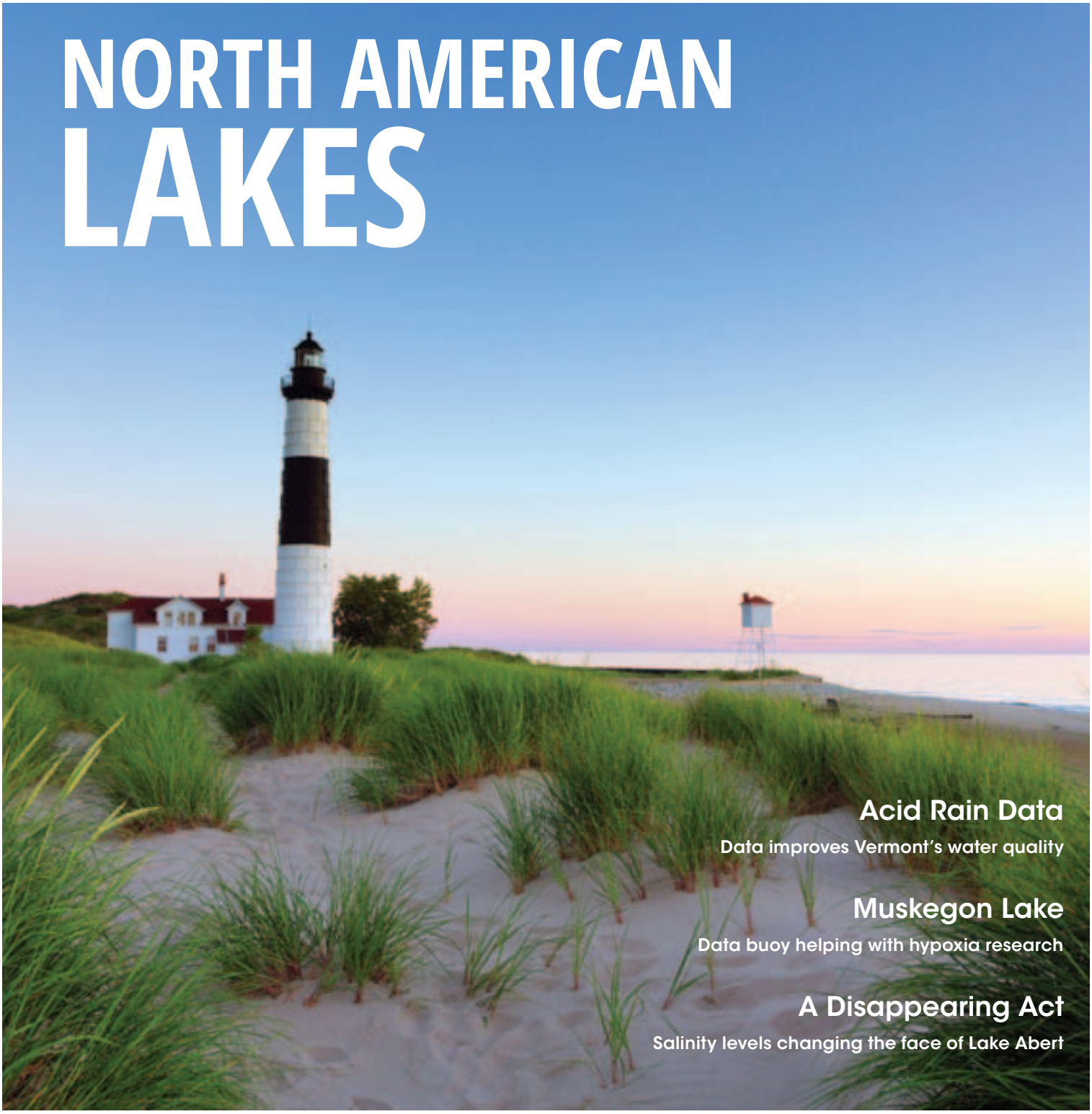
ENVIRONMENTAL
monitor
SUMMER 2018
APPLICATION AND TECHNOLOGY NEWS FOR ENVIRONMENTAL PROFESSIONALS

NORTH AMERICAN LAKES



Acid Rain Data

Data improves Vermont's water quality

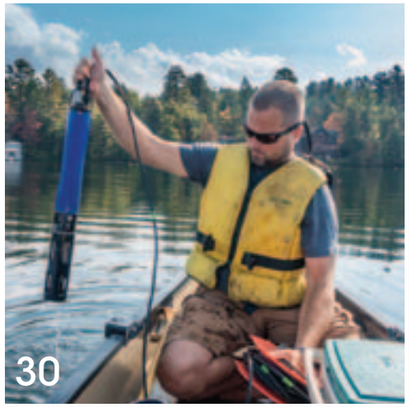
Muskegon Lake

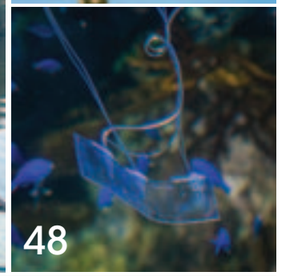
Data buoy helping with hypoxia research

A Disappearing Act

Salinity levels changing the face of Lake Abert

FONDRIEST
ENVIRONMENTAL PRODUCTS





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ENVIRONMENTAL MONITOR | SUMMER 2018

IN THE NEXT EDITION

Environmental research at some of America's most diverse biological field stations will be featured in the next edition. Also included will be an introduction to the newest station, the Fondriest Center for Environmental Studies.

Cover Photo: Big Sable Point Lighthouse in Ludington State Park on Lake Michigan

WELCOME...

Welcome to the Summer 2018 edition of the Environmental Monitor, a quarterly collection of the best of our online news publication. In this edition, we showcase a number of projects taking place in North American lakes.

This includes a look at multiple environmental data buoys collecting data to help with research. The first example is a buoy in Muskegon Lake helping with hypoxia research. The second includes a pair of data buoys that recorded a wave in Lake Superior that reached a record-setting 28.8 feet in height. The buoys collected the data during a storm in October that caused a lot of damage to the coast.

You'll also read about scientists in Vermont using decades worth of acid rain data to help improve water quality. Vermont Department of Environmental Conservation started a long-term monitoring program in the winter of 1979-1980 and has been using the data to prove the efficacy of the Clean Air Act and improve local water quality.

Located in Fairborn, Ohio, Fondriest Environmental is the trusted partner you can turn to for help with environmental monitoring projects. We can assist in everything from planning and monitoring to systems integration, equipment calibration and even staff training. Our applications engineers assemble, integrate and calibrate all equipment – when you get it, it's ready to use. Our specialists have years of experience developing and deploying remote systems and working with leading suppliers such as YSI, Hach, Thermo Scientific, In-Situ, Solinst, NexSens and many more.

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WEB EXCLUSIVES

Read more @ **fondriest.com/news**

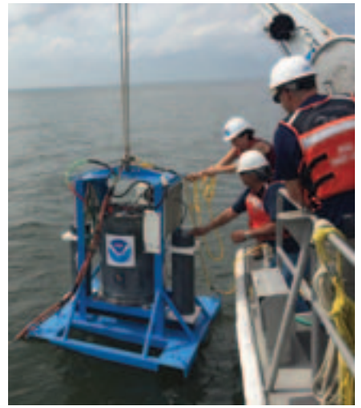
Smart Lake, Healthy Ecosystem: The Jefferson Project at Lake George

The Jefferson Project was begun by researchers at Rensselaer Polytechnic Institute (RPI) in Troy, NY three years ago. The team has gradually transformed Lake George into what is arguably the world's smartest lake, equipped with a tremendous range of sensors and equipment that collect more data points every week than researchers had been able to gather in the 30 years prior to the project's beginning. Project leader Rick Relyea corresponded with EM about the endeavor.

"The Jefferson Project (JP) was inspired by a 30-year study of Lake George by our Rensselaer biologists who documented that the lake was experiencing declining water quality over the decades," Relyea begins.

For the full story: https://www.fondriest.com/news/smart-lake-healthy-ecosystem-jefferson-project-lake-george.htm

Lake Erie HAB Monitoring Network Matures to Protect Drinking Water



When toxic algae in western Lake Erie cut off 500,000 Toledo residents from their tap water in 2014, an effort to cobble together an algae-monitoring sensor network sprang up in the bloom's slimy green wake.

This September, as another bloom spread across the western basin, the coalition of water quality interests behind the project secured more than $2 million in backing to bolster it with the best available toxin-monitoring technology, refine the way it distributes data to the people who need it, and ensure it stays funded well into the future.

"We're really building a sustainable funding model, unifying the network and solidifying it as a permanent observatory," said Ed Verhamme, engineer with LimnoTech, one of the partners on the project.

For the full story: https://www.fondriest.com/news/lake-erie-hab-monitoring-network-matures-protect-drinking-water.htm

Deep-sea Biodiversity Expedition Uncovers Thousands of Creatures

What do more than a dozen new species of crustaceans, Cyclone Marcus, 31 researchers and support staff, more than 40 new records for Indonesia and more than 12,000 marine creatures have in common? The successful South Java Deep-Sea Biodiversity Expedition 2018 (SJADES 2018), of course. Professors Ng and Rahayu led the team on the 14-day expedition. The team returned from their odyssey in April, and Professor Peter Ng, Head of the Lee Kong Chian Natural History Museum of the National University of Singapore, and Professor Dwi Listyo Rahayu, Senior Research Scientist at the Research Center for Oceanography of the Indonesian Institute of Sciences, corresponded with EM about the expedition.

"The overall aim was to see what deep-water animals are in southwestern Java, which is an area not well sampled before," explains Professor Rahayu. "In fact, that whole area has hardly ever been sampled for deep water animals at all."

For the full story: https://www.fondriest.com/news/deep-sea-biodiversity-expedition-uncovers-thousands-of-creatures.htm

Photo: (top) Rensselaer Polytechnic Institute (center) NOAA/GLERL (bottom) SJADES2018

IN THE NEWS

Monitoring and Tracking Ocean Microbes with LRAUVs

Researchers for the University of Hawai'i at Mānoa and Monterey Bay Aquarium Research Institute deployed a small fleet of long-range autonomous underwater vehicles (LRAUVs) in the waters of the Pacific near Hawaii. The LRAUVs automatically collect and archive samples of seawater, enabling scientists to study and track ocean microbes. The team who undertook the expedition was hoping to survey and track Mesoscale eddies within the North Pacific Subtropical Gyre using a suite of oceanographic instruments. Eddies give oceans their swirling, circular motion, as they move against the main water currents of the ecosystem as a whole. The expedition was one-month long, divided into two, two-week long legs.

Now that the LRAUVs have all been recovered and are back in the lab, the team can extract DNA from their filters. The DNA can show how long eddies last, how stable they are, and how they influence ocean systems. The team will use this data to improve current ocean models and, by extension, the predictions of ocean health in the future.

Jacques Cousteau NERR Serves Up Vast Research Possibilities

The 116,000 acres of the Jacques Cousteau National Estuarine Research Reserve (JC NERR) on the coast of New Jersey flourishes with both animals and researchers. Gregg Sakowicz, Field Researcher at Rutgers University and System-Wide Monitoring Program (SWMP) Coordinator at JC NERR has been working at JC NERR since 2003. He and other NERR trainers help to educate new field technicians on SWMP protocol and how to use monitoring equipment.

In addition to the SWMP protocols followed, Sakowicz and others at JC NERR also develop new protocols within the ones provided by the area's NERR. The intent is to expand upon the successful, existing SWMP protocols in place. "We use sondes to gather data on dissolved oxygen, temperature, conductivity, pH, and turbidity. We also conduct a complimentary sampling program that tracks nutrients like nitrogen, phosphorus, and ammonium. We were using YSI 6 series sondes in the early years, but we were able to upgrade following Hurricane Sandy in 2012, and now we've graduated to the newer EXO2 sondes. We would also like to add the total algal probe" said Sakowicz.

Riverkeeper Initiative Tackles Water Monitoring, Activism And Education

Coosa River is a vital part of the communities surrounding it. The river provides drinking water to several municipalities as well as recreation to the citizens. The river is also home to close to 30 endemic species that can't be found anywhere else, the highest percentage in North America. The Coosa River Basin Initiative (CRBI) ensures that surrounding facilities adhere to the standards of the U.S. Environmental Protection Agency's Clean Water Act.

A grassroots environmental protection organization, the CRBI volunteers to protect the Coosa River in Georgia, and is forming a water monitoring partnership with the Berry College Environmental Science program.

The CBRI trains volunteers how to collect monthly water samples from select data points along the river using Lamotte monitoring kits. Now, due to the partnership with Berry College, CBRI will have access to more water monitoring equipment. The tentative plan includes college staff training CBRI volunteers to use equipment including GPS-enabled data loggers. Students of Berry College will also use data collected from the river for their research.

Photo: (left) Catlin Seaview Survey; (center) Patricia McHugh (right) CRBI

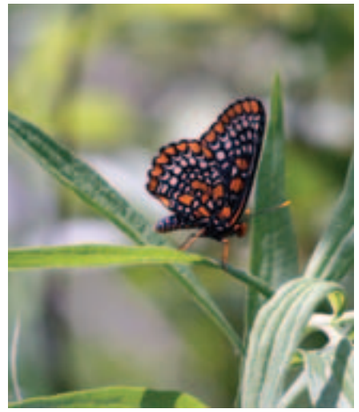
Photo: (left) Ariffin Sandhi, (CC BY-NC-ND 4.0) (Right) Mike Mushala

Thirsty Moss Can Remove Arsenic From Drinking Water

Researchers in Sweden have discovered an aquatic moss, Warnstorfia fluitans, that can remove arsenic from drinking water. The Stockholm University (SU) study found that in a single hour, the moss can reduce the arsenic level low enough to render previously non-potable water safe to drink.

For many Americans that rely on private wells, arsenic contamination is a problem. Arsenic can enter the water supply in various ways including naturally occurring deposits in the ground or agriculture and industrial pollution.

Associate professor Dr. Maria Greger at SU conducted experiments with the moss at mine sites where sediment contains high levels of arsenic. The team used samples of water from the mine sites and found that the moss removed 80 percent of the arsenic in one hour, rendering it safe. The team also investigated how effective the moss is with irrigation water since arsenic contamination in food is also a serious problem. Dr. Greger and the team will now be working towards practical applications of the moss through PhytoEnvitech AB, their remediation company.



The Baltimore Checkerspot at the Beaver Creek Wetlands

The Baltimore Checkerspot, a native butterfly, decreasing in numbers, mostly due to a loss of wetlands. In Ohio, 90% of wetlands are now gone. Incredibly, there is still a place in Ohio where the Baltimore Checkerspot is thriving: Siebenthaler Fen, one of the areas in the Beaver Creek Wetlands. The wetlands consist of a 10-mile corridor with a few roads interrupting it. Fen fed, the wetlands are the sole source of water for most of Greene County, Ohio. Areas of the wetlands that have seen high levels of phosphorus are believed to have come from neighboring homes and golf course runoff.

Jim Amon, Vice President of Beaver Creek Wetland Association, has used a YSI XLM600 sonde to measure temperature, conductivity, salinity, pH, depth and dissolved oxygen in Beaver Creek areas. Such efforts were supported by grants and involved participation by Wright State University students. Students have also monitored the flow of nitrogen and phosphorus through the groundwater of the wetlands and creeks within the BCW corridor and looked at overall groundwater quality.

Caribbean Community Climate Change Centre

In March this year, the Caribbean Community Climate Change Centre (CCCCC) began installation of five new data buoys to expand the Caribbean Coral Reef Early Warning System (CREWS) Network to enhance the regions ability to monitor and study the effects of warming seas.

The installation is being carried out in collaboration with the National Oceanic and Atmospheric Administration (NOAA) and with the assistance of the governments of the recipient countries of Antigua and Barbuda, Grenada, Saint Lucia, St. Kitts and St. Vincent and the Grenadines.

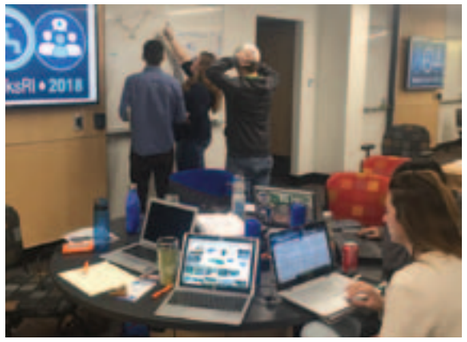
The purchase and installation of the buoys were funded under the United States Agency for International Development's (USAID) Climate Change Adaptation Program (CCAP) which is being implemented by the Center. The expansion of the CREWS Network is aimed at enhancing the collection and availability of critical data from across the Eastern Caribbean by increasing the data points, and improving the region's ability to track changes in a range of environmental variables including sea temperature and water quality.

The Center's partnership with NOAA is part of a global coral reef monitoring network. The new CREWS stations have already begun to provide additional information to Caribbean scientists and researchers to monitor reef health, sea temperature changes, winds (speed and gusts), barometric pressure, precipitation, photo-synthetically active/available radiation (PAR, light), air temperature, and salinity. Other instruments may be added through arrangement with the host countries.

Under a previous sponsorship arrangement, CREWS stations were installed in Belize, Trinidad & Tobago, the Dominican Republic, and Barbados.

Photo: CCCCC

Water Quality Hackathon | University of Rhode Island



All over the United States (and the world) water quality issues are cropping up. Contaminants, aging infrastructure, and new products that have implications for water quality are causing concerns every day. The University of Rhode Island (URI) is hoping that innovative students will help solve some of these problems at the Water Quality Hackathon, March 2 through March 4, 2018.

Hackathon co-organizer Vinka Oyanedel-Craver, an associate professor of civil and environmental engineering at URI, spoke to EM about the plans for the event.

"The event was conceived of as part of the proposed activities in a National Science Foundation award called SCC-Planning: Smart and Connected Residential Water Quality Communities," Oyanedel-Craver explains. "This is a very interdisciplinary proposal with faculty from civil and environmental and Biomedical/Electrical Engineering, working with faculty from Political Science and Behavioral Science, to understand how we can educate residents to collect water quality data in their homes to be used in connection with information collected by water utilities to create a large monitoring network of water quality."

During the hackathon, URI students and students from other colleges will form teams, generate ideas, and then design and build their water quality solutions. Their designs will qualify in the competition for a $1,000 prize if they can improve water monitoring, quality, education and/or communications. The organizers ultimately hope to achieve several goals with this exciting event.

"We hope that students learn more about the problem, generate solutions, and come up with a proof-of-concept to display or show to other participants," details Oyanedel-Craver. "We have also contacted professionals from other academic institutions, companies and state organizations who will participate as mentors or judges to help the student teams to put their ideas into context and see the relevance of their proposed solutions."

Although URI has organized other Hacks, this is the first Water Quality Hackathon for the institution. They are expecting around ten teams of 4 to 6 students, and about 15 mentors and seven judges from different organization and agencies. Successful water hacks have taken place from New Orleans to South Africa, and URI is hoping their hackathon will follow those examples.

One of the truly exciting aspects of the competition is that even the organizers can't be sure what the participants will produce.

"The great thing about these Hacks is that you do not really know what the student teams will come up with," remarks Oyanedel-Craver. "I obviously have my ideas of what I would like to see, but I am really waiting for the student teams. I believe they will wow me with solutions I have not even thought about. I have hope in Millennials!"

Another important aspect of the Hackathon, as conceived of here, is the emphasis on interdisciplinary collaboration.

"I think our work is novel based on the great balance we have achieved among the disparate disciplines such as engineering, social sciences, and health sciences," adds Oyanedel-Craver. "This is so important in the context of working with members of the public to bring them in as active participants in scenarios that have been traditionally restricted to people with medium to high levels of technical expertise."

The fact is that even people with a less technical background have plenty to offer in this context—and everything to gain.

"Advances in portable devices and sensors are allowing people with minimal training to collect meaningful information, and we need to use this fact to develop better monitoring systems that could be useful not only for every day monitoring but also in case of emergency situations," asserts Oyanedel-Craver.

So, if you're in New England or willing to travel, consider checking in at the URI Water Quality Hackathon this weekend.

"You are more than welcome to visit anytime during the weekend, the event is open to everybody," states Oyanedel-Craver.

Photos: (Left) Vinka Oyanedel-Craver / (Right) Michael Salerno

Water Quality Testing | Illinois State University

A new laboratory at Illinois State University is providing important water quality analysis for local agencies and an invaluable learning experience for students.

The university's Department of Geography, Geology, and the Environment opened the Laboratory for Environmental Analysis (LEA) in 2017. The laboratory's first full year was a resounding success with 6,700 water quality samples tested for dissolved nutrients and the employment of graduate and undergraduate students.

"We currently have four internal clients just from our university and seven external clients for which we perform analysis," said Dr. Bill Perry, director of the laboratory.

The LEA evolved from the need to study local water sources to examine how certain farming practices could affect water quality in the streams entering Lakes Bloomington and Evergreen. The two lakes provide water to Bloomington, Illinois residents.

"The streams leading into the lakes have occasionally exceeded the drinking water nitrate limit and have to go through a mediation process," explained Perry. "The water at various times has been above 11-15 milligrams of nitrate-nitrogen per liter. Because of that, many agencies and universities want to know what is entering the lakes."

Aside from scientists and students at Illinois State University, those interested in learning more about water quality in regional streams include the Environmental Protection Agency, Nutrient Research Education Council, The Nature Conservancy, Illinois Corn Growers Association, City of Bloomington, the University of Illinois Urbana-Champaign and the University of Illinois-Springfield.

The local agricultural industry, comprised of mainly corn and soybean farms, is the main cause of the high nitrate levels. According to Perry, the primary focus of most of the research is the need to understand how current and alternative sustainable farming practices affect the water quality. Between 2000-2013, the number of testing samples brought to the university for testing steadily grew.

"In 2013, we applied for a National Science Foundation major instrumentation grant and were able to purchase a flow injection analysis machine that allowed us to run many samples, much faster," said Perry.

The U.S. Department of Agriculture aided the university's Department of Geography, Geology, and the Environment in its efforts to test and learn from local water quality. The new laboratory provides a centralized place for testing.

"The laboratory currently has $2 million in grants from a variety of sources that help with equipment and paying our personnel," said Perry. "We also charge per sample to help pay our laboratory manager and other student workers."

Perry and Illinois State University are dedicated to making the LEA an informative learning experience for students.

"Working in the laboratory gives students hands-on experience in a cutting-edge laboratory that uses EPA certified methods and quality analysis/quality control that are used in the real world," said Perry, "They also learn how to manage the data and work with data sharing methods."

Perry also provides additional instruction on how to manage large volumes of data.

With the new facility up and running and solid educational experiences in place for students, the LEA team is now looking towards next steps and growth. The team plans to apply for additional grants to add more equipment and testing capabilities.

"Ideally, we would like to renovate more space and continue our work with the community," said Perry.

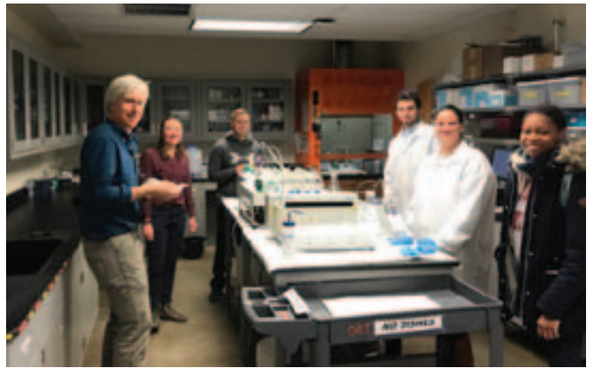


Photo: Illinois State University Laboratory of Environmental Analysis

CB-50 DATA BUOY

NexSens Technology's Latest Water Quality Buoy

The NexSens CB-50 Data Buoy is designed for quick and easy deployment as well as retrieval in lakes, rivers, estuaries, and coastal waters. The buoy is in use worldwide for limnology studies, source water protection, compliance monitoring and emergency response. The buoy can be deployed from small boats, large vessels or even helicopters, making it the ideal choice for applications where water needs to be monitored at a moment's notice or in situations where larger platforms will not work.

When fitted with the NexSens SDL V2 Data Logger, the CB-50 is compatible with a variety of instruments including turbidity sensors, dissolved oxygen sensors, temperature strings, hydrocarbon sensors, fluorometers, multi-parameter sondes, and more. The SDL V2 supports (16) D-size alkaline batteries, and in many situations, provides adequate power for an entire project or season without the need for battery replacement. No solar panels are needed, which further support the compact size and low profile.

The buoy is often deployed with 3/8 chain and a 50 - 70 lb anchor from an integral bottom eye as a single point mooring. Built from the same materials as the larger CB-series buoys including a 316 stainless steel frame, closed cell polyethylene foam and an abrasion resistant polymer coating, the CB-50 will endure the roughest of seas.

NAVIGATION LIGHT

The optional solar marine light has a one to three nautical mile range and securely mounts to the buoys top plate for maximum visibility.

BUOY HULL

Constructed of cross-linked, closed-cell polyethylene foam with a heavy polymer skin, the buoy is abrasion resistant and designed to last for years.

DATA LOGGER

The CB-50 accommodates the NexSens SDL V2 submersible data logging system, which includes an integrated power supply and optional wireless telemetry.

BUOY FRAME

An indestructible, heavy-wall 316 stainless steel frame provides support for the foam hull. The frame can be fitted with sacrificial zinc anodes.

All photos: NexSens Technology

Dr. Nancy Rabalais and members of the LUMCON team prepare to deploy a Sea-Bird Scientific SBE 32 carousel water sampler with a CTD into the Gulf of Mexico.

BATTLING THE DEAD ZONE

BY MINDY COOPER

During the summer of 2017, researchers with the Louisiana Universities Marine Consortium (LUMCON) and Louisiana State University mapped the largest dead zone in the Gulf of Mexico to date.

The Gulf of Mexico meets the shorelines of Alabama, Louisiana, Mississippi, Texas and western Florida and is home to a large fishing industry. Several rivers from the Midwestern watershed flow south into the Gulf, carrying with them sediment, nutrient loads and pollution from fossil fuel burning and wastewater systems.

The problem isn't new, but it is expanding.

Though no consistent data existed before 1985, it is suspected that all of the runoff started becoming a problem in the 1970s, according to Dr. Nancy Rabalais, a marine ecologist, and professor at Louisiana State University. Rabalais, who also holds a position with LUMCON, has led the annual Gulf of Mexico research trip since 1985.

"We think the problem started when the use of nitrates started increasing in the 1950s," Rabalais said. "Based on sediment core testing, it wasn't an issue until the 1970s."

Each year with funding from the National Oceanic and Atmospheric Administration, Rabalais leads a small team of scientists on a weeklong boat trip around the Gulf of Mexico to gather data. Over the last three decades, the team gathered data in an ever-expanding dead zone spanning from May through October. According to NOAA, a dead zone is a low-oxygen area in an ocean or a large lake caused by nutrient pollution from human activities and other factors that deplete the oxygen required to support most marine life.

Each year the U.S. Geological Survey office releases a report on the nutrient loading levels from October to May. Scientists use the data in the report to develop a size estimate of the dead zone in the Gulf of Mexico. With that estimate in hand, the LUMCON team spends a week out in the Gulf gathering samples.

For the trip, the team uses LUMCON's research vessel, the R/V Pelican. The Pelican is a 116- foot oceanographic research boat that is designated as a Universities National Oceanographic Laboratory System vessel. Its capabilities include scientific trawling, large box core sampling, shallow seismic surveys, plankton sampling, and underway sampling with towed water sampling. Users of the vessel are able to select scientific equipment based on research goals.

During the Gulf of Mexico trip, Rabalais' team conducted both water and sediment sampling from 90 data points along the Louisiana coast between the Mississippi River and Galveston. The team used a Sea-Bird Scientific SBE 32 carousel water sampler with a CTD and 12 Ocean Test Equipment Niskin bottles. The system was lowered into the water at each data point and was electronically programmed to measure water quality and close the bottles at specified depths to collect samples. The team also used a box corer to collect bottom sediment and a simple bucket drop to collect surface water for suspended elements.

All of the water samples were tested for inorganic nutrients and chlorophyll. The team also checked salinity and dissolved oxygen levels.

All Photos: LUMCON

116 -foot long oceanographic research boat named the R/V Pelican

"The inorganic nutrients like nitrate, ammonia, ortho-phosphate, and silicate stimulate phytoplankton growth," said Rabalais. "Phytoplankton contributes to high carbon levels at the bottom and its decomposition leads to low oxygen."

Once the oxygen level drops below two milligrams per liter, the area is uninhabitable by marine life. The fish and shrimp will migrate to another area if they can, but those that can't flee will die. During this time, a fishing trawler will not catch any fish in its net.

"This year we saw very low oxygen levels, less than 0.5 milligrams per liter at the nearshore area," said Rabalais.

The dead zone on the 2017 trip measured 8,776 square miles, less than the 10,089 originally projected, but was still roughly the size of New Jersey and the largest to date.

The average size for the last five years is 5,806 square miles.

"The dead zone this year was 4.5 times larger than the Mississippi River Nutrient/Hypoxia Task Force's goal of 1,900 square miles," said Rabalais.

Using the data from each of the 90 sampling locations, the LUMCON team creates a map of the dead zone. The data are used by the Mississippi River Nutrient/Hypoxia Task Force whose mission is to mitigate nitrogen and phosphorus loads in the river. NOAA and the Environmental Protection Agency also use the data. The National Center for Environmental Information makes the data available to the fishing industry as well.

With more than 30 years of data to support the growing dead zone and its causes, one may assume that fixing the problem is a given. That doesn't appear to be the case.

"There are a lot of people and agencies trying to make a difference but we haven't seen a decrease in the May nitrate load," said Rabalais. "The dead zone has been a large area for a very long time."

However, there is hope that the sheer size of the 2017 dead zone will result in changes.

"With this being the largest one that we've mapped to date, there was a lot of press interest," said Rabalais. "There is a lot of education and outreach happening."

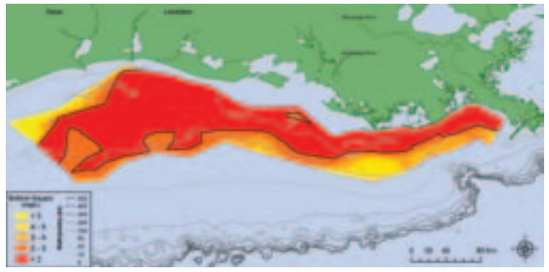
In the meantime, the seasons continue to change bringing an end to the dead zone each year. When cold fronts or hurricanes move in, the water turns over and then there is plenty of oxygen. The fish and shrimp will return even if the ecosystem isn't fully functional.

"At the end of the season there is a lot less food for any returning fish or shrimp," said Rabalais. "There is decreased biomass and biodiversity, and other indicators of an ecosystem that is not functioning."

There is also a possible limit to how large the dead zone can be due to dilution of the nutrients or the strength of the stratification further offshore. But although the size could be limited, the oxygen levels can still plummet.

Long-term changes to the situation require a change in the use of nitrates in agricultural practices. Until that happens, Rabalais remains committed to documenting the situation.

"I hope that the trip funding continues to be available because it decreases every year," said Rabalais. "If you don't know how large the dead zone is, you can't make management decisions."



The 2017 Gulf of Mexico dead zone map. The map was created with data collected by the LUMCON research team.

ACID RAIN DATA DRIVING CHANGE

Left: Dr. Harvey readies the equipment.

The Vermont Department of Environmental Conservation is using decades of acid rain data to improve the state's water quality and monitor for problems.

BY KARLA LANT

Since the 1980s, scientists from the Vermont Department of Environmental Conservation (VT DEC) have been sampling water from acid-impaired ponds and lakes and tracking data related to acidity. The line of inquiry began in response to concerns about acid rain, but DEC scientists now find that the long-term monitoring is not only proving the efficacy of the Clean Air Act but also improving local water quality.

GUARDING THE ENVIRONMENT IN VERMONT

Rebecca Harvey is a VT DEC scientist, and monitoring the state's waterways for acidity and other problems falls in part to her. Dr. Harvey corresponded with EM about this work.

"Vermont is relatively pristine compared to other areas of the country and world, and we (VT DEC) are working very hard to keep it that way," explains Dr. Harvey. "We do have lakes and ponds that are threatened by nutrient loading due to land use, but these nutrient levels are generally still much lower than those measured in lakes/ponds in more heavily populated or farmed areas. We are also observing some interesting trends that seem to suggest that our most pristine lakes are declining in water quality at a greater rate than higher nutrient lakes, which is also of concern and suggests that we need to invest more resources in protecting those areas before we lose them."

The VT DEC has been sampling from lakes and ponds and analyzing samples taken for decades. The Vermont Long Term Monitoring (VLTM) Program was established in the winter of 1979/1980 in response to trends in acidification across the northeast.

"The three main objectives of the program were to 1. determine the current chemical characteristics of the study lakes, 2. estimate seasonal and annual variability in chemical characteristics, and 3. investigate long-term changes in chemical characteristics," Dr. Harvey describes. "By 1982, 184 lakes had been chemically surveyed. From this preliminary screening, 36 lakes were chosen to be chemically monitored on a long-term basis."

All Photos: Dr. Harvey

The VT DEC also completed fish and macroinvertebrate surveys in 1983 and 1987, respectively, on a subset of these ponds. By 1988, limitations in resources mandated that the program be reduced to 25 ponds, and again in 1993, the number dropped, this time to 12 ponds. These 12 ponds are still monitored by the VT DEC at least three times per year.

"Initially, the program monitored pH, gran alkalinity, color, Secchi disk transparency and conductivity, but as we have learned more about recovery from acidification and as our analytical tools have improved, we've since added dissolved ions (Ca2+ Mg2+, Na+, K+, Al, SO42-, NO3- and Cl), silica, total phosphorus, speciated aluminum, and dissolved organic/inorganic carbon (DOC and DIC), to the suite of chemical analyses that we perform," Dr. Harvey details. "Simultaneously, sister programs were initiated in the late 1970s that focused on monitoring nutrients in Lake Champlain and lower elevation 'in-land' lakes throughout Vermont."

SAMPLING WATER ALL OVER THE STATE

Dr. Harvey works hard to get the samples she needs. Each site was selected decades ago, and this consistent sampling has allowed the VT DEC to accumulate years of data about each remote location.

"Sampling locations were established when the program was developed in the 1980s," clarifies Dr. Harvey. "The idea was to focus on lakes that were only impacted by atmospheric deposition and no other anthropogenic impacts such as roads, housing, ski areas, or logging. We sample ponds that are determined to be particularly sensitive to acid precipitation; they are at high elevation and within watersheds dominated by soils and bedrock geology that have low buffering capacity."

Taking a water sample.

During the winter, she uses cross-country skis to access some sampling sites, and some ponds are frozen over. These remote sites offer data that aren't affected by agricultural runoff, road salt, or any other pollutants inherent to more developed areas. It's worth the trouble of clambering out to these areas, even in cold weather, because winter and early spring data offer valuable insights to the VT DEC, revealing how much acid is entering waterways as the snowpack melts.

"Over the course of the winter, snow and pollutants carried on prevailing winds deposit and build up on the snowpack," remarks Dr. Harvey. "In the spring, as temperatures rise and rain melts the snowpack, that accumulation of acidic pollutants hits the lakes and streams over a short period of time. This can cause a quick depression of the pH during a vulnerable time of the year for aquatic life."

These drastic changes in acidity can have serious impacts on the fish and other aquatic life in these waterways.

There is a unique protocol for sampling during each season.

"During the summer (the stratified period), we sample both the epilimnion and hypolimnion at the deepest point of the lake," states Dr. Harvey. "During the fall we sample 1 meter deep only after the lake has mixed (also at the deepest point of the lake), and during the spring we sample at a depth of 1 meter, before the lake has stratified (also at the deepest point). In the spring we also sample the outlets of 7 of the core 12 ponds."

THE RIGHT TOOLS FOR THE JOB

Dr. Harvey and the other members of the VT DEC team are helping to implement a monitoring plan that started decades ago, but they are doing so with the help of newer technologies. For example, during the spring Dr. Harvey works to capture the "acid shock" from melting snow with an automatic sampler.

"We use an ISCO sampler, which is a widely used automatic sampler," explains Dr. Harvey. "It has a pneumatic pump that samples a known volume from the outlet at a known frequency. We have it set up to sample 500 mL every 48 hours at ~noon, but it is fully customizable to sample at whatever frequency the user decides. I visit the sampler about once per week to collect the samples."

At times the most important equipment for Dr. Harvey is whatever helps get her to the sampling site—and sampling equipment she can port there with her.

"Many of our ponds are not easily accessible and require up to 45-60 min of hiking to reach them," Dr. Harvey details. "We use an inflatable raft to access the deepest point of the lake in these cases. We use a Kemmerer to sample at discrete depths in the lake. We collect temperature and conductivity depth profiles using a hand-held YSI meter. During the springtime, we also use a Hydrolab multiprobe with a DO and pH sensor to measure DO/pH profiles."

Once back at the lab, Dr. Harvey and the team analyze some samples themselves and send others out for analysis.

"We perform some analyses ourselves, including measuring pH with a probe, the acid neutralizing capacity using the Gran

titration method, absorbance at 420 nm with a spectrophotometer and color using a visual color comparator," describes Dr. Harvey. "Otherwise, our samples go to the state-run Vermont Agricultural and Environmental Laboratory (VAEL). VAEL is an EPA-certified lab run by state chemists and use an ion chromatograph for dissolved ions, an ICP-MS for metals (including speciated aluminum) and total carbon analyzer for DOC and DIC. We also send split samples to the University of Maine Sawyer Environmental and Research Laboratory for DOC and speciated aluminum."

A RICH CACHE OF DATA PROTECTING THE "AIRSHED"

With such a rich store of data, the VT DEC has a range of options for using it. They have plans in the works for modeling and other data-driven projects.

"We do have an expansive data set, and the opportunities for research are limitless," remarks Dr. Harvey. "We have been focusing on teasing out long-term trends for key chemical and physical parameters recently and have also contributed our data to global initiatives. Our current goal is to use these data to better understand recovery processes in our lakes and ponds."

> **"ACIDIFICATION IS ALSO A VERY COMPLEX CHEMICAL PROCESS, THE MORE WE COME TO UNDERSTAND IT, THE MORE QUESTIONS WE HAVE"**
>
> **- Dr. Rebecca Harvey**
> Vermont Department of Environmental Conservation

Left: Working in the field.

One potentially powerful use for the data is allowing for comparisons with watersheds with more anthropogenic impacts since these waterways are so pristine. Other than what falls from the sky, these ponds have very few inputs changing their chemistries.

"They can serve as models of the water quality status of lakes had development never occurred," states Dr. Harvey. "This lack of anthropogenic influence (besides atmospheric deposition) also allows for interesting comparisons to be made, and for us to investigate the impacts of climate change."

Dr. Harvey has also been working with a DEC statistician and modeler to deal with the problem of censored data.

"The concentration of ions in acid lakes tends to be small, so we can get results that are reported as '<' the detection limit, such as nitrate and potassium," explains Dr. Harvey. "Other times, a data point is missing altogether. To conduct robust trends analysis, we have calculated substitution values that will have the least likelihood to skew the data. Dealing with censored data appropriately is very important yet often gets little consideration by long-term monitoring programs. Improper use of censored data can introduce alien trends and false summary statistics."

Of course, more research and data often prompts more lines of inquiry. "Acidification is also a very complex chemical process, the more we come to understand it, the more questions we have," adds Dr. Harvey.

One of the issues that the decades of data have clarified for Dr. Harvey is the issue of seeing pollution within the big picture.

"Air pollution doesn't care about political boundaries, in thinking about acid precipitation and its impacts on terrestrial and water surfaces," Dr. Harvey states. "So we need to look at the big picture (spatially) and think in terms of 'airsheds,' analogous to 'watersheds.'" KL

Photo: Dr. Harvey

Photo: Ben Haas

FLOATING ISLANDS

Racine County Parks Department uses DIY floating islands to kickoff the Quarry Lake water quality improvement program.

BY MINDY COOPER

A water quality improvement and monitoring program kicked off with innovative, handmade floating islands in one Racine County, Wisconsin park.

Quarry Lake, located in Quarry Lake Park in the city of Racine and the village of Mount Pleasant, was originally a man-made limestone quarry but is now a spring-fed lake. It's a popular location for swimming, scuba diving and fishing. For several decades, the lake experienced algae formation that can prevent its use for popular recreation activities.

Because of this, the county allocated a small amount of funding for studying and improving the lake's water quality.

"There were a few options on the table, as far as how to improve the water quality," said Ben Haas, a park manager for the Racine County Parks Department. "We wanted to focus on treating the water naturally. To get started, the County Board selected a plan developed by Dr. Stephen Lyon from SRL Environmental, University of Wisconsin-Parkside's Professor Joy Wolf."

The plan involved the incorporation of different natural methods for treating the water and converting the sediment. After coring, the sediment will be analyzed so that the researchers know the ideal amount of amendments to add for the conversion. Further down the line, the department will establish regular sampling of both the water and sediment.

The initial part of the plan involved the installation of floating islands constructed with native bulrush plants at specific points throughout the lake. The plants are expected to naturally filter the sediment that is contributing to the algae problem. The floating islands are a low-cost, low-tech option, constructed by the parks department staff and volunteers from PVC pipes, milk crates and bulrush plants.

Each floating island cost roughly $125.

Before selecting the locations for the floating islands, the park department conducted a bathymetry mapping exercise using Garmin Echomap Sonar data and ArcMap software. From that map, the department selected 10 locations best suited for the floating islands and installed them.

The mapping exercise also provided a valuable, in-depth look at the bottom of the lake and the sediment.

"We need to understand what is happening at the bottom of the lake to figure out what is contributing to the algae blooms," said Haas. "We need to understand the sediment to know about the nutrient loads and minimize further algae occurrences."

The team was able to identify where to deploy the floating islands and the best locations to begin regularly sampling the water and the sediment. They will be taking samples from different locations, at different depths to get an accurate picture of what is happening in the water.

"We are trying to do two things. First, we want to provide Racine County with the best water quality data possible for decision making and that is why we are working to establish regular sampling practices," said Haas. "Second, we want to prove that these natural methods, like the floating islands, are effective."

To do this Lyon set up a method of testing the quality of the water going through the islands. After surrounding the floating islands with geotextiles, the team set up a solar-powered submersible pump to move water through the floating islands and test for total suspended solids at the beginning, middle, and end.

"Our hope is to gather enough data to show that the methods are effective. Hopefully, this will lead to more floating islands and people getting back to the lake," said Haas. MC

GRAND LAKE ST. MARYS WATER QUALITY

BY KARLA LANT

A recent study reveals that best management practices for impaired Grand Lake St. Marys has resulted in much less runoff and lower nutrient levels.

How does a lake go from being the Environmental Protection Agency's (EPA's) poster child for cyanobacteria to being in recovery and improving annually? With a concerted community effort, best water quality management practices, and patience. At least, recent research from Stephen Jacquemin, associate professor of biology and research coordinator at the Wright State University-Lake Campus, proves that it's working for Grand Lake St. Marys.

A SERENDIPITOUS STARTING POINT

"When you Google harmful algal blooms and cyanobacteria, the EPA website pops up with Grand Lake right on that page," explains Jacquemin. "At one point Grand Lake was close to the 99th percentile for cyanobacterial blooms. There are certain times of the year where it's literally off the charts."

However, for Jacquemin and his team, knowing what the problem is, means having the ability to generate solutions.

"It's not an impossible situation; we know the cause, it's nutrient pollution," details Jacquemin. "Agriculture is a global engine, not a portion of the economy that you want to shut down, but you have to find a way to do it sustainably."

The water quality of Grand Lake St. Marys has improved significantly over the past ten years, and the study illustrates with data and graphics how agricultural runoff, other nutrients, and new best management practices have affected it.

"There's about a decade's worth of data; the data set that we published on was a long-term data set involving daily water collection that was done by the National Center for Water Quality Monitoring out of Heidelberg University," Jacquemin describes. "The streams are monitored three times a day."

For the past six decades or longer, the National Center for Water Quality has been trying to establish a baseline in the watershed. Jacquemin and the team, therefore, started with a rich source of data although analyzing it took some careful work and a model that could handle the job.

"We created a model that would accommodate a number of different covariates," states Jacquemin. "Water quality data and nutrient data is really kind of problematic from a mathematical perspective. There's a lot of values that are below detection limits, which means you have a lot of values that are close to zero, but you also have a lot of values that are really really high, and not a lot of values in the middle."

Because water quality data also follow whatever flow the water offers, the problem is that much more complex and nonlinear. "We were able to compare the two time periods mathematically, and we were also able to do it visually," adds Jacquemin. "I think that's the most powerful part of the paper; even if you're not a stats person, you can just look, and you can understand this work because you can see trends in the graphics."

Mandatory measures are really just the beginning when it comes to reducing nutrient runoff into Grand Lake, and both Jacquemin and the members of the community know it.

"Grand Lake's really kind of a unique system; it's unlike any place I've worked," explains Jacquemin. "I have found that the folks in the communities that surround the lake are some of the most informed, in terms of water quality issues, I have ever been around. You could walk into a restaurant and you could just randomly ask someone about a water quality question or issue in this community, you say cyanobacteria, people know and it's interesting. I think that helps a lot."

Photos: Phillip Poore

LOOKING INTO THE FUTURE

"This study documents some unbelievably important reductions, some over 50 percent," remarks Jacquemin. "These reductions were most apparent in medium and high flows, which are the most important flows because those are the ones that are the source of the nutrient load. We saw a reduction of between 20 and 60 percent across those—it was really substantial."

However, although the program is a great success, the lake is still a work in progress.

"We're not there yet; here's why," states Jacquemin. "Our starting point was so high, that even though we've come down, we are still higher than most. I emphasize again, this is a success story, but we have so much work to do in the region, and it really needs to be a kind of collective effort."

For people who live near Grand Lake, many of these best practices are visible—another source of pride and evidence of a long-term plan that's working.

"You can see grass waterways where you didn't see them before next to the streams," remarks Jacquemin. "You can see some of the massive wetlands that are being used to filter water before it goes into the lake. We have two artificial, constructed wetlands, and there's another two that are in the works right now. These wetlands can process like 3 million gallons a day in some cases."

Will Grand Lake and its community reach the end goal of a pristine body of water? The data can't tell anyone that—but it certainly proves progress in the right direction.

"I don't have a time frame, I don't know when Grand Lake is going to be crystal clear, or even if it ever will be," adds Jacquemin. "I know that even if it won't be perfect, that doesn't mean that it's not worth it. It's the natural environment; it's worth everything." KL

CHESAPEAKE BAY'S SAV

Efforts to Reduce Stormwater and Nutrients Helping Chesapeake Bay's SAV

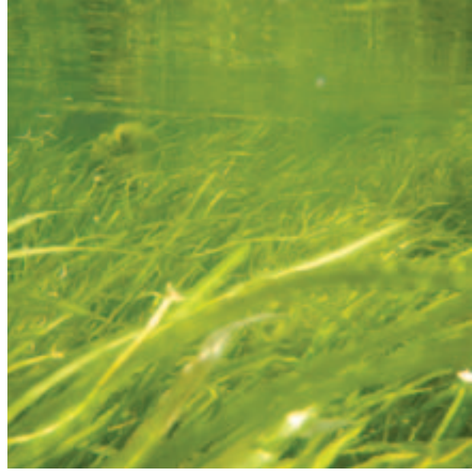
BY KARLA LANT

Photo: Cassie Gurbisz / St. Mary's College

The Chesapeake Bay has been the site of an ongoing water quality and pollution battle for years. In the 1970s, dead fish floated in the Bay along with algae and garbage. A delicate ecosystem at the heart of a heavily populated part of the country, scientists, policymakers and citizens have been working together on each piece of the puzzle in the area. Two of those jigsaw pieces are the stormwater and nutrients that run into the Bay.

Excess nutrients such as nitrogen and phosphorus enter area streams and rivers, and eventually the Chesapeake Bay, nurturing algal blooms and creating harmful conditions for aquatic life. Algal blooms hamper the growth of underwater grasses, and eventually decompose, transforming huge patches of water into suffocating "dead zones." Agricultural, industrial, and urban runoff all produce excess nutrients, and the destruction of habitats and wild areas around the Bay means more impervious surfaces—and fewer chances for the runoff to be absorbed into the ground.

This is where stormwater comes into play. Less stormwater can soak into the ground where it falls in developed areas, and this produces runoff which eventually ends up in the watershed—in this case, the watershed of Chesapeake Bay. Stormwater runoff is far more than just fresh rainwater; it also pulls nutrients, animal waste, chemicals such as petroleum from the road, sediment, and pollution into the water with it. Once there is a fast enough flow, stormwater can also damage stream banks.



Left: *Cassie Gurbisz* ***Middle:*** *Satellite view of Chesapeake Bay* ***Right:*** *Submerged aquatic vegetation*

Photos: (Center) NASA / Jacques Descloitres, MODIS Land Science Team / (Left & Right) Cassie Gurbisz / St. Mary's College

A better understanding of these issues—and the many others that face the Chesapeake Bay—has prompted a number of protective and restorative projects, as well as research in the region. St. Mary's College assistant professor of environmental studies, Cassie Gurbisz, is one of 14 co-authors of a recent study on the progress of long-term reductions of nutrients in the Chesapeake Bay, and she corresponded with EM about the research.

"The EPA Chesapeake Bay Program provided funding for a group of scientists who study submerged aquatic vegetation (SAV) in the Chesapeake Bay to work together to 1) assess what we already know about SAV in the bay and 2) analyze environmental monitoring data to determine what is driving recent trends in SAV abundance," explains Gurbisz.

In the article, the team reports that long-term nutrient reductions have had a positive impact on the ecosystem. Thanks to this reduction—a 23 percent drop in average nitrogen levels and an eight percent drop in average phosphorus levels—together with other restoration incentives, the health of Chesapeake Bay is improving. The resurgence of underwater grasses, now four times more plentiful than before, is most notable to the team, and an unprecedented recovery event worldwide.

What specific activities were the most effective in bringing about this reversal?

"This is still an active area of research," explains Gurbisz. "But preliminary evidence suggests that the largest reductions have resulted from wastewater treatment upgrades. The Clean Air Act has also helped cut nitrogen emissions from power plants and automobiles."

The researchers were able to definitively show that the ecosystem recovery is directly linked to the reduction of excess pollutants like nitrogen and phosphorus. The team connected the state of the Bay and land use by attacking the data in two different ways. They showed how SAV reacts when nutrients are in the water on the one hand, and they also analyzed the cascade of nutrients between the water and the land.

"All of the data came from publicly available environmental monitoring programs," remarks Gurbisz. "For example, the water quality data came from a water quality data hub for the Bay. The SAV data came from the Virginia Institute of Marine Science (VIMS). The watershed data came from satellite imagery and stream monitoring data. A network of many agencies and organizations collect and analyze these data. The Chesapeake Bay Program coordinates the monitoring program, which has been in operation since the early-mid 1980s."

The various participant scientists who undertook the project participated in a series of workshops focused on SAV ecology. This allowed them to collaboratively develop the project's conceptual basis.

"The workshops were funded by the EPA Chesapeake Bay Program with the goal of providing the time and space for scientists to work together to determine what factors are driving recent trends in SAV abundance," details Gurbisz. "SAV recovery is a key goal in restoring the Chesapeake Bay. Local jurisdictions need to know how SAV are doing in their local waters so that they can fine-tune their restoration strategies."

There are two main takeaways from the work. The first is that, although nothing is certain, if nutrient loads stay on track, recovery should continue.

"It's difficult to predict exactly what will happen in the future because other factors, like weather, also play an important role in SAV dynamics," states Gurbisz. "In addition, the recovery is mainly only happening in low-salinity areas of the Bay. However, if nutrient loads continue to decrease, our study suggests that this will help induce further recovery."

The other takeaway? Although this is an inspiring story, now is not the time to get complacent about the restoration of the environment and aquatic ecosystems.

"This is a good-news story about the environment!" remarks Gurbisz. "But it is also important to remember that SAV in the mid and high salinity regions haven't recovered. This is possibly because the species that inhabit these regions need more light than their freshwater neighbors. So if nutrient loads continue to decrease, we could see similar responses in the higher salinity waters. The Bay isn't fully 'restored' yet, but the freshwater recoveries demonstrate that restoration efforts are finally beginning to work. This highlights the need for continued restoration efforts." KL

A DISAPPEARING ACT

Salinity and water levels changing the face of Lake Abert wildlife

BY KARLA LANT

The butterfly effect is a part of chaos theory that points to the sensitive interdependence of all things within a system. One tiny change in a system—such as a butterfly taking off and flying away—can eventually cause large differences down the line.

Ecosystems are an easy lens for interpreting that effect, and research at the University of Montana, Oregon State University, National Audubon Society, and East Cascades Audubon Society suggests that even changing water level in a lake can result in major fluctuations in local wildlife.

25 YEARS AND COUNTING

For more than 25 years, various government agencies and other organizations have collected data on Lake Abert. This is an impressive stretch of time for a monitoring effort by any standard. Nathan Senner, a University of Montana postdoctoral fellow, corresponded with EM about the recent report on the data.

"Yes, the lake has been surveyed off-and-on for the past 25 years, which is a long time by the standards of most ecological studies," explains Senner. "What makes this dataset even more impressive, though, is that much of that effort has been put in by citizen scientists with the East Cascades Audubon Society (ECAS) in Bend, Oregon. Members of the ECAS regularly drive the 3-4 hours from Bend to Lake Abert solely to undertake the surveys."

Initially, it was the Bureau of Land Management (BLM), which manages Lake Abert and part of its watershed, that began to monitor the lake. They were considering designating the lake an "Area of Critical Environmental Concern," and needed to assess the number and diversity of waterbirds using the lake as part of their review. ECAS eventually got involved in response to signs of decline in the health of the lake ecosystem; the people at ECAS were concerned over what that decline might mean for the migratory birds.

"The paper itself, then, was an outgrowth of the efforts and concern of the members of ECAS, as well as the larger National Audubon Society (NAS)," details Senner. "Recently NAS has begun a campaign to advance the conservation of saline lakes in the western United States, and Lake Abert features prominently in that campaign. Once we began digging into the data and found the dramatic effects that reductions in lake area are having on birds using the lake during migration, it became clear that the Lake Abert dataset would make a great case study demonstrating why Audubon is concerned about saline lakes throughout the Intermountain West."

First, biologists with the BLM monitored Lake Abert, and more recently, volunteer observers with the ECAS took over the task. The protocol has remained simple by design.

"Both groups have undertaken (at least) bimonthly bird surveys during spring and fall bird migration along the east side of the lake," Senner describes. "As the amount of water in the lake has decreased over the years, the remaining water concentrates on the east side of the lake and so it has been relatively easy to survey the lake from the highway that runs the length of its eastern shore. The surveys themselves have been fairly standard bird surveys, with observers beginning early in the morning before it becomes too hot, and all birds being counted from stops along the survey route. Keeping the protocol simple creates some limitations for the dataset, but means that it is highly repeatable and easily carried out, which is critical for efforts involving lots of different observers."

Overall, the water levels in Lake Abert have decreased. This is due to both direct human intervention and indirect factors such as the effects of climate change.

"Water levels at the lake have declined quite dramatically over the past few decades—on average, the lake is now about 200 football fields smaller than it was in the early 1990s," states Senner. "That decline has largely been a result of increased water diversion by humans for agriculture but has also to a lesser extent stemmed from climate change-related declines in overwinter snowpack and summer-long droughts. At times in recent years, the lake has thus consisted almost entirely of water coming from freshwater seeps in the bed of the lake itself, and not from any inflow from the greater watershed."

The salinity of the lake has risen, primarily as a result of decreased water levels and the fact that the diversions are limiting the influx of freshwater.

A BENTHIC EMERGENCY

One of the first signs of serious trouble in the Lake Abert ecosystem was visible in the lake's benthic community. Keith Kreuz and the Oregon Desert Brine Shrimp Company were out on the lake every day during the spring-through-fall season harvesting brine shrimp as a part of their business, but it wasn't long before they could see there was a problem.

"Very early on, Keith realized that monitoring the other invertebrates in the lake might be able to help him determine the conditions that could predict brine shrimp abundance," remarks Senner. "He thus monitored the abundance of the other invertebrates in Lake Abert daily and kept track of inter-annual variation in the abundance of these species. Over time this created a pretty amazing dataset on the Lake Abert food web."
Eventually, Kreuz's Lake Abert business became a casualty of the salinity-linked uncertainty in the fluctuations from year to year in the abundance of brine shrimp. When species like brine shrimp can no longer be sustained in the lake, this affects just about every other species in the local ecosystem.

"This is really what we would call a 'trophic cascade' where the direct effects of environmental change on one species have cascading effects on the other species in the ecosystem," remarks Senner. "High salinities are difficult for pretty much all species—except microbes—to tolerate. Birds living in saltwater environments have to eat more than those in freshwater systems because of the increased amount of energy required to deal with all of that salt. That means that birds are only using saline lakes like Lake Abert because invertebrates like brine shrimp are

Photo: Bureau of Land Management Oregon and Washington / cc-by-sa-2.0

Wilson's Phalarope.

normally so abundant. When brine shrimp (and brine flies) are no longer abundant, birds can't get enough energy to handle the high salt loads."

The final component of the study largely made use of remote-sensing data that is available online.

"Dr. Johnnie Moore in the Department of Geoscience here at the University of Montana has grown interested in Great Basin saline lakes and has built models to understand their hydrology and how it is impacted by human activities," adds Senner. "He recently built models specifically related to Lake Abert to identify what was causing the decline in lake levels and how those factors also affected lake salinity."

FOR THE BIRDS

The team monitored several waterbirds in particular as part of this study: Eared Grebes, Northern Shovelers, American Avocets—and three other 'species groups'—Calidris sandpipers, phalaropes, and gulls.

"None of these are currently endangered, but a number of them rely on saline lakes like Lake Abert throughout much of the year," explains Senner. "This is especially true for California Gulls (the most common gull species at the lake), Wilson's Phalaropes (the most common phalarope species), American Avocets and Eared Grebes."

These species are not listed as endangered, but this is really only part of the story.

"Given that none of these species is currently endangered, we might not be so concerned if this were just a story about Lake Abert," remarks Senner. "But because what is happening to Lake Abert is happening to most other saline lakes in the Great Basin—including the Great Salt Lake in Utah and Walker Lake in Nevada—there is the potential for this situation to snowball and quickly have dramatic effects on the health of these species' populations. One of our goals is to prevent train wrecks—i.e., to address problems before these species become endangered."

One of the more interesting aspects of this work concerns the sources of data the team was able to use.

"This work was really only made possible by the confluence of several different sources of data," states Senner. "Co-author Keith Kreuz ran a sustainable brine shrimp harvesting business on the lake for 35 years and this business allowed him to monitor the abundance of invertebrates throughout that time. Co-author Dr. Johnnie Moore is a hydrologist and geomorphologist and he was able to develop models that could pinpoint why the lake area was decreasing and what that decline meant for the lake's salinity. And, as mentioned before, dozens of volunteer citizen scientists were engaged. For my part, it was a matter of figuring out the statistical techniques that could wed these different sources of data. What all of this really speaks to, in my mind, is how powerful it can be to collaborate across fields to try to approach a problem from all sides."

Senner and his collaborators urge us to make an effort to see the saline lakes of America before it is too late.

"During peak migration (when the water levels are right) Lake Abert can hold hundreds of thousands of waterbirds at one time," Senner describes. "And, if you haven't seen phalaropes feed before (look it up on YouTube!), seeing hundreds of thousands of little shorebirds spinning circles in the middle of the lake to catch brine flies is definitely a sight to behold!"

Issues surrounding water diversion and water rights are always touchy, and nowhere in America is this truer than in the West—as everyone connected to the Lake Abert research knows. However, although the water in the West is a scarce and important resource, it's crucial that people see this research as a sign of a management problem troubling the entire watershed and its people, not an isolated wildlife issue.

"We also want to make clear that our take-home message is that the situation at Lake Abert should not be characterized as people versus birds," adds Senner. "The challenge for us is to find ways to manage the lake and its watershed for the long-term benefit of both people and birds." KL

Photo: Lillian Beasley/Audubon Photography Awards

GREAT LAKES METEOTSUNAMI

BY JEFF GILLES

This spring, a pier along Lake Michigan's eastern shore disappeared from view as water levels surged and swallowed the structure whole. The lake receded just as quickly.

The cause was a meteotsunami – a big wave triggered by the confluence of just the right wind speed and pressure generally brought on by a thunderstorm. Though the disappearing act this one pulled on the Ludington pier was a novelty, the phenomenon is potentially dangerous, historically misdiagnosed and poorly forecasted in the Great Lakes.

After a Lake Erie meteotsunami in 2012 swept swimmers off a beach and swamped marinas, Great Lakes researchers honed in on what causes these waves and how to warn beachgoers and boaters one might be on the way. Today, we have a better understanding of how common Great Lakes meteotsunamis are and forecasting tools are in sight.

An analysis of historical weather and lake level data published in the journal Nature found that the Great Lakes typically see around 100 meteotsunamis a year, and a destructive one every 10 years. Past examples had been mislabeled or missed completely because this type of wave was historically poorly understood, with only a couple of researchers in places like Croatia and Russia studying them, according to Eric Anderson, an oceanographer at NOAA's Great Lakes Environmental Research Laboratory.

"When I say a couple, it's literally a couple of folks that have been looking into this maybe on the order of 10 to 20 years," said Anderson, a co-author on the Nature study. "Before that, the terminology wasn't even out there."

Media coverage of the pier-swallowing Ludington wave referred to it as both a meteotsunami and a seiche, another type of large-scale wave that can lead to dramatically fluctuating water levels on the Great Lakes. But that's not what happened here.

"Sometimes I see that and I think, 'OK, we have to do better at explaining the difference between these two,'" Anderson said. "At the same time, I'm also excited that they're covering it or that they're even using the word meteotsunami even if it's thrown in there with seiche."

So what is it? As a thunderstorm propagates over a lake, atmospheric pressure pushes down on the surface. That causes a rise in water level — a wave — on the leading edge of the storm, just like pushing down on a waterbed, Anderson said. If the storm happens to be moving across the lake at the same speed as that wave, it can continue feeding energy into the wave and growing it to a potentially destructive size. A meteotsunami approaching a Great Lakes shore won't look like a normal wave with breaking action the people are familiar with. Instead, they come on as a quick flood of water.

A seiche is also a single large wave caused by strong winds but on the scale of an entire lake. Scientists typically describe it as water sloshing back and forth in a bathtub, with lake levels dropping on one end and rising on the other, oscillating every 4 to 14 hours or so depending on the location.

On a spectrum, meteotsunamis fall between seiches and typical wind waves seen washing up on beaches every few seconds, Anderson said, with a wave period of between 2 minutes and 2 hours.

"In our case, we have a lot of waves (in the historical record) that were in that part of the spectrum that weren't really explained," Anderson said.

> **"THE METEOTSUNAMI THREAT IS A SERIOUS COASTAL HAZARD FOR THE GREAT LAKES THAT HAS TO DATE BEEN UNDERESTIMATED."**
>
> **- Adam Bechle & Chin Wu**
> University of Wisconsin- Madison Department of Civil and Environmental Engineering

June 13, 2013 Meteotsunami event on the Atlantic Coast similar to the meteotsunami that occured on Lake Michigan.

Photo: Buddy Denham / National Weather Service

But those gaps have since been filled in by the Nature study, led by Adam Bechle and Chin Wu at the University of Wisconsin-Madison Department of Civil and Environmental Engineering. That project cross-referenced 17 years of water level data collected every 7 minutes at 32 NOAA with barometric pressure or wind speed data from the same period. They found that meteotsunamis are more common than previously thought, yet "water level oscillations associated with meteotsunamis are not considered in planning or design along the Great Lakes coasts, nor can current forecasting systems predict their occurrence for public safety efforts," they wrote. "In general, the meteotsunami threat is a serious coastal hazard for the Great Lakes that has to date been underestimated."

The study also found these events most commonly occur between late spring and summer — the busy season for Great Lakes beaches. That makes forecasting these waves and warning swimmers and boaters particularly important.

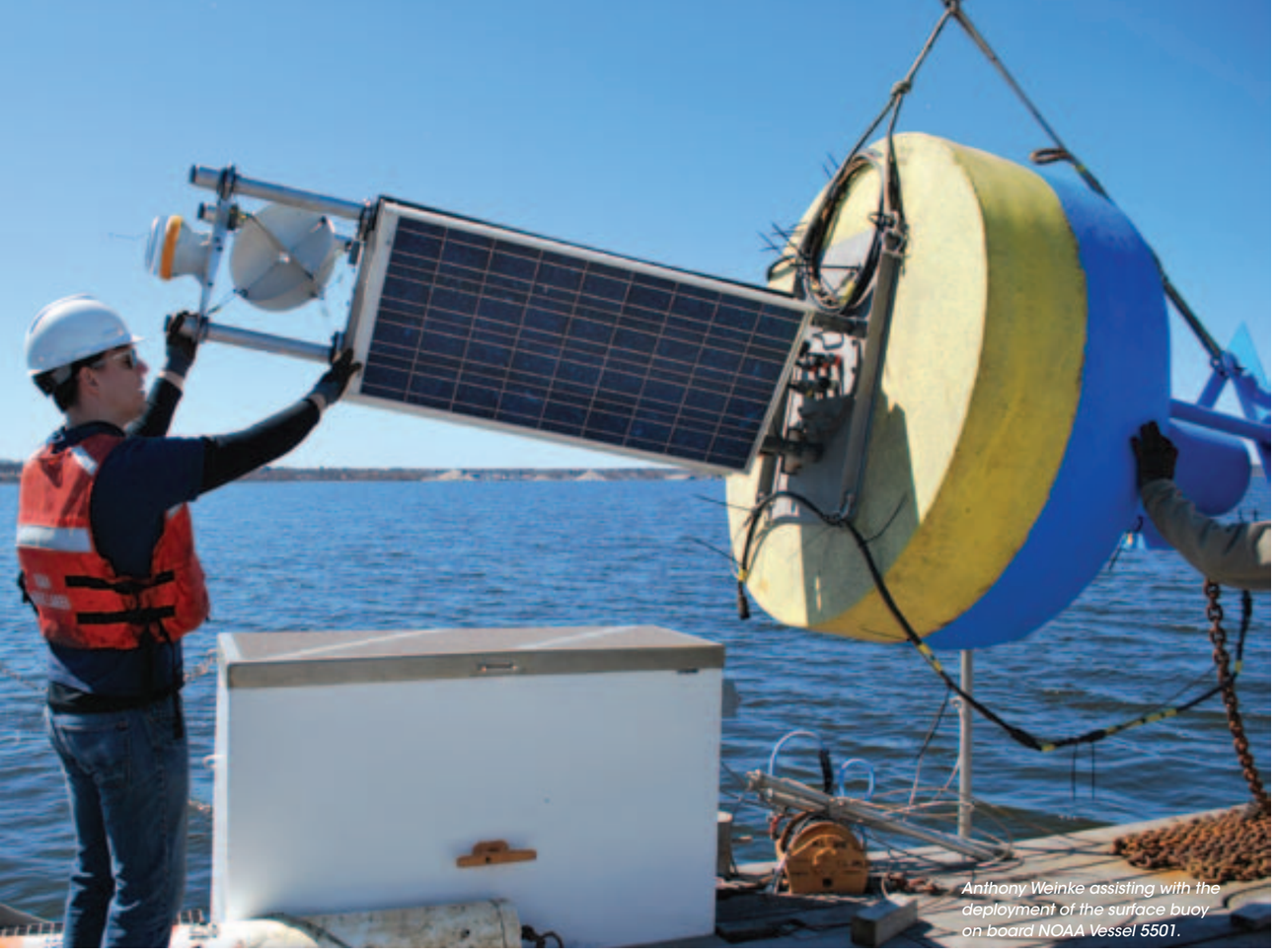
Since meteotsunamis are typically associated with thunderstorms, swimmers tend to get out of the water on their own when one is on the way. But that's not always the case. And the waves are particularly dangerous once they decouple from the storm that created them. Though the storm may dissipate or blow inland, the wave is already in the lake. A meteotsunami that strikes one shore under foreboding skies can reflect and travel to the other side, swamping a beach with perfect swimming weather. That reflection is another level of uncertainty that predictive tools will have to account for, Anderson said.

"We're really looking at honing in on that forecast piece now," he said. "We're not there yet. But it's something I think we'll have in a couple years."

The Nature study also notes that meteotsunami patterns may shift with climate change. That will depend on how certain types of storms become more or less common in the future. Take derechos — long-lived, straight-line windstorms known for damaging winds — for example. One of the strongest such systems on record in the U.S. blew from Minnesota to New York 20 years ago, producing hurricane-strength winds and a Lake Michigan meteotsunami that capsized a tug boat.

Derecho conditions could become more intense in the region, Anderson said. Wave speeds are based on depth and will stay roughly the same in the Great Lakes. But how that syncs up with future derechos could change.

"They could change so that derechos are suddenly going at just the right sweet-spot speed to produce more meteotsunamis. Or maybe it's going to happen the other way and they're going to be going too fast," Anderson said. "Exactly how that plays out remains to be seen." JG



Anthony Weinke assisting with the deployment of the surface buoy on board NOAA Vessel 5501.

DATA BUOY POWERS MUSKEGON LAKE HYPOXIA RESEARCH

BY JEFF GILLIES

Sixty years ago, the famous ecologist George Evelyn Hutchinson wrote, "A skillful limnologist can possibly learn more about the nature of a lake from a series of oxygen determinations than from any other chemical data." Since then, oxygen measurements have only grown more relevant as the problem of hypoxia expands in lakes, oceans and estuaries across the globe.

But ecologists' ability to measure oxygen has grown too. When Hutchison wrote that in 1957, the "series of oxygen determinations" produced by a data buoy like the one floating on Muskegon Lake in Michigan was unthinkable.

"Every year it takes about a hundred thousand oxygen measurements at four different depths in the water column," said Bopi Biddanda, professor of water resources at the Annis Water Resources Institute, which operates the Muskegon Lake Observatory buoy.

The buoy has been collecting water quality data since 2011 — data now powering new research that captures with unprecedented clarity the lakewide hypoxia afflicting this Great Lakes estuary every summer and fall. Two recently published studies detail the cycle of oxygen depletion in the lake's bottom waters, and the ecological impacts from bacteria to fish. Muskegon Lake sits along Michigan's west coast at the mouth of the Muskegon River, which drains the second-largest watershed in the state. Deeper insights into its hypoxia problems could help restoration efforts on this economically important lake and others like it.

"Really, it's a model Great Lakes estuary," Biddanda said. "It's at the land-water interface and carries with it that entire watershed's signal."

CHRONICLING HYPOXIA

One of the studies, published in an April issue of the Journal of Great Lakes Research, combines three years of buoy data with more than a decade of ship-based sampling to show that hypoxia is an annual occurrence in Muskegon Lake. The paper leads off with the Hutchinson quote, a literary move that Biddanda was surprised made it past the journal's editors.

"We were worried they would want us to take it out, that it was too classy or something," he said.

But the quote stayed, perhaps because the study goes a long way to prove the utility of time series of high-resolution oxygen data. Long-term manual sampling programs on Muskegon Lake had hinted at this, but the buoy data make it especially clear.

"Up to 2011, there was only anecdotal evidence — an occasional measurement. Some seasonal measurements, some sampling of bottom waters noted low oxygen," Biddanda said. "But nothing enough to really paint continuous and consistent and irrefutable evidence that hypoxia occurs every year."

Additional sampling during the study period showed that conditions throughout the lake matched those and the buoy location. The researchers calculated that around 10 to 30 percent of the lake volume is hypoxic for one to three months, which Biddanda called "substantial."

ECOLOGICAL EFFECTS

Another study, this one published in an April issue of the journal Ecosystems, shows how the lack of oxygen in the bottom waters reshapes the ecology of the lake at every level, from bacteria to fish.

The most notable result of the Ecosystems study was the high phosphorus concentrations they found in the hypoxic bottom waters compared with the surface waters, where it was almost undetectable. That's likely result of a chemical change that occurs under low dissolved oxygen that releases phosphorous previously bound to metals in the sediment, according to lead author and Annis research technician Anthony Weinke

All of that dissolved phosphorus in the bottom water might play an important role in fueling the harmful algal blooms that sometimes plague the lake. There is some evidence that phycocyanin — an indicator of harmful algal blooms — shows an increase following these mixing events. The thought is that algae and cyanobacteria got a boost when strong winds occasionally mix the phosphorus-rich bottom waters into the top layer.

"Kind of like a feeding frenzy for a period after the mixing event to get nutrients that they didn't already have," Weinke said.

Higher up the food chain, the researchers found stark evidence of habitat degradation for fish during hypoxia. Muskegon Lake is a productive fishery, and one round of netting at the bottom during peak dissolved oxygen in November found 67 fish of nine different species. But during peak hypoxia, sampling at the same location netted no fish at all.

FLOATING HYPOXIA

One peculiar finding showed that during periods of hypoxia the dense, cooler mass of low-oxygen water didn't always settle to the bottom of the lake as is normally the case. Instead, the hypoxic water was "floating" on a layer of even colder, oxygen-rich water. During such times when coastal upwelling is occurring, cold oxygenated" water from Lake Michigan was occasionally creeping up into the channel and plunging down into Muskegon Lake and slipping along the lake bottom. That pulled more and more cold water in like a conveyor belt, Biddanda said, occasionally reaching as far up as the mouth of the Muskegon River.

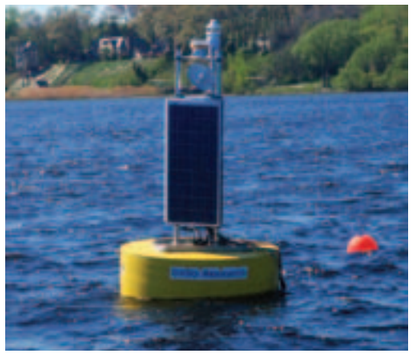
The impacts of these intrusions aren't fully understood, Biddanda said.

"It sounds like a good thing, right? Oh look, this lake in the summer and early fall is experiencing bottom-water hypoxia. And in comes this nice oxygenated cold water," he said. "But then there's this floating of the hypoxia exposure to more of the shallow layers which may not have occurred before."

So fish that were swimming up in the water column to avoid the low-oxygen water have to swim up even higher, turning even more of the lake into an inaccessible habitat. And sampling during these periods didn't show any noticeable uptick in fish abundance during the influxes of Lake Michigan water, Weinke said.

All of these findings — Lake Michigan water intrusions, sediment phosphorus regeneration, bottom water nutrient mixing — merit further study, Biddanda said. And a better understanding won't just benefit Muskegon Lake. The system serves as a good model for other freshwater estuaries, especially the drowned river mouth lakes around the Great Lakes. And though it's small, it's also a good analogue for Lake Erie, which also suffers from severe hypoxia and harmful algal blooms.

"There have been times where I'm talking at seminars and I'll ask, 'Has anybody thought, is this guy talking about Lake Erie?' And most would lift their hands," Biddanda said. JG



All photos: AWRI

***Left:** Students Rachel Ratliff and Katie Knapp out on a submerged buoy maintenance run with Bopi Biddanda on board AWRI's Pontoon. **Right:** The Muskegon Lake Observatory has been collecting high-resolution water quality data since 2011.*

MIRROR LAKE SALT LEVELS

Left: Corey Laxson using EXO water quality sonde. Right: Liz Yerger and Cory Laxson of the Adirondack Watershed Institute pulling a sled full of field equipment.

The annual monitoring report on Mirror Lake in upstate New York reveals that salt levels are still a problem despite reduced local use of road salt.

BY KARLA LANT

For 20 years now, interested parties have been monitoring water quality in Mirror Lake, a relatively small lake nestled in upstate New York's Adirondack Park. This area is a getaway for many urbanites, but the smaller population doesn't mean the lake's water quality isn't under threat. In fact, concentrated patches of development have led to increasing salt and chloride levels that locals are now working to lower.

THE ARA 2018 WATER QUALITY REPORT

The annual AuSable River Association report on Mirror Lake water quality reveals that increasing chloride and salt levels may have major effects on the lake's overall health—and this isn't a new concern.

"We started monitoring the lake in May 2015 and issued the first report in March 2017," Dr. Brendan Wiltse, Science and Stewardship Director of the Ausable River Association (ARA) told EM. "This is our second annual report on the lake. The lake has been enrolled in a citizen monitoring program (CSLAP; Citizen Statewide Lake Assessment Program) since 1998, but that program does not assess sodium and chloride concentrations."

ARA monitors Mirror Lake using standard limnological protocols. "We measure temperature, dissolved oxygen, specific conductance, and pH at 1m intervals through the water column on a bi-weekly basis year-round," explains Dr. Wiltse. "We also collect a 2-meter integrated surface water sample and a discrete sample using a Kemmerer sampler 1m off the bottom during each visit. pH, conductivity, alkalinity, total phosphorus, nitrate, ammonium, total nitrogen, chlorophyll-a, chloride, sodium and calcium are analyzed at the Paul Smith's College Adirondack Watershed Institute."

This careful work shows that long-term trends in chloride, conductivity, and sodium remain a challenge for everyone concerned with the health of the watershed.

"The underlying geology has very little chloride and the only other natural source is atmospheric deposition," details Dr. Wiltse. "As a result, the median concentration for unimpacted Adirondack lakes and streams is 0.24 mg/L of chloride. The surface water concentration in Mirror Lake is around 40 mg/L or 167-times higher than we would expect for an Adirondack lake. Road salt is definitely the source of the additional salt, especially in this heavily developed, small watershed."

In fact, the team documented elevated chloride concentrations from the bottom of the lake, and there is evidence that these higher concentrations are interfering with the lake's natural seasonal turnover process.

"During the winter, the stormwater runoff that directly enters the lake has extremely high concentrations of salt," Dr. Wiltse states. "The highest we have measured to date is 2,400 mg/L of chloride, which is 10,000 times higher than the median concentration for unimpacted Adirondack streams."

All Photos: Brendan Wiltse

The added salt renders stormwater denser. Due to the small size of the lake, the water flows along the lake bottom, accumulating at depth.

"Throughout the winter, we are able to see the sodium and chloride gradually accumulate from the bottom of the lake upwards," describes Dr. Wiltse. "The density differences in the water column due to salt add the energy required to mix the lake; our preliminary modeling shows a 75 to 200-times increase. The lake receives relatively little wind exposure due to its orientation and surrounding topography. This, combined with the salt-induced density differences, prevented the lake from mixing in 2017 and we expect it won't mix in 2018 as well."

Moreover, the team now has comparative data to bolster their theory.

"In 2016, the winter was more mild, less salt was applied, and ice-out occurred about 1 month earlier," remarks Dr. Wiltse. "That spring the lake did turnover due to reduced salt-induced density differences and a prolonged spring mixing period."

A lack of turnover results in lower dissolved oxygen concentrations in the hypolimnion of the lake. "This is a threat to the lake trout and rainbow trout found in the lake, and increases internal nutrient loading," adds Dr. Wiltse.

A FOCUSED APPROACH TO A LOCAL PROBLEM

The areas surrounding Mirror Lake have reduced their use of road salt. Although these measures have made a positive difference, the problem is not entirely solved.

"Local government is trying to reduce the amount of salt they use, but we haven't seen a substantial shift in the chemistry of the lake as a result," remarks Dr. Wiltse.

In the report, the team explains that part of the issue is indeed how much salt is used, and another issue is even spreading of salt concentrations. This is because it requires more energy to turn over the lake when the salt is unevenly distributed. Determining a set of best practices based on this issue is one area of future research for the team.

"We are focused on measuring the amount of salt applied to the watershed from all sources (state, municipal, and private)," explains Dr. Wiltse. "With this data, we can model how salt moves to the lake and what amount of reduction is needed to restore turnover. Once we know what our target is we will assist stakeholder in implementing best management practices that will achieve those reductions."

The team will also focus on building a water balance and chloride mass balance for the lake moving forward. This way, they will be better able to accurately model and predict the effectiveness of proposed management actions.

"[The Mirror Lake] area is seen as a large protected area that may not be susceptible to these sorts of problems, but there are pockets of concentrated development that deal with many of the same problems as much larger urban areas," states Dr. Wiltse. "Therefore, it is important that we don't overlook the impacts in these areas out of the false belief that they are fully protected." KL

LITTLE BUOY BIG WAVES

BY JEFF GILLES

A record-setting wave in Lake Superior recorded by a set of buoys

A pair of lonesome data buoys bobbing off Michigan's storm-whipped Lake Superior shore were suddenly the stars of the state this fall when they captured the largest waves ever measured on the Great Lakes.

The buoys, near Granite Island and Munising, each recorded 28.8-foot significant wave heights during a storm that caused hundreds of thousands of dollars in damage along the coast. The record wave height exceeded the previous 27.6-foot record set by a Michigan Tech buoy near Houghton, MI in 2012. To give some perspective on the rarity of these types of events, waves at the record-capturing buoys only climbed above 12 feet four times throughout 2015 and 2016.

A headline-grabbing event like that shows how buoy data can help the public wrap their minds around the otherwise unimaginable power of a wild Lake Superior storm — one that claimed the lives of two people swept off the rocks at a popular overlook. But it also highlights the utility that these beacons have throughout the field season when the waves aren't quite so eye-popping.

The lake freighters that pass through Superior are concerned with the big 10- to 15-foot waves, said John Lenters of Lentic Environmental Services, who helps manage the buoys with Northern Michigan University and the Superior Watershed Partnership. But in terms of public safety, kayakers and recreational boaters generally aren't crazy enough to go out on those days. Managers want to know whether the waves are going to stay below 2 feet or get closer to 3 or 4 because that's when it gets dangerous.

"It's those 3- to 5-foot waves where people go out and test their limits and get caught in waves that are too big for them to handle," Lenters said.

Even if the Oct. 24 storm's immense wave action kept the boaters off the water, it still drew spectators.

"It was like people were lining up for the circus," Lenters said of the crowds he encountered in Marquette on his way into the office for some buoy-related work. Waves were already washing over Lakeshore Boulevard that hugs the Upper Peninsula city's waterfront. He turned around and headed for Munising, stopping along the way to capture some footage of the waves himself.

Lenters kept his eye on the data from the buoys throughout the storm, sometimes wondering whether the moorings or electronics would survive the ride. Previous storms had, wave by wave, shifted a buoy a quarter-mile from its original location. Previous buoys larger than the NexSens CB-450 deployed last year had broken free from their moorings. With enough force, water could also squeeze into the modem case, shorting out the system and draining the battery.

The gap in the data after the shutdown makes Lenters wonder whether an even larger wave group could have moved through after the buoy went quiet. Even if it continued to report, it is possible that the 28.8-foot record doesn't even reflect the biggest wave from this storm.

An accelerometer in the buoy measures every wave, but the buoy only reports the average of the largest third of those waves over a certain time period. This metric, called the significant wave height, could easily mask a single rogue wave two or three times larger than what the buoy reports, Lenters said.

It's also possible a larger group of waves slipped between the two buoys that each captured the 28.8-foot measurement. A visualization of modeled wave heights put together by National Weather Service meteorologist Greg Mann at the National Weather Service showed a purple bullseye representing the highest wave action.

"It was about a 30-foot wave group moving across the lake and it happened to just slam right in between those two buoys," Lenters said. "From models, we estimate there were higher waves. It got me thinking: clearly this isn't the biggest wave ever on the Great Lakes," Lenters said. "It's just the biggest ever measured."

Sensor-based wave measurements in the Great Lakes only go back to 1979 when NOAA first placed buoys in the lakes to aid freighters, said Ed Verhamme, an engineer with LimnoTech, a consulting firm that helped initially deploy the Granite Island and Munising buoys back in 2015. Before 1979, wave heights were mostly based on human observations.

The NOAA buoy record begins just five years after the Edmund Fitzgerald sank on a night that the captain of another nearby freighter reported 30-to-35-foot waves. A NOAA simulation of wave heights based on weather conditions from that storm estimated waves averaging over 25 feet and one in a hundred waves climbing to 36 feet.

The NOAA buoys are near the centerline of each lake — an area that will rarely see the largest waves because it isn't subject to as much fetch as the nearshore areas, Verhamme said. And until recently, NOAA's National Data Buoy Center set a cutoff of 25 feet for its wave height records because they assumed anything larger meant a sensor was on the fritz. NOAA has since raised the cutoff to 50 feet.

While the true height of the Great Lakes' tallest wave is up to speculation, there's no question that weather on Lake Superior during that week this past October was one for the record books. Just three days after the record wave from the north, another storm blew in from the east that churned waves up to 19.4 feet at Granite Island. Mixed with the lake's near-record water levels at the time, Lenters said we're unlikely to see anything like that one-two punch again soon.

"When I think about two major wave events in the same week combined with high water levels, I would say a million-to-one that that's probably unprecedented in the historical record," Lenters said, meaning that "it probably hasn't happened in a couple hundred years." JG

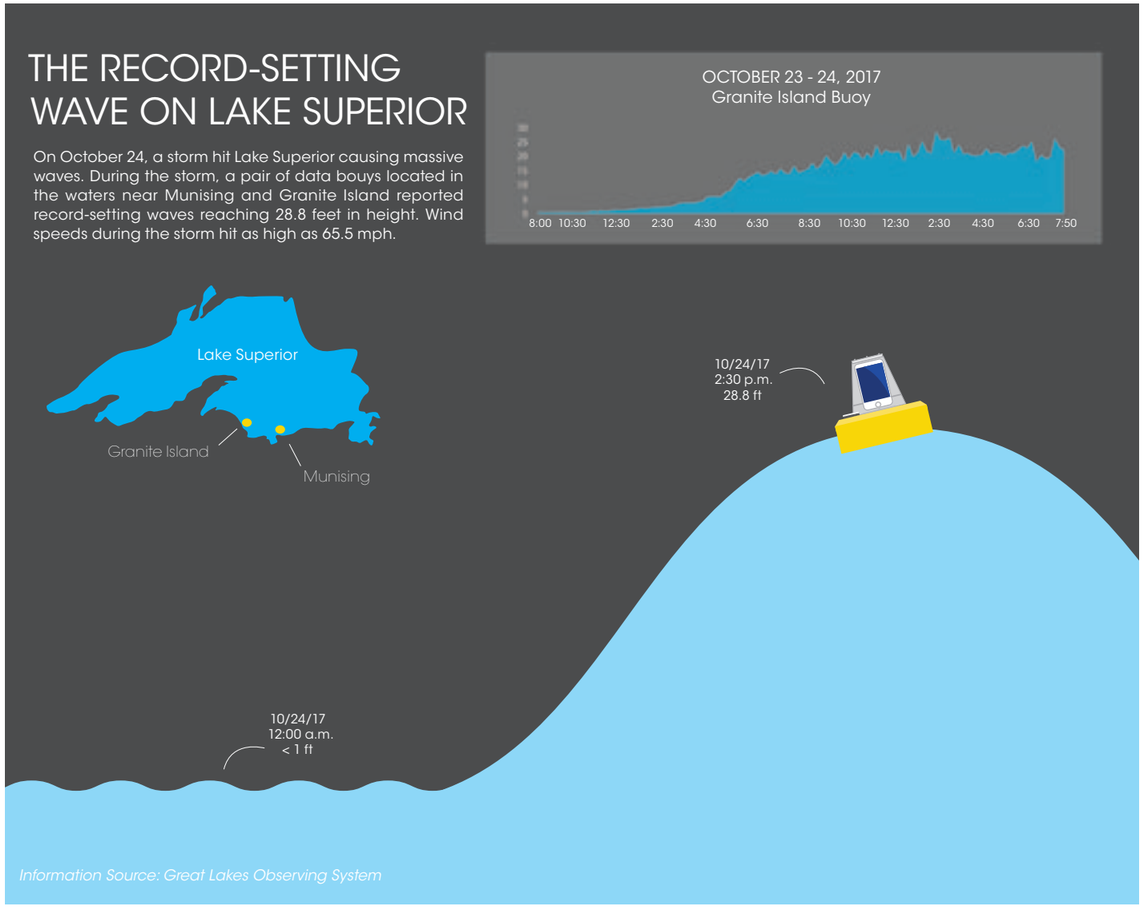


Photo: John Lenters / Graphics: Katy Schwarz / Fondriest Environmental

GREAT LAKE GREAT RIVER

St. Louis River imbues Lake Superior NERR with its unique character. Monitoring includes SWMP, keeping an eye on purple loosestrife and other issues.

BY LORI BALSTER

Hannah Ramage using a paddle board to sample our long term vegetation plots that became inundated with high water in 2017.

Hannah Ramage and the St. Louis River go back several years. "I went to the University of Minnesota at Duluth for my master's degree, where I did research on the St. Louis River estuary," says Ramage, now the Monitoring Coordinator for Lake Superior National Estuarine Research Reserve (NERR). "Working here was a great opportunity to keep doing the research that I loved doing," she says. "I've always been drawn to this NERR system."

Lake Superior NERR research consists of many pieces. Abiotic monitoring is performed, which includes continuous water monitoring and meteorological monitoring. Water quality monitoring is done at several stations chosen to reflect a continuum of lake to river water influence. The Lake Superior NERR is situated on a freshwater estuary where the St. Louis River meets Lake Superior. Monitoring is done using YSI EXO2 sondes now, but prior to that YSI 6600 series sondes were used. "Sondes are deployed for up to one month," says Ramage. "They are also calibrated monthly."

In addition to the System Wide Monitoring Program (SWMP) that all 29 NERRs use, Lake Superior NERR is also experimenting with sending their EXO2 sondes under St. Louis River ice this year. "We want to see how well the probes do for us," says Ramage. "We've seen high chlorophyll-a concentrations under the ice and want to keep an eye on it. We want to see if there are algal blooms." The sondes collect temperature, conductivity, dissolved oxygen, turbidity and pH data. One station, at Barkers Island, closest to the exit of the River, right at the end of the dock, also has a sonde with a chlorophyll a and a total algae sensor. Barkers Island has a live setup in coordination with NOAA that transfers all Barkers Island data telemetrically. Barkers Island is also the site of the education center, Lake Superior Estuarium. The sonde furthest upstream is on Oliver Bridge, by the town of Oliver, WI. This particular sonde is stored in a housing attached to the bridge. Another site housing a sonde is at the Blatnik highway bridge. Both bridges have the same kind of sonde housing.

There is also a special site on the Pokegama Bay, where the Pokegama River meets the St. Louis River estuary. "That is our sentinel site for SWMP," says Ramage. "It's a unique part of the river: it's very turbid." A meteorological station is also part of the Pokegama Bay site.

Like all NERRs, Lake Superior NERR does vegetation monitoring. However, the Lake Superior site has a different emphasis than some other NERRs: invasive species. "We are concerned with invasive species here," says Ramage. "The St. Louis River estuary contains the largest port in the Great Lakes (by tonnage), and therefore we get a lot of non-native species introductions. There's an invasion of purple loosestrife, which chokes out native plant species when it gets a chance. We specifically monitor for purple loosestrife at our sentinel site, as it's very adaptable and prolific across areas. It competes with sedges and grasses. There's also rusty crayfish; they're an issue too. Round gobies, Eurasian ruffe, tubenose goby, spiny water flea…all of them have come here, and they influence the ecosystem."

Interestingly, some invasive species are currently being controlled naturally. "Zebra mussels are a devastating invasive species in many other places, but here they don't have enough nutrients in most of areas of Lake Superior, so they're confined to the harbor, along with quagga mussels," Ramage explains.

Purple loosestrife can sometimes be controlled in Pokegama Bay by very high water. "Of course, in that case, none of the typical native vegetation was growing either," Ramage says. "We don't have the final data for 2017 yet."

Ramage's colleague, Shon Schooler, Lake Superior NERR Research Coordinator, does the most work on the purple loosestrife issue, as well as the rusty crayfish. Besides Ramage and Schooler, there are two undergraduates from the University of Minnesota and the University of Wisconsin-Superior who also perform research tasks at Lake Superior NERR. Students calibrate sondes, collect monthly water nutrient sampling and conduct their own research. "We also have an Education Coordinator, Deanna Erickson, who likes to get students engaged in research with us," says Ramage. In addition to the tasks those students perform, there are many students who act as citizen scientists (volunteers) from both Wisconsin and Minnesota. "We'd like to get more participation from more college students, too," says Ramage. Around 60-100 students participate throughout the year, and many K-12 and college students use the education facilities at Lake Superior NERR. "Students get grab-samples (water samples), sonde water quality data, which gets utilized in the lab," says Ramage. "Shon teaches an Environmental Research Methods class at the University of Wisconsin-Superior. We have programs all year." The Reserve is a state-federal partnership with the University of Wisconsin-Extension being the primary Wisconsin partner and NOAA is the federal partner.

In the past few years, the estuary has gone through some changes. "There was a big flood in the St. Louis River in 2012, which had effects we are still understanding. We also discovered that there were high levels of chlorophyll-a under the river ice, despite the cold weather. We didn't really expect winter algal blooms," she says. "We don't have baseline data to compare how unusual the under-ice algae phenomenon is." In Lake Superior NERR, floods have become more common in recent years. "We've also seen that whatever happens to the St. Louis River affects the Lake," says Ramage.

The St. Louis River estuary is "a Great Lakes Area of Concern," Ramage mentions. "Historically, the river has seen some significant contaminants." Researchers have been looking at how much sediment the river is moving in the water column, and what materials the river is moving. "It would be great if we could get a team of people to better monitor flood events," says Ramage.

During her career studying the St. Louis River estuary, and during her time at Lake Superior NERR, Ramage has developed a great appreciation for the uniqueness of doing research in the Lake area. "We have a very dynamic system here," she says. "Recently, because of high water levels in Lake Superior, our long-term vegetation monitoring has revealed areas where conditions have rapidly changed. Also, Lake Superior water levels affect conditions way upstream, more than you might think. In Pokegama Bay, for example, habitat can change completely because of Lake levels. Plant communities can change drastically here over the course of a single year."

As time goes by, Ramage continues to enjoy research at Lake Superior NERR. "The Great Lakes have great appeal," she says. "I grew up near Lake Michigan, and when you grow up near a huge lake like that, you never want to leave."

She especially likes the freshwater estuary, something Lake Superior NERR has. "They're different from coastal estuaries," she says. "We have a really dynamic river here and a huge commercial port. It's a really rich place to do abiotic and biological research."

Ramage also likes the local community. "There's a really palpable sense of making connections with people who have devoted their lives to upholding this place. We have challenges here, such as remediating contaminants, restoring fish and wildlife populations, and restoring wetlands and shorelines. But the community here definitely gives you a sense of optimism. There's a feeling here that we can fix it!" LB

Photos: (Left & Center) Hannah Ramage / (Right) Tracy Ledder

Left: *Water quality station on Barker's Island.*
Center: *Student technician using a EXO2 water quality sonde.*
Right: *Leo Dressen downloading data from meteorological station in Pokegama Bay.*

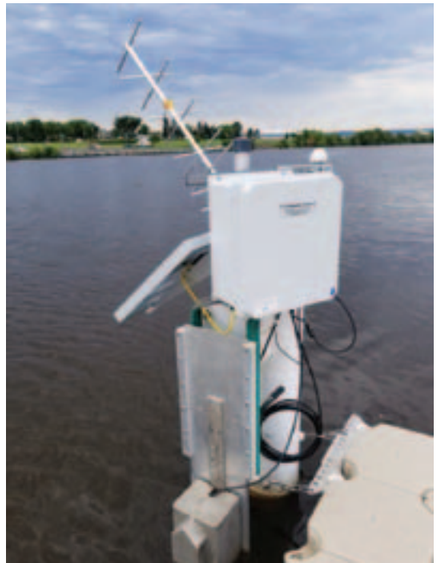


Photo: Dr. Shon Schooler

MISSISSIPPI RIVER WATER QUALITY MONITORING

MWMO Interns Christi Wahlstrom, Melissa Burton and Anna Johnson collect macroinvertebrate samples from one of the Kasota Ponds.

BY MINDY COOPER

One organization in Minnesota is keeping a close eye on the northern part of the Mississippi River through an extensive water quality monitoring effort that includes the river, a stormwater drainage system, and local lakes and wetlands.

The Mississippi Watershed Management Organization — also known as the MWMO, a special purpose local unit of government in Minneapolis, Minnesota — is responsible for monitoring the water quality of the 14-mile stretch of the Mississippi River that runs through Minneapolis and St. Paul.

Starting at Lake Itasca in Minnesota, the Mississippi River flows south for 2,230 miles, bordering or passing through 10 states until it flows into the Gulf of Mexico. It provides a home for many species of fish, mussels, amphibians and reptiles, as well as a flyway for many species of birds during migration. Additionally, the river provides drinking water for at least 50 cities, according to the U.S. Environmental Protection Agency.

It's no secret that the water quality from the river is a main contributor to the large dead zone in the Gulf every year.

All of this makes monitoring the river's water quality a necessity and MWMO, a small but robust organization, is dedicated to being a steward for their designated 14 miles of the Mississippi River.

"Our stretch of the river includes a water intake for the City of Minneapolis drinking water supply and it is also designated for recreation activities like fishing and swimming," said Udai B. Singh, the organization's water resources director who has a Ph.D. in civil and environmental engineering.

Other agencies have monitored the 14-mile stretch of the Mississippi River at a few locations. The MWMO began tracking the river at six monitoring sites in 2015 and added two more monitoring sites in 2016. The MWMO is currently focusing on building baseline data.

"Prior to 2015, we gathered three years of water temperature, pH, dissolved oxygen, and conductivity data at multiple depths at six monitoring locations. This monitoring was conducted to determine whether the river within our stretch becomes stratified at any point during the year or remains hydraulically mixed from top to bottom," said Singh. "In 2015, we began collecting samples for water quality analysis. We want to establish a 10-year baseline of data, so we aren't drawing conclusions from the data right now."

With a staff of only 15 full-time employees, which includes five environmental scientists, the organization performs bacteria and water quality monitoring in its stretch of the river, as well as water quantity and water quality monitoring in the stormwater drainage system of the watershed. Bacteria monitoring is done every second and fourth Thursday of each month, regardless of the weather. To collect water samples, the specialists plunge a sample bottle one foot below the water's surface. The samples are analyzed in a laboratory for E.Coli.

"During rain events, the E.Coli levels are typically higher," said Singh. "We recommend that residents avoid recreation activities in the river for three days after a rain event."

The results of the bacteria monitoring showed that during the months of August and September in 2016 at least four sites exceeded the acceptable standard for E. coli presence in the water.

Water quality monitoring is done from the organization's 14-foot Jon boat. The team uses a horizontal water sampler (also known as a Van Dorn sampler) to grab water samples from the middle of the river as long as weather permits. During the colder months, the samples are taken from the shore or by lowering the sampler from a bridge. The samples are analyzed in a laboratory for, nutrients, sediment, chloride, heavy metals, biochemical oxygen demand (BOD), and Chlorophyll-a.

They also use handheld YSI ProPlus sondes to collect dissolved oxygen, conductivity, salinity, water temperature and pH value measurements.

In addition to monitoring the river itself, the MWMO pays attention to the watershed as a whole.

"We want to know the condition of the water before it reaches the river," said Singh.

To capture that data, the organization focuses on the local stormwater drainage systems and developed an extensive monitoring plan that includes six stormwater outfalls into the river and one stormwater pipe. The quality of the water in the stormwater drainage systems is affected by the land uses of the area surrounding it. In the MWMO watershed, the surrounding areas include residential, commercial, and industrial developments. When it rains, all of the surface debris and pollution is transported into the stormwater drainage systems and eventually into the river.

The data could potentially show which areas are carrying more pollution into the river and provide a starting location for mitigation efforts.

The organization monitors water quality and quantity. To ascertain the water quantity, each site is equipped with an area/velocity sensor that is connected to an area/velocity flow module. The sensor and flow module provide water level and velocity data. When coupled with the area dimensions of each pipe, MWMO is able to use this data to figure out the discharge from the stormwater pipe.

Water quality monitoring is conducted with Isco 6712 automatic samplers. These pre-programmed samplers include twenty-four one-liter plastic bottles for composite sample collection and are connected to the area velocity flow module. When the water level reaches a certain value above baseflow, the sampler starts sampling. More bottles are filled as a preset volume of water passes the sensor.

Once collected, the bottles are composited by a monitoring specialist by pouring an equal amount of water from each

All photo: MWMO

MWMO Intern Peter Swan downloads and checks data at a stormwater monitoring site in Minneapolis Minn.

sampler bottle into a plastic bottle. The combined sample is taken to a laboratory for analyses similar to the samples taken directly from the river.

Stormwater monitoring also includes the use of a YSI ProPlus sonde and a Secchi tube to measure the transparency of the water.

Although the organization isn't currently drawing conclusions from the data, it is available to the public upon request and will be made available via the MWMO's website in future. While the main focus of the water monitoring efforts is currently on gathering enough baseline data to draw conclusions and make water management decisions in the near future, the time on the river is valuable for the staff and the community.

"From being on the river so much, we are able to act as eyes and the ears for the river," said Singh.

The community recognizes the work that MWMO is doing. In the past, members of the organization were called in during crisis situations, such as the I-35W bridge collapse that killed 13 people in 2007.

"When that happened members of our team were called to monitor any effect on the river," said Singh.

The MWMO is also a partner of the City of Minneapolis in the Illicit Discharge Prevention Program. MWMO's participation in that initiative helps alert the city to any illicit discharge to the river.

The organization's work doesn't stop with water quality monitoring. In addition to those efforts, MWMO funds capital grant projects that are large-scale stormwater management projects or improve the habitat and water quality within their watershed. Education and outreach is also a big component of their work. MWMO's headquarters (also called the Stormwater Park and Learning Center) provides a green infrastructure learning experience and other education initiatives.

"We have come a long way. We started with a team of two staff in 2002 to a fifteen-member team now. We put a comprehensive watershed plan in place and do monitoring and water quality projects. We continue to work with the public with education and outreach," said Singh. "Our organization is now positioned to be a champion of and advocate for the river." MC

DISSOLVED OXYGEN MEASUREMENTS

HOW SENSORS MEASURE DISSOLVED OXYGEN

The most common method for dissolved oxygen measurement is with a DO sensor and meter. Sensors can also be connected to a shoreside or buoy-based data logger. Colorimetric methods offer an approximation and require hands-on mixing of reagents, and the traditional lab method, a Winkler titration is not well suited for field determination. Therefore a sensor-based system is the best option.

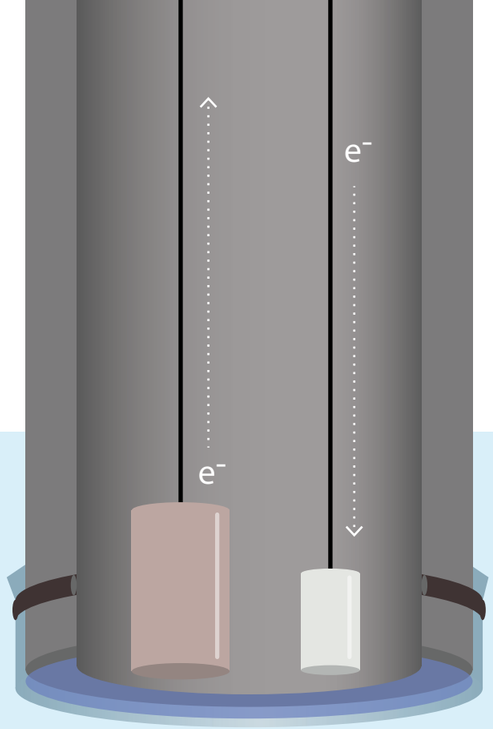
Electrochemical (galvanic and polarographic) sensors were first used in the mid 20th century and are still in widespread use today. Optical sensors offer lower maintenance, fewer issues from fouling, longer deployments and are typically the sensor of choice today. All of these sensors can provide accurate results and reliable performance when properly deployed and maintained.

All sensors incorporate a semi-permeable membrane optimized for the diffusion of oxygen molecules. The membranes on galvanic and polarographic sensors are typically very thin, and the electrodes are suspended in an electrolyte solution under the membrane. Regular maintenance and calibration are required. Membranes on optical sensors are typically more robust resulting in longer deployments. Maintenance and calibration can be extended for months, although biofouling may require the use of a submersible wiper. Most multi-parameter water quality sondes include optional wipers.

Amplified sensor signals are processed by the meter or data logger and are proportional the amount of oxygen dissolved in water. Calibration is typically performed in a wet air environment (water saturated air), although some projects require calibration in an air saturated water solution (air purged through water). This is known as 100% air saturation but may be corrected for elevation above sea level.

For more information visit the Fondriest Environmental Learning Center
www.fondriest.com/environmental-measurements

All graphics: Fondriest Enironmental



GALVANIC

In a galvanic dissolved oxygen sensor, the electrodes are dissimilar metals. The metals have different electro-potentials based on how readily they give or accept electrons. When placed in an electrolyte solution, the potential between dissimilar metals causes them to self-polarize. Electrons travel from the anode to the cathode. The anode is oxidized and oxygen is reduced at the cathode. The current produced by the reduction is proportional to the partial pressure of the oxygen in the water.

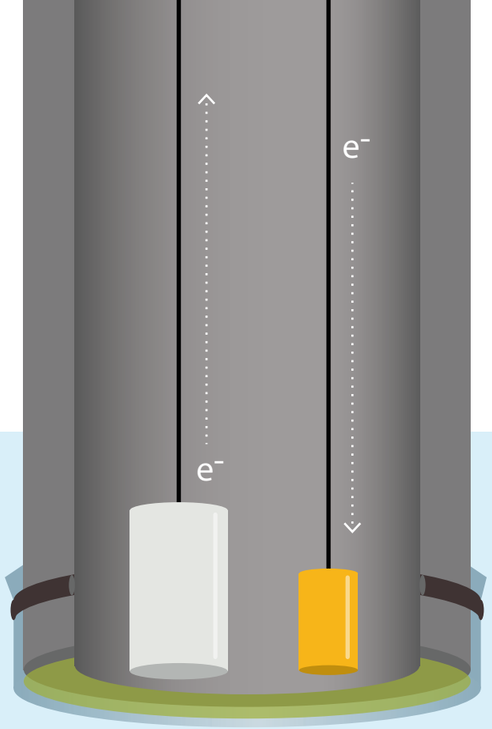
- SILVER OR NICKEL ANODE
- NaCl
- ZINC OR LEAD ANODE
- MEMBRANE

PROS

The sensor is self-polarized and requires no warmup, unlike polarographic sensors.

CONS

Oxidation of the zinc electrode continues to occur even when not in use and may need to be replaced more often.



POLAROGRAPHIC

A polarographic dissolved oxygen sensor consists of a silver anode and a noble metal cathode, such as gold or platinum, in an electrolyte solution. The electrodes are polarized with an external voltage. When oxygen diffuses across the membrane, the molecules are reduced at the cathode, increasing the electrical signal. The polarizing potential is held constant while the sensor detects changes in the electrical current caused by the oxygen reduction. The measured current is proportional to the partial pressure of the oxygen in water.

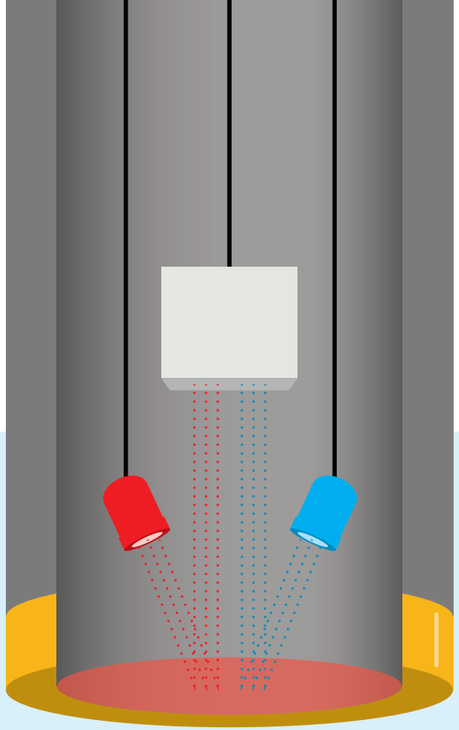
- SILVER ANODE
- KCl
- GOLD CATHODE
- MEMBRANE

PROS

Maintenance is less frequent than with galvanic technology and sensors are more affordable than optical sensors.

CONS

A 5-10 minute warmup for polarizing the electrodes is typical before calibration or measurement.



OPTICAL

An optical dissolved oxygen sensor measures the interaction between oxygen and certain luminescent dyes. When exposed to blue light, these dyes become excited (electrons gaining energy) and emit light as the electrons return to their normal energy state. When dissolved oxygen is present, the returned wavelengths are limited or altered due to oxygen molecules in solution interacting with the dye. The measured effect is inversely proportional to the partial pressure of oxygen.

- BLUE EXCITATION LIGHT
- PHOTODETECTOR
- RED REFERENCE LIGHT
- CAP

PROS

Electrode maintenance should be far less frequent, and an anti-fouling wiper can extend deployments for several months.

CONS

Price of the sensor alone (not including a meter or data logger) can range from $700 to $1500.

Sierra Wick, Seasonal Aquatic Research Technician, with HOBO temperature logger in coldwater stream.

CLEVELAND METROPARKS

Where conservation meets innovation.

BY LORI BALSTER

Winner of a 5th National Gold Medal Award for Excellence in the Field of Park and Recreation Management, Cleveland Metroparks is known for its 23,000 acres that include eighteen reservations, hundreds of miles of trails, eight golf courses, two lakefront parks and a zoo. While much effort has been put into conserving pristine natural areas, a lot of work has also gone into improving the nexus of animal and human habitats.

Cleveland Metroparks (CMP) manages thousands of acres of wetlands, streams and forests in an effort to protect urban watersheds and maintain the buffer between human and wildlife dwellings. Pollution, algal blooms, invasive species and stormwater are all areas of concern for the Metroparks, which border Lake Erie, an area rich in both wildlife, industry and urban development.

By providing naturally functioning forests, wetlands and riparian buffers via the park system, studies estimate an annual value of five million dollars to the greater Cleveland area. Not only has CMP made watershed protection a priority, they have created a nationally recognized Watershed Stewardship Center. The Center is devoted to making watershed stewardship a central focus via education, scientific monitoring and environmental restoration.

Photo: Claire Weldon

"I was drawn to Cleveland Metroparks because they were building a center specially dedicated to improving our local waterways: the Watershed Stewardship Center," says Jenn Grieser, Senior Natural Resource Manager, Urban Watersheds, for Cleveland Metroparks. Grieser has an MPA degree in Natural Resource Management and Environmental Policy from Indiana University and has worked for CMP for almost eight years. "It's also been exciting to work in diverse types of watersheds at CMP, from cool, groundwater-fed creeks to warm-water rivers, flat meandering courses to steep and straight streams, urban to rural." The Watershed Stewardship Center opened in 2013. It includes interpretive displays as well as actual stormwater control measures around the building, transforming current stormwater management theories into practical application.

"We have about 50,000 visitors annually," says Grieser. "The mission of our facility is to improve our urban watersheds by advancing the science of stormwater management, applying what we've learned and involving the community in this endeavor. We want to tell a richer story about stormwater management using our Center. We've managed to get additional funding to do this. Each year, we have layered on more questions and delved deeper than before. Our newest phase of research with Kent State University is largely through a special gift from the Ingalls Family Foundation."

The Kent State University (KSU) work has been a collaborative effort of Grieser, Claire Weldon, Aquatic Research Coordinator at CMP, KSU Department of Geology's Anne Jefferson and Lauren Kinsman-Costello, with the KSU Department of Biological Sciences.

The latest work compared the efficacy of a green roof vs. bioretention cells at dealing with stormwater runoff. The green roof consists of a vegetation layer, soil layer, filter layer, drainage material and roof layer. The bioretention cells consist of an inlet from the road or parking lot, native plants, a temporary ponding area, an overflow inlet above ground, a mulch layer below, bioretention soil below that and a gravel bed below that. The study included water quantity and quality monitoring for the green roof and bioretention systems.

"Our initial study showed that the green roof exported phosphorus," says Grieser. "The Park Manager was following guidance on green roof maintenance from the manufacturer. But it turned out that we did not need to add fertilizer to the green roof to encourage growth, as there was already sufficient phosphorus in the soil." In nature, phosphorus is relatively sparse and is the chemical limiting growth in the environment. Growth does not occur unless sufficient levels of phosphorus are present. In urban environments, fertilizer is ubiquitous, and phosphorus is relatively plentiful. In those cases, phosphorus runoff can cause unintended, even deadly growth, such as Harmful Algal Blooms (HAB) in areas with runoff. "The roof captures rain at 100 percent in a typical shower, but if there's a large storm event the roof can't capture all the water," says Grieser.

The CMP and KSU researchers found that the green roof did not perform as well as the bioretention cells at capturing stormwater. "This is important, as the climate change data we have seen suggests that we will be seeing more intense weather events like severe storms and floods in the future," says Grieser.

One of the strategies for reducing runoff is placing what Grieser calls a "working wetland," such as the one planted next to the Watershed Stewardship Center, at the bottom of the "treatment train" – a series of stormwater control measures linked together to enhance overall performance. Wetlands excel at removing excess nutrients and pollutants from water, so long as there is not so much that the wetland becomes overwhelmed. The Center's stormwater was in need of filtering. In addition to phosphorus runoff from the green roof, there was also runoff from a nearby landfill that needed treatment. "The wetlands capture stormwater. What happened was the landfill flow was bypassing a stream. Instead, it entered the working wetlands that KSU was monitoring." Turbidity data taken before and after overflow from the landfill showed the influence of the landfill runoff on the wetlands. While the working wetland by the Center aids in improving water quality, it also acts as a habitat for wildlife such as turtles, frogs and birds.

__Left:__ Northeast Ohio Regional Sewer District, Installing flow meters in stormwater manhole in Parma. __Right:__ Flowmeter on it's hanger. The probe is 10-15 feet down, installed in sewer district in Parma.

"Urban areas have unnatural water flow," Weldon explains. "Impervious surfaces allow water to flow directly into streams during storms. In a natural habitat, water flow is more gradual and comes into contact with more land and more vegetation before going to a stream. The residence time of the water on the land in nature is significantly longer, making the water receive better filtration from the soil and vegetation, improving the water quality." Efforts are also being made to restore Cleveland's canopy, which would also have the effect of obstructing rainfall and increasing rainwater residence time naturally.

"Bioretention cells have proven to be a good way of slowing water down and improving water quality," says Grieser. "Pervious pavers can also help. Cisterns, which are basically glorified rain barrels, are another method we have of effectively dealing with runoff."

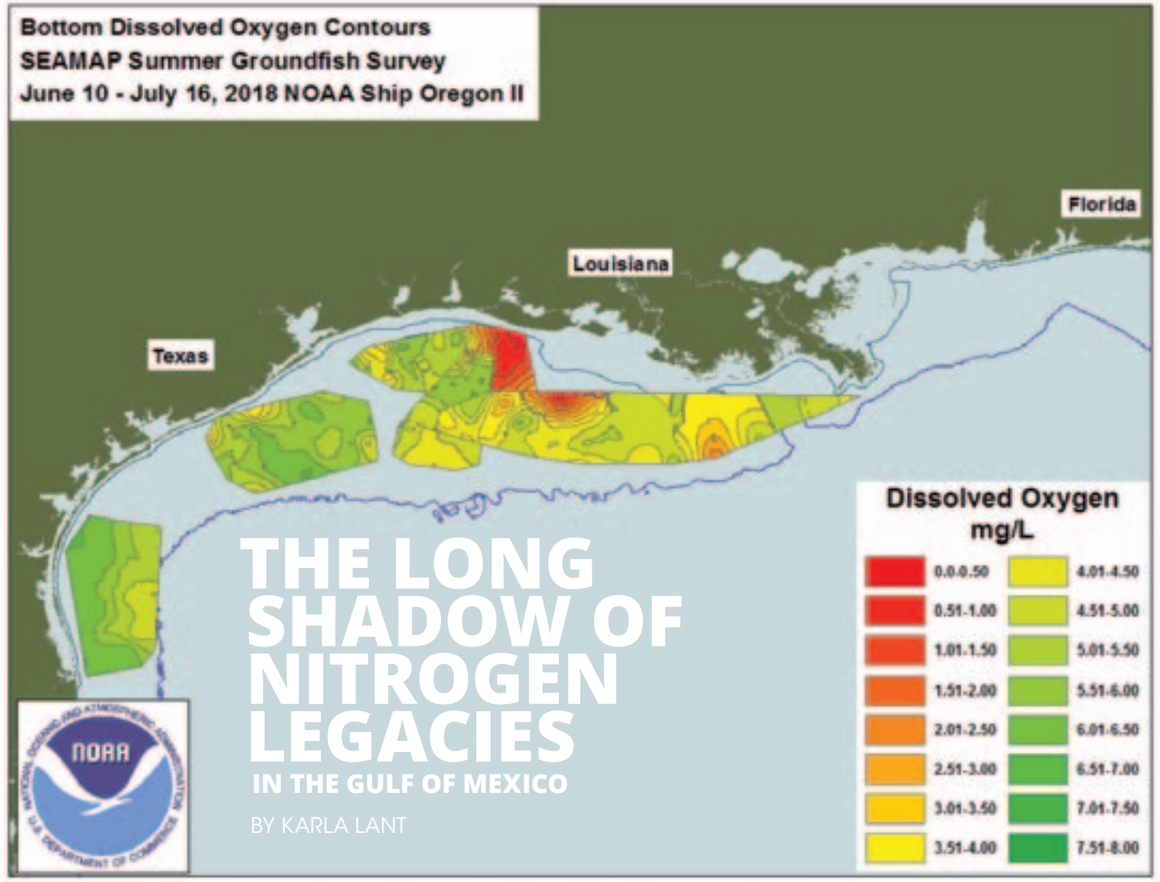
Weldon, holder of a BS degree in Biology from Baldwin Wallace and a seasoned 11-year veteran of CMP, maintains data gathering equipment and oversees data transfer to research partners. "For the Watershed Stewardship Center, we use ISCO 2150 area velocity flow meters, HOBO U20s water level monitors, soil moisture sensors and a nearby weather station. The equipment used to monitor soil moisture on the Watershed Stewardship Center green roof is a HOBO micro station (H21-002) and a HOBO soil moisture sensor EC5 (S-SMC-M005). In the near future, we will be adding PME turbidity sensors and HOBO conductivity sensors," she says.

Gathering data and dealing with environmental monitoring equipment often comes with challenges. "Equipment is all different, and often finicky in its own way," Weldon mentions. "Sometimes it's not the equipment itself that's being difficult, it's the environment the equipment needs to be placed in. Sometimes you have to deal with small diameter pipes, and it's difficult to get probes where they need to be. Batteries have to be changed out, sometimes two or three times a year. Extreme heat or cold can shorten battery life significantly. Cables can get worn out and need replacing. Some equipment is good for three to ten years, however. Some of our HOBO equipment has batteries that operate for years. Our flowmeters are submerged in outflow pipes. They measure what's coming off the landfill or working wetland of the bioretention cell. We use the HOBO equipment for groundwater measurements."

In addition to a strong research program for KSU graduate students, CMP also has a Watershed Volunteer Program for citizen scientists. "For this particular project, we train them to gather water samples and take corresponding measurements," says Grieser. About a half dozen volunteers participated in the earlier phases of this project, but interest is growing. The Park District has a cadre' of 100+ certified watershed volunteers to recruit for this research. The new training program for Watershed Volunteers starts mid-July.

While there is still much work yet to be done by researchers and volunteers, both Weldon and Grieser have enjoyed their years with CMP. "Cleveland Metroparks is diverse," says Weldon. "I grew up with CMP. It has always had so much to offer. There's always something new here. I've also enjoyed getting to intimately know our streams. I like learning how to use new equipment and troubleshooting new problems. It's never boring." Grieser adds, "I enjoy interacting with dedicated staff and volunteers that love our natural resources. I also enjoy the research challenges. There's been a lot of discussion in the technical world about having a research plan up front that basically follows the data from collection to analysis and publication. In some cases, we have instrumented streams or storm sewers without knowing exactly who will do the analysis and reporting. And for the most part, we have found interested academics or consultants. So I've been glad that we could anticipate potential research and/or management interest, and be able to provide quality data." LB

Photos: Claire Weldon



THE LONG SHADOW OF NITROGEN LEGACIES

IN THE GULF OF MEXICO

BY KARLA LANT

New research from a University of Waterloo team indicates that achieving Gulf of Mexico water quality goals may still take decades rather than years. This suggests that current policy goals may be too ambitious—but not that management and restoration efforts aren't working.

To place this into context, though, it helps to look into the past.

The water quality in the northern Gulf of Mexico has become increasingly impaired over time. Since the 1950s in particular, both widespread use of commercial fertilizers and intensive livestock production across the Mississippi River Basin have meant more nitrogen running into the Atchafalaya and Mississippi Rivers, and from there into the Gulf.

Every year starting in late spring, a dead zone forms in the northern Gulf of Mexico. It expands throughout the summer and finally ends in the autumn. Scientists began to notice this phenomenon in the 1980s, and they began conducting annual surveys of the dead zone in 1985. The zone forms when subsurface waters become so depleted of dissolved oxygen that they can no longer support most forms of aquatic life—even life that normally thrives in the area.

The zone stretches from west of the Mississippi Delta, off the coast of Texas, and over the continental shelf off the Louisiana coast. As oxygen depletion starts in late spring, the oxygen-depleted subsurface waters which are thick with nutrient-rich discharge from the Atchafalaya and Mississippi Rivers generate algal blooms. As the blooms die, bacteria biodegrade them, further depleting the oxygen in the subsurface water. Many organisms that cannot escape the area die of hypoxia.

Since measurements began in 1985, scientists have noted the expansion of this dead zone. By 2002, the dead zone was approximately the size of New Jersey, over 20,000 square kilometers. Last year it spanned more than 22,000 square kilometers.

Among the key questions for the Waterloo team: are management and restoration strategies working? And if the dead zone is still growing, how can we tell? Department of Earth and Environmental Sciences postdoctoral fellow Kimberly Van Meter, lead author of the paper, and Professor Nandita Basu, senior author of the study, corresponded with EM about the work.

"I am from Iowa, where Corn is king; I grew up feeling like row-crop agriculture was a part of the natural landscape!" explains Van Meter. "Nandita [Basu] started out her career as an Assistant Professor in Civil and Environmental Engineering at the University of Iowa. Iowa is a place that struggles with water quality, as nitrate runs off of the fields and gets into groundwater and nearby streams, eventually making its way to the Gulf. It's also a place where people are very concerned about finding ways to improve agricultural management practices and to reduce the negative environmental impacts of farming. In our work, quantifying time lags between implementation of conservation measures and seeing real, measurable improvements in water quality, we hope to improve our understanding of how what we do today will impact our ability to achieve environmental change."

Photo: NASA / NOAA (www.ncddc.noaa.gov/hypoxia/products/)

Photo: Van Meter et al.

It's a fair point. In places like Iowa, large investments into fixing the dead zone in the Gulf have been made. To many, it feels like there's little progress—or even like things are getting worse. The team analyzed more than 200 years of agricultural data to model the ways that nitrogen accumulates in soil and groundwater to more accurately predict how it will travel to the coast in future decades.

"The excess nitrogen that is applied to crops or that leaches off of animal feedlots today may take many years to actually make it to nearby rivers," states Basu. "Nitrogen can accumulate within the soil layer or in groundwater. In many cases, subsurface travel times for nitrogen are on the order of decades."

The result is extensive lags in time between when conservation measures are implemented by farmers and visible improvements in water quality. While most scientists are used to taking this kind of a long-term view, for policymakers, it's not always so easy.

"The Nutrient Task Force developed a plan to reduce the average area of the summer hypoxic zone to less than 5,000 km2," details Van Meter. "The target year for achieving this goal has now been set at 2035. Other scientists have shown that a 60% reduction in nitrogen loading from the Mississippi River would be necessary to achieve this goal."

The team's modeling results reveal that even with the immediate adoption and implementation of very effective conservation measures, it will take approximately 30 years for the excess nitrogen that's already accumulated in the agricultural land to deplete.

"In our model, we have coupled simulation of soil nitrogen dynamics with a travel time-based model of groundwater transport," Van Meter describes. "In the travel time model, we simulate the subsurface as a large distribution of travel pathways, with a distribution of travel times to the catchment outlet. Some of these pathways may have very short travel times (a year or less), while others may have travel times of more than decades. This modeling approach allows us to realistically estimate how long it will take excess nitrogen to cycle through the landscape, from the point of application at the land surface to the coast."

Of course, this problem is not solely in the lap of agricultural lands bordering the rivers that drain into the Gulf.

"The dead zone in the Gulf is understood to be driven by nitrogen coming down the Mississippi River," remarks Basu. "The majority of that nitrogen comes from what we call nonpoint sources, meaning that nitrogen from corn fields in Iowa or Illinois, or anywhere across the Mississippi basin can make it's way to small streams and eventually to the Gulf. In other words, local actions, far from the Coast, are having major impacts on downstream waters."

Furthermore, when a dead zone gets as large as this one is, there are additional complications inherent to the recovery process.

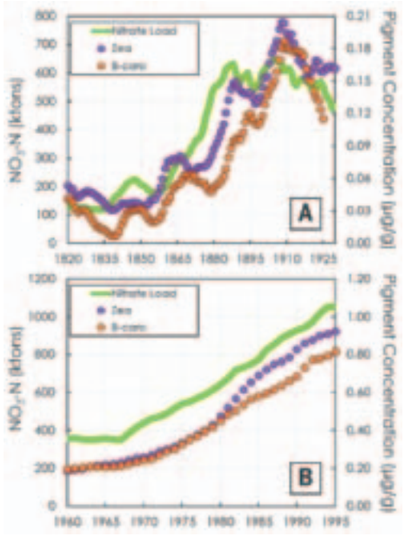
"Once we actually achieve the reductions in loading from the watershed, it has been estimated that it might take at least another 5 years for the Gulf to fully respond," adds Van Meter. "Nutrients like nitrogen and phosphorus accumulate in sediments and can then be released again sometime in the future, meaning that even if nutrients are buried, they can still negatively impact water quality. This 'internal loading' effect can increase time lags to achieving the improvements we hope to see in water quality."

Now, the research team is expanding their analysis to include phosphorus, another important driver of dead zones.

"Both nitrogen and phosphorus are known to be major contributors to hypoxia and the development of dead zones in coastal areas," details Basu. "While nitrogen is generally understood to be a key player in marine systems like the Gulf, phosphorus is more frequently the major driver of eutrophication in freshwater systems—think of inland lakes and wetlands. Lake Erie, for example, has been experiencing record-setting algal blooms in recent years, largely driven by nonpoint source phosphorus pollution from agricultural watersheds. The preliminary results from our models suggest that time lags for phosphorus are even longer than those for nitrogen. The implications of these findings in the Great Lakes region are significant, as the Great Lakes Commission as well as state and provincial governments have set a goal to reduce phosphorus loads to Lake Erie's Western Basin by 40%."

However, although there's a long road ahead for the Gulf of Mexico's recovery, the team stresses that this isn't bad news, per se. In fact, the restoration efforts are working—and everyone involved should know that.

"We think it's important to understand that this is not a negative or 'depressing' message," adds Van Meter. "In fact, it's just the opposite. Farmers and watershed managers currently feel frustrated when they make changes but don't see any real changes in water quality. What we are saying is that many of the things we are doing right now are working, but it takes time to see the results. We believe that we have already made important first steps on our way to improving water quality in the Gulf." KL



POGO mini Soil Moisture Sensor

The Stevens HydraProbe POGO mini soil moisture sensor makes soil spot sampling quick and easy. Instantly measure soil moisture, conductivity, and temperature. Includes integrated Bluetooth for easy operation with a free smartphone app.

ProSample Portable Sampler

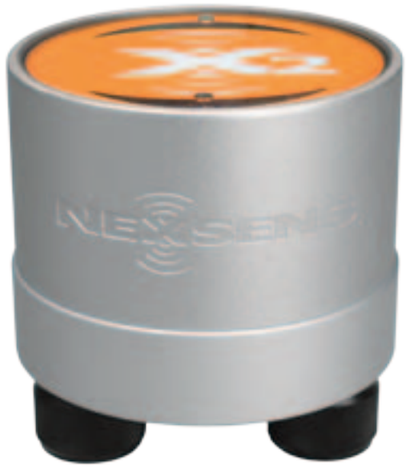
The YSI ProSample P is a full-sized, portable, discrete or composite sampler with optional SDI-12 connectivity designed for use in surface water, stormwater, and wastewater applications.

200WX-IPX7 Ultrasonic WeatherStation

The Airmar 200XW-IPX7 is a more robust weather sensor option to meet the operational challenges of harsh open water environments. Integrated GPS, accelerometer & compass for navigability.

X2 Environmental Data Logger

The NexSens X2 all-in-one environmental data logger can be controlled from any internet browser using a smartphone, tablet, or PC. It automatically recognizes sensors, through an extensive integrated sensor library and sends data to the web via wireless communication, all with ultra-low power consumption.

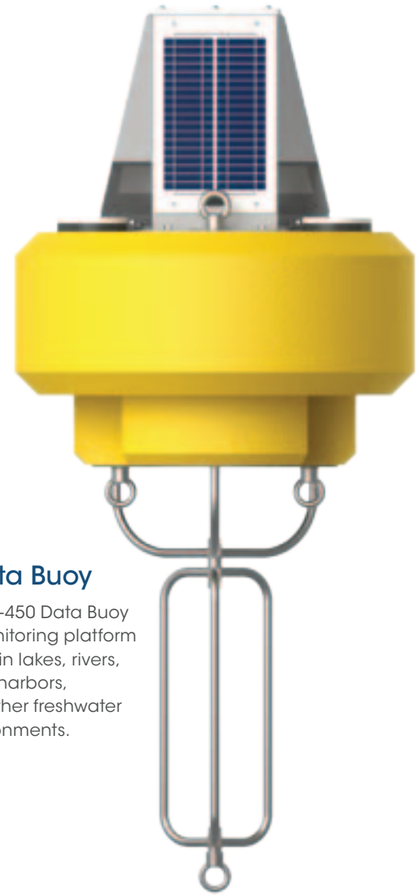


ProDSS Multi-Parameter Water Quality Meter

The YSI ProDSS (digital sampling system) provides extreme flexibility for the measurement of optical DO, turbidity, conductivity, pH, ORP, ammonium (ammonia), nitrate, chloride and temperature along with depth.

LevelVent Water Level Logger

The Solinst LevelVent provides instantly accurate water level data without the need for barometric compensation, making the data 2x more accurate than the Levelogger.



CB-450 Data Buoy

The NexSens CB-450 Data Buoy is a floating monitoring platform for deployment in lakes, rivers, coastal waters, harbors, estuaries and other freshwater or marine environments.

Arrow 100 GNSS Receiver

The Eos Arrow 100 is a high-accuracy GNSS receiver for your smartphone, tablet, or notebook computer with 60cm real-time accuracy using free SBAS.

BIOINSPIRED

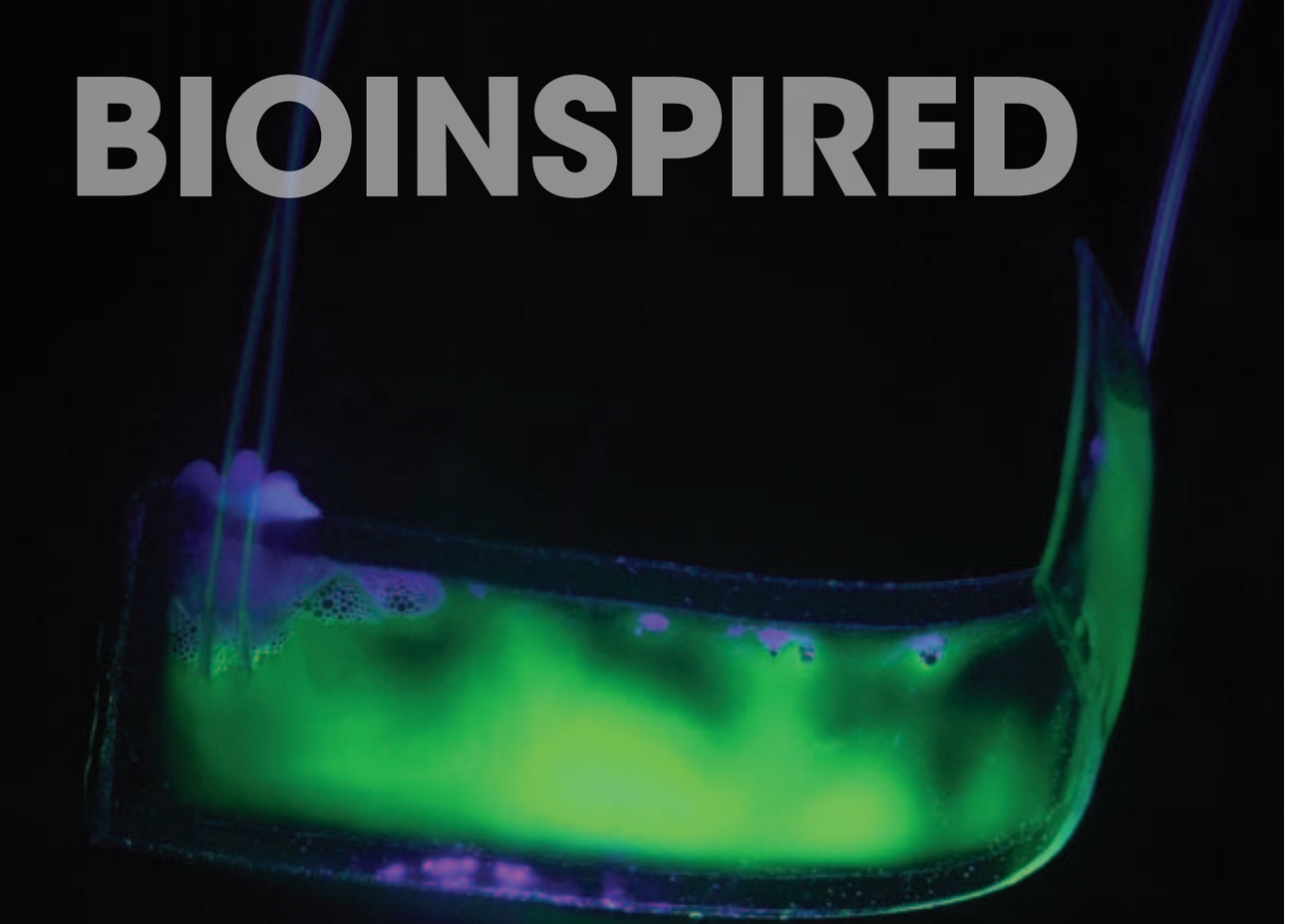


Photo: UC San Diego Jacobs School of Engineering / David Baillot

BY KARLA LANT

A UCSD team has developed a soft, translucent eel robot that moves silently underwater that will someday carry a suite of sensory instruments.

Like a strangely plump, foot-long, glowing ribbon, a translucent soft robot is swimming silently through saltwater tanks in California. The robot is a product of the Bioinspired Robotics and Design Lab within the UC San Diego (UCSD) Jacobs School of Engineering.

"This design was inspired by the eel larva, also known as leptocephalus," UCSD engineering PhD student Caleb Christianson explains to EM. "These eels are transparent and are able to swim silently through the water."

The robot is 22 cm long, 5 cm tall, and 1.5 mm thick. Instead of using an electric motor to propel itself, the robot moves using water-filled artificial muscles and a transparent electronics board that stays at the surface of the water. "It has six artificial muscles (based on dielectric elastomer actuators) in it that we activate in a controlled sequence with a microcontroller," adds Christianson.

Most robots deployed in the world's oceans today are like tiny submarines, rigid and moved by propellers, relatively noisy for marine creatures. This technology represents a step away from this kind of intrusive monitoring.

"Two key advantages of soft robotics over traditional, rigid robots are their improved safety and adaptability," details Christianson. "When working around fragile objects or living creatures, soft robots provide a safer alternative because of their inherent compliance. In addition, since they are flexible, they can more easily adapt to changing, uncertain environments."

The research is also unique in its incorporation of the environment into the robot's design: the salinity of the water is what helps the robot generate power to move. Cables feed voltage to both the pouches of water inside the robot's artificial muscles and the salt water it's immersed in. The muscles activate when the robot's electronics deliver positive charges inside of the robot and negative charges in the water around it; the muscles bend, causing the robot to swim with an undulating movement.

"The microcontroller sends a signal to high voltage converters, which put out 7.5 kV across each of the muscles, with respect to the outside water which is grounded," Christianson clarifies. "Despite the high voltage, the actuators work at very low current, which allows them to be used safely. While many other researchers use an opaque conductive material for the electrodes (e.g., carbon grease or carbon nanotubes), we use water, which is conductive enough to charge and discharge the actuators."

INNOVATION IN SOFT ROBOTICS

Other researchers have created robots using similar technology, but always with semi-rigid frames inside to maintain tension to power the robots. This study proves that a much softer robot is possible since the frames are not needed.

"The artificial muscles that we use in this robot are called dielectric elastomer actuators," states Christianson. "These are essentially stretchable capacitors, in which two parallel conductive materials sandwich a non-conducting, elastomeric (rubber-like) layer. One way to improve the performance of these actuators is to pre-stretch the dielectric layer, which requires the use of a rigid frame to hold that pre-strain. This imparts some amount of rigidity to the structure. In our design, we use non-prestrained elastomers, which means that the entire structure is soft."

Since the team is using water and transparent dielectric elastomers, the entire structure is translucent.

"This allows the robot to have 'passive camouflage,' which allows it to blend into the environment naturally," adds Christianson. "It also enables us to use different dyes in the fluid electrodes, such as the fluorescent dye shown here."

In fact, one future application may involve filling the conductive chambers within the artificial muscles with fluorescent dye for signaling. The fluorescent dye is what causes the glow in some images of the robot.

"It was recently found that certain eels will fluoresce," Christianson describes. "While the real reason for the fluorescence is up for debate, one purpose may be to help the eels locate each other during full moon spawning events. Since it's challenging to use radio waves for communication underwater, an alternative may be to use some sort of visual signaling. In this paper, we've demonstrated that the approach is feasible but the implementation and development is reserved for future work."

Also coming in the future for the research team will be increasing the robot's lifespan, equipping it with sensors, and enabling it to dive deeper.

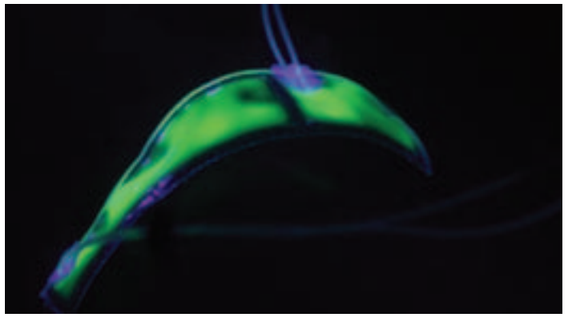
"Improvement of the fabrication approach to increase the lifetime of the robot is reserved for future work, as is further optimization of the artificial muscles (e.g., their geometry) and their actuation sequence based on the natural motion and performance of the eel," remarks Christianson. "In this work, we have only tested in aquariums. Development of a robust ballast system for deeper dives is reserved for future work, but may involve the addition of weights or air bladders depending on the desired depth and the relative densities of the materials."

Eventually, the researchers anticipate housing a suite of sensors in the robot's head—and maybe in different locations on its body.

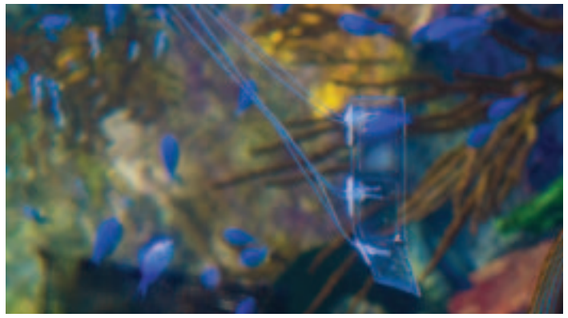
"It seemed to me to be a natural choice since many creatures have sensors (e.g., eyes, ears, nose, etc.) in their head," states Christianson. "There is also merit in distributed sensing, which will need to be explored in future work. We have not yet explored which sensors to include, which should be based on the needs of those who are interested in underwater exploration."

Ultimately, that's the hope of Christianson and the research team in a nutshell: an innovative soft robot that can be put to many different monitoring uses in the oceans. KL

Photos: (Left) UC San Diego Jacobs School of Engineering / David Baillot (Right) UC San Diego Jacobs School of Engineering / Kyoka Matsunaga

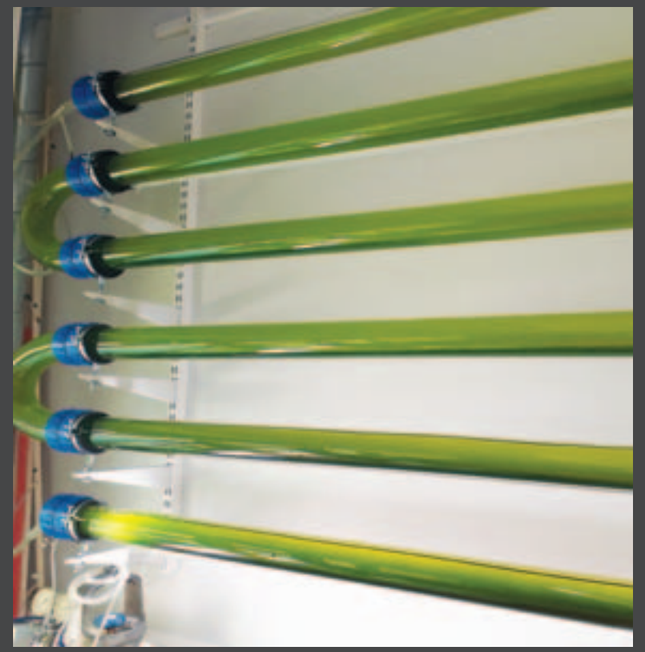


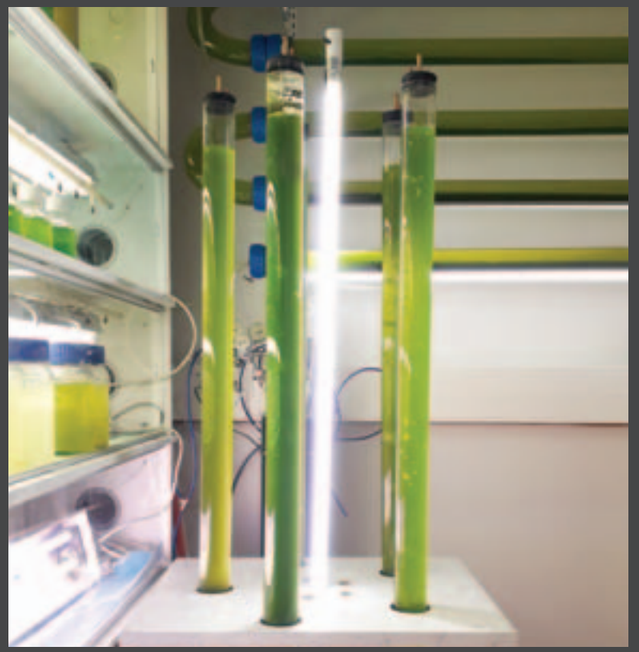
Robotic device exported from 4K video footage.



Researchers tested the robot in tanks at the Birch Aquarium at the Scripps Institution of Oceanography at UC San Diego.

microalgae





Treating Wastewater and Producing Clean Energy with Microalgae

BY KARLA LANT

On a planet that feels a little smaller every day, scientists are always looking for sustainable sources of food, low-impact and low-cost ways to produce clean water, pollution mitigation strategies, and sources of clean energy. Researchers from the University of Eastern Finland have recently found a solution to multiple problems in using Chlorella vulgaris, a universal freshwater microalga.

EXPLORING THE USES OF MICROALGAE

"Wastewater treatment is energy demanding and requires the use of expensive toxic chemicals, which cause secondary pollution," explains University of Eastern Finland Associate Professor of Water Chemistry Amit Bhatnagar. "Although wastewater treatment using microalgae is a proven eco-friendly solution, sometimes microalgae cannot grow well in wastewater due to low or high concentrations of certain nutrients or high concentrations of pollutants. Thus, this technology first requires proper optimization to achieve the best results."

That's exactly what the team set out to do with this work, with the aim of making C. vulgaris a meaningful treatment option. According to Prof. Bhatnagar, the paper and pulp industries are important to Finland's economy; this means that the pulp industry is the third largest producer by volume of wastewater, a byproduct that can harm both the environment and human health.

Paper and pulp wastewater, in particular, is carbon-rich but nitrogen and phosphorus-poor. Nitrogen and phosphorus are nutrients that microalgae must have to grow, so the team had a problem to solve as they began.

"The requirement for nutrients can be achieved by adding other wastewater which is rich in nutrients (such as aquaculture wastewater), thus offering the possibility of microalgae cultivation in industrial wastewaters without the addition of macro and micronutrients to the algal medium," details Ehsan Daneshvar, PhD student in Prof. Bhatnagar's research group. "Thus, this approach offers eco-friendly, low-cost and effective wastewater treatment and subsequent production of value-added products from microalgal biomass."

The next question: which species of microalgae? The team chose to trial C. vulgaris for several reasons.

"Chlorella vulgaris is a universal freshwater microalga," Prof. Bhatnagar describes. "This microalga can tolerate different environmental conditions and grows fast. Cultivation of C. vulgaris, even in high volumes of wastewater, is easy. Finally, C. vulgaris can grow very well in different types of wastewaters, which have low salinity."

PUTTING C. VULGARIS TO THE TEST

The team conducted the trials in three main phases. In the experiment's first step, the team used local lake water (LW), aquaculture wastewater (AW), pulp wastewater (PW), and mixtures of pulp wastewater and lake water (PWLW) and pulp wastewater and aquaculture wastewater (PWAW); the three types of water with different ratios, instead of deionized water, to prepare the microalgal medium. This allowed the researchers to select experimental units with the highest algal growth during the experiment's second phase, and use them to evaluate the feasibility of C. vulgaris cultivation both with and without the addition of macro and micronutrients.

Next, the team evaluated wastewater treatment after optimizing the growth conditions. Finally, they analyzed biochemical compositions and fatty acid methyl esters (FAMEs) to evaluate how effectively the microalga produced bioenergy.

All Photos: Dr. Amit Bhatnagar, University of Eastern Finland

The team found that the best ratios of PW to AW (or PWAW) were 80:20 and 60:40 for culturing the microalga. The highest dry algal weight without adding micronutrients was 1.31 g/L in 60% PW:40% AW. When the team reviewed how efficiently the microalga removed nutrients and organic compounds, they determined that C. vulgaris has the potential for PWAW treatment and accumulation of carbohydrates and lipids. This was true for any wastewater containing enough of the right nutrients.

"Generally, wastewaters containing higher concentrations of nutrients (nitrogen and phosphorus) are highly suitable for the cultivation of C. vulgaris and other microalgae species," remarks Prof. Bhatnagar. "Examples include municipal wastewater, aquaculture wastewater, livestock wastewater, dairy wastewater and agriculture wastewater."

However, Prof. Bhatnagar cautions that although microalgae can tolerate harsh wastewater environments, in most cases microalgae cannot be cultivated directly in the wastewater. This is because wastewater usually contains very high concentrations of toxic compounds, such as dyes, heavy metals, and pharmaceuticals. This only means that the microalga works best under optimized conditions, such as mixing the right kinds of wastewater or diluting them for better cultivation conditions.

THE FUTURE OF MICROALGA TREATING OUR WATER

Right now, microalgae like C. vulgaris are already part of wastewater treatment in some countries, including some places in the United States. However, if the team is able to further optimize their system, it may be used more frequently in the future—especially since it really addresses at least two important issues.

"Clean water and energy supply are two important challenges of the 21st century," states Prof. Bhatnagar. "Microalgae can address both these issues. Nitrogen and phosphorus compounds (sources of eutrophication in the environment), among other macro and micronutrients, are considered as the main fertilizers for the cultivation of microalgae. As microalgae grow in wastewater by using these nutrients, the concentrations of these will be decreased and the produced microalgal biomass can be used further to produce bioenergy. Biodiesel (from lipids), bioethanol (from starches) and biogas are the main bioenergy products which can be obtained from the microalgae."

The team is primarily working to adapt this technology for wastewater treatment and for recovering resources such as bioenergy, metals, and nutrients from water and wastewater. They also plan to develop bio-based products from microalgae for different applications. Although there are no consumer applications envisioned as yet, the main stakeholders of this technology—including wastewater treatment plants, bioenergy companies, and the aviation and biotechnology industries—given the range of uses here the team is likely to be busy. Furthermore, microalgae-based technologies generally already have a number of consumer applications, so the full potential of this research will unfold over time.

"Microalgae can help in combating various global challenges including climate change, food insecurity, wastewater management, and more," adds Prof. Bhatnagar. "Moreover, microalgae is a sustainable food and fuel source for the future." KL

> **"CLEAN WATER AND ENERGY SUPPLY ARE TWO IMPORTANT CHALLENGES OF THE 21ST CENTURY"**
>
> **- Professor Amit Bhatnagar**
> Associate Professor of Water Chemistry, Eastern Finland

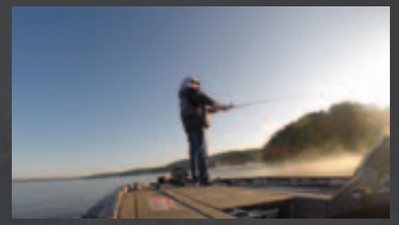
WATCH, RECORD, & SHARE
DIRECTLY ON A SMARTPHONE

The FishSens SondeCAM HD underwater camera streams video to mobile devices and other compatible displays.

The research-grade camera features the latest low-lux image sensor for clear color and high definition visuals in various light conditions. Underwater video can be viewed in real-time or recorded and shared directly on any supported smartphone or tablet. An integrated WiFi module allows for wireless streaming.

An ultra-durable aluminum body protects the SondeCAM and can operate at depths up to 100 feet in both freshwater and marine environments. A scratch-resistant lens and polymer bumper ensure years of service.

An easy-to-use mobile App is available for both IOS and Android.



FISHING

SEARCH & RESCUE

HABITAT

INSPECTION

SondeCAM HD
UNDERWATER CAMERA

IN THE GREAT LAKES

RESEARCH FROM AROUND THE BASIN

HURON

Plastic is a widely publicized topic for being a prominent threat to our oceans, but how does it impact inland lakes? Small pieces of plastic, called microplastics, are abundant in the Great Lakes, causing concerns for how plastic pollution is having an effect on water quality and wildlife. As a way to supplement further understanding of the extent of plastic pollution in the Great Lakes, the Lake Huron Centre for Coastal Conservation (LHCCC) is piloting a citizen-science based microplastic sampling project to collect data on the presence of microplastics in nearshore environments and to increase awareness of the problems associated with plastic pollution in Lake Huron. This initiative utilizes 50 volunteers around the Lake Huron and Georgian Bay coast to collect two 1-liter water samples from the water's surface using the protocol outlined by NOAA Sea Grant. These samples are brought into local high schools where they are filtered and examined by students under the guidance of LHCCC staff. This project provides a great opportunity to connect with numerous shoreline communities through our dedicated volunteers and provides an in-depth understanding of the extent to which humans can influence the world's largest source of freshwater.

Tineasha Brenot, the Lake Huron Centre for Coastal Conservation. (2018) https://www.lakehuron.ca/

MICHIGAN

The Cooperative Institute for Great Lakes Research (CIGLR), partnered with the National Oceanic and Atmospheric Association (NOAA) and the Great Lakes Environmental Research Laboratory (GLERL) maintain a network of monitoring systems in the Great Lakes (GLOS) that provide a number of services to both local residents and researchers. The network includes two data buoys, autonomous underwater vehicles (AUVs) and gliders. The team aims to provide up-to-date forecasts that ensure a safer recreational environment and help with early warning systems. A Long-Term Research Program is in place which uses gliders to survey Lake Michigan annually, while Harmful Algal Bloom (HAB) monitoring and forecasting are aided by the use of AUVs, with plans to include acoustic telemetry. Great Lakes CoastWatch works in tandem with GLOS using remotely sensed data to improve mapping, research, and policymaking in the Great Lakes.

CIGLR and NOAA-GLERL (2018). Great Lakes Observing System (Press Release). Retrieved from https://ciglr.seas.umich.edu/project/great-lakes-observing-systems/

Photo: (Huron) Tineasha Brenot; (Michigan) National Park Service

SUPERIOR

A team comprised of 36 researchers from six institutions and 11 organizations came together to study mercury levels in the Upper Peninsula and the entire Great Lakes region. The group proposes time frames for overall mercury reduction using 3D tropospheric chemistry models for each of three policy-making scenarios. Mercury is classified as an atmosphere-surface exchangeable pollutant (ASEP), contributing to its toxicity and persistence in the environment. Noel Urban, a professor of environmental engineering, works with Michigan Tech to raise awareness of mercury legacy in the Great Lakes. Including anthropogenic sources and variations in local environments, the study aims to bridge the gap between scientists and the public to raise awareness of the growing mercury threat in fish populations which are consumed by local communities.

Environmental Monitor (2018). Bringing the Complex Picture of Mercury Pollution in the Great Lakes into Focus. (News Article). Retrieved from https://www.fondriest.com/news/bringing-complex-picture-mercury-pollution-great-lakes-focus.htm

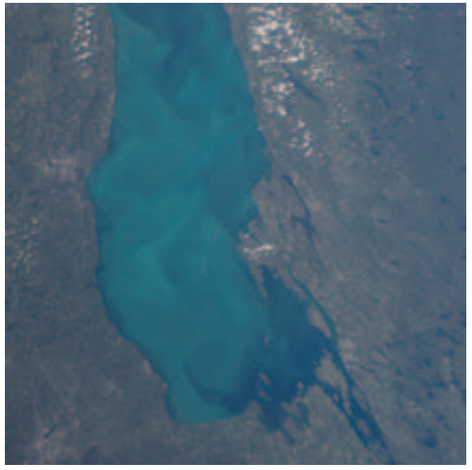


Photo: (Superior) Sarah Bird/Michigan Tech; (Ontario) NASA; (Erie) NOAA - Aerial Associates Photography, Inc. by Zachary Haslick

ONTARIO

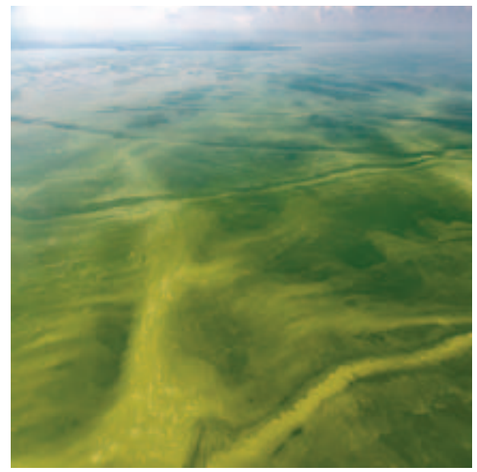
The record-breaking high water levels surrounding Lake Ontario in 2017 caused massive problems for the community. Not only did the water levels reach up to three meters over the average, but they have also remained higher, about 5 inches, according to the Army Corps of Engineers (USACE). The group estimates that water levels will not be as high as in 2017, based on the amount of rain this year compared to last years, as well as observations. People in the community have continued to see a loss of property along shorelines and damage in areas where the water level has remained above the average. Shoreline erosion is the most common issue seen by members of the community following the recent change in water level which is partially due to the high cost of repair. This is a concern and researchers are currently monitoring the area, adjusting the regulatory outflows and inflows, providing flood control options and building a better forecast for the future.

Niagara Gazette (2018). Damage persists along Lake Ontario (News Article). Retrieved from http://www.niagara-gazette.com/news/local_news/damage-persists-along-lake-ontario/article_ed4a0fb3-5c3c-5529-8392-cc5016eff64c.html

ERIE

Kasich administration in Ohio announced that it would declare the open waters of western Lake Erie impaired. Many shorelines along the lake have suffered this same fate, although this is a first for its open waters. Following years of opposition in favor of agricultural concerns, this was a major reversal. No immediate changes come from the open waters being declared as impaired, but the hope is that it will bring about change. Erie has struggled with problems like algae blooms for a while now, but increased rain and excess nutrients have made the issue worse. If Ohio doesn't show how they plan to implement an effective conservation practice, the EPA will be forced to step in. The future of Lake Erie depends on both city officials and agricultural programs to work together to solve the issue.

Environmental Monitor. (2018). Inside the Struggle to Designate Lake Erie's Water Impaired (News Article). Retrieved from https://www.fondriest.com/news/inside-struggle-designate-lake-eries-water-impaired.htm



SAVING BUZZARDS BAY

Paula and Len Boutin.

Citizen Scientists, Researchers Band Together to Save Buzzards Bay

BY LORI BALSTER

When she saw an ad in her local paper 20 years ago, Paula Boutin was immediately intrigued. "They were asking for citizen scientists to volunteer and help gather information to save Buzzards Bay," she says. "I signed up. I've always thought of myself as an environmentalist." As a resident of a waterfront home in Wareham, MA, Paula was happy to pitch in and help protect the Bay, not only for herself but for her neighbors and the wildlife living there, too. Four years later, her husband Len joined her. Today, Paula has been volunteering to save Buzzards Bay every year for 20 years, Len for 16.

Using sampling poles made by Horacio's in New Bedford and gradated by Tony Williams, Director of Monitoring Programs for Buzzards Bay Coalition, along with toolboxes provided by the Coalition, Paula, Len and other citizen scientists of diverse ages and backgrounds come together each year from May to September in Buzzards Bay, ready to help monitor the Bay's health and keep an eye on changes in the Bay that might be of concern. "The fact that we can notify researchers immediately if we see something out of the ordinary is one of our favorite things about the program," says Len.

Tony Williams has organized and trained citizen scientist volunteers for many years. Volunteers are organized in May. Williams provides the volunteers with handbooks and data sheets, then assigns them sampling sites to go to for data gathering. The citizen scientists provide crucial data Buzzards Bay Coalition would not be able to collect without them. "We just wouldn't have the staff or resources otherwise," says Rachel Jakuba, Science Director for Buzzards Bay Coalition. "We're grateful for their help, and they enjoy it every year. We recently had a volunteering record: 166 citizen scientists took part in data gathering. It's been a very successful program."

To take data, volunteers are given metal sampling poles. These poles hold two sampling bottles with rubber stoppers, which Williams assembles. The citizen scientists are instructed to drop the bottles to a certain depth in the Bay. The toolbox sampling kit has a thermometer, graduated cylinder, Secchi disk, rinse bottle, safety glasses and hydrometer. They also contain Hach dissolved oxygen chemistry test kits. Instructions in the handbook are provided for all testing procedures, including calculating salinity and determining dissolved oxygen using the Hach kit. The Secchi disks are used to monitor water clarity. Handbooks also explain the importance of checking for weather and tides using a Beaufort scale, which expresses how windy and wavy it is.

While the Buzzards Bay Coalition citizen science data gathering methods have been mentioned in a previous Environmental Monitor article, there have been a few changes since 2016: thermometers now are FisherBrand and have digital readouts accurate to one decimal place. Previous thermometers had tick marks and were only accurate to the degree. Another change is that a neighborhood pond, Quicksand Pond, was added to the study. "Because we added Quicksand Pond, we also gained 15 more citizen scientists who lived in the area and wanted to participate," says Jakuba.

Water samples are taken about every five days during the May to September sampling periods. For two days in July and August water samples are collected to be tested for nutrients and delivered to a partner lab at the Marine Biological Laboratory. For those samplings, volunteers get additional bottles, ice packs to keep the samples preserved, syringes and a filtering apparatus for filtering for particulates.

In training sessions at the beginning of each season, volunteers get pre-printed data sheets which they submit each week with their testing results. Tony, Rachel and an assistant do all the water quality assessment and data analysis using the information they get from volunteer data sheets.

Citizen scientists provide weekly information on Buzzards Bay temperature, salinity, dissolved oxygen and water clarity. During July and August, they provide information on Bay nutrients including nitrogen, phosphorus and chlorophyll. The Ecosystems Center at the Marine Biological Laboratory (MBL) in Woods Hole does the analytical work for the nutrient samples. Rich McHorney and Lindsay Scott at the MBL perform nitrogen, phosphorus and chlorophyll analysis and MBL Fellow and Woods Hole Research Center Senior Scientist Christopher Neill oversees the program and provides technical support to the program.

Dissolved oxygen samples are also collected, but they must be collected in a certain way: in a specific three-hour window from 6-9 AM. The data must be collected at that time, not long after the sun has risen when plants are beginning photosynthesis, which can alter dissolved oxygen results. There are now over 200 data collection stations in Buzzards Bay.

Volunteers are told up front about the time commitment involved in sampling: the volunteer needs to commit to sampling for the entire collection period. About an hour of sampling is required per day. "The time commitment is not an issue for most people. They don't mind and are happy to do it," Williams says. "We get people from all kinds of backgrounds. Many are non-scientists but we get scientists too. Sometimes we even get whole families. Usually, our volunteers are high school age or older. We take people of all educational levels. The program is really quite user-friendly. I'm the one who typically does the volunteer coaching. Some need a little more encouragement than others, but in the end, most jump on board and collect data for the whole duration."

Among the few requirements for citizen volunteers are they must be vigilant when using equipment and they must be able to stand or work on the dock, pier or bridge to take samples. Some volunteers go out in boats to sample. Nutrient samples, for example, are typically taken using boats. Volunteers keep the sampling equipment with them but hand over physical samples for nutrient analysis.

Baywatcher volunteer Brian O'Rourke decants a water sample from his sampling pole in Falmouth, Massachusetts.

Baywatcher volunteer Jamie Alves collects a water sample from the Acushnet River.

Photo: (Top) Mary Lou O'Rourke / (Bottom) Chris Saulnier

Photo: Len Boutin

Buzzards Bay Coalition continues to monitor the health of the Bay and reach out to the surrounding community through its Baywatchers citizen scientist program. The word about the program is spread through a Buzzards Bay Coalition newsletter and a website, www.savebuzzardsbay.org Letters are sent to previous volunteers to encourage them to stay involved. "Volunteers also recruit more volunteers," says Williams.

The Buzzards Bay Coalition, a non-profit organization, operates the Baywatchers citizens' monitoring program under the auspices of a quality assurance project plan approved by the EPA and the Commonwealth of Massachusetts. This plan is reapproved every five years.

"We actively use the data citizen scientists collect in resource management. We also use the data to make water quality assessments, and use it for developing nitrogen level assessments," says Jakuba. "The role of citizen scientists in maintaining the health of Buzzards Bay can't be overstated. The citizen scientists are the heart of the program."

Citizen scientists Paula and Len Boutin plan on continuing to volunteer for many years to come. "Working in this program has been a pleasure," says Paula. "We have watched the Bay improve over time because the people who live here have developed a greater appreciation for it and have worked to protect it. There's less trash in the Bay now that people have really been taught over the years to take care of it, and not take it for granted."

"We've also seen birds return as the Bay has improved," says Len. "We're getting more ospreys now and more bald eagles."

"Once one of them dropped a scallop on our lawn," Paula laughs. "That was a surprise! We didn't use to see things like that. But it tells us the birds of prey are doing well."

Being a citizen scientist at Buzzards Bay has led to other surprises, too.

"Once we saw a pipefish…we think it came from the Gulf Stream. Sometimes creatures get lost. It was very pretty," says Len. "If we lived somewhere else, we never would have seen something like that. The Bay is a unique place."

"We love it here," says Paula. "We try to recruit more citizen scientists whenever we can. We want people to respect the Bay! If everyone does that, the Bay will be here for people to enjoy forever." LB

NAVATICS MITO UNDERWATER DRONE

BY KARLA LANT

The MITO recording a sea turtle

The Navatics MITO underwater drone provides a steadier alternative to shaky, unstable underwater cameras. The remotely operated underwater vehicle (ROV) is equipped with advanced active stabilization and a 4K camera, so anyone with the purchase price can explore up to 165 away and 40 feet beneath their boat—all without ever getting wet or dizzy.

The MITO, Navatics first drone, reached its funding goals in about five hours on Kickstarter. Fay Wong, PR Director for Navatics, told EM about the MITO.

A unique tether that both extends the battery life with a built-in solar panel and that transmits signals back to the controller is used to deploy the drones. The drone can navigate about 165 feet away from the boat or shore depending on tether length and is rated to dive up to 135 feet.

What sets the drone apart, however, is its "advanced active stabilization," which prevents the choppy, dizzying footage that many underwater cameras and ROVs produce.

"Our stabilization algorithm reads values from various sensors, including a depth sensor, gyroscope, accelerometer, and magnetometer, to best decide how fast each thruster should rotate," details Wong. "The commands are then sent from the processor to the thrusters. In addition to the stabilization algorithm, we also use specially-designed thrusters and drivers; these allow us to control the rotation speed and behavior of each individual thruster down to the very fine details."

The drone's two-hour run time (or four-hour run time with solar power boost) is minimally impacted by this system.

"Stabilizing equates to hovering underwater, so it does not impact the power consumption by a whole lot," remarks Wong. "Without any extra payload on the drone, it is capable of hovering for four hours straight on a single charge."

The MITO's existing payload consists of a 4K, 30 fps camera and built-in LED video lights.

"MITO is equipped with a wireless transmission system," Wong elaborates. "It can deliver HD quality, 30 frames per second real-time, live video via a neutrally-buoyant cable that runs up to a waterproof communication buoy. Users can explore the underwater world through Navatics App using their smartphones up to 500m away from the buoy. Navatics MITO can operate in low light underwater condition because it has dual 1000 lumen LED lights to illuminate a clear path underwater, and Inertial Measurements Unit and pressure sensors measure its depth and orientation."

"Navatics MITO can hover even in a strong current and keep its orientation and focus regardless of the complex environment underwater," adds Wong. "The four thruster design also enables its body to actively adjust its tilt angle from -45 ° to 45 ° while moving forward and backward to obtain solid footage from a new perspective."

MITO has a number of features that make it ideal even for non-technical users. For example, its app, which works on almost any smartphone, offers users built-in color correction.

"We felt that easy one-click color correction would save users time and effort," Wong explains. "They can share the color-corrected images and video directly to social media. We are also working on bringing other new filters and functions like image enhancement to MITO."

The app also allows the controller to attach to the smartphone, for live streaming in 1080p. Furthermore, the MITO is specifically designed to fit into a carry-on or backpack, at 15 inches long and 6.6 pounds.

"We actually talked to many people from different backgrounds and industries, some of them scientists," states Wong. "They asked if the ROV is capable of carrying an extra payload so that they can put on extra sensors or 360° cameras on the bracket. We are working on an algorithm that would let us takes heavier payloads without affecting the performance of the ROV, and we will update everyone once this algorithm is up and running on the Navatics MITO!"

Ultimately, for the Navatics team, the work is about far more than enjoying the ocean as a hobbyist.

"More than anything else, we would really like to work with the scientific and conservationist communities to find out what small, consumer-grade ROVs can do for the environment," Wong adds. "We, as humans, take so much out of the ocean every day. Apart from their exploration and entertainment purposes, we would be more than happy to see consumer-grade ROVs helping scientists and conservationists with ocean monitoring and research."

Next generation iterations will hopefully go deeper and further—while staying just as stable. The MITO will retail for $1,999.

Photo: Navatics

KEEPING WATER PUMPS WORKING IN KENYA

SweetSense Inc, provides sensors and data collection platforms to global health initiatives in developing countries.

BY MINDY COOPER

A start-up company out of Portland State University is harnessing commercially available sensor technology to make a difference in health initiatives for developing nations.

SweetSense Inc., a spin-out from the university's Sustainable Water, Energy and Environmental Technologies (SWEET) Laboratory, manufactures and distributes products developed in the laboratory to the global health community.

"The SWEET lab has developed a custom data collection and analytics platform that can be applied to improve rural international development. SweetSense is working to get the products into the hands of the people who need them, where they can make a real difference" said Dexter Gauntlett, the business development director for SweetSense.

SweetSense combines a variety of sensor technologies with cellular and satellite technology for data reporting. Those products are designed to be installed in community/household-level fixtures like borehole water pumps, latrines and hand-washing stations. The collected data is transmitted to the Sweet Data online collection tool that can be downloaded from any browser with a protected login.

One area where the products are already making a difference is Kenya.

The company is part of a 21-organization public-private partnership dedicated to increasing the number of citizens in Kenya that have regular access to water and improving water management. Known as the Kenya Resilient Arid Lands Partnership for Integrated Development or Kenya RAPID, the effort is led by the Millennium Water Alliance and the United States Agency of International Development. It includes partners across many industries.

Kenya is a very dry, drought vulnerable area that makes farming and raising livestock for sustainability very difficult. Research has shown that only 37 percent of the population has access to readily available water. Kenya RAPID wants to increase that to at least 50 percent. To do that, the group is focusing on five counties, Garissa, Isiolo, Marsabit, Turkana and Wajir.

The effort has many moving parts. SweetSense is working to improve water management through the use of data.

SweetSense SAT, a product of SweetSense Inc is shown. The product is currently being used to monitor water pipe functionality in Kenya.

"The emphasis of the past 30 years in the development sector has been installing as many water pumps as possible in the area because it was believed that more pumps meant more water," said Gauntlett. "But 50 percent of the pumps fail in the first few years."

In the past when a pump failed, officials were only made aware of it through citizen complaints or through employee spot checks that were performed at lengthy intervals. In some instances, a pump could be down for a year before receiving maintenance.

SweetSense and the Kenya RAPID team are using the company's sensor technology to revolutionize and speed up this process and drastically decrease the days that a pump is down.

"We believe that it's cost effective to invest in systems that use remote sensor communication and alert a technician immediately when the pump needs serviced," said Gauntlett. "Area officials are able to monitor water pumps from their desks, they no longer need to drive long distances to check the pumps. They can fix pumps before they completely malfunction and also make informed decisions on the maintenance scheduling."

The technology is already making an impact.

"SweetSense sensors have been very useful in providing real-time information on functionality in remote locations of northern Kenya," said Doris Kaberia, chief of party and Kenya programs director from Millennium Water Alliance.

In addition to Kenya, SweetSense has deployed their products in India, Nepal, Indonesia, the Philippines, Rwanda, Kenya, Uganda, Ethiopia, Haiti and other countries. More than 1,000 of its sensors have been installed worldwide.

Photo: SweetSense

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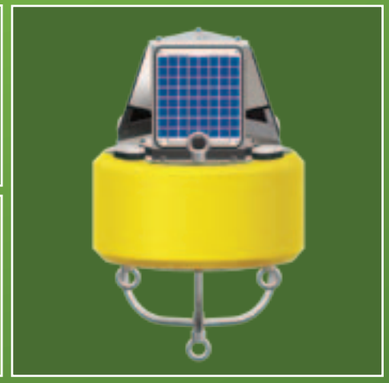

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