IAGLR
LAKES Letter

CONTENTS

In this issue, we take a look at technology used to support large lake research.

LAKEBED 2030

A VISION OF COMPREHENSIVE GREAT LAKES MAPPING COVERAGE

by **Hans W. Van Sumeren**

The need exists for better mapping across broader areas within all large lakes of the world. Consider, for example, the Laurentian Great Lakes and their limited high-resolution bathymetry and substrate data. Estimates of coverage for the Great Lakes basin vary from 4 to 12 percent, lagging behind the 18-percent coverage achieved for the world's oceans (Mayer et al. 2018). In fact, we have significantly more information at a much higher resolution for the surface of Mars than we do for either the Great Lakes or the world ocean. Such large gaps indicate a need for data collection strategies that streamline access, emphasize standards and competencies, and prioritize areas of need to benefit multiple user groups. New collaborative approaches combined with accessible data repositories and technological advancements can help move us closer to a well-understood Great Lakes basin, and may allow us to one day realize a complete and comprehensive view of the basin's lakebed.

Seabed 2030 is a collaborative project between the Nippon Foundation and the General Bathymetric Chart of the Oceans. The project aims to bring together all available bathymetric data to produce a definitive map of the world ocean by 2030. A Lakebed 2030 project could similarly drive support and the development of strategies for obtaining 100-percent coverage for the Great Lakes. The Marine Technology Society collaborated with Northwestern Michigan College (NMC) in Traverse City, Michigan, to hold the Great Lakes TechSurge–Lakebed 2030 conference in October. Stakeholders shared their perspectives and experiences to better understand bathymetric lakebed mapping. They discussed current practices, new approaches, successful partnerships, and lessons learned, and they identified several challenges and opportunities.

From a Great Lakes perspective, fulfilling this vision of 100-percent coverage requires building capacity at local, regional, and international scales and further developing (or creating) collaborations that freely share collected data, technological advances, and workflow strategies. We must further classify, compile, and process these data into a robust and freely accessible digital repository that clearly defines existing coverage and data resolution. Gaps in data coverage could then be assessed and prioritized through continuing collaborations.

Advancements in technology promote new collection strategies for mapping the gaps, and they provide opportunity for innovative approaches in meeting these needs. Specifically, rapid advances in acoustic

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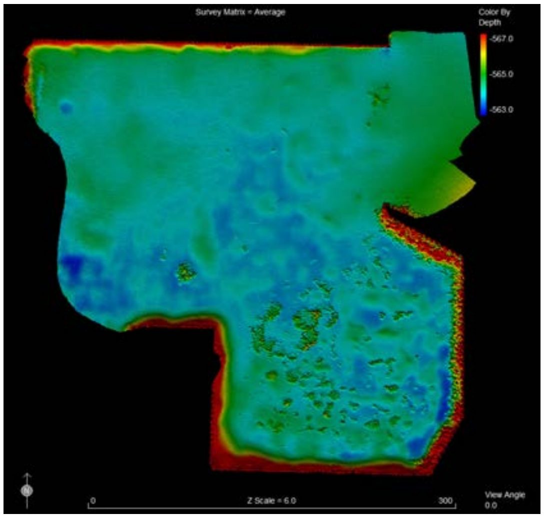
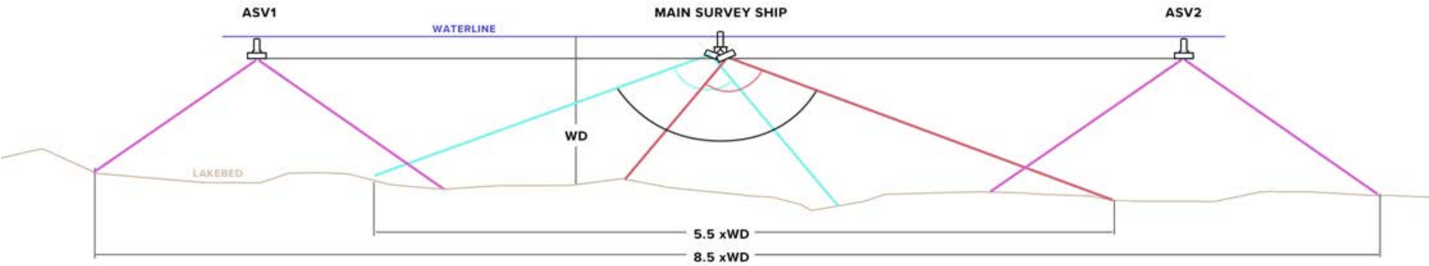


Credit: Mike Mutschler, Seahorse Geomatics and Matthew Moss, White Lake Dredge & Dock

Data collected over a 20-minute period using an autonomous surface vehicle with onboard multibeam sonar in NMC's Great Lakes Campus harbor on Grand Traverse Bay, Lake Michigan, in Traverse City, Michigan.



Courtesy David Neff, eTrac

"Megaswath" with two ASVs on either side of the main survey ship. Data collection covers a swath nearly a 1 kilometer wide.

technology and robotics are leading to innovative approaches that maximize efficiency, resolution, and visualization of the entire Great Lakes and other water bodies throughout the world. Multibeam sonar data can provide a broad understanding of the lakebed bathymetry, substrate, and water column all in a single pass. Unmanned surface vessels, autonomous underwater vehicles, and long range sub-surface gliders now navigate all marine domains equipped with a wide variety of sensor packages. The use of these platforms extends data collection windows and requires significantly fewer personnel for operation. Further developments in unmanned aerial systems can capture near-shore environments at a much lower cost and faster response.

Recent mapping in the Straits of Mackinac included the use of multiple autonomous surface vessels virtually coupled to a manned survey vessel, which allowed for a near doubling of the swath of mapping coverage without requiring additional personnel or time on task. Data collection advancements like this have revolutionized our ability to comprehensively visualize the lakebed and water column. What began as single depth and position measurements taken by a lead line and sextant has evolved into massive amounts of data being collected in a single ping: multiple depths at decimeter resolution and highly accurate positions, identification of lakebed features, significant substrate identification, and complete water column coverage.

We have significantly more information...for the surface of Mars than we do for either the Great Lakes or the world ocean.

The bathymetric mapping systems used today can collect data across multiple frequencies at swath widths of more than three times the water depth (as pictured above). This use of multiple frequencies provides multi-spectral backscatter return from the lakebed, with each return providing significant delineation in habitat classification and general lakebed structure. Staggering those frequencies during a single collection pass ensures comparability of the backscatter across all frequencies thus allowing the user multiple perspectives of the lakebed in a single transect.

Realizing a comprehensive map of the Great Lakes will require significant contributions from beyond the formal mapping and science channels. Integrating commercial off-the-shelf (COTS) mapping technologies into crowdsourcing opportunities represents an additional approach toward reducing the gaps in data coverage and accelerating the vision of Lakebed 2030. COTS technologies are improving in quality and accessibility, and could be used to outfit ferries, commercial ships, and recreational vessels to collect data during their normal operations.

A successful Lakebed 2030 project will produce a definitive map of the Great Lakes and, in so doing, will empower policy decision making, sustainable use of the lakes, and the scientific research that relies on comprehensive information on the Great Lakes.

Photo by Hans Van Sumeren

NMC students conducting multibeam sonar operations. The college offers numerous training programs in support of marine sectors such as mapping and surveying, data processing, and subsurface marine technology. Graduates of its marine technology undergraduate program are 100% employed in the marine industry, and they work throughout the world including in many positions within the Great Lakes region. NMC also offers professional development opportunities designed for the working professional in multiple areas of marine technology.

Hans W. Van Sumeren is director of the Great Lakes Water Studies Institute at Northwestern Michigan College.

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UNDERWATER ROBOTS

HELPING NOAA TO BETTER UNDERSTAND HARMFUL ALGAL BLOOMS IN THE GREAT LAKES

by **Gabrielle Farina**

In late August 2019, two underwater robots zigzagged beneath the surface of western Lake Erie to test new technology that autonomously monitors and measures in near real time the toxicity of Great Lakes harmful algal blooms (HABs). This was the second year in which the National Oceanic and Atmospheric Administration (NOAA) tested these robots and the first year that two were sent out at the same time. These field trials are part of an ongoing collaboration between NOAA, the Monterey Bay Aquarium Research Institute (MBARI), and the Cooperative Institute for Great Lakes Research (CIGLR). Project researchers tested these underwater vehicles to see how well they worked in a shallow, turbid, freshwater system and to see what tweaks were needed to make them part of NOAA's efforts to forecast, monitor, and understand HABs in the Great Lakes.

HABs develop when excess nutrients from fertilizers, sewers, and water treatment plants wash into the Great Lakes causing algae to grow out of control. Continuous monitoring of them is important because the toxins they produce can contaminate drinking water and pose a risk to people and animals.

"The ability to measure algal toxins on the fly using autonomous vehicles will be a game changer for researchers and resource managers," says Chris Scholin, president and CEO of MBARI. "Lake Erie and Monterey Bay are the only places in the world where this has been attempted."

The robots, known as long-range autonomous underwater vehicles (LRAUVs), each had a unique mission that helped scientists study the HABs. The first robot, named *Tethys*, searched for patches of algae that might be toxic to determine how far each discovered bloom extended and where it was most concentrated. The other robot, *Makai*, carried a third-generation Environmental Sample Processor (3G ESP) known as a "lab in a can" to measure levels of microcystin, a liver toxin produced by the cyanobacteria that commonly comprise Lake Erie HABs. Whenever *Tethys* found bloom patches likely to have high microcystin concentrations, it informed an operations team, which sent *Makai* to measure toxin levels in that area.

LRAUVs collect high-quality data efficiently, cost-effectively, day and night, and in all weather conditions. They can provide more detail about how far a bloom has spread and how fast a bloom is moving than can traditional sampling from a boat. This information can also help complete satellite data gaps, which often result from cloud cover in the

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"The ability to measure algal toxins on the fly using autonomous vehicles will be a game changer." — Chris Scholin

Photo by Ben Yair Raanan © 2019 Monterey Bay Aquarium Research Institute

The LRAUV *Tethys* glides through the green, algae-rich waters of Lake Erie to determine the extent and intensity of the bloom.

Great Lakes region. In addition, onboard 3G ESPs can measure algal toxin levels in near real time, a process that otherwise takes overnight to complete. These features help drinking and recreational water managers stay ahead of treatment plans and keep water safe. Once fully operational, these underwater robots will give NOAA the ability to detect, monitor, and map HABs and their toxicity on a 24/7 basis.

"We are always looking for ways to improve our understanding of harmful algal blooms in the Great Lakes, and having the ability to continuously detect and report on these blooms would be a big boost to our efforts," says Debbie Lee, director of NOAA's Great Lakes Environmental Research Laboratory. "Harmful algal blooms have a big impact on Great Lakes residents, and, by teaming up with MBARI to advance technological innovations of these LRAUVs, we're working to protect lives here in the Great Lakes and beyond."

To read more about this project and Great Lakes HABs, check out the full article on NOAA's Oceanic and Atmospheric Research website.

Gabrielle Farina is a Jamison Professional Services contractor and science communications specialist. She is currently working with NOAA's Great Lakes Environmental Research Laboratory.

Photo courtesy of CIGLR

CIGLR scientist Russ Miller and summer fellow Lauren Marshall prepare LRAUV *Makai* for deployment in Lake Erie.

Up close and personal with Lake Superior periphyton

by **M. Megan Woller-Skar and Ali Locher**

Periphyton is the collection of organisms including algae, fungi, and bacteria that attach to submerged surfaces in freshwater ecosystems. As primary producers, they collect energy from the sun and make it available to other organisms in aquatic food webs. Periphyton communities in the Great Lakes can provide clues as to how fluctuating water levels due to climate change may affect aquatic communities, the health of aquatic systems, and the quality of water for human use. The compositions of these communities vary even within small geographic areas as they respond to depth- and location-specific chemical and physical factors such as temperature, nutrients, and substrate geology. To get a close look at these communities and their habitats, we need detailed photos and maps of the lake bottoms where they live.

Photo by M. Megan Woller-Skar

Launching the *IVER 3* in Lake Superior.

We used Michigan Technological University's fully autonomous underwater vehicle, the *IVER 3*, to collect amazing, high-resolution (<10 cm) bathymetric images using side scan sonar at three locations in Lake Superior along the Keweenaw Peninsula. These bathymetric data are allowing us to map small-scale variations in substrate and to model factors that may influence the presence and composition of periphyton communities. In addition, the data will help us predict how lake level changes forecast for Lake Superior will potentially impact its periphyton community assemblages. In the face of increasing demands on water resources, it is vital that we understand the implications of a changing climate on aquatic systems in the Great Lakes. The *IVER 3* will help collect data to allow us to do just that.

M. Megan Woller-Skar and Ali Locher are associate professors in Grand Valley State University's biology department.

iNaturalist

EXCITING RESEARCH POSSIBILITIES LURK IN ACCESSIBLE DATASET

by **Austin Happel**

Smartphones are seemingly everywhere. It's estimated that 81 percent of Americans and 66 percent of Canadians now own these devices, which are capable of taking photos, logging GPS coordinates, and accessing the Internet. Citizen science projects take full advantage of this technology, having evolved from using pen and paper, to computer, to smart phone apps for collecting and recording data while engaging the public in research.

iNaturalist is one such app. With it, any person can upload geotagged photos of plants and animals, and both they and other iNaturalist users can participate in identifying the organisms. Observations are cataloged by taxonomy, region, and other characteristics, and they can be pooled as iNaturalist projects. For example, the *Amazing Aberrants* project catalogs observations of rare color morphs of species (e.g., albinism), whereas the *Great Lakes Fish Finder* project seeks to increase the number of freshwater fish observations made in the Great Lakes region. To date, more than 28 million observations representing 239,500 species throughout the world have been uploaded to the iNaturalist open-access database.

Photos taken by iNaturalist users of Creek Chub (top left), Largescale Stoneroller (*Campostoma oligolepsis*; top right), Bluehead Chub (*Nocomis leptocephalus*; bottom left), and Blacknose Dace (bottom right) exhibiting evidence of black spot grub infections.

Of those millions of observations, 1.2 percent are of fish. As a fish nerd, I began to explore this dataset to see how I could both use the data and persuade others to upload fish photos to increase the dataset's size. What angler doesn't already take pictures of their catches? I decided the best way to convince others to begin using iNaturalist was to illustrate how the data could be used for scientific purposes. Maybe I could match the range of a spreading invasive species with that shown in the USGS Nonindigenous Aquatic Species database, or the timing of when a migratory species appears in an area with known spring ice-off periods, or maybe come up with something new as I played with the data.

I began exploring iNaturalist, seeing what fish species were commonly posted, and noting where observations were more common. I also determined what some of the pitfalls of using the data would be. While doing so, I noticed that some of the fish had visible evidence of infection by black spot grub trematodes. These parasites live in fish's flesh, and, as protection, an infected fish's immune system surrounds the trematode with fibrous material and melanocytes, a process that creates the visible black spot that gives the disease its moniker.

Having seen these spots on a few fish, I decided to start categorizing fish on iNaturalist based on black spot presence versus absence. I started with Creek Chub (*Semotilus atromaculatus*) because people seemed to have held them closer to the camera for their photos (likely due to their small size), which made it easier for me to analyze their skin for black spots. Smaller fish also tend to have more translucent skin, making the black spots more visible. After reviewing some 550 Creek Chub photos, I mapped each animal's location using the photos' geotags. I was surprised to see more infected Creek Chub in the southern part of Canada than elsewhere. I then looked at black spots in other species and found the same geographic distribution pattern for infected versus not infected Blacknose Dace (*Rhinicthys* spp), *Nocomis* spp., and *Campostoma* spp.

I recently published these data (Happel 2019). Not only does my publication show there is a pattern to where fish exhibit symptoms of black spot grub infections across North America, it also demonstrates that data collected using citizen-science-based platforms such as iNaturalist can offer exciting research opportunities. Hopefully others will begin to use this large, freely accessible database of observations, and will also promote the contribution of additional fish (and other) observations.

Austin Happel is a research biologist with the Daniel P. Haerther Center for Conservation and Research at the John G. Shedd Aquarium.

20 YEARS & COUNTING

THE CONTINUING EVOLUTION OF THE MOLECULAR LIMNOLOGIST'S TOOLBOX

by **Steven W. Wilhelm, Helena L. Pound, and Robbie M. Martin**

It has been two decades since the tools of modern molecular biology—primarily DNA and RNA sequencing—have been commonly available to limnologists. As DNA sequences provide the blueprint for all living organisms and many viruses, researchers can use sequence information to determine which organisms are present in a sample and the metabolic potential these organisms may have. From viruses (Stough et al. 2017) to fish (Thomsen and Willerslev 2015), and whether in sediments (DeBruyn et al. 2009) or open waters (Steffen et al. 2017), these molecular tools can be employed in the assessment of any biotic community, its members, or its processes. With careful interpretation, this information has incredible power and still unrealized potential.

Today, DNA-sequence-based molecular methods generally fall into one of two broad categories. **Targeted** approaches typically use the **polymerase chain reaction** to amplify marker genes whose sequences contain key information about the identity or functional potential of an organism or community. A classic example includes the 16S rRNA gene as it is highly conserved among bacteria and archaea; sequencing this gene gives researchers an idea of which prokaryotic species are present in a microbial community. Alternatively, **shotgun** approaches attempt to sequence all genes in a sample to assess that community's functional potential. DNA sequencing (i.e., **genomics**) can provide a blueprint that indicates what cells *may* try to do. This blueprint helps researchers to predict possible responses of a microbial community to perturbations in its environment. On the other hand, RNA sequencing (i.e., **transcriptomics** for single species or **meta**transcriptomics for an entire community) can reveal what cells *are* trying to do. Given the rapid turnover of RNA in cells, researchers can view actual community responses that occur in minutes to hours.

Sequencing technology has evolved at a rapid pace during the last two decades. While typical sequencing in the 1990s commonly topped out at 50–100 sequences per sample, shotgun sequencing can now routinely generate billions of individual DNA or RNA **reads** per project,

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Definitions and jargon for modern molecular ecology in lakes

Targeted: any methods that address a specific gene (or set of genes) in a sample

Polymerase chain reaction (PCR): a method in molecular biology to make thousands to millions of copies of a specific DNA segment

Shotgun: any methods that address random DNA or RNA targets

Genomics: the field of biology focusing on the structure, function, evolution, mapping, and editing of genomes

Transcriptomics: the field of biology focusing on the examination of whole RNA molecules expressed by organisms across biological conditions

Meta-XXX: the prefix "meta" describes approaches used in mixed populations or samples

Reads (aka sequences; aka transcripts in the context of RNA): specific copies of DNA or RNA that have been analyzed using sequencing approaches

Bioinformatics: methods and software tools for understanding biological data, or an interdisciplinary field of science that combines biology, computer science, information engineering, mathematics, and statistics to analyze and interpret biological data (see examples below)

- Assembly: aligning and merging short nucleic acid fragments to form a longer sequence in an effort to reconstruct the original sequence
- Annotation: identifying the locations of genes and coding regions in a nucleic acid sequence to determine what those genes do
- Recruitment: matching short reads from sequencing efforts to longer assemblies or genomes to determine the relative occurrence of specific sequences in a sample

Proteomics: the large-scale study of the protein complement of an organism or community of organism

Metabolomics: the large-scale study of small molecules, commonly known as metabolites, within cells, tissues, or organisms with 30–50 million reads being common for every sample (e.g., Tang et al. 2018). This deeper exploration of the genetic content that modern molecular techniques enable is particularly pertinent to studies of the biogeochemical processes in lakes. Bacteria are a major driver of these processes, and, as they persist ubiquitously at abundances of 105 to 106 per mL of lake water (DeBruyn et al. 2004), their abundance and distribution make them excellent targets for molecular assessment as sufficient bacterial material can be collected for community analyses from just a few cups of water. One example of such a molecular assessment is the estimation of the quantity of toxin-encoding genes in a cyanobacterial bloom (pictured). This metric provides a relative measure of the bloom's toxin potential and can be used in conjunction with nutrient and temperature data to help biologists and water managers understand when high toxin loads might occur in a given water body (Rinta-Kanto et al. 2009). Increased ability to analyze genetic content using molecular tools, accompanied by parallel advances in **bioinformatics**, allows for the simultaneous characterization of nearly all biological processes for each member of a microbial community. By analyzing samples collected to have spatial and temporal variability, researchers can tease apart how the millions of microbes in every milliliter of water work together to shape lake function.

While modern molecular techniques allow assessment of much about the microbial community, we note that some of these approaches are only semi-quantitative. Shotgun sequencing, for example, provides information in terms of relative, not absolute, numbers in a sample; as such, it allows for powerful comparisons of shifts in function or community member activity, but it does not provide complete quantification. However, targeted approaches performed for an entire community can allow for absolute quantification. Evolving technological adaptations can further improve the quantification precision of these approaches.

Both technological adaptations of existing molecular tools as well as new molecular technologies are on the horizon. Examples of technological adaptations include digital PCR, which is a more precise and sensitive alternative to conventional and real-time quantitative PCR, and **proteomics**, which uses liquid chromatography coupled to sophisticated mass spectrometry to identify specific proteins in a sample. Interpretation of proteomics data can provide for a robust, semi-quantitative assessment of proteins, which are both longer-lived and, in many cases, more indicative of actual metabolic function than are RNA transcripts. In contrast to these existing tools, **metabolomics** is a still-emerging molecular technology that assesses small molecules in a biological sample and uses this information to infer the active biochemical pathways within communities. Metabolomics can be particularly powerful for detecting major perturbations in a system, but, as

Photo courtesy Steven W. Wilhelm

A toxic cyanobacterial bloom near the Taihu Laboratory for Lake Ecosystem Research in China. Microcystis blooms have become a global problem in recent decades, and the tools of the modern molecular limnologist are shedding light on the factors that promote and constrain such events.

homeostasis is something all cells work toward (Steffen et al. 2015), minor changes in a community may not be detected by this method.

Ultimately, how modern limnologists use molecular tools is a function of both the research question being asked and the limitations of each tool. DNA-based approaches can only be used to interpret community potential, while RNA-based and protein-based assessments indicate actual activity. Metabolomics is an appealing approach to investigating large-scale system disruptions, but any application of this tool must consider that it may not be able to detect minor system disturbances. Finally, the style applied to many of these approaches matters: while a shotgun-styled approach allows for assessment of a broad spectrum of the community, it produces results that are generally only relative in nature; in contrast, absolute quantification is achievable with targeted approaches, but the necessarily narrower scope of targeted assessments can make them less than desirable for some studies. Ultimately, and in spite of their limitations, the tools of the modern molecular biologist hold great promise for limnologists in the future.

Helena Pound is a doctoral student and Robbie Martin a postdoctoral fellow in the Department of Microbiology at the University of Tennessee. Steven Wilhelm is the Kenneth & Blaire Mossman Professor at the University of Tennessee and a faculty member in the Department of Microbiology. The Wilhelm lab has had an active research program with interests in viruses, bacteria, and harmful algal blooms in large lakes around the world since 1998.

GETTING REAL

REAL-TIME TECHNOLOGY PROVIDES GREATER INSIGHT ON WATER QUALITY ISSUES

by **Jill Crossman, Elizabeth Striano, and Aaron Fisk**

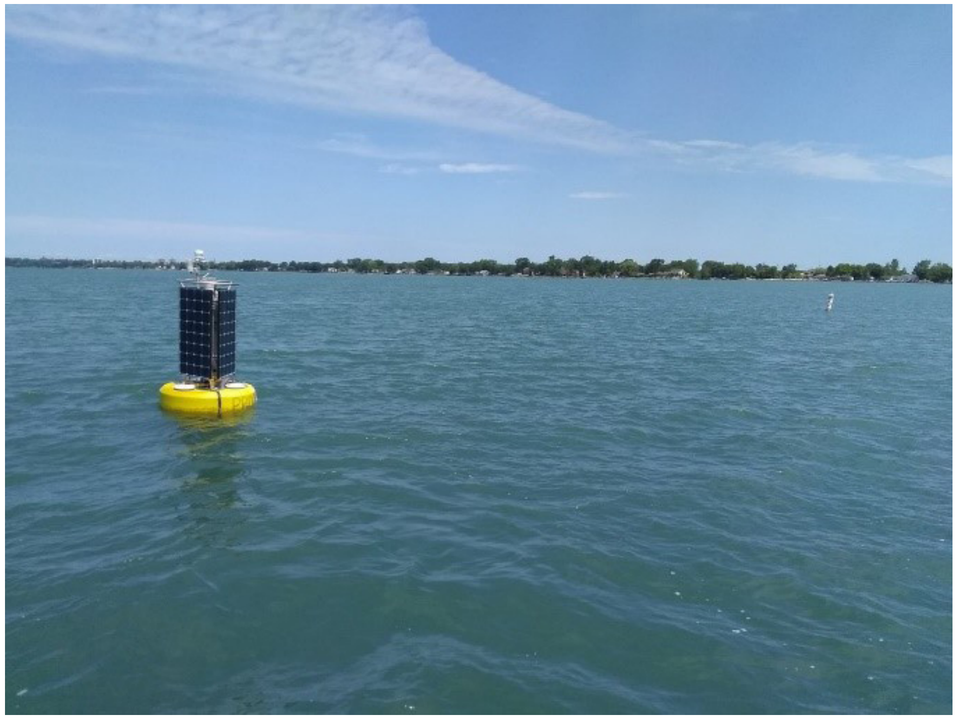

Photo by Jill Crossman

An ErieWatch buoy in the Lake Erie western basin at the mouth of the Detroit River.

Harmful algal blooms (HABs) and the low dissolved oxygen concentrations associated with them are a growing concern for large water bodies throughout the world. HABs have resulted in fish kills and drinking water advisories, which collectively have caused estimated economic losses of up to US$71 million per year within Lake Erie alone. HABs have been linked to excessive nutrient inputs, specifically those of nitrogen and phosphorus, and in the 1980s, were successfully managed by reducing phosphorus inputs to lakes. Recently, however, bloom frequency and toxicity have increased. Scientists and resource managers have proposed several hypotheses for this bloom resurgence, including changes in phosphorus bioavailability and increases in water temperatures, turbidity, and internal nutrient loads. Determining the specific sources of these water quality issues is challenging in the constantly changing Great Lakes environment with its multiple stressors. Without knowing the cause, it is impossible to find a solution; as a result, HABs issues persist within the Great Lakes. However, new technologies that enable real-time monitoring of nutrients in these water bodies are helping to provide some answers.

Traditional water quality monitoring practices such as discrete sampling and laboratory analyses are expensive and labor intensive. As a result, nutrient samples are typically only taken at monthly or bimonthly intervals. The limited amount of data that results from this low sampling frequency combined with high rates of environmental flux create uncertainty in quantification of lake conditions. For example, concentrations of soluble reactive phosphorus (SRP), generally considered to be the most bioavailable phosphorus fraction, can vary greatly throughout the day. During heavy rainfall, SRP values can change by hundreds of micrograms per liter over just a few hours. In addition, nutrient concentrations in collected samples can change during transport to the laboratory as is the case for SRP, which is particularly sensitive to both microbial uptake and release as compared to total phosphorus (TP). Because of this variability, meaningful representations of lake phosphorous conditions require near-continuous measurements of both SRP and TP levels.

New technologies that enable real-time monitoring of nutrients in water bodies are helping to provide answers.

Due to these limitations in data resolution, scientists have, to date, been unable to measure the impact of nutrient management strategies on the relative bioavailability of phosphorus in large water bodies. The Real-time Aquatic Ecosystem Observation Network (RAEON) aims to address this technical hurdle by providing Canadian researchers with the infrastructure, staff, and data management needed to enable collection of nutrient and other HABs-related data in real time. Based at the University of Windsor, RAEON is directed by Katelynn Johnson and funded by a CA$15.9 million grant

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recently awarded to RAEON lead Aaron Fisk by the Canadian Foundation for Innovation.

RAEON supports research that contributes to management, rehabilitation, and enhancement of ecosystem services. One such program is ErieWatch, developed and run by Jill Crossman, an early career researcher at the University of Windsor. ErieWatch, which consists of a network of four biogeochemical monitoring platforms located across the western basin of Lake Erie, aims to identify drivers of HABs in the region. The platforms support new real-time wet chemical analyzers called WIZprobes, in addition to meteorological stations and more traditional *in situ* monitoring technologies for dissolved oxygen, light, chlorophyll *a*, and temperature. Every hour, the WIZprobes can sample the water to analyze three types of phosphorus present: dissolved, soluble, and total. This represents the first time that TP can be analyzed in remote locations, aided by the WIZprobes' new low-power digestion techniques. Solar-powered portable units transmit live results to in-office computers using telemetry.

Photo by Jill Crossman

An ErieWatch buoy in Pigeon Bay, in the western basin of Lake Erie. A WIZprobe is deployed below the waterline.

These platforms, and the WIZprobes specifically, have provided scientists with the ability to more accurately quantify phosphorus concentrations in large water bodies and to monitor biochemical variables at resolutions that better capture process interactions. Scientists are only just starting to use WIZprobes in North America as they require large networks of instruments and regular maintenance by highly qualified personnel, including calibration and validation in the field; obstacles that RAEON is helping to address.

The four biogeochemical research platforms of ErieWatch are part of the first international smart-sensor network in the Great Lakes, created by both RAEON and NOAA's Great Lakes Environmental Research Laboratory. This network is monitoring hydrodynamics as well as nutrient, dissolved oxygen, phycocyanin, and chlorophyll *a* levels across Lake Erie's western basin. Data are uploaded to the Great Lakes Observing System for public access and to help answer many questions such as the following: What effects are management strategies having on SRP:TP ratios? Does a short-term change in SRP:TP encourage algal bloom formation? Is there a specific trigger that causes an entire bloom to become toxic?

The revolutionary real-time network approach of these technologies offers a better alternative to traditional sample collection methods that can limit the frequency, duration, and scope of environmental research programs. By implementing novel technologies for analyzing underlying process interactions, programs such as RAEON and ErieWatch have the potential to reduce threats posed by HABs and, more broadly, to transform conventional approaches to freshwater resource management to the benefit of policy makers, managers, residents, other users of Ontario watersheds, and the global research community.

Photo by Jill Crossman

A WIZprobe and reagent canister (center), pump (left), filters (bottom center), and distilled water (right).

Jill Crossman is an assistant professor in the School of Environment at the University of Windsor and developed the new research program ErieWatch. Elizabeth Striano is a science writer and principal of A Green Footprint LLC. Aaron Fisk, a Tier 1 Canada Research Chair in Changing Great Lakes Ecosystems at the University of Windsor, is the program leader of RAEON.

AQUAHACKING

USING TECH TO TACKLE FRESHWATER ISSUES

by **Catherine van Reenen**

"Hacking" describes using technical knowledge to overcome persistent problems, which range from the simple (is there an easier way to tie my shoes?) to the complex (how can cities coordinate snow removal more efficiently?). Indeed, just about anything can be hacked. Why not water?

AquaHacking does exactly that. This multi-stage, start-up competition challenges students and young professionals to design practical engineering, web, and mobile solutions to the problems plaguing North America's freshwater lakes. Its multidisciplinary teams of hackers compete for seed money and incubator space, with end goals of developing demand-driven solutions and launching new businesses that may have measurable impacts on freshwater issues.

Launched in 2015 by the de Gaspé Beaubien Foundation in Montréal, AquaHacking has thus far engaged more than 1,500 youth in 12 critical water issues and supported the launch of 18 start-ups. For example, the 2018 winner, Geosapiens, produced E-Nundation, a software tool that performs flood simulations to assess their potential impacts and support effective flood risk-management procedures. Water Rangers, AquaHacking's first winning team, is also one of its most successful start-ups. The organization offers a web-based data collection platform and portable water-testing kits to enable citizen scientists to sample water quality, upload their data, and track specific issues such as algal blooms and pollution over time.

Tech competitions like AquaHacking are an emerging strategy for tackling freshwater issues across the globe. Erie Hack, for example, is a water tech challenge launched by the Cleveland Water Alliance in 2017 in which coders, developers, engineers, and water issue experts generate solutions to issues affecting Lake Erie. Similarly, in 2018 a Milwaukee nonprofit, The Water Council, started a global Tech Challenge devoted to identifying new freshwater technologies based on topics selected by corporate sponsors, while the Global Water Tech Hub Alliance, a project of the Neterhlands-based Water Alliance, established an open platform to help match water issues with relevant solutions.

Photo courtesy of AquaHacking

A hacker team presents their solution at the 2018 AquaHacking semifinal in Toronto, Ontario.

What distinguishes AquaHacking and its international counterparts from traditional hackathons is a long-term focus on real-world problems with well-defined end users. While most hackathons are weekend affairs, the AquaHacking Challenge is an eight-month endeavor. As the problems plaguing our freshwater lakes are as multifaceted and complex as the stakeholders involved—from researchers, NGOs, and governments to industry, entrepreneurs, and regulators—it takes time both to understand the scientific processes at play and to build relationships across sectors. Because of the extended timeline AquaHacking uses in its tech challenges, competing teams can engage key stakeholders throughout the challenge to ensure they have support from expert mentors in water, technology, and business as they build their solutions. The solutions developed as a result of these synergies are well worth the extra time needed: they are more likely to be effective, and, more importantly, they have a better chance of being implemented by end users.

After five years of holding successful competitions in the Great Lakes-St. Lawrence region, AquaHacking is going national in 2020 with regional competitions planned in British Columbia, Atlantic Canada, and Lake Winnipeg. The AquaHacking Lake Winnipeg Challenge will be hosted by the International Institute for Sustainable Development (IISD), and it aims to find innovative solutions to issues such as microplastics pollution, algal blooms, and pharmaceutical contaminants.

IISD's AquaHacking Lake Winnipeg team will be hosting information sessions for potential participants throughout January 2020 at various university and college campuses. Although major competition events will take place in Winnipeg, teams can participate in person or virtually. Participants from both within and beyond the Lake Winnipeg watershed are welcome.

Catherine van Reenen is the AquaHacking project coordinator for the IISD.

AquaHacking @ IAGLR20

AquaHacking's Lake Winnipeg semifinal will be held June 8–12, 2020, at IAGLR20 in Winnipeg, where you can meet the hackers, learn about their solutions, and hear the top five teams present their pitches. The winning team will be determined at the final in October 2020.

For more information, contact cvanreenen@iisd.ca or visit the AquaHacking website.

“Smart skin” for sea lamprey detection

by Xiaobo Tan

The ability to selectively pass fish along a waterway has emerged as a high priority for the conservation, management, and restoration of Great Lakes fish communities. Deterioration of dams in Great Lakes tributaries and the recognized need to restore connectivity between lakes and tributaries have increased the urgency of developing strategies to allow passage of native and desirable fishes while blocking and/or removing invasive or undesirable fishes. A primary challenge to developing selective fish passage structures in the Great Lakes is preventing successful passage of sea lamprey (*Petromyzon marinus*) at fishways near dams, where their detection is key.

Funded by the Great Lakes Fishery Commission Sea Lamprey Research Program, researchers at Michigan State University and the United States Geological Survey’s Hammond Bay Biological Station are working on a “smart skin” technology that can autonomously detect the suction of adult sea lampreys. The smart skin consists of arrays of soft pressure sensors embedded in a flexible substrate, which allows it to be mounted on variably shaped surfaces within or near fishways. Using the distinct pressure profile created by lamprey mouth suction, the researchers hope to detect the attachment of lamprey to the smart skin and then trigger a localized electrical stimulus to repel or deter it. In addition to its potential use for selective fish passage, smart skin technology also could be deployed in streams to determine the timings of sea lamprey entry and upstream migration for improving understanding of their refuge-seeking behavior.

Photo by Hongyang Shi

A sea lamprey attaching to a smart skin prototype.

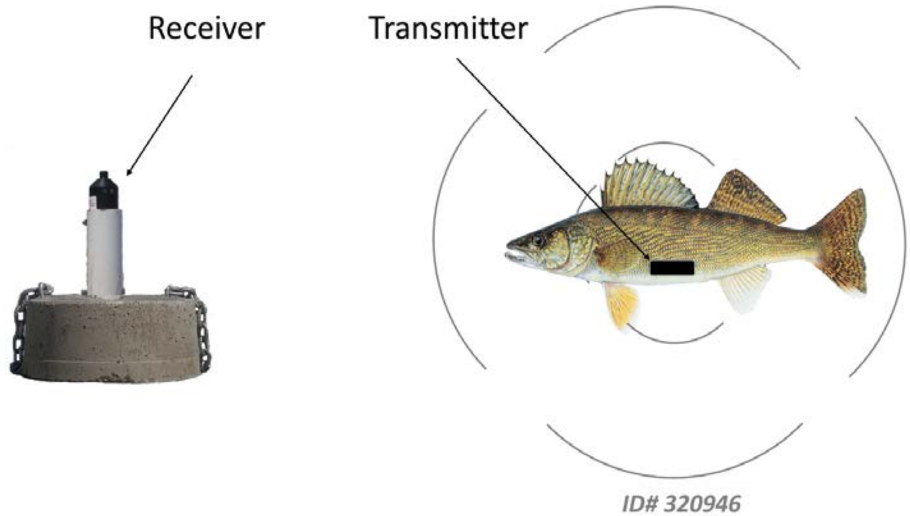
Xiaobo Tan is a professor in Michigan State University’s department of electrical & computer engineering.

ACOUSTIC TELEMETRY

BIG ADVANCES IN TECHNOLOGY LEAD TO BIG DISCOVERIES IN FISH MOVEMENT

by **Christopher S. Vandergoot**

To implement management actions designed to promote long-term viability of exploited fish stocks in the Great Lakes basin, fisheries biologists must understand the timing and geographic range of these economically and ecologically important species. Historically, biologists examined fish movements using rudimentary approaches (e.g., attaching external tags made of metal or plastic) that provided only cursory information (e.g., release and capture locations) about fish behavior. Recent advances in acoustic telemetry technology have accelerated discovery, expanded both the scope and nature of our questions, and facilitated collaborative research among fishery researchers and managers throughout the Great Lakes region.



Courtesy of Christopher Vandergoot

Biologists are able to track fish movements by implanting acoustic transmitters into the body cavity and monitoring where they travel as they pass by acoustic receivers. Each transmitter has its own unique identification number, which allows biologist to determine individual or group movement patterns.

Recent advances in acoustic transmitter and receiver technology have revolutionized how telemetry is used to understand how the characteristics of fish populations influence fish movement patterns in relation to physical lake conditions. Specifically, a trend over the past few decades toward smaller yet more powerful transmitters has allowed researchers to monitor the movements of increasingly smaller fish over more prolonged periods of time. For example, acoustic telemetry technology is being used to assess post-stocking survival, habitat use, and movement patterns for juvenile lake sturgeon (Lake Erie), juvenile cisco (Lake Ontario), and round goby (Lake Huron) for up to a year depending on how the transmitters are programmed. Similarly, the ability to passively monitor an area for the presence/absence of transmitter-tagged individuals is an advance that has materialized over the past few decades. Historically, researchers would have had to follow fish around with mobile hydrophones to track their movements; however, today researchers are able to deploy stationary acoustic receivers that passively monitor areas for telemetered fish over extended time periods (i.e., up to 15 months). Both of these technological innovations are providing unsurpassed research opportunities only fantasied a few decades ago.

Technological innovations are providing unsurpassed research opportunities only fantasied a few decades ago.

Today, these acoustic telemetry advances provide fishery researchers with an unprecedented ability to understand where, when, and why fish move. Using an expansive array of acoustic receivers deployed throughout the Great Lakes basin via the Great Lakes Acoustic Telemetry Observation System (GLATOS), studies examining both broad- and fine-scale movement patterns have been underway since 2010. In Lake Huron, researchers were able to better understand recruitment bottlenecks by learning what type of spawning habitat stocked and wild lake trout selected. Similarly, fine-scale movement patterns of invasive sea lamprey and grass carp are being evaluated throughout the basin to inform control efforts. By combining auxiliary sensors (i.e., for depth and temperature) with standard acoustic transmitters, researchers are able to address how fish respond to changing and variable lake conditions such as temperature, turbidity, harmful algal blooms, and anoxia (i.e., lack of oxygen in the water). Furthermore,

continued

because the GLATOS network extends throughout all five Great Lakes and their associated interconnecting waters (i.e., St. Marys River, Huron-Erie Corridor, Welland Canal), it is now feasible to understand how fish movements relate to physiochemical characteristics within the Great Lakes ecosystem at geographic scales that were previously impractical, or even impossible, to address.

While conducting scientific research across large geographic scales is often logistically and administratively difficult, these challenges present new avenues for collaboration and innovation. For example, GLATOS researchers assist each other with gear deployments and maintenance, share research findings, and collaborate on new research endeavors. Futher, in association with other research going on in the Great Lakes basin, GLATOS researchers anticipate using autonomous underwater vehicles to monitor fish movements in collaboration with the Real-time Aquatic Ecosystem Observation Network based out of the Great Lakes Institute for Environmental Research at the University of Windsor. By combining fish movement and physical lake condition data, researchers will be able to gain a better understanding of the population dynamics of Great Lakes fish stocks and the management actions need to ensure their long-term sustainability in the face of a changing climate. ∎

Photo by Charles Krueger

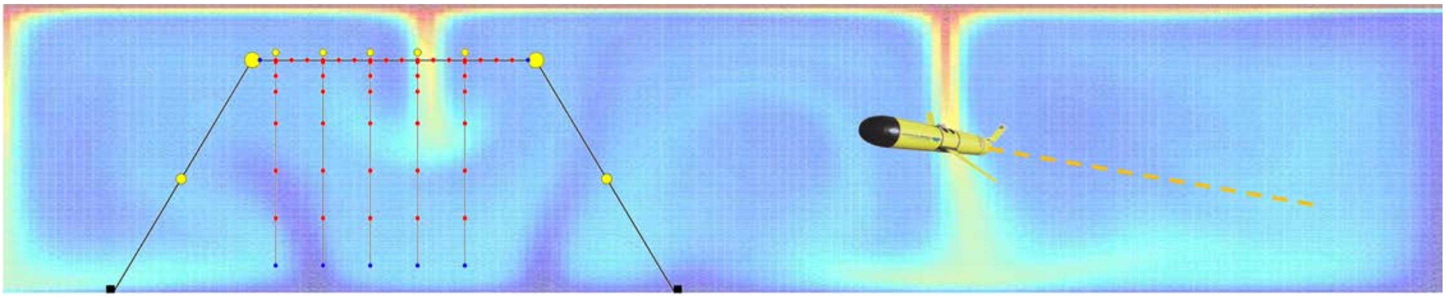
Fishery research biologists deploying acoustic receivers as part of the Great Lakes Acoustic Telemetry Observation System receiver network.

Christopher S. Vandergoot is an associate professor at Michigan State University's Center for Systems Integration and Sustainability and director of the Great Lakes Acoustic Telemetry Observation System.

OLD TECH, NEW APPROACH

INNOVATIVE USE OF MOORING AND GLIDER TECHNOLOGY TO STUDY LAKE SUPERIOR CONVECTIVE PROCESSES

by **Jay Austin**



Courtesy of Jay Austin

Conceptual drawing of the horizontal mooring and glider path against a convective background. Red dots represent thermistors, yellow dots represent flotation devices, and blue dots represent pressure sensors.

To study new phenomena, sometimes we need to reconsider either how we use traditional technologies or how we interpret the data they provide.

Take, for example, the study of springtime convective processes in Lake Superior. Convection can occur when a water column is below its temperature of maximum density (about 4° C) and sunlight heats the near-surface water causing it to become denser and sink to the bottom. This movement displaces deep water toward the surface and provides a pathway for water column constituents to travel from the lake's surface to its bottom in just a few hours in even the deepest parts of the lake. The ecological significance of this circulation has been explored in shallow lakes (e.g., Yang et al. 2017), but is poorly understood in deeper lakes like Superior. Recent work (Austin 2019) suggests convective cells dominate the circulation of Lake Superior for two to three months of the year, a significant portion, indicating the need for exploration of deep lake convective processes.

One challenge in studying these processes is that we're not that good at measuring the relatively narrow widths of convective cells. Most traditional observational techniques, such as CTD profiling or single-point moorings, assume that horizontal variability occurs on scales much larger than does vertical variability. In most cases, this is a reasonable assumption as vertical structure is driven by water column light penetration and density stratification. However, recent results suggest springtime convective cells have lateral scales on the order of just tens to hundreds of meters, making traditional approaches unviable. We are meeting this challenge with two new approaches: first, an innovative way to interpret data collected in a traditional fashion; second, a new design for a platform on which to deploy standard instrumentation.

Interpreting data in a new way

Autonomous gliders are becoming a mainstay of oceanographic research, and are starting to be used more frequently in large lake research. A usual way to interpret data collected along the gentle slope (1:2) of a typical glider's path is as a representation of a vertical profile, as would be collected by a CTD profiler. Yet for fairly narrow convective cells, variability along the glide path also may reflect lateral variability. Such may be the case for data collected during springtime convection, and estimates of the abundance of anomalously warm regions have allowed us to place some preliminary constraints on the size of convective plumes and cells.

Standard tech, new design

To further address the issue of variability on very short lateral scales, we recently designed, built, deployed, and recovered a large "horizontal mooring" with support from the National Science Foundation. This mooring allowed us to deploy a two-dimensional array of precision thermistors. The platform is large, standing 150 meters tall, and the instrumented portion spans a width of 180 meters. It carries 48 RBR TR-SOLO thermistors and seven pressure sensors used to verify orientation of the mooring as currents displace it. This mooring was accompanied by several auxiliary platforms including a meteorology buoy and a current profiler. The data collected are allowing us to study the development of individual convective cells. This is a great example of how a traditional technology, like off-the-shelf thermistors, deployed in an innovative fashion allows us to ask (and answer!) questions that we otherwise might not be able to address. Insights from this research will provide us with a greater understanding of how the convective processes of the largest of the Great Lakes behaves for several months of each year.

Jay Austin is a physics and astronomy professor with the Large Lakes Observatory, University of Minnesota, Duluth.

A TINGE OF ORANGE

EPA DEPLOYS AUTONOMOUS UNDERWATER GLIDER TO EXPLORE LAKE ERIE HYPOXIA; GLIDER RETURNS WITH A TINGE

by **Tom Hollenhorst and Paul McKinney**

In support of the 2019 Lake Erie Cooperative Science Monitoring Initiative, the Environmental Protection Agency "flew" its autonomous underwater glider (a Teledyne Slocum G2) to explore the recurring hypoxic zone of the lake's central basin.

The zone's hypoxia is exacerbated by the seasonal growth and subsequent decomposition of a large amount of plankton (algae and zooplankton). This decomposition depletes the benthic dissolved oxygen concentration to below 2 mg/L, resulting in the late summer formation of a hypoxic layer that typically extends from 1 to 5 meters above the lake bottom. Lake Erie's hypoxic layer negatively affects its aquatic habitat and biota, creating a large area sometimes referred to as a "dead zone."

In its investigation of the dead zone, the glider traveled nearly 500 kilometers during a three-week mission funded under the Great Lakes Restoration Initiative. It completed more than 10,000 vertical profiles of the water column while collecting temperature, conductivity, and chlorophyll data in addition to dissolved oxygen concentrations.

When it was retrieved after its exploration, the normally bright yellow glider was stained orange. This color was likely imparted by the hypoxic layer's dissolved iron oxidizing onto the glider's body while it traversed the water column. Although there is more to investigate, some researchers have hypothesized that the excessive iron hydroxide that forms under hypoxic conditions may correlate with the amount of phosphrous released from the sediment. Regardless, it seems EPA's glider encountered a geochemically reactive environment in the hypoxic zone of Lake Erie!

Ecologist Tom Hollenhorst and ORISE participant Paul McKinney are with the U.S. EPA Great Lakes Toxicology and Ecology Division.

Photos by Ben Alsip (top left) and Tom Hollenhorst

EPA's glider (which is normally bright yellow, top left) was stained orange by high concentrations of iron (bottom left and right) as it collected data in the hypoxic bottom waters of Lake Erie's central basin.

KUDOS

Congratulations to the following IAGLR members on their accomplishments.

ALEXANDRA (SASHA) BOZIMOWSKI for accepting a position as an ecologist at the U.S. Geological Survey Great Lakes Science Center in Ann Arbor, MI, working on coastal wetland ecosystems.

CATHERINE FEBRIA (Great Lakes Institute for Environmental Research, University of Windsor) for her selection as a Tier 2 Canada Research Chair in Freshwater Restoration Ecology.

THOMAS JOHENGEN for his selection as director of Michigan Sea Grant. Johengen most recently served as associate director and research scientist for the Cooperative Institute for Great Lakes Research at the University of Michigan. He operated out of the NOAA Great Lakes Environmental Research Laboratory in Ann Arbor, where he worked for nearly three decades alongside both academic and federal scientists. Johengen earned his Ph.D. at the University of Michigan with prior degrees from Florida State University and Michigan State University. His research interests include harmful algal blooms, the impact of invasive species on lower food webs, ballast water management and the transfer of invasive species, and observing technologies. Johengen was a past member of the IAGLR Board of Directors, served as a conference co-chair, and is a recipient of IAGLR's Chandler-Misener Award for best paper in the *Journal of Great Lakes Research*.

KEVIN OBIERO for defending his dissertation "Aquaculture and rural livelihoods: Analyzing technology adoption and impacts on food and nutrition security in Eastern Africa" from the University of Natural Resources and Life Sciences, Austria. He is centre director and research scientist at the Kenya Marine and Fisheries Research Institute and a member of the board of directors of the African Center for Aquatic Research and Education.

Submit kudos to
lakesletter@iaglr.org

Welcome new members

The following members joined the association between August and October 2019.

James Last Keyomb Atalitsa
Benjamin Bailey
Ben Burke
Kyle Cissell
Cheryl Coale
Cynthia Collier
Marissa Cubbage
Yingqing Deng
Michael Gora
Chia-An Lin
Ashley Moerke
Benard Mucholwa Simiyu
Daniel Myers
Jess Robson
Lewis Sitoki
Jane White
Ryan Williams

Lakes Letter is published quarterly by the International Association for Great Lakes Research, a scientific organization made up of researchers studying the Laurentian Great Lakes, other large lakes of the world, and their watersheds, as well as those with an interest in such research.

Edited by Paula McIntyre, IAGLR Communications Director, with copy editing assistance from Heather Siersma

IN MEMORIUM: JOSEPH HENRY LEACH (1931 –2019)

A true friend of the Great Lakes has passed away, leaving a legacy of accomplishments to protect and conserve one of the most important ecosystems on Earth. Joseph Leach graduated from the Ontario Agricultural College (Guelph, Ontario) in 1954. While his early career focused on banking, he eventually returned to academia and, in 1969, received his doctorate at the University of Aberdeen, Scotland. As a research scientist in the Ontario Ministry of Natural Resources in Wheatley, Ontario, Joe's research interests were holistic in nature and focused on the lower food web of Lake Erie with respect to sustaining the sport and commercial fisheries of the lake. He also was a strong advocate for comparative ecology, and using this framework played a major role in leading research efforts to quantify the effects of the zebra mussel invasion on the structure and dynamics of Great Lakes food webs.

Joe served as IAGLR president and organized its 21st annual conference in 1978. He received IAGLR's Anderson-Everett Award (1992) and Lifetime Achievement Award (2008) for his dedication and commitment to Great Lakes research. He served on many committees of both the Great Lakes Fishery Commission and the International Joint Commission and thus played a major role in integrating fisheries and water quality management. Perhaps his greatest contribution was his ability to bring people with different expertise together to develop the science framework for the implementation of the ecosystem management approach endorsed by both Canada and the United States.

With his smile and wisdom, along with a dram of good scotch, Joe stands among the very best of Great Lakes researchers. Thank you, Joe, for your friendship and your many contributions. Your love for the Great Lakes will always be an inspiration for all of us.

—Mark Fitzpatrick and Doug Haffner