael McCormick
*Research Assistant*

*Lauren Marshall
*Research Assistant*

Russ Miller
*Mechanical Technician Intermediate*

Heidi Purcell
*Research Area Specialist Intermediate*

*Sara Prendergast
*Research Assistant*

*Reem Raba
*Hydrological Modeler*

*Charles Ramsey
*Research Assistant*

Anna Schmidt
*Food Web Laboratory Analyst*

Ellie Simon
*Research Assistant*

Joeseph Smith
*General Programmer/ Analyst Intermediate*

*Dack Stuart
*Research Lab Specialist Associate*

Daniel Titze
*Hydrodynamic/Wave Modeler*

David Wells
*Research Technician Senior*

Michele Wensman
*Benthic Ecology Research Technician*

### *Postdoctoral Research Fellows*

Tian Guo

Yi Hong

*Yao Hu

Yuchun (Yoyo) Lin

*Qianqian Liu

Timothy Maguire

Nathaniel Marshall

*Freya Rowland

## EXECUTIVE BOARD

Thomas Johengen
*Acting Director, CIGLR, University of Michigan*
(Ex-Officio)

Carl Gouldman
*Director, U.S. IOOS Office, NOAA National Ocean Service*

Deborah Lee
*Director, NOAA GLERL*
(Ex-Officio)

Brad Orr
*Associate VP for Research, Natural Sciences and Engineering, University of Michigan*

Jonathan Overpeck
*Samuel A. Graham Dean, School for Environment and Sustainability, University of Michigan*

Steven Thur
*Director, National Centers for Coastal Ocean Science, NOAA National Ocean Service*

## COUNCIL OF FELLOWS

Thomas Johengen
*Acting Director, CIGLR, University of Michigan*

Andrew Barnard
*Director, Great Lakes Research Center, Michigan Technological University*

John Bratton
*Senior Scientist, LimnoTech*

Philip Chu
*Physical Scientist, NOAA GLERL*

Patrick Doran
*Associate State Director for Michigan, The Nature Conservancy*

Aaron Fisk
*Professor, Great Lakes Institute for Environmental Research, University of Windsor*

Steve Fondriest
*President, Fondriest Environmental*

Casey Godwin
*Assistant Research Scientist, CIGLR, University of Michigan*

Donna Kashian
*Associate Professor, Wayne State University*

J. Val Klump
*Director, Great Lakes Water Institute, University of Wisconsin - Milwaukee*

Maria Lemos
*Professor, School for Environment and Sustainability, University of Michigan*

Phanikumar Mantha
*Professor/Associate Chair for Graduate Studies, Michigan State University*

Dennis McCauley
*President and Principal Research Scientist, Great Lakes Environmental Center*

Ashley Moerke
*Director, Center for Freshwater Research and Education, Lake Superior State University*

Mike Murray
*Staff Scientist, National Wildlife Federation Great Lakes Regional Center*

Steve Ruberg
*Group Leader, Marine Instrumentation Lab, NOAA GLERL*

Lars Rudstam
*Director, Shackelton Point Field Station, Cornell University*

Alan Steinman
*Director, Annis Water Resources Institute, Grand Valley State University*

Robert W. Sterner
*Director, Large Lakes Observatory, University of Minnesota Duluth*

Bryan Stubbs
*Executive Director & President, Cleveland Water Alliance*

Donald Uzarski
*Director, Biological Station and Institute for Great Lakes Research, Central Michigan University*

Hank Vanderploeg
*Research Ecologist, NOAA GLERL*

Chris Winslow
*Director, Stone Laboratory, Ohio Sea Grant, Ohio State University*

Tom Zimnicki
*Agriculture Policy Director, Michigan Environmental Council*

*Indicates research institute personnel transitions

## Stand Up for Great Lakes: Paddleboarders raise money for Great Lakes research

On June 18, 2019 three men from the group Stand Up for Great Lakes successfully paddleboarded across Lake Erie, traversing international waters and rough waves all in an effort to raise awareness for Great Lakes environmental issues. The nearly 80-mile, 24-hour trip began at Belle Isle State Park in Michigan, home of the Dossin Great Lakes Museum, and ended at Catawba Island State Park in Ohio. Joe Lorenz, Kwin Morris, and Jeff Guy have now crossed Lakes Superior, Huron, Michigan, and Erie, with Lake Ontario on the horizon for 2021. As each lake paddle is completed, Stand Up for Great Lakes uses the publicity surrounding their trips to raise and donate money to a nonprofit organization that is making a difference in protecting the Great Lakes. The men dedicated the $17,000 in proceeds from their Lake Erie crossing fundraiser to CIGLR, which, Joe Lorenz says "is doing spectacular work with algal bloom research and efforts to safeguard the Great Lakes ecosystem. They are experts in Great Lakes issues, and we are thrilled to have them on our team." CIGLR is using the donated funds to support student fellowships that train the next generation of Great Lakes scientists.

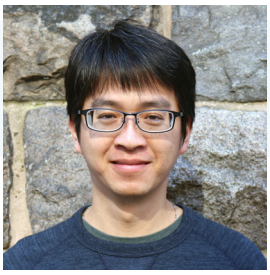
"Crossing Lake Erie" documentary.

# CIGLR welcomes new members to our team!

**Andrew Camilleri** joined CIGLR as a Benthic Ecologist to work with Drs. Ashley Elgin (NOAA GLERL) and Casey Godwin (CIGLR) on research to understand the interactive effects of harmful algal blooms (HABs), hypoxia, and invasive mussels in the Great Lakes.

**Hayden Henderson** joined CIGLR as an Observing Systems Engineer working with Mechanical Technician Russ Miller (CIGLR), supporting both field and laboratory efforts related to the Synthesis, Observations and Response System (SOAR) project.

**Holly Kelchner** joined CIGLR as an Aquatic Ecology Research Analyst working with Drs. Casey Godwin (CIGLR) and Reagan Errara (NOAA GLERL) to execute the western Lake Erie harmful algal bloom (HAB) monitoring cruises and laboratory toxin analysis efforts.



**Yuchun Lin**, PhD, joined CIGLR as a Postdoctoral Research Fellow working with Assistant Research Scientist Dr. Ayumi Fujisaki-Manome. Their research uses numerical modeling and data analyses to understand Great Lakes ice hotspots, ice cover predictions, and wave-ice interactions.

**Michael Fraker**, PhD, joined CIGLR as an Assistant Research Scientist. His research develops predictive models that link biological to physical processes in aquatic ecosystems. He is currently researching the interactions between piscivores, larval fish, and zooplankton in Lake Erie. Fraker uses a variety of approaches (observational, experimental, mathematical), to understand ecological systems.

**Yi Hong**, PhD, is a CIGLR Postdoctoral Research Fellow collaborating with NOAA GLERL and the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, to improve NOAA National Water Model predictions for the Great Lakes basin.

**Clayton Kingdon** joined CIGLR as a Modeling Data Analyst working with Dr. Michael Fraker (CIGLR), Dr. Mark Rowe (NOAA GLERL), and Peter Alsip (CIGLR) on the Coordinated Science Monitoring Initiative where he uses programming tools to analyze data and evaluate model performance.

**Timothy Maguire**, PhD, is a Postdoctoral Research Fellow working with Drs. Casey Godwin (CIGLR) and Craig Stow (NOAA GLERL). His research uses a variety of frequentist, Bayesian, GIS, and artificial intelligence/machine learning techniques to develop numerical water quality models in the Great Lakes.

**Nathan Marshall**, PhD, is a Postdoctoral Research Fellow working with Drs. Rao Chaganti (CIGLR) and Hank Vanderploeg (NOAA GLERL) to utilize environmental DNA (eDNA) to assess fish and zooplankton community composition across the Great Lakes.

**Kelly McCabe** joined CIGLR as a Biogeochemistry Laboratory Analyst working with Dr. Casey Godwin (CIGLR) to better understand Great Lakes aquatic biogeochemistry related to harmful algal blooms, hypoxia, and invasive species.

**Anna Schmidt** is a Food Web Laboratory Analyst working with Dr. Michael Fraker (CIGLR) to organize and execute field sampling and laboratory analyses related to zooplankton, larval fish, and *Mysis* ecology in the Great Lakes.

# In the Media

### ASIAN CARP

- **Study: Asian carp could find plenty of food in Lake Michigan**, Associated Press
- **Favorite food not on the menu? No problem for Asian carp – they eat almost anything**, Great Lakes Echo
- **Lake Michigan's 'Plankton Desert' no problem for Bighead carp**, Peninsula Pulse
- **A mussel poop diet could fuel invasive carp's spread across Lake Michigan**, Science News
- **New study finds Asian carp could survive throughout Lake Michigan**, Wisconsin Public Radio
- **Asian carp could be a lot worse to the Great Lakes that previously thought, UofM study shows**, Fox 2 Detroit
- **Asian carp have never breached a body of freshwater the size of Lake Michigan. Here's the bizarre way they could survive and thrive in the world's fifth largest lake**, Chicago Tribune
- **U-M study: Asian carp capable of surviving in much larger areas of Lake Michigan than previously thought**, Michigan News
- **Study: Asian Carp could expand across greater area of Lake Michigan than previously thought**, Michigan Radio
- **Study: Asian carp could thrive in Lake Michigan, despite earlier doubts**, Bridge

Read our stories.

### HARMFUL ALGAL BLOOMS

- **Fighting polarization in algae bloom controversy**, Great Lakes Echo
- **Editorial: Protecting the Great Lakes - from parched places far away and algae blooms within**, Chicago Tribune
- **Large lakes worldwide share many of the same threats**, Great Lakes Echo
- **Algae researchers to fan out across Lake Erie to collect water samples Aug. 7**, UT News

### WATER LEVELS

- **No lawsuit gainst the IJC can stop high Lake Ontario water levels**, The Buffalo News

### INVASIVE SPECIES

- **A recent history of Great Lakes nonindigenous species**, Michigan State University Extension
- **GLANSIS risk explorer evaluates the potential for Great Lakes biological invasions**, Michigan State University Extension
- **Great Lakes Water Life database documents biodiversity of Great Lakes native species**, Michigan State University Extension
- **Stakeholder engagement inspires a new design for GLANSIS database**, Michigan State University Extension

### OTHER STORIES

- **Linking Land and Lakes: Protecting Great Lakes' coastal wetlands**, PBS
- **Crossing Lake Erie**, 9 and 10 News
- **Herpetologist highlight**, Herpetologists League

# Peer-Reviewed Publications


Alsip, P.J., H. Zhang, M.D. Rowe, D.M. Mason, E.S. Rutherford, C.M. Riseng, and Z. Su. 2019. Lake Michigan's suitability for bigheaded carp: The importance of diet flexibility and subsurface habitat. *Freshwater Biology.* 64(11):1921-1939. (DOI:10.1111/fwb.13382).

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.* 45(3):480-489. (DOI:10.1016/j.jglr.2019.02.003).

Chen, D., Q. Liu, J. Xu, and K. Wang. 2019. Model-based evaluation of hydroelectric dam's impact on the seasonal variabilities of POC in the coastal ocean: A case study of Three Gorges Project. *Journal of Marine Science and Engineering.* 7(9):320. (DOI:10.3390/jmse7090320).

Chen, X. and F. Zhang. 2019. Development of a convection-permitting air-sea-coupled ensemble data assimilation system for tropical cyclone prediction. *Journal of Advances in Modeling Earth Systems.* 11(11):3474-3496. (DOI:11:3474-3496).

Davenport, E.J., M.J. Neudeck, P.G. Matson, G.S. Bullerjahn, T.W. Davis, S.W. Wilhelm, M.K. Denny, L.E. Krausfeldt, J.M.A. Stough, K.A. Meyer, G.J. Dick, T.H. Johengen, E. Lindquist, S.G. Tringe, and R.M. McKay. 2019. Metatranscriptomic analyses of diel metabolic functions during a *Microcystis* bloom in western Lake Erie (United States). *Frontiers in Microbiology.* 10(2081). (DOI:10.3389/fmicb.2019.02081).

Eppehimer, D.E., D.B. Bunnell, P.M. Armenio, D.M. Warner, L.A. Eaton, D.J. Wells, and E.S. Rutherford. 2019. Densities, diets, and growth rates of larval alewife and bloater in a changing Lake Michigan ecosystem. *Transactions of the American Fisheries Society.* 148(4):755-770. (DOI:10.1002/tafs.10171).

Fang, S., D.D. Giudice, Scavia, C.E. Binding, T.B. Bridgeman, J.D. Chaffin, M.A. Evans, J. Guinness, T.H. Johengen, and D.R. Obenour. 2019. A space-time geostatistical model for probabilistic estimation of harmful algal bloom biomass and areal extent. *Science of Total Environment.* 695. (DOI:10.1016/j.scitotenv.2019.133776).

Fujisaki-Manome, A., D.G. Gill, T. Guo, E.J. Anderson, and M.C. Lemos. 2019. Knowledge co-production in a research-to-operation (R2O) process for development of a Great Lakes ice forecast: Reflection from a stakeholder engagement workshop. *Journal of Operational Oceanography.* (DOI:10.1002/essoar.10501135.1).

Gronewold, A.D., J.P. Smith, L.K. Read, and J.L. Crooks. 2020. Reconciling the water balance of large lake systems. *Advances in Water Resources.* 137. (DOI:10.1016/j.advwatres.2020.103505).

Guo, T., D. Gill, T.H. Johengen, and B.L. Cardinale. 2019. What determines the public's support for water quality regulations to mitigate agricultural runoff? *Environmental Science & Policy.* 101:323-330. (DOI:10.1016/j.envsci.2019.09.008).

Guo, T., E.C. Nisbet and J.F. Martin. 2019. Identifying mechanisms of environmental decision-making: How ideology and geographic proximity influence public support for managing agricultural runoff to curb harmful algal blooms. *Journal of Environmental Management.* 241:264-272. (DOI:1016/j.jenvman.2019.04.021).

Hamlin, Q.F., A.D. Kendall, S.L. Martin, H.D. Whitenack, J.A. Roush, B.A. Hannah, and D.W. Hyndman. 2020. Quantifying landscape nutrient inputs with spatially explicit nutrient source estimate maps. *Journal of Geophysical Research: Biogeosciences.* 125(2). (DOI:10.1029/2019JG005134).

Jackrel, S.L., J.D. White, J.T. Evans, K. Buffin, K. Hayden, O. Sarnelle, and V.J. Denef. 2019. Genome evolution and host-microbiome shifts correspond with intraspecific niche divergence within harmful algal bloom-forming *Microcystis* aeruginosa. *Molecular Ecology.* 28(17):3994-4011. (DOI:10.1111/mec.15198).

Lekki, J., G. Leshkevich, S.A. Ruberg, D. Stuart, and A. Vander Woude. 2019. Airborne hyperspectral and satellite imaging of harmful algal blooms in the Great Lakes region: Successes in sensing algal blooms. *Journal of Great Lakes Research.* 45(3):405-412. (DOI:10.1016/j.jglr.2019.03.016).

Liu, Q., M.D. Rowe, E.J. Anderson, C.A. Stow, R.P. Stumpf, and T.H. Johengen. 2020. Probabilistic forecast of microcystin toxin using satellite remote sensing, *in situ* observations and numerical modeling. *Environmental Modelling & Software.* 128. (DOI:10.1016/j.envsoft.2020.104705).

Manning, N.F., Y.C. Wang, C.M. Long, I. Bertani, M.J. Sayers, K.R. Bosse, R.A. Shuchman, and D. Scavia. 2019. Extending the forecast model: Predicting Western Lake Erie harmful algal blooms at multiple spatial scales. *Journal of Great Lakes Research.* 45(3):587-595. (DOI:10.1016/j.jglr.2019.03.004).

Moore, T.S., J.H. Churnside, J.M. Sullivan, M.S. Twardowski, A.R. Nayak, M.N. McFarland, N.D. Stockley, R.W. Gould, T.H. Johengen, and S.A. Ruberg. 2019. Vertical distributions of blooming cyanobacteria populations in a freshwater lake from LIDAR observations. *Remote Sensing of the Environment.* 225:347-367. (DOI:10.1016/j.rse.2019.02.025).

Qiu, H., S.K. Hamilton, and M.S. Phanikumar. 2019. Modeling the effects of vegetation on stream temperature dynamics in a large, mixed land cover watershed in the Great Lakes region. *Journal of Great Lakes Research.* 581. (DOI:10.1016/j.jhydrol.2019.124283).

Rowe, M.D., E.J. Anderson, D. Beletsky, C.A. Stow, S.D. Moegling, J.D. Chaffin, J.C. May, P.D. Collingsworth, A. Jabbari, and J.D. Ackerman. 2019. Coastal upwelling influences hypoxia spatial patterns and nearshore dynamics in Lake Erie. *Journal of Geophysical Research: Oceans.* 124(8):6154-6175. (DOI:10.1029/2019JC015192).

Rowland, F.E., C.A. Stow, T.H. Johengen, A.M. Burtner, D. Palladino, D.C. Gossiaux, T.W. Davis, L.T. Johnson, and S.A. Ruberg. 2020. Recent patterns in Lake Erie phosphorus and chlorophyll a concentrations in response to changing loads. *Environmental Science & Technology.* 54(2):835-841. (DOI:10.1021/acs.est.9b05326).

Sayers, M.J., A.G. Grimm, R.A. Shuchman, K.R. Bosse, G.A. Leshkevich, S.A. Ruberg, and G.L. Fahnenstien. 2019. Satellite monitoring of harmful algal blooms

in the Western Basin of Lake Erie: A 20-year time-series. *Journal of Great Lakes Research.* 45(3):508-521. (DOI:1016/j.jglr.2019.01.005).

Sayers, M.J., K.R. Bosse, R.A. Shuchman, S.A. Ruberg, G.L. Fahnenstiel, G.A. Leshkevich, D.G. Stuart, T.H. Johengen, A.M. Burtner, and D. Palladino. 2019. Spatial and temporal variability of inherent and apparent optical properties in western Lake Erie: Implications for water quality remote sensing. *Journal of Great Lakes Research.* 45(3):490-507. (DOI:10.1016/j.jglr.2019.03.011).

Shahraki, A.H., D. Heath, and S.R. Chaganti. 2019. Recreational water monitoring: Nanofluidic qRT-PCR chip for assessing beach water safety. *Environmental DNA.* 1(4):305-315. (DOI:10.1002/edn3.30).

Stauffer, B.A., H.A. Bowers, E. Buckley, T.W. Davis, T.H. Johengen, R. Kudela, M.A. McManus, H. Purcell, G.J. Smith, A. Vander Woude, and M.N. Tamburri. 2019. Considerations in harmful algal bloom research and monitoring: Perspectives from a consensus-building workshop and technology testing. *Marine Science-Frontiers.* 6(399). (DOI:10.3389/fmars.2019.00399).

Stone, J.P., K.L. Pangle, S.A. Pothoven, H.A. Vanderploeg, S.B. Brandt, T.O. Hook, T.H. Johengen, and S.A. Ludsin. 2020. Hypoxia's impact on pelagic fish populations in Lake Erie: A tale of two planktivores. *Canadian Journal of Fisheries and Aquatic Sciences.* 00:1-18. (DOI:10.1139/cjfas-2019-0265).

Stow, C.A., Q. Liu, and E.J. Anderson. 2020. Nutrient loading and nonstationarity: The importance of differentiating the independent effects of tributary flow and nutrient concentration. *WIREs Water.* 7(1). (DOI:10.1002/wat2.1396).

Sturtevant, R.A., D.M. Mason, E.S. Rutherford, A. Elgin, E. Lower, and F. Martinez. 2019. Recent history of nonindigenous species in the Laurentian Great Lakes, An update to Mills *et al.*, 1993 (25 years later). *Journal of Great Lakes Research.* 45(6):1011-1035. (DOI:10.1016/j.jglr.2019.09.002).

Sun, L., H. Qiu, J. Niu, B.X. Hu, J.F. Kelly, D. Bolster, and M.S. Phanikumar. 2020. Comparison of negative skewed space fractional models with time nonlocal approaches for stream solute transport modeling. *Journal of Hydrology.* 582. (DOI:10.1016/j.jhydrol.2019.124504).

Vander Woude, A., S. Ruberg, T. Johengen, R. Miller, and D. Stuart. 2019. Spatial and temporal scales of variability of cyanobacteria harmful algal blooms from NOAA GLERL airborne hyperspectral imagery. *Journal of Great Lakes Research.* 45(3):536-546. (DOI:10.1016/j.jglr.2019.02.006).

VanMensel, D., S.R. Chaganti, I.G. Droppo, and C.G. Weisener. 2020. Exploring bacterial pathogen community dynamics in freshwater beach sediments: A tale of two lakes. *Environmental Microbiology.* 22(2):568-583. (DOI:10.1111/1462-2920.14860).

Weinke, A.D. and B.A. Biddanda. 2019. Influence of episodic wind events on thermal stratification and bottom water hypoxia in a Great Lakes estuary. *Journal of Great Lakes Research.* 45(6):1103-1112. (DOI:10.1016/j.jglr.2019.09.025).

Ye, X., P.Y. Chu, E.J. Anderson, C. Huang, G.A. Lang, and P. Xue. 2020. Improved thermal structure simulation and optimized sampling strategy for Lake Erie using a data assimilative model. *Journal of Great Lakes Research.* 46(1):144-158. (DOI:10.1016/j.jglr.2019.10.018).

Zhang, F., M. Minamide, R.G. Nystrom, X. Chen, S. Lin, and L.M. Harris. 2019. Improving Harvey forecasts with next-generation weather satellites. *Bulletin of the American Meteorological Society.* 1217-1222. (DOI:10.1175/BAMS-D-18-0149.1).

Zhang, H., E.S. Rutherford, D.M. Mason, J.T. Breck, M.T. Wittman, D.M. Lodge, X. Zhu, T.B. Johnson, and A.Tucker. 2019. Modeling potential impacts of three benthic invasive species on the Lake Erie food web. *Biological Invasions.* 21:1697-1719. (DOI:10.1007/s10530-019-01929-7)

Zimnicki, T., T. Boring, G. Evenson, M. Kalcic, D.L. Karlen, R.S. Wilson, Y. Zhang, and J. Blesh. 2020. On quantifying water quality benefits of healthy soils. *Bioscience.* 70(4):343-352. (DOI:10.1093/biosci/biaa011).

# Non-Peer-Reviewed Publications:

Baer, M. 2019. The effect of single versus dual nutrient control on phytoplankton growth rates, community composition, and microcystin concentration in the western basin of Lake Erie. Master's Thesis approved by the School for Environment and Sustainability at the University of Michigan.

Boucher, N.W. 2019. Examining the relative effects of nutrient loads and invasive Dreissena mussels on Lake Michigan's food web using an ecosystem model. Master's Thesis approved by the School for Environment and Sustainability at the University of Michigan.

Fujisaki-Manome, A., D.G. Gill, E.J. Anderson, T. Guo, and M.C. Lemos. Report on the Great Lakes ice forecast workshop. Submitted to the University of Michigan Graham Sustainability Institute. November 2019.

Lower, E., N. Boucher, P. Alsip, A. Davidson, and R. Sturtevant. 2018 Update to "A risk assessment of potential Great Lakes aquatic invaders." NOAA Technical Memorandum GLERL-169b. September 2019. (DOI:10.25923/ev88-7488).

Nalepa, T.F., L.E. Burlakova, A.K. Elgin, A.Y. Karatayev, G.A. Lang, and K. Mehler. Abundance and Biomass of Benthic Macroinvertebrates in Lake Michigan in 2015, with a Summary of Temporal Trends. NOAA Technical Memorandum GLERL-175. March 2020. (DOI:10.25923/g0d3-3v41).

Sturtevant, R. and P. Alsip. Thermocyclops crassus. NOAA Great Lakes Aquatic Nonindigenous Species Information System. September 2019.

Sturtevant, R.A., E. Lower, N. Boucher, P. Alsip, K. Hopper, S. Iott, D. Mason, A. Elgin, and F. Martinez. 2018 Update to "An impact assessment of Great Lakes aquatic nonindigenous species." NOAA Technical Memorandum GLERL 161b. September 2019. (DOI:10.25923/meg8-v434).

Wang, J., T-Y. Yang, J. Kessler, H. Hu, and P. Chu. Great Lakes ice duration, winter severity index, cumulative freezing degree days, and atmospheric teleconnection patterns, 1978-2018. NOAA Technical Memorandum GLERL-174. January 2020. (DOI:10.25923/88c9-hm22).

# Annual Photo Contest Winners

## CIGLR IN ACTION

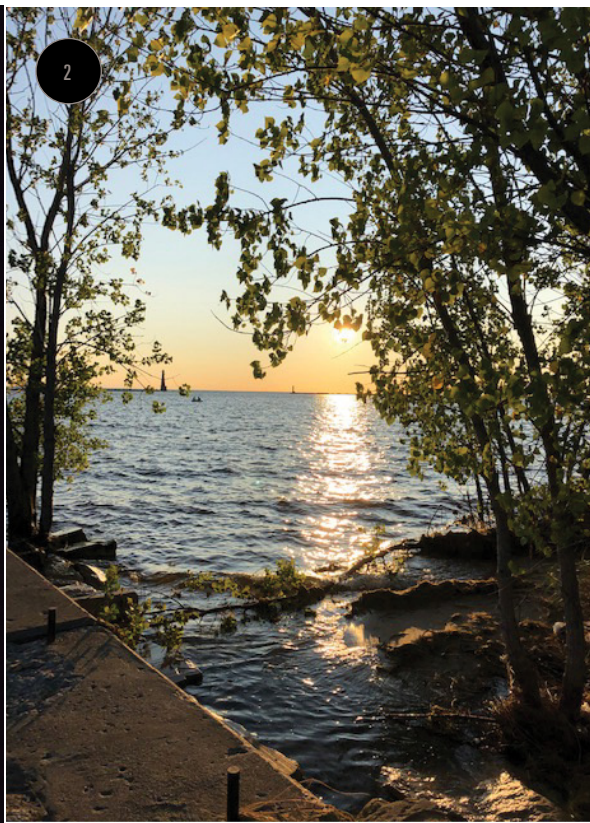



With a universal passion for water, the Great Lakes, and science, photographers from the Cooperative Institute for Great Lakes Research seek to tell their stories through the lens. For the third year in a row, the CIGLR Photo Contest entries feature images that inform, inspire, and amaze.

1st place: *Tom, Bugs, Lake Guardian,* Casey Godwin

2nd place: *Port Hole Early Spring Laurentian,* David Wells

3rd place: *Night Owls,* Dack Stuart


Viewing scenery through CIGLR lenses is always an inspiration. The artful stories that emerge offer shared experiences and adventure through our Great Lakes research.

1st place: *Moonrise,* Dack Stuart

2nd place (tie): *Lake Michigan,* David Wells

2nd place (tie): *Scum: Landward Invasion,* Dack Stuart


Explore more photos.

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

Cooperative Institute for Great Lakes Research
University of Michigan
G110 Dana Building
440 Church Street
Ann Arbor, MI 48109-1041



# Great Lakes Science for Society

The Great Lakes are the most critically important freshwater resource on the planet. They support the fourth-largest economy in the world and provide clean drinking water to more than 35 million people. CIGLR leads exciting new research, trains the next generation of scientists, and turns research into action for safe and healthy Great Lakes communities. To take action and support our Great Lakes, consider a donation today.

**Make a donation.**