ENVIRONMENTAL
monitor
SUMMER 2022
APPLICATION AND TECHNOLOGY NEWS FOR ENVIRONMENTAL PROFESSIONALS

WILDFIRE SMOKE & THE FOOD CHAIN

IoT for Smarter Aquaculture
Remote Monitoring Applications Abroad

The Frozen Frontier
Chasing Data In Antarctica

Cloud Data and Water Quality Monitoring
Susquehanna River Basin Commission

Welcome...

Welcome to the Summer 2022 edition of the Environmental Monitor, a collection of the best of our online news publications. In this issue, we showcase researchers from across the globe and IoT applications for environmental monitoring.

From the continuous monitoring occurring in the Susquehanna River Basin region of the United States to fish farms in Malaysia, this latest edition covers a variety of remote monitoring methods. Empowered by cloud data, researchers in Malaysia, Australia, the United Kingdom, the United States and elsewhere spent the year gathering data and publishing their findings to the public.

Our writers also sought out science professionals that are dedicated to harnessing data. Featuring stories from a marine technician in Antarctica, an outreach specialist in Michigan, and researchers from across the world, this edition showcases the diversity of science.

Located in Fairborn, Ohio, Fondriest Environmental is the trusted partner you can turn to for help with environmental monitoring projects. We assist in everything from planning and monitoring to systems integration, equipment calibration and training. Our specialists have years of experience integrating and deploying remote systems and working with leading suppliers such as YSI, Hach, Thermo Scientific, Solinst, NexSens and many more.

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ON THE COVER

Front: Wildfire smoke near Mount Shasta, California in 2022. Photo taken by Erin Suenaga. (See Pg. 24).
Back: Diver collecting freshwater mussels in the Apalachicola River Basin, FL. Photo Taken by Greg Zimmerman of Enviroscience, Inc.

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Anna McBee; Dawn Hintz; Emma Jones

IN THE NEXT EDITION

Subscribe to read the next edition of the Environmental Monitor, focusing on *biodiversity*. Stories will feature in-depth analysis of ecological diversity in vegetation, soil, animals and microorganisms.

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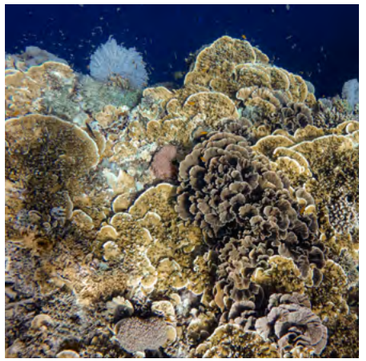


Marine Cold Spells: The Flip Side of Global Warming

While many of her colleagues around the globe are studying marine heat waves and temperature rise effects related to global warming, Yuxin Wang's team focused on the opposite: global marine cold spells. Climate change has led to the increased variability of weather and temperature, harming wildlife. For example, a severe 2010 cold-water event caused unprecedented mortality to corals of the Florida reef tract and reversed previous survivorship patterns.

Charles River Algal Blooms Prompt A Floating Wetland

The Charles River used to be a swimming hotspot for Cambridge and Boston residents. Unfortunately, decades of industrial pollution and nutrient runoff have degraded water quality and eliminated public swimming in the Lower Charles, but a movement is afoot to get Boston and Cambridge back in the water. An experimental floating wetland and new research and analysis of water quality data that shows a possible effective detection system for algal blooms on the Charles River are two new steps toward the goal of safe, accessible swimming.

Harnessing the Gulf Stream for Renewable Energy

The Gulf Stream, the massive western boundary current off the east coast of North America, moves water from the Gulf of Mexico north and west across the Atlantic Ocean. There's a lot of energy in that much moving water, and researchers are trying to put it to use. At one such spot off the coast of North Carolina, researchers have dropped moorings and research instruments to study the current. Recently deployed mooring, subsurface buoy, and other monitoring instruments collect measurements that characterize the current and identify oceanic water masses in the area.

IOT FOR SMARTER AQUACULTURE

REMOTE MONITORING APPLICATIONS ABROAD

"SMART DEVICES WHICH COMMUNICATE TIMELY, ACCURATE INFORMATION TO OPERATORS WILL BRING HUGE IMPROVEMENTS"

– KEVIN QUILLIEN, R3-IOT

With aquaculture booming, IoT may be the future of the market. Fish have been farmed for millennia but only recently has the industry achieved such a vast scale. As overexploitation and climate change threaten wild fish stocks, aquaculture is increasingly framed as an alternative that can provide a low-carbon and healthy protein source.

But, as the global population grows, the industry has the monumental task of meeting the increasing demand for seafood. In order to provide higher yields economically and sustainably, it is turning to the Internet of Things, or IoT.

IoT refers to technology that pulls data from smart sensors to the Cloud and crunches it using analytic software tools, including artificial intelligence (AI), to monitor and improve efficiency or productivity.

Photo: Matthew Pierce, NSW DPI

(Top) Oyster Farm on the Clyde River.
(Bottom) Freshwater bleached oysters.

New South Wales, Australia

In Australia, New South Wales (NSW) is home to the Clyde River. The estuary is famous for oyster farms that contain a series of sensors mounted on buoys. These sensors are part of the Estuary Sensor Platform, a tool built for the Climate Smart Pilots (CSP) project, which was launched in 2018. The project aims to understand how digital technology can help farmers track and respond to changing conditions through data collection and decision-making tools.

"Clyde oyster farmers face challenges such as poor access to local weather data, heatwaves, and water quality in harvest areas," said project officer, Matt Pierce. "The Estuary Sensor Platform includes IoT sensors for salinity, temperature and an automatic weather station that provides on-farm data, a cloud-based system to store and process the data, and a dashboard for data access, visualizations and alerts. The system uses low-power, wide-area network protocol (LoRaWAN) and transmits measurements multiple times a day."

Estuarine environments are renowned for complex weather systems that can be difficult to predict. Local, real-time data is a strong step forward, enabling confident decision-making. For example, data on salinity, temperature and rainfall can help farmers predict and prepare for harvest areas opening or closing, providing extra peace of mind.

(Top) Matthew Pierce, NSW DPI; (Bottom) Professor Dato Dr. Mohamed Shariff Mohamed Din

Selangor, Malaysia

IoT is also taking off in Malaysia. After receiving a grant from the Malaysian Technical Standards Forum Bhd (MTSFB) to develop a proof-of-concept on aquaculture, researchers from other educational institutions began incorporating IoT. For example, the Universiti Tenaga Nasional (UNITEN) and Universiti Putra Malaysia use IoT to detect changes in water quality parameters, analyze the data and provide fish and shrimp farmers with information. Increased practice and data collection enable better decisions on farm environments. Farmers have more references in regards to the health status of fish, shrimp and feeding levels, says Ms. Dipika Roy of Universiti Putra Malaysia.

"Cutting-edge technology such as IoT, coupled with AI and image analytics, will improve environmental conditions for species to grow in and help farmers achieve a higher yield. It has a lot of potential and will be very beneficial in the future," she said.

"If we can detect whether a certain parameter is heading toward dangerous levels, we can act quickly," added Dr. Abdul Rashid Mohamed Shariff of Universiti Putra Malaysia. "This is a huge benefit. We also believe that IoT could draw more young people to fish and shrimp farming as they are increasingly attracted to the concept of smart aquaculture."

(Bottom) Aquaculture tanks in Malaysia.

Glasgow, Scotland

As with any technology, IoT does not come without challenges. Deploying it can be expensive, especially for offshore and remote installations. Security and connectivity are critical to ensure that networks and data are not vulnerable to hacking or cyber-attacks. The biofouling of equipment requires regular cleaning, while parts can become lost, stolen, or caught up in debris.

Poor connectivity must also be addressed if the industry wants to digitize, says Kevin Quillien, co-founder and CTO at R3-IoT. The UK firm delivers a satellite-enabled connectivity platform that forms the foundation of any digital transformation, providing end-to-end data services from smart devices anywhere, regardless of existing infrastructure.

Developed to help future-proof fish farms, the platform is built on an open interface to easily integrate into existing and future IoT systems to provide resilient, automated data transmission.

"Digital transformation will be key to aquaculture's progress," said Quillien. "Smart devices which communicate timely, accurate information to operators will bring huge improvements. Digitizing operations enables local and central teams to obtain more insightful information about their sites in higher volumes, empowering them to make informed decisions, understand the cause of any issues, and improve safety and productivity. Data acquired over time can reveal deeper insights into environmental impact, feed optimization and create predictive models for better decision-making."

(Top) Allan Cannon (Co-founder and CEO) and Kevin Quillien (Co-founder and CTO) of R3-IoT.
(Bottom) An R3-IoT kit on site at a fish farm in Scotland.

Integration of IoT and Aquaculture is Inevitable

"It's inevitable that digital will play a significant role in how aquaculture operates in the future – but this is dependent on having access to reliable, continuous connectivity across all sites regardless of location. Intelligent connectivity solutions are crucial to helping the industry unlock the potential of digitization."

Aquaculture has a vital role in food security and development; therefore, streamlining processes and increasing efficiency is critical for the future of aquaculture. More relevant data will need to be collected using new technologies, but once the benefits of this are clear, the return on investment will become evident, leading to much better outcomes. BW

(Left) Aeration to provide sufficient oxygen to cultured animals. IoT can monitor low oxygen levels and give warning or switch on the aerators to overcome the problem.

Photos: (Top) R3-IoT; (Bottom) Professor Dato Dr. Mohamed Shariff Mohamed Din

IoT ENVIRONMENTAL MONITORING SYSTEMS

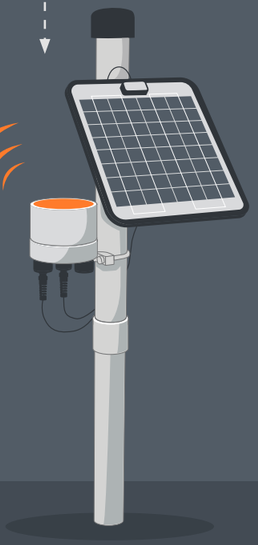
What Is IoT?

IoT, or the Internet of Things, describes the network between items that contain sensors, software, and other technologies intended to connect and exchange data across systems via the World Wide Web.

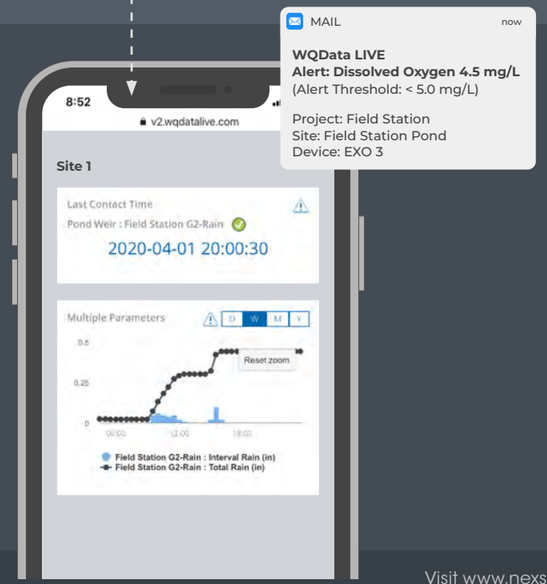
Environmental Monitoring Systems

With the right system, water, air and soil sensors may all be IoT-compatible. Wi-Fi, cellular, satellite and radio telemetry options are all available with a multitude of data loggers which can connect environmental monitoring systems to the cloud.

SENSOR DATA



Data is chopped into multiple codes called packets. Packets then hop from device to device until reaching the final destination. The receiving device then compiles the multiple packets into the original, cohesive message. The smaller packets allow for faster, more efficient data transfers, creating the fast-growing and fast-moving internet of today.



Why Is It Important?

Stay ahead of emergencies and system malfunctions with mobile alerts from deployed systems.

Minimize site visits and sampling trips through remote monitoring and off-site data assessment.

Environmental data from IoT systems is readily available to the public and local institutions.

Visit www.nexsens.com for more information.

MARS ON EARTH

This is Laguna Caliente, a boiling lake located in the Poás Volcano of Costa Rica. Researchers exiting the chasm can be spotted on the left. Sampling requires caution, breathing barriers and protective equipment and attire considering the chemical makeup of the volcano is less like that of Earth and much closer to Mars.

If the heat wasn't enough, the pH of Laguna Caliente is near 0, making it severely acidic. The lake is also full of toxic metals. Despite the harsh conditions within the Poás Volcano, life flourishes.

See "Poás Volcano Gives A Glimpse Of Life On Mars," Pg. 22

Water Quality Buoy

The CB-25 Data Buoy from NexSens Technology is an affordable and easy to deploy platform for both water and atmospheric observations. At 18" hull diameter and less than 30 lb. weight, it can be deployed from a small boat with ease. The buoy integrates the X2-SDLMC Submersible Data Logger, which includes a rechargeable battery with integrated solar panels to power the system continuously.

The CB-25 pairs well with the new YSI EXO3s, a compact sonde for monitoring major water quality parameters, including: temperature, conductivity, depth, dissolved oxygen, pH, ORP, total algae (phycocyanin or phycoerythrin along with chlorophyll), turbidity, fluorescent dissolved organic matter (fDOM), and UV nitrate. The sonde can also output four calculated parameters including salinity, specific conductance, total dissolved solids (TDS) and total suspended solids (TSS). An optional central wiper is available to clean all sensors prior to each measurement.

Available with integrated 4G cellular or Iridium satellite communications, the CB-25 buoy sends data in real-time to the cloud-based WQData LIVE datacenter. In a basic configuration, this free service allows users to securely access and analyze data, as well as share data through an API or auto-report. Subscription-based tiers of WQData LIVE are also available for advanced reporting, alarming, and data management.

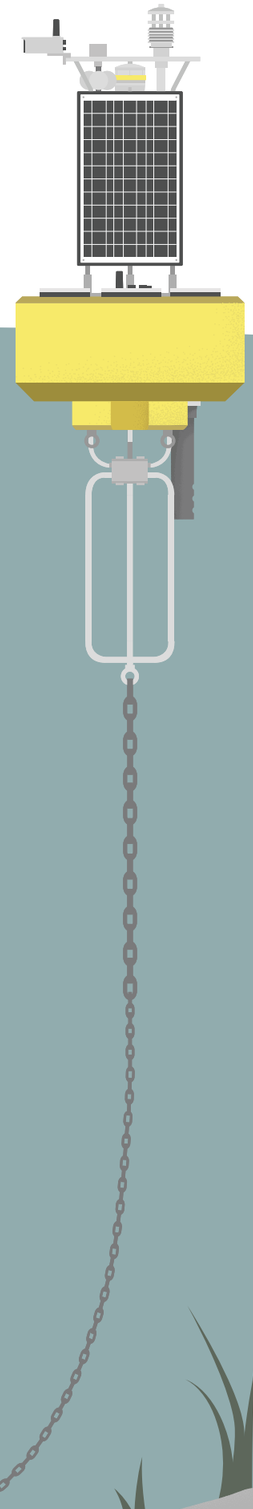
(Left) YSI EXO3s Multi-Parameter Water Quality Sonde. (Right) NexSens CB-25 Data Buoy with YSI EXO3s Multi-Parameter Water Quality Sonde attached to the optional instrument cage.

Data Buoy Features

- 4G cellular or Iridium satellite telemetry
- Supports a variety of environmental sensors
- Autonomous battery & solar power
- Rugged polymer-coated foam hull

BUOY CAMERA KEY FOR ERIE RESEARCH

(Left) Jeanette Schnars, Ph.D. (Regional Science Consortium), Doug Nguyen (Nexsens), and the crew from Lakeshore Towing LLC preparing for the buoy deployment after staff from PA DCNR assisted with loading the buoys on the boat. All four buoys were successfully deployed on May 5, 2022 in the Pennsylvania waters of Lake Erie which are now collecting water quality, wave, weather, and video data which is being posted in real-time at www.PALakeErieBuoy.com



3D Rendering: NexSens Technology, Inc.

(Below) NexSens CB-1250 Data Buoy with EWC Environmental Webcam

Photo: Steve Curtze; Illustration: Emma Jones/ Fondriest Environmental, Inc.

Jeanette Schnars has been the Executive Director of the Regional Science Consortium, a cooperative research leader located on the shore of Lake Erie, for 15 years. In that time, she has overseen some major technological innovations, such as the increased use of buoy cameras. "We were actually one of the first research groups to use video monitoring on a buoy," she recalls.

The Regional Science Consortium (RSC) is a non-profit collective of researchers and educators that facilitates knowledge gathering and dissemination regarding the Lake Erie and Ohio River Basin ecosystems for K-12, member colleges, and the general public.

"The focus is on research and education, creating educational opportunities and experiences, and putting applied research information into the hands of waterfront managers as well as those overseeing water quality, wetland restoration, and state agency functions. We provide information so they in turn can provide better management," says Schnars.

The RSC has four buoys on Lake Erie and two weather stations along the shoreline; they all provide real-time data to managers, researchers, and the public. They also offer a long-term database with well over a dozen parameters that show how conditions have changed over time.

"These are useful for research and monitoring projects. We can compare the parameters buoys and weather stations are measuring to the data that is being collected," Schnars explains.

The buoys are equipped with weather stations and a water quality sonde, which measures water temperature, dissolved oxygen, turbidity, pH, and a blue-green algae sensor used to monitor Harmful Algal Blooms (HAB).

The buoys also have a wave meter that measures wave height, maximum wave height and wave period. All data is updated every 20 minutes. Two of the buoys also include a video camera, capturing 10-second videos every hour. Buoys are deployed from May through October annually.

"The data collected by the buoys is processed through NexSens and is then posted to our website. All of the data is stored and can be accessed to examine changes or trends over the years. We've been collecting data since 2007," Schnars mentions. "Our data is provided in real-time to the Great Lakes Observing System (GLOS), the NOAA National Data Buoy Center, and the NOAA National Weather Service."

Fishermen use the buoy and buoy video data to find water temperature, wind velocity, and wave conditions. Local windsurfing groups and kayaking groups also use the buoy camera data.

Erie Bird Observatory also uses the buoy camera and data, as they plan their fieldwork to monitor the different populations of birds at Presque Isle State Park. The video data provides a visual of environmental conditions, which may provide insight into the behaviors of the birds they monitor.

Other users of the buoy video data also include Lakeshore Towing, a small business aiding boaters on Lake Erie and Presque Isle Bay. Lakeshore Towing also deploys and retrieves the buoys each year. In addition, other users include the PA Fish and Boat Commission Law Enforcement, the U.S. Coast Guard, and the U.S. Border Patrol.

"They were installed as another line of data for us to compare to the wave meter data, so we could determine if the wave meter was recording accurately. However, it turned out that the public also uses the video data. It lets them answer questions like, 'What does a three-foot wave look like?'" Schnars explains.

Wave height and wave period data are uploaded every 20-minutes, and the video is uploaded each hour as a 10-second video. Waves are typically 3-feet or less on a good day for boating. Storm events may have 12-15 foot waves.

The tallest wave measured by the buoy was in 2015, measuring 26.5 feet during a severe storm event. But wave height isn't the only important information boaters need to know. "The buoy video also gives the public information on the presence of waves with whitecaps," says Schnars.

"We have no other way to capture this information. Whitecaps on waves indicate rougher conditions, which is useful for boaters, fishermen, and others to know. The buoy cameras will give those who want to go out on the water a more complete picture than the simple wave measurement."

"The buoy cameras have operated very well," Schnars says. "NexSens worked with us to make everything compatible, and we really have had few technical challenges over the years. Even with the continual exposure to wind, water, and waves, we have not had to do much maintenance. Not to mention, the cameras have captured some great videos of storm events and sunsets."

In the future, Schnars and others plan on raising money to continue and potentially upgrade all things buoy, including operations, repairs, towing, and maintenance. Many organizations make donations to keep the RSC buoys going. RSC would need about $10,000 to $25,000 or more per year to maintain the buoys.

Last year the RSC received a generous grant from the PA Fish and Boat Commission to support the buoy program and make the many necessary upgrades. The Great Lakes Observing Grant of $100,000 originally funded the nearshore buoy's construction, deployment and retrieval. Buoy probes may last 2-5 years while, alternatively, wave meters need to be replaced, weather stations need to be upgraded, and cellular modems need to be upgraded as technology advances. LB

MONITORING BUOY SUPPORTS NAUTICAL ARCHAEOLOGY

Researchers from the University of Cádiz prepare the buoy for deployment.

For as long as humans have inhabited Europe's Atlantic coast, the ocean has been a great source of wonder and mystery. History is full of fascinating tales of epic endeavors, new discoveries of fearless explorers, fishing communities inextricably linked to the bounties of the sea, cultural interactions (both peaceful and not), and voyages that went awry during monumental storms or simply due to bad luck.

In the south of Spain, at the boundary between the Atlantic Ocean and the Mediterranean Sea, one such tale involves a long-lost merchant ship that went undiscovered from the 16th century until 1984. Believed to be carrying valuable goods from Italy, it sank just across from Gibraltar in the Algeciras Bay at a point called La Ballenera.

"The Ballenera wreck is probably a merchant ship with a homogeneous cargo of Ligurian origin, with the characteristic ceramic productions from the area around Montelupo, Pisa and Florence, as well as other raw material products," says marine researcher Pablo López Osorio from the nearby University of Cádiz.

The University is shedding light on this piece of history and other similar underwater artifacts in a unique way - by using monitoring buoys equipped with sensors and subsea cameras to document the nautical archaeology project and share it with the public.

THE TIDE MARINE HERITAGE PROJECT

The efforts of the University of Cádiz are part of a larger multinational initiative to boost marine tourism and preserve cultural heritage. Commonly known as TIDE, the official project name is the Atlantic Network for Developing Historical Maritime Tourism. The project "focuses on the sustainable development of onshore and underwater sites of historical interest on the Atlantic Area coastline."

Long-lasting and environmentally ethical development is achieved by assisting organizations with research projects and the development of ecotourism products and experiences. These can be related to anything from trade and emigration to forts, battles and invasions.

Diving and shipwrecks, of course, fit right in with this objective. A particular emphasis is placed on certain historical periods such as the Napoleonic era, Spanish Armada, World Wars, and Atlantic Migrations.

The TIDE partnership consists of members from seven diverse European regions: Ireland, Northern Ireland, England, France, Portugal and Northern and Southern Spain. Newfoundland and Labrador in Canada are also participants in the transcontinental project. Project partners seek to share digital tools and historical assets across regions to create niche maritime tourism packages with an emphasis on sustainability.

For its part as one of the founding members of TIDE, the University of Cádiz has focused on nautical archaeology at sites like the Ballenera shipwreck. While not a tourist attraction open to the general public, diving trips are organized while the archaeologists are working so that people can better understand the methodology of archaeology and the importance of the discovery.

Additionally, the University has established a graduate-level program for Nautical and Underwater Archaeology. This UNESCO-recognized program was the first of its kind to be offered in Spanish at its inception in 2016. The program focuses specifically on the research and preservation of underwater cultural heritage.

Photos: University of Cádiz

THE BALLENERA EXCAVATION

The initial survey of the Ballenera wreck in 1984 extracted a small amount of ceramic materials. The recovered items were subsequently restored at the end of the 1990s and published in a small exhibition. The University of Cádiz became involved later on to continue the exploration.

According to López, a wide variety of goods have been recovered since. Some of the items found are:

- An abundant quantity of common ceramics and glass bottles
- Decorative ceramic productions known as Blue on White
- Stone and iron projectiles for cannons and falconets
- Well-preserved wooden boxes with metalized organic matter due to submersion
- Prestige items such as crockery, bottles, pewter, and armament
- Nautical devices including paperweights of nautical charts, artillery compasses, and measuring elements

Besides the physical goods, information obtained by studying the shipwreck is helping to uncover deeper cultural contexts from the 16th century. "Our campaigns arise from several questions that are still unanswered and are of great interest," says López.

Some points of interest include accurately pinpointing the chronology of the wreck, determining the cultural affiliation of the vessel itself (not just the cargo), and analyzing the materials to paint a picture of daily life on a Mediterranean merchant ship of the late 16th century. Nautical archaeology is a growing field of study. Its importance to global history is palpable; incorporating a monitoring buoy into this research allows researchers to understand the ecological conditions of research sites.

HOW A MONITORING BUOY MAKES A DIFFERENCE

Documentation and dissemination are not as straightforward for nautical archaeology compared to onshore excavations. A core component to aid with this aspect of the project is a floating monitoring buoy platform equipped with an array of high-tech instruments.

The platform itself is a NexSens model CB-650 data buoy supplied by OceanNet S.L. It supports a topside weather station to determine the precise location and meteorological conditions at the site and a multiparameter sonde to track the important water quality factors in the marine environment. However, the highlight of the system is its four underwater cameras which broadcast live video feeds wirelessly to shore.

López and his colleague Luis Mariscal are the marine telecommunications researchers responsible for implementing the buoy-shore communication system. The cameras are wired to a solar-charged power supply and wireless transmitter installed inside the watertight data well of the monitoring buoy. Each of the four cameras is fixed at a point of interest on the excavation site.

The video feeds are currently available only to project personnel, but the team is currently working on a publicly available display. In the future, the monitoring buoy may also be moved to other similar nautical archaeology sites. "The buoy is meant to be located in whatever underwater site we are working on," says López. Little by little, this modern technology is helping to uncover centuries-old nautical mysteries. MV

(Left Page) The buoy and underwater cameras are positioned for monitoring of the shipwreck site.

Diatoms Dominate Muskegon Lake In A Cold And Rainy Year

Climate change-driven volatility is changing lakes at the base of their food webs.

That's one way to interpret new research that documented such a change in Muskegon Lake on the coast of Lake Michigan. Researchers found that, in one particularly rainy and cool year, normal phytoplankton diversity and patterns were cast aside. Instead, one group of algae dominated the entire year, offering a glimpse into the kinds of surprising changes that could happen in the future.

"Phytoplankton are a very responsive group of organisms," said Jasmine Mancuso, whose research detailing the change in the lake was published in October in the Journal of Great Lakes Research.

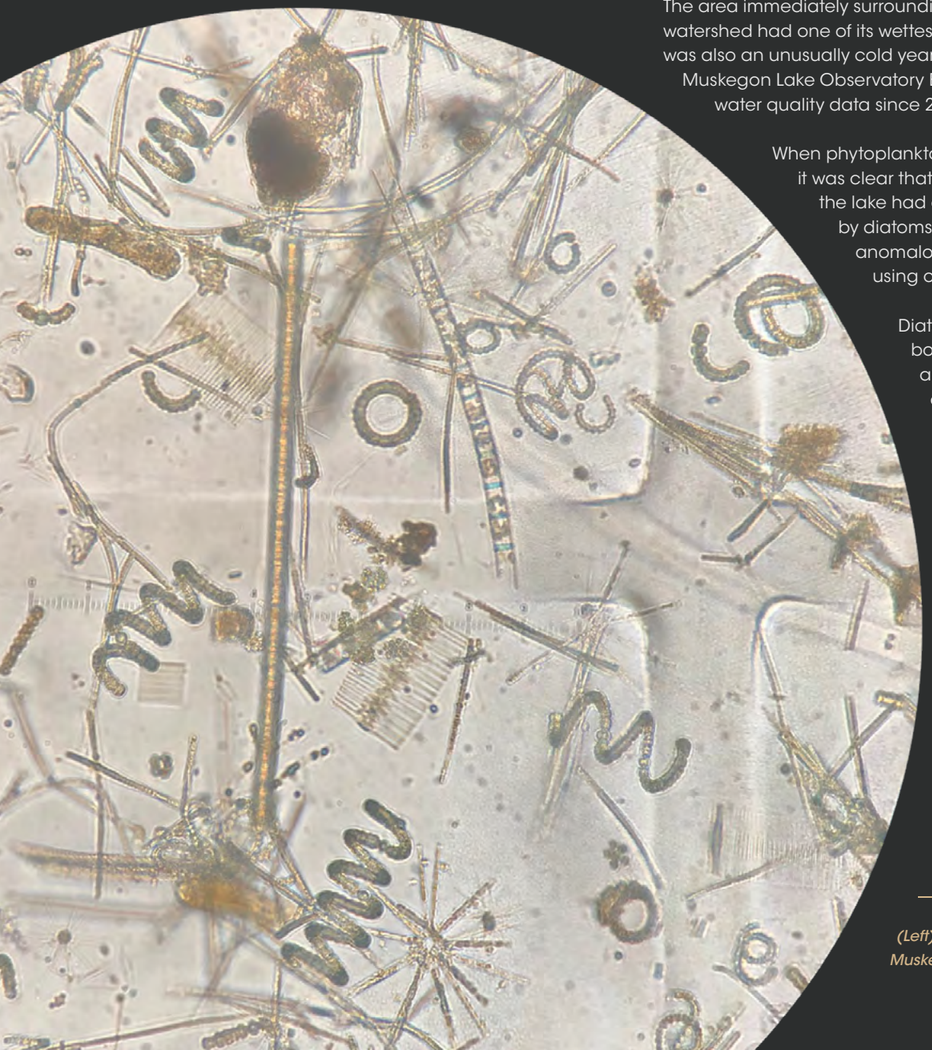
While many understand climate change to mean continuously warmer weather, Mancuso said a key part of the picture is increased instability, which might include stretches of colder, wetter weather. Her research shows how lakes might respond.

COLD, WET AND FULL OF DIATOMS

The area immediately surrounding the Muskegon Lake watershed had one of its wettest years on record in 2019. It was also an unusually cold year, according to data from the Muskegon Lake Observatory Buoy, which has been collecting water quality data since 2010.

When phytoplankton samples were examined, it was clear that the plankton community in the lake had a unique makeup dominated by diatoms. Mancuso explained the anomalous phytoplankton community using climate data.

Diatoms, one of the world's most bountiful phytoplankton, typically are the most abundant group of algae in Muskegon Lake in the spring before other groups of phytoplankton grow more plentiful. After waning in the summer, they become more abundant again in the fall, though they are accompanied by other groups of algae. The lake typically has three spikes in phytoplankton abundance, consistent with patterns seen in other temperate lakes. Diatoms dominate only for the earliest when the water is cool and well mixed.



(Left) A phytoplankton sample from Muskegon Lake.

Photo: Jasmine Mancuso

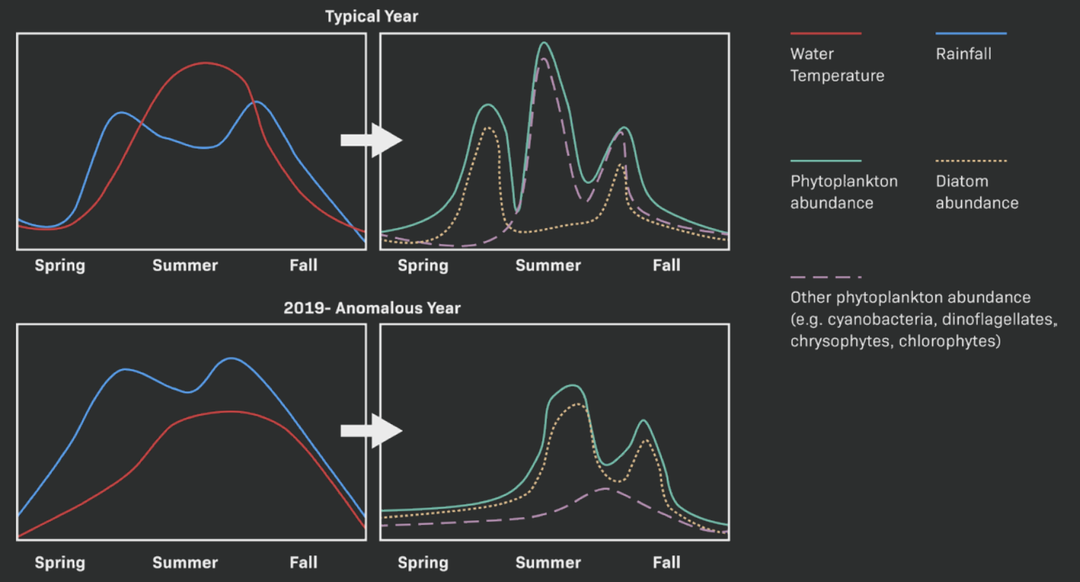


Photo: Journal of Great Lakes Research/Elsevier

IN 2019, EVERYTHING WAS DIFFERENT

Mancuso found that diatoms were the most abundant group of species for the entire year and that the typical three-spike pattern was absent. Her research suggests a couple of reasons colder and wetter weather could boost diatom populations.

The lake stratified in late June, much later than normal due to the cool, long spring. Increased rainfall helped water cycle through the lake faster throughout the year. Frequent rainstorms also kept the water column well-mixed throughout the year. These environmental conditions favor diatoms over the other types of algae that dominate the lake later in a typical year.

CLIMATE CHANGES FOR LAKE FOOD CHAINS

One cold, rainy year was likely enough to make big changes at the base of Muskegon Lake's food web, but her research didn't look to document any effects in the organisms that feed on phytoplankton.

Diatoms are one of the favorite foods of certain fish, so the shift documented in 2019 could actually be a positive for some fish, said Bopaiah Biddanda, a professor of water resources at Grand Valley State University and Mancuso's advisor. Even if some species of fish might have benefited from a large presence of diatoms, any substantial change to the food web could disadvantage others and have negative consequences throughout the ecosystem, Mancuso noted.

Most years in the late summer, Muskegon Lake is also affected by harmful algal blooms dominated by cyanobacteria. In 2019, the diatom-dominated lake had a much-reduced cyanobacteria bloom.

Conditions that favor diatoms (cool and well-mixed water) specifically disadvantage cyanobacteria (which prefer warm and stratified water).

While 2019 was a surprise event and research of effects up the food chain didn't occur in this study, it surely has some effect.

"Those are definitely food web consequences," said Biddanda. "What the plankton are, is what the fishes end up eating."

VOLATILITY ALONG LAKE MICHIGAN'S COAST

Muskegon Lake is a drowned river mouth estuary, a fairly common type of lake along Lake Michigan's eastern coast, Mancuso said. That could mean the effects seen in this lake happened elsewhere in the region during 2019 as well.

Climate change means that the lake may experience more climatic variation in the future, especially in terms of both temperature and precipitation.

"The water cycle is the one that goes most haywire," Biddanda said. "That could mean—though it's impossible to predict exactly—more disruption to phytoplankton communities in the future, with consequences for the entire food web."

"The effects of warming are going to be patchy," Biddanda said. Changes seen in one year may not be replicated at a different time or in a different place.

Though the effects on phytoplankton (and lakes as whole units) are difficult to predict, climate change makes events like those in 2019 much more likely.

"Climate change has repercussions," Mancuso said. AB

Engaging People, Engaging Lakes:

How The Public Can Help Aquatic Systems

(Right) Lake monitoring volunteers sort through aquatic plant samples during an on-lake survey.

Photo: MiCorps

Jo Latimore's interest in aquatic ecology dates back to her childhood, spending time at her parents' North Michigan cabin, exploring the water nearby. Today she is a senior academic specialist, aquatic ecologist, and outreach specialist at Michigan State University in the Department of Fisheries and Wildlife, in her thirteenth year in the position. Latimore's primary interests include lake appreciation and engagement.

"Most people appreciate our lakes. They like to look at, fish on, and boat on them. However, they don't necessarily appreciate our lakes as an ecosystem," Latimore said. "It's the health of the lakes that lets us use them recreationally. We use our educational programs to give people the information they need to help keep our lakes healthy so we can continue to enjoy them for years to come."

(Above) Ransom Lake is a small northern Michigan lake undisturbed by shoreline development.

VITAL ISSUES FACING MICHIGAN WATERWAYS

"We're seeing invasive plants and invertebrates in all waterways, including inland lakes and shorelines. We're also trying to mitigate the effects of residential development," said Latimore. Invasive plants include Eurasian watermilfoil. In the Great Lakes there is lots of international shipping, and Eurasian watermilfoil likely originates from ship ballast. "It's also proven to be especially hard to eradicate because, while there is herbicide that can treat it, it can unfortunately hybridize with native Northern watermilfoil, and some of these hybrids are unaffected by the herbicide," Latimore explained.

Another, newer invader is the New Zealand mudsnail. It eats lots of algae, leaving little for native species to consume. "They have been hard to deal with because they're very tiny and easy to miss," said Latimore. "They may be coming from people's waders when they go from one spot to another to fish."

As far as invasive fish, Latimore said that fortunately, there are no Asian carp in inland water in Michigan so far, unlike in many other places. On the other hand, they do sometimes see aquarium releases, mainly goldfish, who grow fast, eat a lot, reproduce fast, outcompete native species, and spread diseases to native fish.

Photo: Jo Latimore

Residential development is another issue Michigan faces. To determine the impact of the residential development on ecological connections, Latimore and her team with the Michigan Clean Water Corps (MiCorps) program teach volunteers to "score the shore" which means dividing the lake into sections and grading them using a variety of factors that illustrate how successfully wildlife will be able to live in the area.

THE TURTLE TEST

One scoring method used is whether the area passes "the turtle test." Essentially, this test asks: can a turtle still travel from the lake up onto the shore and do its normal activities, such as breeding and/or finding food?

Another scoring method involves rating the shoreline: is natural vegetation growing at and around the shoreline? "We hope to see native flowering vegetation, tall vegetation, deep rooted vegetation, trees, and shrubs. We also want to see riparian areas," mentions Latimore. "These preserve the shoreline and prevent erosion, and they're good for wildlife. Mowed vegetation, on the other hand, gets a low score. Grass is not good because its root system is so short (only 1-2 inches). It doesn't prevent erosion like native vegetation, and most wildlife doesn't thrive on turf grass."

MiCorps volunteers retrieving sampling devices for further analysis.

WHAT CAN THE PUBLIC DO TO HELP LAKES?

Latimore said there is a lot they can do and have already been doing. "The public is the main thing that helps our aquatic systems," Latimore said. "We heavily depend on volunteer collected data sets. We educate our volunteers in what degradation looks like, and they can see it firsthand. That makes them more confident to speak up about issues."

Gathering data gets the public to personally engage with the lake. "While people who fish the lakes tend to understand that the number of fish they find is directly related to lake health, hands-on sampling helps them connect even more with the lakes," explained Latimore. In addition to those who fish, many volunteers who collect data are owners of lakefront properties who want to do their part to help protect the lakes.

"We train our volunteers; they don't need a science background," said Latimore. However, more experienced volunteers can gather different types of data, such as chlorophyll monitoring data in the summer months and dissolved oxygen monitoring. Advanced volunteers can map the whole lake for plant management.

LONG-TERM MONITORING

Stream monitoring data has been gathered since the 1990s. Other data gathered includes macroinvertebrate monitoring, vegetation, depth and width of channels, substrates, and wood structures in streams. MiCorps is the network of volunteer water quality monitoring programs under which all the data is organized. Generally, the programs are aimed at adult volunteers, though sometimes teachers participate and bring their students along. Older students can sometimes get involved on an individual basis.

Latimore also finds it important to deliberately choose types of monitoring that will appeal to volunteers to encourage them to get and stay engaged. "Aquatic entomology is basically the use of insects to gauge aquatic health. Some insects are especially sensitive to pollution, sediment loading, and oxygen amount, so we monitor them to determine aquatic health. Those insects include stoneflies and caddisflies.

However, the public likes some other types of charismatic insects, such as dragonflies, so we monitor those too, since the public has an interest…even though dragonflies are not that sensitive to pollution. They are ambush predators, so they do need a good base of insects for prey. So their presence or absence can also give us a clue about aquatic health," she explained.

LEARNING FOR THE FUTURE

In the future, Latimore hopes a very popular Introduction to Lakes online class offered by MSU to the public will continue to attract students. Funding and support for a similar Introduction to Streams class for the public have already been secured. While current volunteers are largely lake property owners, Latimore hopes to engage more non-owners in the future as well, since many people use the lakes besides lakeside property owners.

Lake appreciation, especially as an ecological system, will always be a theme in Latimore's interactions with the public. "In a way, we 'suffer from abundance' here," Latimore mentioned. "We have so many high quality lakes that people can take their health for granted. But in reality, it takes work to keep lakes and streams healthy and free from erosion, invasive species, and other problems."

"But with the public's help, and using a proactive approach, we hope to keep our Michigan waters places everyone can enjoy now and many years from now." LB

Photos: MiCorps

POÁS VOLCANO GIVES A GLIMPSE OF LIFE ON MARS

To get an idea of what life would be like on Mars, you don't need to travel millions of miles away–instead, you could go to Costa Rica and visit the Poás Volcano and its crater lake, Laguna Caliente.

"Collectively, the suite of alteration minerals at Poás crater and identified across Mars at relict hydrothermal sites shows strong correlation, indicating the high temperature and highly acidic geochemical processes occurring at Poás are quite relevant to understanding past hydrothermal processes on Mars," says Justin Wang, a graduate student at the University of Colorado, Boulder.

Wang is currently conducting research at the Laboratory for Atmospheric and Space Physics alongside his advisor, Brian Hynek. Wang is currently a master's student in aerospace engineering. Wang, Hynek, and others have spent years studying the Poás Volcano and Laguna Caliente, finding similarities between the area and what is presently known about the Martian landscape.

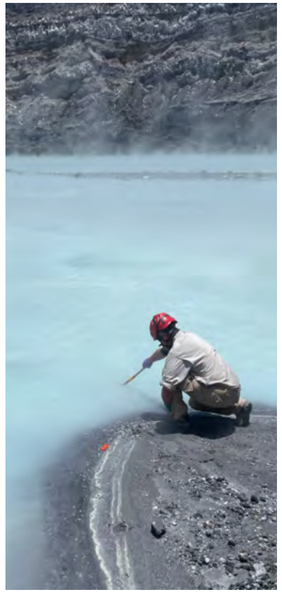
Wang notes that similar chemical reactions ongoing in the Poás Volcano also were known to have occurred on Mars. "Hynek's astrobiology paper in 2018 describes this to the best detail. It explains that fumaroles have provided alteration minerals that are akin to a variety of relict hydrothermal sites on Mars. For example, jarosite is a relatively common alteration product at Poás, as is gypsum, and these materials are both found in putative relict hydrothermal deposits on Mars," says Wang.

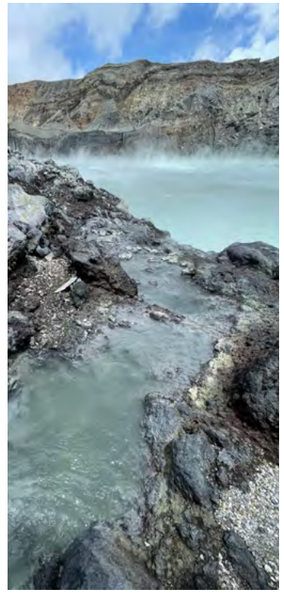
He also notes, "Hydrated silica is another common alteration mineral that is widespread at Mars hydrothermal analog sites and on inferred similar paleo-environments on Mars. The high-temperature silica phase of tridymite is also widespread around Poás fumaroles and was recently detected in Gale crater by the Curiosity rover."

He further mentions, "Dissolved iron at Poás leads to abundant hematite and occasional goethite, which are common products across relict hydrothermal systems on Mars, such as within Gusev crater. Elemental sulfur is ubiquitous around the active fumaroles, forming large tabular crystals and occasionally solidified flow ribbons of previously molten sulfur.

Collectively, the suite of alteration minerals at Poás crater and identified across Mars at relict hydrothermal sites show a strong correlation, indicating the high temperature and highly acidic geochemical processes occurring at Poás are quite relevant to understanding past hydrothermal processes on Mars."

Photos: Justin Wang





While the environment of Poás Volcano was extreme, the equipment needed for Wang's study was fairly typical for sampling. "We sampled using nitrile gloves on hand and dipping Falcon tubes into Laguna Caliente. We also took some samples attached to a pole in order to be farthest away from the shore. You have to be really careful when performing sampling by hand here since the pH of Laguna Caliente is near 0," says Wang. The lake is also full of toxic metals.

Despite the incredibly harsh and highly toxic environment, life flourishes. While the life at Poás is not very diverse, what is there has been determined by metagenomics studies to be highly adaptable. Wang found a dominance of Acidiphilium spp. in his samples, and this was true for his study and one conducted several years prior.

The other microorganisms he found weren't extremophiles, they were typical soil and root microbes believed to be introduced to the lake from rainfall. Acidiphilium spp. makes sense as the dominant microorganism in Laguna Caliente, as it is a well-known acidophile found around the world in hydrothermal environments and acid mine drainages.

Interestingly, while Wang's samples exhibited low biodiversity, they hosted a wide range of genes and adaptations. They included many genes that pump hydrogen ions (for acidity) and many other toxic metals (such as arsenic) out of the cell to survive.

(Left) The Poás Volcano crater and Laguna Caliente from the crater edge.

(Above) Justin Wang sampling the Laguna Caliente.

What Wang found to be most interesting in the metagenomes were the numerous metabolism genes discovered. The found materials included genetic pathways to create energy using sulfur, iron, arsenic, carbon fixation (like plants), simple and complex sugars, and bioplastic granules (which microorganisms can generate and use as energy and carbon reserves during stress or starvation).

Wang was surprised that, even though there were numerous phreatic eruptions that influx toxic metals, extreme acidity, and heat to the lake, some of the same microorganisms in the same environment persisted over the years. Compared to the first study, when the team was only looking at the microbial diversity in the lake, the second study also looked at the metagenome of the samples, where his team was able to analyze the genetic adaptations of the microorganisms. The two earlier studies gave them a clue about how these organisms survive in these environmental extremes and helped develop their theories of how life persists in the Poás Volcano.

"Our main goal was to assess how life on Mars, if it did exist, could survive long-term in hydrothermal environments," summarizes Wang. "The Poás Volcano represents an extreme of both Earth life and of Martian analog environments, and so studying the biology in the Poás Volcano helps study an extreme case on Mars. We believe hydrothermal systems on Mars are some of the best suited environments for life throughout the planet's history, and so another goal of this research is to critique that belief further."

The Poás Volcano study is ongoing and will undoubtedly continue to reveal the incredible abilities of living organisms to survive even in the most challenging places. LB

Wildfire Smoke Alters A Lake's Food Chain From Top To Bottom

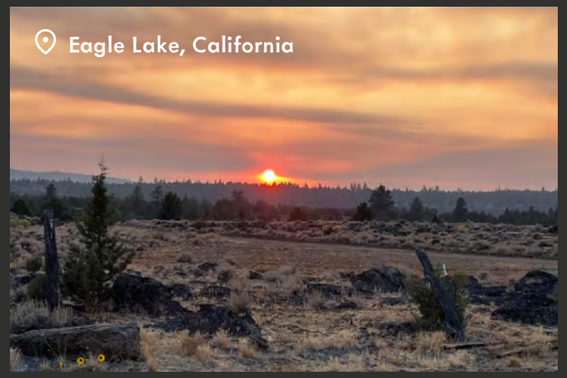
Wildfires have been big news the last couple of years. Australia's wildfires in 2019 and 2020 and the Amazon rainforest fires in 2021 made headlines around the world. The American west has had record-breaking burns in recent years, blanketing cities in dangerous amounts of smoke and sending haze across the continent to the east coast.

While smoke has clear and apparent effects on the sky, new research finds it changed the ecology of Castle Lake, a freshwater lake in California, in 2018.

"There are some studies that have analyzed the effect of human health in respiration with the smoke of wildfire," said Facundo Scordo, a postdoctoral researcher at the Global Water Center of the University of Nevada—Reno. "What we found in the paper is that the respiration of the lake has been affected by the smoke in the same way it affects human life."

Smoke can alter a lake's temperature and primary production. It can even change where fish are. During a particularly smoky period, rainbow trout that regularly turn up in shallow water sampling were gone. "We were very surprised because we come every year and, with the same methodology, this is the first time [no rainbow trout were caught]," said Scordo who authored the study on Castle Lake in California with a team from University of Nevada—Reno, Rensselaer Polytechnic Institute, Miami University (Ohio), University of California—Davis. The paper was recently published in *Scientific Reports*.

Changes to the lake's ecology occurred up and down the food web, down to the very bottom.



Fire near Eagle Lake, CA in 2022.

CHANGES TO PRIMARY PRODUCTION

Smoke cover reduces the light available to algae. Both photosynthetically active radiation and UV-B radiation. Photosynthetically active radiation fosters algae production and, under normal conditions, penetrates deeper into the lake. While much of this light is blocked by shallower algae, deeper algae have evolved to use the smaller amount of light that comes through. This is usually where the maximum concentrations of chlorophyll are found in the lake.

Under smoky conditions, photosynthetically active radiation was reduced enough that this maximum never developed, Scordo and his colleagues found.

Smoke also blocked UV-B light that harms algae cells. In shallower water, smoke shielded algae and allowed it to grow more. "So both good and bad light were reduced," Scordo said. "But the good light penetrates to the first meter of the lake."

Primary production actually increased in the shallower parts of the lake, leaving them murky and unattractive. Castle Lake is used recreationally by campers, hikers, swimmers, and fishers. Besides the murky, unattractive water, recreational fishers would feel the effect of another surprising finding in Castle Lake.

Fish apparently abandoned the lake edge for deeper water. No brook or rainbow trout were caught in places they normally occur. It's hard to say where in the lake they went because technical difficulties knocked sonar monitoring offline for the 2018 season.

"If we had those sonar deployed in that smoke year we could have explained the whole trophic chain," Scordo said.

AT THE FOREFRONT OF A GROWING ISSUE

This research is some of the first research to look at the effects of wildfire from a distance. Similar studies in different lakes are planned.

The study demonstrated that wildfires can affect lake ecosystems that are hundreds of miles away from them. In 2020, smoky haze blew from California to the United States' east coast, raising questions about the effects of smoke on a national level, Scordo said. While 2020 saw more fires and more area burned, for Castle Lake 2018 was the smokiest on record.

The reasons behind the trend of larger and more intense fires is still debated, but climate change is one clear culprit. Much of the western United States is gripped in a serious drought and record high temperatures in June point to the reality of a hotter and drier climate in the future.

Climate change may mean that snow melts sooner, leaving soil and vegetation drier. It may allow populations of tree-killing pests to expand in size and range, creating more dead vegetation that burns easier.

The highly visible transport of smoke across the United States and this research shows that wildfire response and risk are not isolated problems in the west and California. Ecosystems, like Castle Lake, which aren't burned directly, still feel profound effects.

"Not only the lake that is in a basin that is burning can be affected, but lakes 100 to 1000 miles from where the fire is burning," Scordo said. It warrants a national response, he said.

There are still plenty of questions to be answered about smoke and aquatic ecosystems. Scordo says research into smoke's effects on other bodies of water, the length of the effect and if there are any cumulative effects for water frequently covered in smoke.

New PhD students at the Global Water Center of the University of Nevada—Reno will begin examining smoke's effect on other types of lakes soon.

With the rate of wildfire in the west, researchers should have plenty of opportunity to answer the other questions, too. AB

(Left) Ash from wildfire smoke deposition on the coast of Lake Tahoe, CA in 2022; (Top Right) Wildfire smoke above Castle Lake, CA in 2022; (Bottom Right) Ash collector to collect wildfire smoke deposition on the coast of Lake Tahoe, CA in 2022.

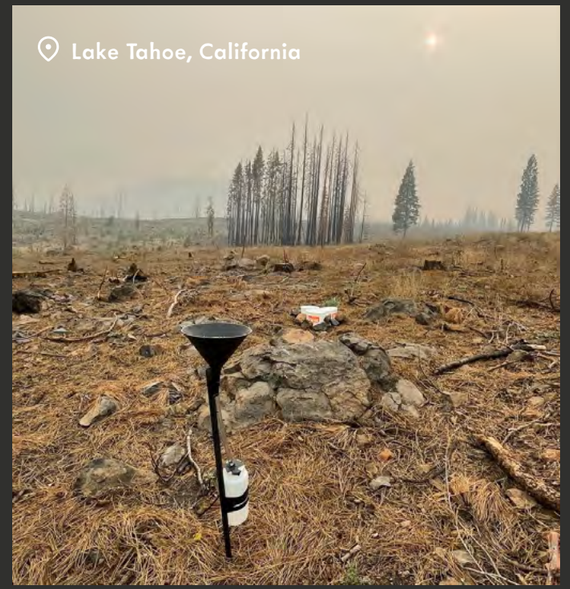


Photo: Sudeep Chandra

Photo: (Left, Bottom Right) Sudeep Chandra; (Top Right) Erin Suenaga

Map: Emma Jones/ Fondriest Environmental, Inc.

Ancient Lakes

Lake Baikal

Nurseries For New And Diverse Species

Lakes that have supported human settlements for thousands of years are starting to feel humans' effects in rapidly developing and significant ways.

From climate change to nutrient loading to plastic pollution, ancient lakes are straining under some of the least welcome contributions of humanity. The changes could have consequences for the diversity of life within the lakes and the human populations that rely on it.

And, while ancient lakes have been around long enough to weather past climatic changes, the changes occurring now are so rapid, the end result is uncertain.

Stephanie Hampton, a professor in the Center for Environmental Research, Education and Outreach at Washington State University, has studied Lake Baikal, the world's oldest lake, for years. Her literature review in Limnology and Oceanography documents the ecological changes affecting ancient lakes around the world.

Those changes include climate change, changes to lake levels, invasive species, eutrophication, overfishing and toxic contamination. They include threats, like climate change, that stem from global populations and economies; and others that come directly from the local human populations that spring up around the long term, stable source of freshwater and food that many ancient lakes provide.

Cities and the farms that support them send industrial, agricultural and domestic pollutants to lakes. The study notes metals and chemicals from factories and nutrients from agricultural land. Residents of cities add pesticides, pharmaceuticals and personal care products.

As of yet, pharmaceuticals and personal care products are poorly understood as pollutants, even as they continue to appear in ancient lakes around the world.

The challenges facing ancient lakes are not unique or unfamiliar environmental threats. They threaten other, younger lakes and oceans. But, when they come for ancient lakes, they degrade resources distinctly valuable to science and the populations that rely on them.

Ancient lakes have provided unique ecological conditions that have made them nurseries for new and incredibly diverse species.

Lake Baikal has 340 species of amphipod, a kind of small crustacean, while most lakes have three or four, Hampton said.

From the world's only freshwater seal in Lake Baikal to the incredibly diverse group of cichlids in Africa's great lakes, ancient lakes are hotspots of biodiversity and home to a lot of species that can be found nowhere else, she said.

Losing this biodiversity and the opportunity to study it is a grave concern, Hampton said. "Once it's gone, it's gone."

Ancient lakes also are long-term record keepers of geological and biological activity in the area.

"Because they lie at the lowest point in the landscape, like all lakes, they've been collecting this history in their sediment for as long as they've been around," Hampton said.
The history in lakes' sediment contains all sorts of information.

Photos: Stephanie Hampton

Paleolimnologists read sediment cores and identify changes in chemical and biological indicators to understand the past. Sediment cores in a lab can lead to insights about ancient climate, plant life and geological events, Hampton said. Sometimes plankton that can diapause, or lie dormant for years, wake up after years trapped in the sediment after it's brought into favorable lab conditions.

Ancient lakes have provided millennia of favorable conditions for humans, too: fresh water and a readily available source of food.

"As a human being, you can understand why," Hampton said. "It's a concentration of resources, fishing, fresh water and a really diverse landscape that can support pretty big settlements of human beings."

Some of the oldest human settlements are associated with ancient lakes.

To varying degrees, these unique contributions of ancient lakes are threatened by the changes they are experiencing. Where change does threaten the lakes' value to science, or human flourishing or biodiversity, the threat is greater for the speed at which change is happening.

"The changes are just so fast," Hampton said. Her study notes that lakes have likely undergone larger changes than now, but not as quickly.

Lake Victoria, one of the African Great Lakes, may have dried up completely at one point in the distant past, the study notes, but these huge swings took place over huge periods of time.

As human impacts like development, deforestation and overfishing continue to accelerate in some places, the lakes are being forced to change faster than any other time in their considerable history.

"There's been a lot of human disturbance, some of which has only been intense or becoming more intense in the last fifty years. For a lake that's over 130,000 years old, fifty years is a blink of an eye," Hampton said. The same is true of climate change, Hampton said.

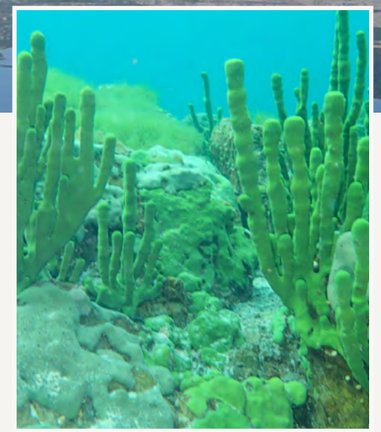
After thousands of years spent evolving in a relatively stable lake, some organisms are being forced to adapt faster than may be possible.

Because ancient lakes have been around so long, they are often home to some truly remarkable results of evolution. In Lake Baikal, amphipods likely have split into more species than in any other lake in the world: over 300.

Amphipods in Lake Baikal thrive along the coast. As climate change warms the lake, they are likely to move deeper to avoid rising temperatures, pushing them farther from the shoreline habitat they are adapted to.

Shorelines are especially vulnerable because they feel the impact of development or changes in the watershed before other parts of the lake.

"When humans disturb a landscape, the first thing that reacts is typically the nearshore environment where nutrients or sediments or other pollutants will hit the lake first," Hampton said.



"That's where a lot of the biodiversity of Lake Baikal is."

When that biodiversity includes highly diverse populations, like amphipods in Lake Baikal, science can lose something that exists in few other places, if anywhere.

"There are people studying [Lake Baikal's amphipods], but there's so much basic biology that needs to be done," Hampton said. "It would really be a shame to lose the opportunity to know more about them and their function in the lake."

Lake Baikal's amphipods are unique to it. But, the characteristics and challenges it shares with ancient lakes around the world, whether large or small, arctic or tropical, old or really old, demands greater attention. Attention and action are needed to save these "natural laboratories." AB

(Top) The southwestern shore of Lake Baikal on a calm day.

(Right) A forest of branched sponges in Lake Baikal. Sponge forests are unusual in lakes.

Ancient Lakes

Lake Tanganyika

Different Lakes, Different Decisions

Ancient lakes are facing a suite of rapid, unprecedented anthropogenic changes. While ancient lakes are spread around the world and vary widely from lake to lake, their incredible age, which can reach into the tens of millions of years, makes them unique resources to science.

They host incredible biodiversity and long sediment records. They are vital sources of food and water for millions of people. In a changing world, ancient lakes' value as scientific and natural resources and the incredibly diverse life they contain is under threat.

Lake Tanganyika's tropical climate feels climate change effects like a few other ancient lakes around the world, Lake Tanganyika contains surprising instances of speciation.

Cichlids exist around the world, but, like Lake Baikal's amphipods, in Lake Tanganyika (and a few nearby lakes), they have diversified in remarkable ways.

There are cichlids that raise their offspring in their mouths, cichlids that eat only the scales of other fish, cichlids up to three feet long and cichlids that can fit inside a snail's shell, said Catherine O'Reilly, a professor in the department of geography and geology at Illinois State University, who studies Lake Tanganyika.

Shoreline disruptions and climate change are putting pressure on them as well. And, the lake's overall fish populations could be on the decline as the lake warms with the climate.

Lake Tanganyika relies on a windy season to destratify, not seasonal shifts in lake temperature like non-tropical lakes. As the lake's surface water gets warmer, it resists mixing with the deeper, cooler water.

"It gets more and more like oil on water," O'Reilly said.

Lake mixing cycles nutrient-rich water from the lake's depths up to the surface, fueling the growth of plants and algae that feed fish.

In recent years, the number and size of fish have both decreased in Lake Tanganyika, said O'Reilly, who is wrapping up a study looking at the cause of this trend.

Climate factors and overfishing could both contribute. Either way, the changing lake could have major implications for the people who rely on it for food.

Historically, the lake has provided fish, a really important source of protein, to surrounding communities. Up to 40% of animal protein consumed in the surrounding area might come from the lake, O'Reilly said.

But on land, fish is getting more expensive while fishing is becoming a less financially rewarding business, she said.

Looking ahead in a rapidly changing environment, "One of the things we do know, especially from these ancient lakes, is that the lake is going to be fine, no matter what happens," O'Reilly said. "They have experienced so many swings in Earth's conditions."

But that doesn't mean they won't lose endemic species or emerge unchanged.

"Whatever we're losing right now, we're never getting back," O'Reilly said. "They're not going to evolve in the exact same way."

Map: Emma Jones/ Fondriest Environmental, Inc.

Photos: Bill Perry

"It's going to be different for each situation and different communities are going to make different decisions,"

- Stephanie Hampton

The risk of losing biodiversity and fish for food requires additional attention. O'Reilly noted a new initiative to do increased monitoring on the African Great Lakes.

"The reason we talk about Lake Tanganyika is that we don't have very good data for many of these other lakes," she said. "There's a lot of interest in figuring out how to take better advantage of those technologies to better figure out what's really changing." Only with baseline data can the scope of changes to lakes be fully understood.

Stephanie Hampton, a professor in the Center for Environmental Research, Education and Outreach at Washington State University who has studied Lake Baikal, the world's oldest lake, echoed the need for monitoring, especially along the lake shore, where pollutants and excess nutrients enter the lake, sometimes causing eutrophication. "You really want to monitor near the shoreline because that's where the changes will typically first occur. So, if you see eutrophication nearshore, before it is seen offshore, at that early stage you have a better chance to address it--potentially reverse it," she said. By the time it is detectable offshore, the problem is usually much worse.

But, speaking generally about ancient lakes is difficult because all old lakes aren't the same.

"It's going to be different for each situation and different communities are going to make different decisions," Hampton said.

Whatever unique cocktail of industrial pollution, warming waters, increased nutrient load, changing lake levels or threats to biodiversity ancient lakes face, they will each respond in their own unique way. And, the wildlife and people that call these lakes home will have to adapt as well. AB

(Top) A buoy monitoring air and water in Lake Tanganyika.

(Right) Researchers applaud as they launch a buoy that will monitor air and water in Lake Tanganyika.

Photos: Anna McBee

THE FROZEN FRONTIER:
CHASING DATA IN ANTARCTICA

For Paul Savoy, sailing on the Nathaniel B. Palmer research vessel as part of the United States Antarctic Program (USAP) has been a dream come true, a “mountain top” for his career. “I grew up reading about the age of exploration, and the great polar explorers back in the day. Antarctica is one of the last remaining frontiers, along with the deep ocean and outer space. I was delighted to discover Antarctic research covers all three, with deep ocean research happening on the icebreakers and cosmological experiments at the South Pole. I’ve been applying for a job down here since I was 18. I got shortlisted a few times, but never actually got picked up until I was 32. Now I’m 35, and finally headed to the ice. Wish me luck!”

Savoy is a marine technician (MT) on the voyage. MTs assemble, operate, and maintain the science equipment, and even fabricate parts from scratch if something is forgotten or broken. They also handle deck operations and run the small boats, all in the extreme environment of Antarctica. “MT positions are one of the last great job opportunities for generalists, as we are required to do so many different things on board,” says Savoy. “Welding, woodworking, boat handling, science, heavy equipment, mechanical repair; a thousand other things. We aren’t the best at any one thing; instead we have to be able to do a million different things to a professional standard. That suits me. I think cultivating polymathy was the best possible prep.”

The USAP was founded in 1959 and manages all U.S. scientific research and related logistics in Antarctica, including aboard ships in the Southern Ocean. USAP works with universities, research institutions, and government agencies from all over the globe. “USAP pushes the boundaries of knowledge and technology.

(Left) Marine technicians navigate an inflatable boat through ice to retrieve science staff from a remote deployment. Note that the size and condition of this ice easily hides hazards such as rocks or even larger, more dangerous chunks of ice.

Marine technicians on the rear deck of the icebreaker Nathaniel B. Palmer assess the rigging of the aft winch during deployment of a trawl net, used to determine populations of various species at a given depth.

"A HUNGER FOR ADVENTURE."

There's thousands of ongoing studies and experiments, on everything from cosmic neutrino detection to mapping ocean currents globally. I'm really hard pressed to think of an arena of science that USAP isn't involved in somehow," says Savoy.

On Savoy's current mission, scientists will collect various data involving seal tagging, whole ocean chemical profiles with a conductivity-temperature-depth (CTD) rosette, drilling marine sediment cores, running trace metal sampling tests on seawater, and more. "It's also common for NASA and other groups to put atmospheric sniffers on board to test for various molecules as we travel- sometimes refrigerants, sometimes radioisotopes, sometimes others. The boat itself gathers bathymetry pretty much all the time. Each experiment yields HUGE amounts of assorted data. It's expensive to be out there, so we really try to wring every drop of science we can from our efforts.

For instance, The CTD groups run dozens, sometimes hundreds of tests per sample on a wide array of parameters, and the rosette itself is usually equipped with an acoustic doppler current profiler, which tells us about particulate loading and movement at a given depth in the ocean. That data is used to map currents and nutrient flows and so on," Savoy explains.

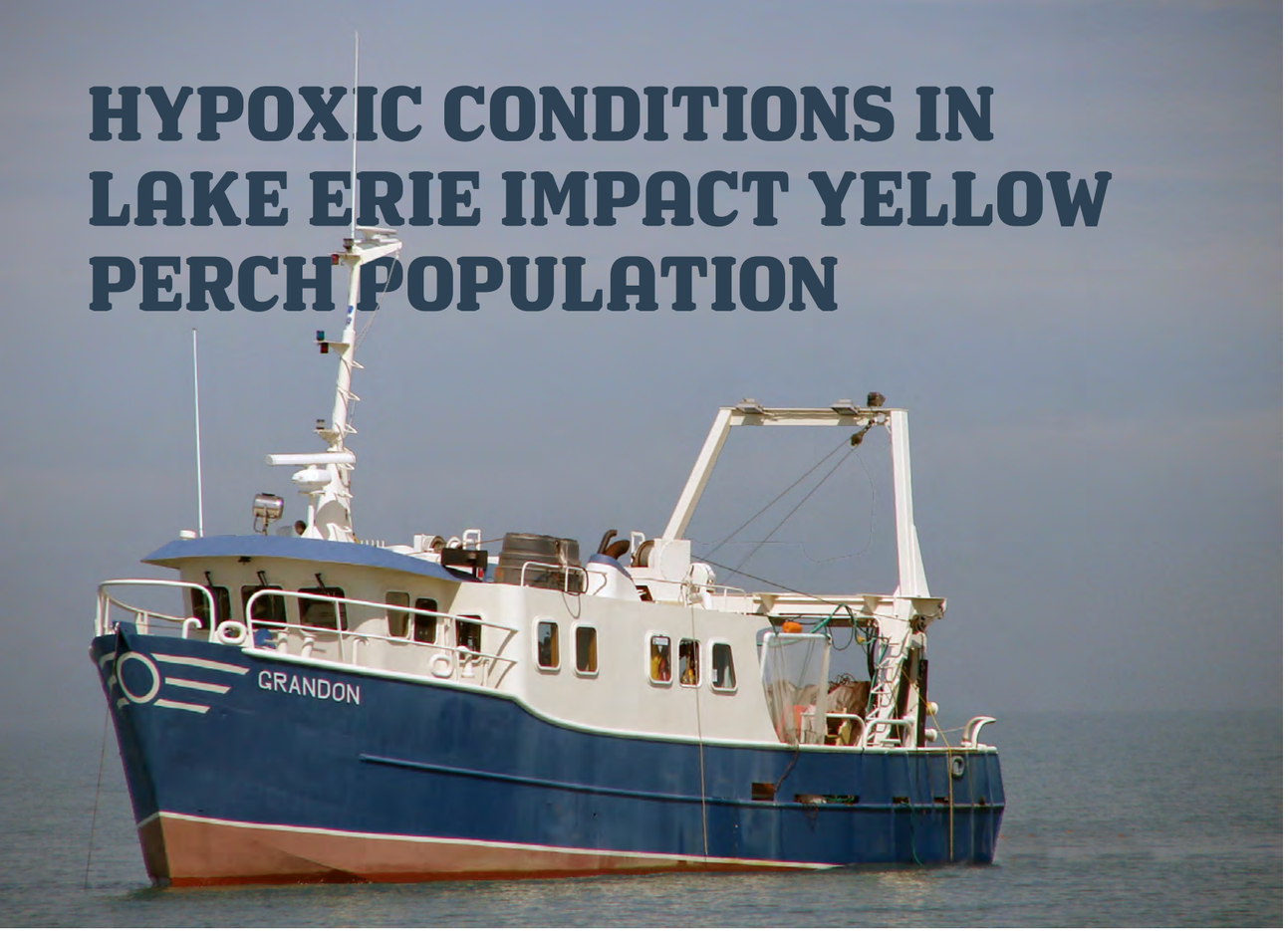
Some of the major issues in Antarctic research right now concern specific glacier complexes. "Different research groups have different priorities, but one of our major concerns is the future of the Thwaites glacier complex, and its effects on global sea level rise, ocean currents, and weather. We're also trying to understand how glaciers interact with land masses as they melt, and use that data to refine models for predicting other glacial systems around the world," says Savoy.

"The only downside of being an MT is that the researchers often take years to parse and analyze the data we've collected, and we don't see the results until they are made public. We don't get to personally see trends as they emerge from the raw data."

Savoy was drawn to the voyage by the science and the rigors of gathering data in the extreme environment of Antarctica, but the lure was also the larger adventure itself. "I had a lot of personal goals in coming here; I wanted to cross it off my bucket list, and I wanted to challenge myself and reclaim some things I've lost along the way. But perhaps more importantly… I'm a teacher at heart, and I really enjoy using my Antarctic experiences to encourage curiosity and a hunger for adventure in kids," Savoy reflects. "They all think being a scientist exclusively means a lab coat and test tubes and impossible math. And sometimes it does. But I love teaching teenagers that sometimes science means a beard and a big wrench and monster waves. There's far more adventure left in the world than people imagine, and we can do good things with it." LB

Photos: Anna McBee

HYPOXIC CONDITIONS IN LAKE ERIE IMPACT YELLOW PERCH POPULATION



With the largest commercial fishery and a prolific sportfishing industry, Lake Erie's yellow perch are a treasured study subject for environmental scientists. Daily bag limits and other public wildlife regulations rely heavily on the work of scientists like Ann Marie Gorman, one of the Fisheries Biologists responsible for coordinating the Ohio Department of Natural Resources' Central Basin Bottom Trawl Survey.

The survey, ongoing since 1990, conducts seasonal assessments of the bottom fish community in Erie. It aims to index annual recruitment and catch-at-age of yellow perch. The data is combined with trawl, commercial and recreational harvest information from agencies around the lake (MIDNR, PAFBC, NYS-DEC, OMNRF) and are used by the Yellow Perch Task Group of the Great Lakes Fishery Commission (GLFC) to generate annual population estimates and recommended harvest levels. The Lake Erie Committee uses this information to set the annual lake-wide quota for yellow perch.

The team trawls for fish for 10 minutes at each sampling site; 57 sites from Lorain to Ashtabula. They catch and identify different age groups and distribute those numbers to estimate and forecast the population for each age group. The same trawls and sites are used each year to allow comparisons from one year to the next.

An obstacle the team has come up against is that fish behave differently in the presence of a thermocline or low oxygen conditions at different times of the year, posing a real challenge to execute fair, uniform trawls.

"Prior to when I started at the Fairport Fisheries Research Station 15 years ago, biologists noticed that the low oxygen conditions in the Central Basin seemed to have a negative effect on the number of yellow perch caught in our trawls," noted Gorman.

"Since then, we have been collaborating with the Lake Erie Biological Station (USGS), the Aquatic Ecology Lab at Ohio State, the Sandusky Fisheries Research Station (ODNR's west basin office), and the State University of New York Environmental Science and Forestry at Syracuse (SUNY ESF) to better understand how hypoxia affects the distribution and health of yellow perch and how these changes may impact our annual population estimate," Gorman expanded.

Bacteria consume oxygen while feeding on dead material like algae in the hypolimnion, resulting in the low oxygen conditions. These oxygen-poor conditions persist each year until strong winds and waves associated with autumn storms mix the layers once again (lake turnover).

Photo: ODNR

The dynamic hypolimnion typically exhibits a hypoxic and sometimes anoxic environment that can significantly disrupt the yellow perch populace.

"Not being limnologists, our initial understanding of hypoxic conditions was extremely simplistic, and we expected to easily classify each trawl as being hypoxic or normoxic for our analysis. When we began taking multiple dissolved oxygen profiles at each trawl, we realized how patchy and dynamic hypoxic areas could be. Sometimes trawls began in hypoxic conditions and ended in normoxic conditions, indicating that we crossed a horizontal hypoxic edge and potentially an aggregation. Sometimes the same spot was hypoxic at one point in time and normoxic a few hours later," explained Gorman.

The trawl typically fishes the bottom 1.8 m of the water column. If the hypoxic layer is thinner than the height of the trawl, the team may trawl through a fish aggregation at the vertical edge. This could result in a contradictorily high catch at a site that appears to have low levels of dissolved oxygen at the bottom.

"Hypoxic conditions (how low the dissolved oxygen gets, how thick the hypoxic layer is, how long hypoxia lasts into the fall, and how far hypoxic conditions are spread spatially) are worsening and occurring more frequently, even in the shallow west basin," explained Gorman. "By developing a method to standardize catch rates for the influence of hypoxia, we hope to improve the accuracy of annual population estimates."

Similar to water sloshing in a bathtub, the low-oxygenated shelf moves and shifts below, typically lying anywhere from 2-12 feet from the lake's bottom. To avoid low dissolved oxygen, yellow perch may aggregate nearshore of where the thermocline intersects the lake bottom (i.e., the horizontal edge) or above the hypolimnion (i.e., the vertical edge).

"We became especially concerned in August of 2008 when we caught over 10,000 age-0 yellow perch in one 10-minute tow," explained Gorman. "This was the second highest age-0 catch we'd ever had, but it was surrounded by catches that were well below average. We later determined that we had trawled across a hypoxic edge and that we had hit a large aggregation of fish."

Including that trawl would have ranked that year's class in the top 15th percentile. However, as tracking progressed through that year's class of age-1 and age-2 fish, further data determined it should only rank in the 40-60th percentile. That portion of the population would have been severely overestimated led to an unnecessarily elevated quota and harvest.

"We anticipate that understanding the behavioral response of yellow perch to hypoxia will help us improve our annual population assessments, although the dynamic and patchy nature of hypoxic conditions has made this an extremely difficult task," said Gorman. "We are working with collaborators to generate a more sophisticated approach for handling this issue."

Age-0 and Age-1 fish caught in the Central Basin Bottom Trawl Survey.

Currently, the team uses the YSI ProDSS Multi-Parameter Water Quality Meter to record temperature and dissolved oxygen profiles at the beginning and end of every trawl. Trawl surveys are dependent on periods of stratification (i.e., pre, during and post-stratification surveys), and they also use this instrument to verify lake turnover.

They collaborate with Ohio State and Sandusky Fisheries Research Station to develop models to assess the link between catch rates and the presence or absence of hypoxia along with the thickness of the hypoxic layer. They are working to pair this site-scale information with a lake-wide 3D model of hypoxia.

"Our goal is to improve our annual population estimates through a better understanding of the relationship between yellow perch distributions and hypoxic conditions. We are collaborating with Drs. Libby Marschall and Ben Marcek at Ohio State to model yellow perch habitat using environmental variables including temperature and dissolved oxygen. Results from this work will help us determine if modifications to our survey locations could improve annual population estimates."

The team has collaborated on and continues to assist with several offshoots of this research. Dr. Karin Limburg (SUNY ESF) is a co-PI on an NSF grant to develop novel approaches for exploring the spread and impacts of deoxygenation in fish species from Lake Erie, the Gulf of Mexico, and the Baltic Sea, including the use of otolith microchemistry, eye lens chemistry, and environmental toxicology.

"We anticipate research from Ohio State in the very near future using acoustic telemetry tagging to assess fine-scale behavior of adult yellow perch in relation to hypoxic conditions. Results from this work could help us better understand how far away and how quickly yellow perch can respond to hypoxia and what levels of hypoxia they can withstand and for how long."

The Central Basin Bottom Trawl Survey will continue to assess the relationship between hypoxia and yellow perch distributions until a sophisticated method is developed for addressing the potential effects of hypoxia on population assessments.

NEW TECH AIMS TO MAKE ALGAL BLOOM MONITORING FASTER AND MORE DYNAMIC

The fight against harmful algal blooms is getting a bit quicker, nimbler and more precise thanks to new technology that provides a cell-by-cell, colony-by-colony view of bloom make up and toxicity.

"Typically a cyanobacteria community is highly variable. Certain species will dominate one week such as Microcystis aeruginosa (Fig. 1), and then another will dominate the next week or so," said Dr. Scott Gallager, president of CoastalOceanVision, Inc. a company that hopes to change the way algal blooms are monitored with their new technology, Continuous Particle Imaging and Classification System (CPICS) and HABStats, a Raman Imaging Flow Cell Cytometer.

The instruments, which measure algal blooms with a combination of imaging and spectroscopy, will provide water quality managers with a new, real-time monitoring tool to keep water safe and accessible.

CPICS is an underwater microscope that captures images of and identifies the microscopic single-cell or colonial alga and cyanobacteria by species using Deep Learning artificial intelligence.

But because some species of algae can look similar to each other, HABStats further characterizes and classifies each cell or colony using Raman spectroscopy, a vibrational spectroscopy. A laser shines intense monochromatic light on each cell, causing its molecules to vibrate and shift the spectrum of light reflected back. Molecules reflect a unique spectrum of light, which HABStats analyzes to more finely identify each species of algae.

"That shift in wavelength is a function of specific chemical compounds and molecular structure," said Gallager. The light each algal cell reflects back "can be considered a fingerprint of a specific group of compounds representing a cell."

Those specific compounds might be unique to an algae species and useful for determining what type and how many of a given species is present.

The specific compounds detected might also be toxins. Since toxic algae can vary in toxicity over their life span, Raman spectroscopy gives HABStats a snapshot of toxicity within an individual cell at a specific moment in time. With near constant monitoring, the algae and toxicity identification can track an algal bloom's make up and level of toxicity in real-time.

The current methods for monitoring algal blooms are slower and more labor-intensive than necessary, Gallager said.

A city's water manager needs to keep an eye on algal blooms. A toxic bloom can cause disruptions to drinking water supplies, as it famously did in Toledo, Ohio, in 2014.

Oftentimes, drinking water managers rely on manual sampling and identification of algae. After water is collected, cells are counted and identified under a microscope by expert algal taxonomists. Managers know they might have a problem if cell counts are too high for problematic cyanobacteria like Microcystis, a fairly common freshwater cyanobacterium that can produce the liver toxin microcystin.

But, just knowing a drinking water source has too many potentially toxic cells doesn't mean it's toxic at that time. A specific and complex toxicity test needs to be run. That's a test many cities aren't equipped to carry out and samples may need to be sent away to another lab to be analyzed, which could take up to several weeks, in some cases, Gallager said.

CPICS and HABStats could eliminate a lot of that labor and time spent waiting for results. Water managers will no longer risk closing off non-toxic water or leaving toxic water open to the public while waiting for results.

By identifying cyanobacteria species and quantifying toxins in the field, these instruments go a long way toward "eliminating the taxonomist," Gallager said. They could represent big savings in time and money in water quality management.

Because CPICS and HABStats can relay such specific information to a central website in real time, they might help researchers not just monitor algal blooms for threats to drinking water, but better understand how they work.

Several instruments positioned throughout a water body could reveal in fine detail how algal blooms grow and develop or move around on a windy day. Tests have already provided insight into the daily movements of cyanobacteria in a lake on Cape Cod, where the system is being tested.

"They're migrating from depth up to the surface and then back down to depth in a period of 24 hours," Gallager said. "By taking hundreds of samples per minute, we're able to characterize that behavior very accurately. And that kind of data just didn't exist before."

This vertical migration may occur because of physiological processes within the cells: Carbohydrates build up in cells when they photosynthesize near the surface. The heavy carbohydrates cause them to sink where, away from the sunlight, the cyanobacteria consume the carbohydrates through respiration. The production of Nitrogen gas in the morning then makes the newly buoyant cyanobacteria float to the surface again.

Raman spectroscopy is revealing changes in carbohydrates within the cyanobacteria that might explain how and when colonies are migrating up and down within the water column, Gallager said.

Gallager believes that, although it has passed every test so far, HABStats needs to pass a few more before it's ready for prime time.

This summer, it will be out in Lake Erie's Sandusky Bay where it will help Dr. Timothy Davis, a Ryan Family Endowed Professor at Bowling Green State University, study the bay's dynamic toxic cyanobacterial blooms.

"These blooms are much more dynamic and change much more quickly than we currently can measure," Davis said. The much finer resolution provided by HABStats could push researchers' knowledge of cyanobacterial blooms forward.

Sandusky Bay's blooms are dominated by Planktothrix agardhii, a common bloom-forming cyanobacterium. Planktothrix agardhii has toxic and non-toxic strains that look identical under a microscope. Identifying and quantifying total Plankothrix populations is only part of the picture. HABStats' Raman spectroscopy will identify whether or not the microcystin-producing strains are present and what percentage of the total Plantothrix agardhii population they represent.

HABStats could be useful beyond the near real-time view of the bay's cyanobacterial blooms, Davis said. Davis and his BGSU colleagues will sample Sandusky Bay at nine different sites on a weekly basis from June to October. Higher-resolution data could be useful in developing more accurate predictive forecasts of bloom toxin concentration.

Assuming the testing goes well this summer, HABStats could be ready for prime time soon and change the way algal blooms are understood. AB

> "THESE BLOOMS ARE MUCH MORE DYNAMIC AND CHANGE MUCH MORE QUICKLY THAN WE CURRENTLY CAN MEASURE."

Photo: NOAA Great Lakes Environmental Research Laboratory

A harmful algal bloom in the western basin of Lake Erie.

Cyanobacterial bloom on Lake Mendota with graduate students preparing to collect samples.

Cyanobacteria: Elemental Cycling In Lakes

Lakes are subject to many forces ranging from the climate to the presence or lack of individual chemicals and their movements in the lake system. One of the many forces acting on lakes is bacterial action, which is a major player in phosphorus, nitrogen, and carbon cycling in lake systems. These, in turn, influence eutrophication and water quality in lakes.

Trina McMahon, professor of civil and environmental engineering at the University of Wisconsin-Madison, described how bacteria affect cycling of these three major chemical elements in lake systems, and how lake health is impacted.

"All cells need carbon, nitrogen, and phosphorus for building DNA and to make cell structures. They are not toxic. Blue-green algae (cyanobacteria) consume them and perform photosynthesis. Insects, fish, frogs, and other animals eat the algae and use its nitrogen and phosphorus to make DNA and proteins. Then when these animals die, the carbon in them gets turned to CO2," McMahon explained.

The phosphorus, nitrogen, and carbon cycles in lakes are not necessarily independent processes, but are largely related and integrated, said McMahon. "Nitrogen cycling is the most complex, and can sometimes be independent from the carbon and phosphorus cycles, but all three are interconnected inside organisms."

Phosphorus, nitrogen, and carbon cycling processes in lakes relate to eutrophication and water quality in ways that are both natural and anthropogenic. Lakes tend to naturally get more enriched in phosphorus over time, the amount of carbon available in them for cycling is essentially unlimited, and blue-green algae can even take nitrogen from the air, said McMahon.

Since phosphorus can only come from land, it is the limiting reagent in the lake system. Human activities accelerate the eutrophication process by adding more phosphorus to the cycle, and also by adding nitrogen and phosphorus linkages. Phosphorus can come from agriculture and also from wastewater treatment.

Photo: Riley Hale

Phosphorus cycling of the lakes can also be considered on an annual basis: seasonal events may cause nitrogen and phosphorus deficits compared to other times of the year. McMahon mentioned that flooding often causes a massive inflow of nutrients, but calm weather and warm temps can cause BGA blooms that would suck up nutrients, and thus, one or the other becomes limiting.

As far as which bacteria are driving phosphorus, nitrogen, and carbon cycling processes, McMahon said some are well understood, but many are not. Algae and cyanobacteria control a lot of the cycling. Some of the bacteria have been well studied. Fonsibacter, for example, is known to be making an impact on cycling and won't easily grow outside of the lake.

Metagenomics data from the lakes is also employed to look at bacterial genomes and compare them to see if they are from distinct microorganisms. But even then, many do not have specific identifications; it is just known whether they are similar or different microorganisms. Many have IDs no more specific than a string of letters and numbers. "You can see in their DNA what they do, what functions they are performing: like eating sugars, consuming phosphorus, etc., as the signatures are in their genomes," McMahon explained.

Some of the blue-green algae/cyanobacteria involved in lake chemical cycling are Microcystis, Anabaena, Planktothrix, and Aphanizomenon. Of the algae, Chlorophyta is known to be important.

McMahon became interested in studying bacterial populations in lakes through her training in engineering and sewage treatment. "We use bacteria to clean water, but not algae or cyanobacteria," she said. "Bacteria carry out the same functions in both wastewater and in lakes. However, we find that there is 10 to 100 times higher nitrogen, phosphorus, and carbon in wastewater than in a lake." Nocardia and Zoogloea are typical bacteria in wastewater. Bacteria remove 99% of these chemical species. Accumulibacter, on the other hand, appears in both wastewater and in lakes. Accumulibacter makes polymers out of phosphates and stores them inside its cells.

Information collected in the lakes by McMahon and her colleagues included: concentration of nitrogen species (nitrates, nitrites, ammonia, urea), temperature, dissolved oxygen, and light measurements, as well as DNA data.

One of the questions McMahon has considered in her research is: what is a healthy lake? "We don't have a good definition of that yet," she says. "It depends on what you decide has value. Humans don't like green water, so to us that is undesirable and clear water is preferred, but what we have seen in lakes with zebra mussels, for example, is that they filter the water and make it clear but that is actually not a good thing, since it destroys the food web and causes fish populations to collapse. Lake Michigan is very clear and clean now because of zebra mussels…but clean has been bad for the fish populations."

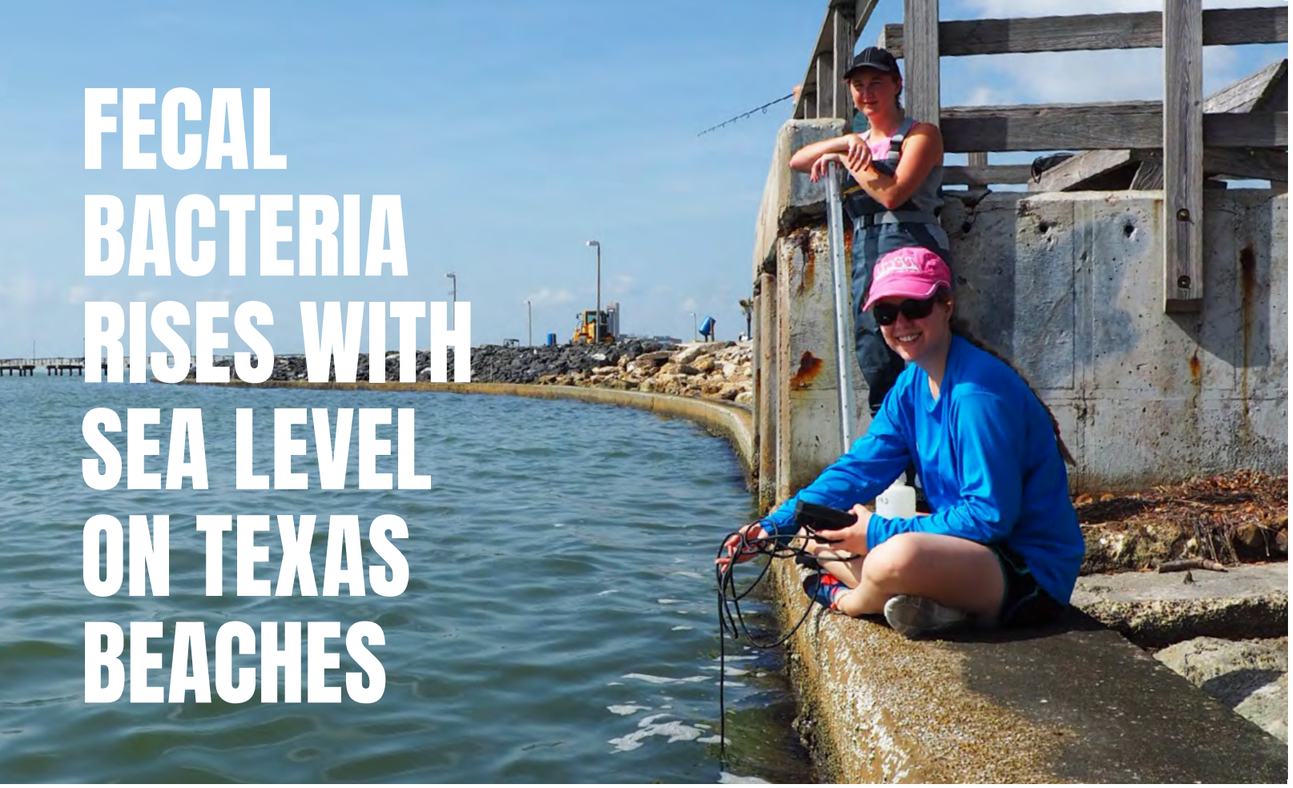
While the question of what a healthy lake is can be subject to some debate, there are some activities people agree are beneficial to lake health. McMahon suggested that keeping zebra mussels out of lakes that don't have them yet is helpful. Washing boats off between uses and keeping septic tanks from being drained in lakes are good practices, too, as is keeping lawn fertilizer out of the lake. McMahon also recommended not removing lake wood, as it can be a fish habitat.

Sometimes there is a struggle with stormwater runoff going into lakes, but this can sometimes be improved by getting more natural vegetation in the area to slow the water down for soil absorption instead of carrying contaminants to the lake. "Lake associations—neighbors' grassroots efforts to do native plantings—have had a significant impact," McMahon noted. "We've also found we make an impact disseminating our research to Wisconsin, Minnesota, and Michigan to raise awareness of what people can do to help our lakes." LB

(Left) Measuring water clarity in Lake Mendota. (Middle) Sampling bacteria in Lake Mendota. (Right) Collecting samples to measure nutrients in Lake Mendota.

Photos: (Left to Right) Riley Hale; Robin Rohwer; Patricia Tran

FECAL BACTERIA RISES WITH SEA LEVEL ON TEXAS BEACHES



As climate change lifts the sea level in the Gulf of Mexico, it's lifting levels of enterococci bacteria on Texas's beaches, too.

New research out of the Gulf shows that high levels of enterococci bacteria, which come from humans and other animals and can cause disease, are correlated with proximity to large human populations and sea level rise and are increasing over time.

The research highlights an area of growing concern for public health and safety on popular recreational beaches. While sea level is projected to continue rising, it's not a guarantee that bacteria levels will as well.

"Bacterial pollution could be expected to increase as time goes on and as the coastal population is increasing and as sea levels continue to rise," said Nicole Powers, the lead author of the study and a recent doctoral graduate from Texas A&M—Corpus Christi.

"The sea level rise and population growth affecting the beaches in Texas affects coastal communities around the world; the bacteria problem on the Gulf is also a problem elsewhere."

A team of researchers from Texas A&M—Corpus Christi and the Texas General Land Office analyzed beach water quality data from 2009-2020. Their analysis was recently published in Marine Pollution Bulletin.

"We set out to look at recent spikes in the bacteria levels in certain regions along the Texas Coast, but we had data that spans back over ten years," Powers said. The focus shifted to long-term trends.

Of the 66 beaches the team analyzed, 22 regularly exceeded the U.S. EPA action level for beaches. (The EPA recommends that beach samples not exceed a geometric mean of 35 colony-forming units of enterococci per 100 milliliters and that samples not exceed 130 colony forming units per 100 milliliters over in more than 10% of samples.)

All but one of the beaches exceeded this recommendation multiple times and 19 beaches broke the scale—they exceeded the upper limit of detection. Harris County, which includes Houston, and Matagorda County exceeded the U.S. EPA limits more than 20% of the time.

Over time, enterococci levels have been increasing in coastal Texas. It was one of three correlations, along with rising sea levels and population that the analysis revealed.

THE PROBLEM WITH ENTEROCOCCI

Enterococci serve as a proxy for other fecal bacteria that could harm beachgoers.

"In US surface waters, outdoor recreational activities such as swimming, boating, and fishing account for approximately 4 billion recreational events annually.

These recreational events result in 90 million gastrointestinal, respiratory, ear, eye, or skin-related illness," the study reports. These illnesses cost $2.2-3.7 billion.

Bacteria is the leading cause of surface water problems in Texas. A 2019 report by the Environment America Research and Policy Center and Frontier Group found that over half of America's beaches exceeded bacteria standards at least once in the previous year.

The beaches examined in this study are regularly used for recreation. The data used in the study came from the Texas Beach Watch program, which monitors water quality data at recreational beaches along the Gulf Coast.

POSSIBLE CAUSES FOR RISING BACTERIA LEVELS

The study found correlation but didn't look at specific causes. Some potential explanations have been found elsewhere.

Rising sea levels can compromise septic systems, which can then leak sewage into the environment.

"It isn't necessarily the number of septic systems in coastal areas that are causing high bacteria levels," Powers said. "I'm not saying that it's bad to have septic systems, by any means—it could have to do with the age and maintenance of those systems, as well as the condition of underground sanitary sewer systems too."

Research in North Carolina showed septic and sewer systems being harmed by rising sea level and increased rainfall. Others made similar findings in Rhode Island and in Florida.

The relationship between cities and enterococci pollution makes sense, too, since more people will produce more of the bacteria.

The team also found a difference between beaches along bays and beaches along the Gulf coast. Gulf coast beaches, which are flushed by waves more than the calmer, more protected bayside beaches, had lower levels of enterococci. Bayside beaches had higher levels of enterococci and were often closer to large cities, as well.

"Sea level rise and population growth are not limited to the Gulf coast," the authors write. Many coastal communities face similar challenges.

The Environment America Research and Policy Center and Frontier Group report showed that 85% of Gulf Coast beaches exceeded bacteria recommendations for at least one day in 2018. But, 67% of West Coast beaches examined did as well.

The East Coast, which had the best numbers of any region included, had 48% of beaches exceed the recommendation on at least one day. (The Great Lakes, which face different challenges than marine coastal regions, had 68% of beaches over the limit at least one day.)

The infrastructure problems that contribute to this issue of bacterial pollution can be remedied. One way authorities can begin tackling this problem, according to the study's authors, is by "focusing on the maintenance and repair of coastal infrastructure that is susceptible to damage from urbanization and rising sea levels."

"This isn't just a doomsday event. There are things we can do to help and make this problem better," Powers said. AB

(Left) Nicole Powers and Hailey Harkless sampling the water in Corpus Christi Bay, Texas to look at enterococci concentrations as well as host-specific fecal markers for humans, canines, and gulls.

(Right) Powers holds a petri dish with enterococcus bacteria collected from Corpus Christi Bay.

Photos: Sandra Marbach; Nicole Powers

SNOTEL: A NETWORK FOR MONITORING SNOW

While many of us think of snow men, snow forts, and Currier & Ives prints as our yards turn white in December and January, for Mike Strobel, Director of the National Water and Climate Center at the USDA Natural Resources Conservation Service, snow isn't just something to enjoy during the winter months, it's something to think about all year round. It's also the foundation of the last fourteen and a half years of his career with the Snow Survey and Water Supply Forecasting program and using SNOTEL, the Snowpack Telemetry data-gathering network.

Strobel's career began 40 years ago as an Ohio State undergraduate fascinated with climate science. Since then, he has worked on teams to collect ice and snow samples all over the globe, from 18,600 feet in Peru to deep in the ice in Antarctica. He's also a veteran of snow and ice data collection in Alaska and Greenland, studying hydrology and glaciers. All along the way, he has become part of the Snow Survey's lengthy history.

What is now the Snow Survey and Water Supply Forecasting program as part of the Natural Resources Conservation Service began with the Soil Conservation Service. "The snow data collection actually began in 1906 by a professor at the University of Nevada-Reno and our agency has handled this since the 1930s," Strobel notes. "We have 12 western states collecting snow information, for the purpose of predicting spring and summer water supplies.

This is extremely important for agricultural planning and irrigation purposes. From January to June we collect snow depth information, and its water equivalent.

SNOTEL, which is an automated system, as we think of it today, didn't start until the late 1970s. The data collected then and now includes the depth and weight of snow, from which we can calculate the water content. We currently have 889 SNOTEL sites and over 1,000 manual sites. We gather other data at the SNOTEL sites as well, including temperature, precipitation and solar radiation data."

While the older manual data was in many cases only taken once a month, the current SNOTEL data are collected continuously and transmitted every hour. SNOTEL is exceptional not only in how often it takes data, but also in where it collects data. SNOTEL is in high-altitude mountainous areas –above the range of the rain-snow transition. SNOTEL sites are also in protected areas where wind is not eroding snow. They are often in Forest Service, Wilderness and National Parks areas, and they are often in areas closed to the general public.

"We can look at snow data and compare it to 30 year periods, referred to as the 'normals,' to see how it rates to the same date over that period (i.e., is the current condition above or below normal)," said Strobel. "Before the automated data from SNOTEL, we had manual measurements. We still take manual measurements now, to supplement the SNOTEL data or in areas where we don't have SNOTEL stations. We continue to take manual measurements because that helps us calibrate our SNOTEL data, and because we don't have automated equipment in all locations. Our agency and our co-operators still take measurements at over 1,000 sites each year. Our measurements are taken from January to June, and in addition to the U.S. data, we also work with Canada to use their snow data for our forecasting."

An important focus in Snow Survey and Water Supply Forecasting research is participating in the development of new methodologies to collect snow data. Fixed wing flights and LIDAR are being used by many groups to gather snow information. Satellite data collection is also being used. There are efforts to constantly improve forecast models and improve data quality and delivery. Other factors, such as dust on snow, is also important in its effects on snow albedo and the timing of melt, as are temperature increases and changes in the rain-to-snow transition zone.

Horse packing trip to SNOTEL station, Shoshone National Forest, Wyoming

Photos: Mike Strobel

Recent trends seen in SNOTEL data include increasing regional annual temperatures. "Some of the hottest years we've ever had on record have occurred in the past decade," Strobel observes.

There have been trends with snowpack as well. Typically in the past, the maximum snowpack would be around April 1st, but now the peak snowpack in many areas seems to be happening earlier. Peak runoff also is happening earlier in many areas. For many stations, the rain-to-snow ratio is increasing. "That's important because snowpack relates closely to temperature," said Strobel.

Major goals of the Snow Survey and Water Supply Forecasting program and the SNOTEL network include providing the best science and information to farmers and water managers as possible. Good information is critical so that farmers can better utilize what water they have. Besides agriculture, users such as hydroelectric power and municipal water agencies, for example, use SNOTEL data for reservoir operations management.

"Water supplies in the West are precious, so we need to make sure we give managers the best forecasts and science we can," said Strobel. "So many people rely on what we do, and that makes our jobs all the more valuable."

In the future, Strobel sees many opportunities with the program and using SNOTEL. "There are so many opportunities to use improvements in the technology," he said. "We plan on working to collect more data, more SNOTEL sites, more collaboration with federal, state, and local groups, and more tools for farmers. Generally, we plan on helping people achieve even better water management."

Lastly, Strobel wants to emphasize that yes, you can absolutely build a career out of snow, and not just any career…a truly great one. "This job is the best job in the world! I have been able to work in so many beautiful and remote locations that people would pay to go to recreationally, but I got to experience as part of my work. My career here has been so meaningful and rewarding to me. I've loved traveling by helicopter and horseback to get to places off the beaten path that most people don't get to see, taking snow and soil samples, and networking with other researchers. It's been so much fun. It's been a great job and I'd highly recommend this career to anyone." LB

Photos: Mike Strobel

HYPOXIA IN A CHESAPEAKE BAY TRIBUTARY

The Chesapeake Bay is the site of recurring seasonal dead zones: areas of low dissolved oxygen where aquatic life struggles to survive if it can at all. In 2020, a dead zone in the Maryland portion of the bay was one of the smallest since 1985, when record keeping began. The hypoxic area in the Virginia portion of the bay was smaller and briefer than many years previous.

But the problem isn't gone yet, and looking forward, climate change will play a big role in determining the size and severity of dead zones throughout the bay. It could make it harder to get hypoxia under control in some places.

New modeling of one estuarine tributary in the Chesapeake Bay shows that climate change-driven warming of the estuary and the oxygen levels of the neighboring Chesapeake Bay may have a bigger role in driving hypoxia than nutrient reductions within the watershed.

FINDING THE FACTORS THAT INFLUENCE HYPOXIA

Hypoxic conditions often occur where rivers drain nutrient-rich water into a larger body of water. Those nutrients spur algae growth in surface waters, which consumes a lot of oxygen as it sinks to deeper waters, dies and decays. Because each estuary's watershed, water movements, and vulnerability to external forces like winds and warming are unique, it's hard to generalize among hypoxic zones.

The Chester River estuary on Maryland's eastern shore was given a close look by Jeremy Testa of the Chesapeake Biological Laboratory at the University of Maryland Center for Environmental Sciences, and a team of researchers. They tested factors affecting hypoxia in forward-looking, idealized numerical model simulations.

The strongest effect came from the open-water boundary exchanges—the mixing of Chester River water with that from Chesapeake Bay.

Photo: NASA

When water in the bay was richer in oxygen, hypoxia in the Chester estuary was reduced. Using the dissolved oxygen value for 2001, one of the best years for dissolved oxygen on record, Testa and his colleagues found that deep water hypoxia reduced by up to 50 percent. But in years when Chesapeake Bay had extensive hypoxia, the Chester estuary takes in these low-oxygen waters.

Warming the water by 1.25 degrees Celsius decreased dissolved oxygen by 4-7 percent.

These two factors both had a stronger influence on the deep water hypoxia of the Chester River estuary than localized nutrient reductions. The model found reducing available nitrogen and phosphorus had only a negligible effect on the deep-water dissolved oxygen levels.

These findings point to the challenges of global warming and the importance of improving conditions for the whole bay.

CHANGING CLIMATE, CHANGING CONDITIONS

The full effects of changing climate on hypoxia in the Chester River estuary aren't known. "In Chesapeake Bay, the altered magnitude and seasonality of precipitation and sea level rise are also projected to change (along with warming), and the hydrodynamic response to these forces will have diverse and interactive impacts on circulation, phytoplankton productivity, and hypoxia," the authors write in the study.

The Fourth National Climate Assessment predicts "increasingly frequent and intense storms, heavy precipitation events, warmer water temperatures, and a rise in sea level in the Chesapeake Bay," all which could impact hypoxia in different ways.

Greater precipitation could wash more nutrients into the water and enhance stratification, Testa said. "We typically think more precipitation, more hypoxia." Sea level rise could have many different effects on hypoxia in the Chester River, and most of these effects were not addressed in the study, Testa said.

Climate change may also change the ecosystem in other ways, favoring new species, altering the shoreline, and changing how water and nutrients are processed in the watershed.

While incidents of hypoxia nationwide increased by a factor of 30 from 1960-2008, according to the Fourth National Climate Assessment, it's difficult to predict exactly how all the drivers of hypoxia will interact in the coming decades.

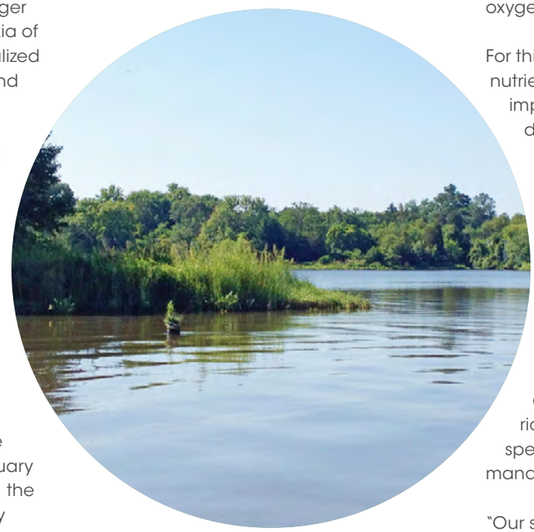


Photo: Jeremy Testa

A SURPRISING FIND ABOUT NUTRIENT REDUCTION

Any time you try to project future conditions, there's a certain amount of uncertainty baked in, Testa said.

"These are kind of idealized simulations," he said. "They're not true projections."

That means the relative importance of each factor could be different. While a fifty percent reduction in nutrient load didn't significantly improve dissolved oxygen within the deep regions of the model connected to Chesapeake Bay, years from now, a larger reduction could prove to be an important part of improving conditions. Or nutrient reductions may have effects in other regions of the estuary that were not a focus of this study.

The authors were looking at hypoxia in the main channel of the estuary, which is about 18 meters (59 feet) at its deepest. An estuary like the Chester River's also contains a bunch of smaller, shallower branches. The majority of the estuary has a depth of less than six meters (about 20 feet).

The shallower portions of the estuary can experience a diel hypoxia cycle. Here, shallower, nutrient-rich water can become hypoxic at night, but when the sun rises and algae again start photosynthesizing and producing oxygen, the hypoxia is relieved.

For this type of hypoxia, it's possible that nutrient reductions would have a larger impact and Testa notes that he hasn't done the appropriate monitoring and modeling to understand the effect of local nutrient loads on shallow-water hypoxia.

"Nutrient management is more important in different places within the estuarine complex," Testa said.

The fact that the Chester River estuary was so affected by oxygen rich water from Chesapeake Bay speaks to the importance of nutrient management on a basin-wide capacity.

"Our study may have found that the effect of Chesapeake Bay may be really important relative to local watershed nutrient management in the Chester River. But that also means that reductions in Chesapeake Bay hypoxia resulting from broader nutrient reductions will translate into a place like the Chester River," Testa said.

A basin-wide effort could pay local dividends for the Chester River. AB

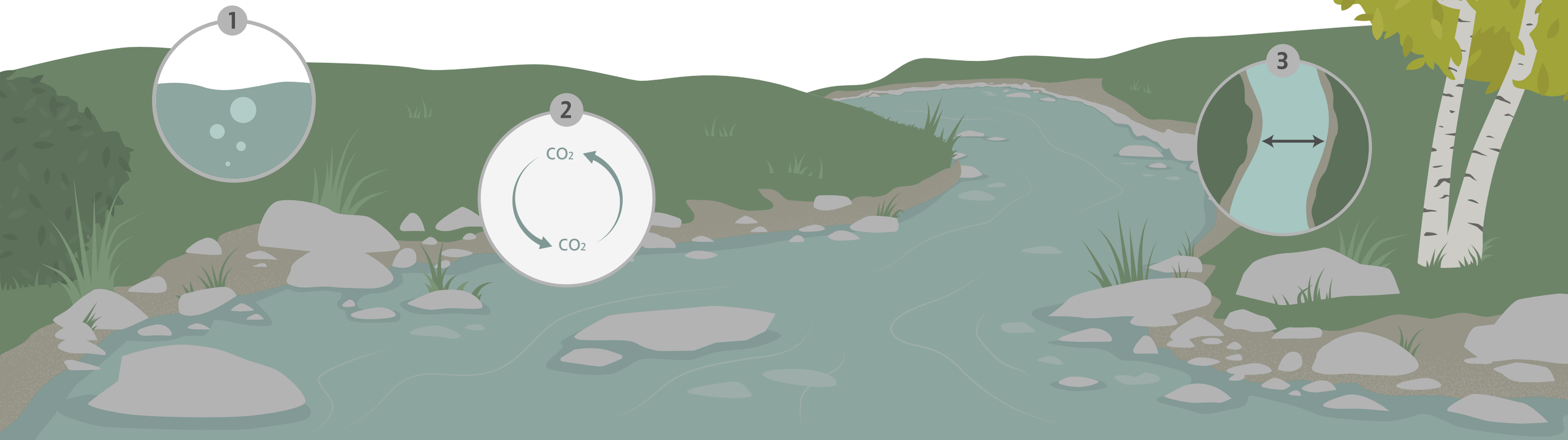
(Left) A satellite image shows sediment flowing into Chesapeake Bay in 2011.

(Above) The Chester River.

STAYING WITHIN BUDGET:

CARBON PLANNING

"In order to know how close we are to reaching the carbon budget, an extensive knowledge of types of carbon input and their magnitudes, as well as their fluctuations over time, is needed."



While we usually concern ourselves with budgeting money or time, we should be thinking about another type of budget: the carbon budget. The carbon budget refers to the amount of carbon exchange, especially carbon dioxide, allotted on an annual basis to prevent the earth from reaching an increase of 2-degrees Celsius all over the globe. If a 2 degree increase does occur, global warming effects are expected to be catastrophic and irreversible.

In order to know how close we are to reaching the carbon budget, an extensive knowledge of types of carbon input and their magnitudes, as well as their fluctuations over time, is needed. A recent study by Yale attempted to pull in the input of the carbon dioxide production of rivers and streams, along with terrestrial carbon dioxide production, to see what effects those might have on the overall carbon budget. The study contained close to 6,000 data points.

WHAT IS THE CARBON BUDGET?

Shaoda Liu, School of Environment, Beijing Normal University, and previously a postdoctoral researcher at Yale, says that a carbon budget "involves any carbon flux that might affect total carbon in the atmosphere." Liu says that the carbon dioxide production from rivers and streams may not be huge compared to the total carbon and could be 2 or 3 petagrams of carbon per year, or it could be a significant portion of the net exchange between the atmosphere and land/ocean surfaces.

Ultimately, many factors go into the budget and it can vary greatly over regions and over time. The carbon dioxide production of rivers and streams is highly dependent on hydrology. More of a monthly carbon dioxide flux occurs in northern or Arctic regions compared to tropical and southern temperate rivers.

STUDYING CARBON PRODUCTION

Some global carbon production is natural, and some is anthropogenic. Liu said that terrestrial ecologists "are not currently accounting for that. They have no way of properly accounting for it. But if you look at net carbon, it is significant." Liu's study estimates CO2 emitted from rivers and streams can be up to 20 to 30 percent of global carbon emissions from fossil fuels.

Illustration: Emma Jones/ Fondriest Environmental, Inc.

Liu says there are three factors needed for gathering fluvial CO2 data (see illustration above):

1. pCO2 partial pressure of C02 in dissolved water.
2. Gas transfer rate- the rate at which methane or CO2 goes through the water/air interface.
3. The total surface area of inland waters.

In terrestrial ecosystems, the primary exchange of CO2 is in gas form. In the past, fluvial CO2 information was taken from water ecology data, where the amount of carbon dioxide was determined indirectly, based on pH, alkalinity, temperature, or other data collected. Currently, people are getting more direct carbon dioxide measurements by using headspace measurements, such as by taking gas into GC-FID or infrared instruments to measure carbon dioxide concentration. These are quick, direct measurements. "There are lots of people doing field work on carbon dioxide from rivers and streams. Our calculations are based on other people's work," says Liu.

Liu's study has an advantage over other, previous estimates. "We have used direct measurements of carbon dioxide, so our study is more accurate than those using pCO2 water ecology data. We have also managed to incorporate changes in the data that others have not. We have been able to capture seasonal variability with the concentration, gas transfer velocity and water surface area." The gas exchange rate can vary depending on hydrology, so this is valuable information that can be incorporated into the calculations. Liu and his team are catching that variability. "People have never done that before," he says.

REALISTIC CARBON PLANNING

When asked if he believes it's possible to stay under the carbon budget, Liu said he did not believe the Intergovernmental Panel on Climate Change had a very effective framework to use for evaluation. "We need more work to really say that. We are trying to incorporate terrestrial and water data to get a sense of that," he mentions.

In his early work, Liu and his team looked at climate change's relationship to the global water cycle and the global carbon cycle. In the future, Liu will be looking at how the predicted existence of more extreme precipitation events due to climate change will affect the global carbon cycle. LB

Photo: SRBC

CLOUD DATA AND WATER QUALITY MONITORING

SUSQUEHANNA RIVER BASIN COMMISSION

As technology becomes more closely interwoven with water quality monitoring, some organizations have found themselves forced to catch up, but not the Susquehanna River Basin Commission (SRBC). The SRBC has had a long-standing relationship with remote data collection. With the establishment of their Early Warning System (EWS) in 2003 and their Remote Water Quality Monitoring Network (RWQMN) in 2010, the commission has shown clear dedication to water quality monitoring.

The EWS and RWQMN merged to become the Continuous Instream Monitoring system. Environmental scientist Dawn Hintz shares, "The original intent of the RWQMN was completely related to natural gas, to the unconventional natural gas industry." However, the SRBC saw great potential in continuing to invest in water quality monitoring and expanding into other areas of focus. "Since that point, we have realized how much value we could have by looking at our entire basin," states Hintz.

The EWS started in 2003 with just two monitoring systems located upstream in New York. In 2012, the RWQMN had more than 45 stations throughout the basin. The commission expanded the network in 2016, shifting its focus outside of natural gas production. Today, the CIM system is about to reach 70 remote monitoring systems disbursed throughout the Susquehanna River Basin region.

Hintz studied agronomy and soil science in school but found her way to SRBC in 2002. "I was looking for a job that would be a mix of indoor and outdoor work," she describes.

Despite her field of study not being directly related, soil knowledge was easily transferable to water quality.

The transition to managing the RWQMN, now called the CIM system, in 2010 was easy thanks to shared data interests. The CIM network focuses specifically on obtaining information on the following parameters: Water temperature, specific conductance, pH, Dissolved oxygen, Turbidity.

For the SRBC, a remote monitoring system is a top priority. Hintz recalls that "we do have a somewhat large basin, so this allows us to have monitoring happen at these sites without someone having to be there on any type of regular basis."

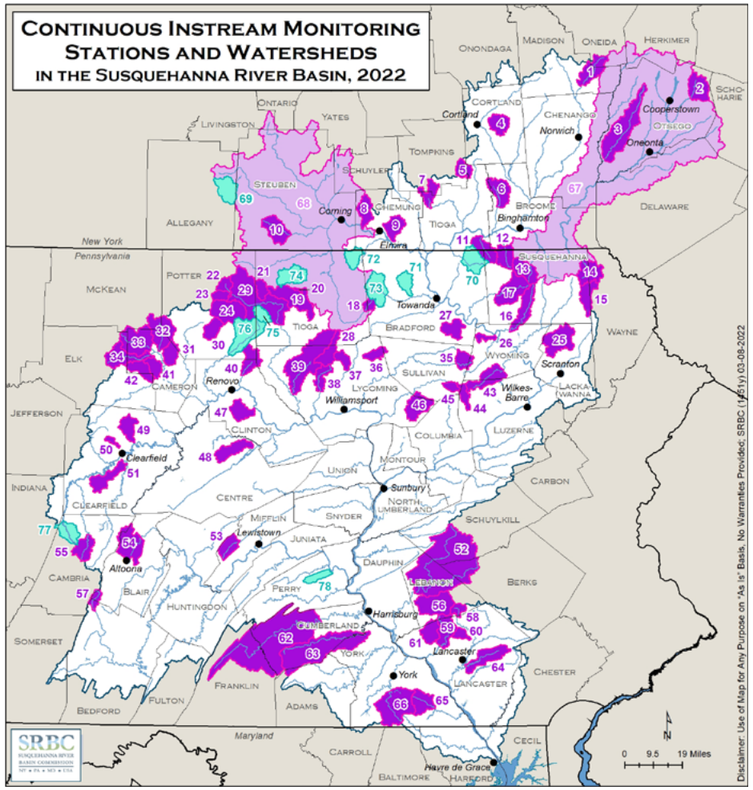
The remote systems also allow for larger data sets and make trends easier to spot. Hintz points out, "Discrete samples have a lot of value as well, but obviously you could be missing anything that is happening in between--especially when it comes to a spill, any type of pollution, or general storm events." Continuous sampling can occur more consistently and cost-effectively with a remote system.

With manual data collection, scientists have to traverse to sampling sites to either conduct discrete sampling or have to download data regularly. Having to go to the site to retrieve data is inconvenient as it prevents valuable data from reaching the website in a timely manner.

Hintz adds, "Real-time is the easiest for us to manage because we can see what's happening in-house. If we see a problem, we can send our staff to see what's going on without losing a whole month's worth of data."

Remote data collection allows passive monitoring and for researchers to only be present when necessary, allotting more time to be dedicated elsewhere.

Trout Run, Clearfield County, PA



"You can build this large data set with continuous monitoring. We're beginning to look at water quality trends," states Hintz. "About 2/3 of our sites have at least 10 years of this data, so we feel confident to be able to look and see if there are any trends."

A trend report is planned to be released this summer and will outline exactly what the commission has seen since the inception of the network.

Climate change is a big topic in the water quality world, and these long-term observations allow for changes to be observed over time. Fortunately, Hintz notes, "We haven't seen huge shifts, which is actually good. You're not looking for streams to degrade."

Even without major shifts, monitoring minor changes is just as important. Hintz says that temperature has been a significant point of focus recently, even by outside organizations.

Monitoring temperature consistently and over a long period can show the gradual rise or fall in temperature compared to the larger shifts observed by manual sampling.

Temperature changes have a rippling effect on aquatic ecosystems. Stakeholder groups from all sides have reason to care about temperature shifts. People living in the basin see how water quality variances impact the environment around them, and state governments rely on the river as a water source.

While long-term trends are important for observing subtle changes in water quality, the data also impacts the immediate future. The publicly reported data helps guide water treatment facilities.

Hintz explains that water quality alerts seen by water treatment facilities (often turbidity warnings), let them "know they may need to change their water treatment process."

The real-time data collection is enabled by NexSens' X2 data logger with either 4G LTE cellular or Iridium satellite communications and hosted digitally in a SQL database that is then transferred to the website. The data server collects information and automatically alerts providers, much earlier than manual testing efforts, if something is wrong.

Since the SRBC covers part of New York, Pennsylvania, and Maryland, there are both governmental and local groups invested in the data. "Most of our data is online--it's all public," Hintz says.

While the commission has expanded the CIM system gradually over the past several years, they are likely reaching a pause on installing new stations as the commission prefers to rotate existing systems when possible. Hintz explains, "If we have interests in certain areas, then we'll shift rather than put a new station out."

Fortunately, the data gathered by the Continuous Instream Monitoring system is publicly available and exists to better the region and encourage early response in emergencies. Hintz adds, "The good thing about us is that we don't work by state boundaries. We can monitor the whole Susquehanna River Basin. So we cover the southern tier of New York, half of Pennsylvania and a small portion of Maryland before it flows into the Chesapeake bay."

"The Susquehanna River Basin Commission is a federal/interstate governmental agency responsible for protecting and wisely managing the water resources within the 27,500 square-mile Susquehanna River Basin without regard to political boundaries. The Susquehanna rises and flows through New York, Pennsylvania, and Maryland into the Chesapeake Bay." The SRBC continues to serve the residents of the Susquehanna River Basin by providing accurate and public water quality data. SB

Image: SRBC

THE TINIEST CARS

UNDERSTANDING THE EFFECTS OF MICROPLASTICS ON CORAL

(Left Page) Coral collections for laboratory studies often take place at Kāne'ohe Bay.This site will also be included in the microplastic survey.

(Right) Exposure of Montipora capitata (Rice coral) to polypropylene microplastic spheres to explore the effects of microplastics on coral reproduction.

Photo: Keiko Wilkins; Illustration: Emma Jones/ Fondriest

Like the microplastics she studies, Keiko Wilkins arrived at this point in her life through a long, multi-dimensional, and at times unexpected journey. Today she is a second-year graduate student in the doctoral program at the University of Hawaii, a graduate assistant at Kewalo Marine Laboratory, but her journey began in Pickerington, Ohio, a far cry from the sea.

"I always had an interest in water, and I swam competitively," she recalls. "I knew I wanted to study biology, but did I want to do research or education? So I explored biology further. My academic advisor worked on lakes and I focused on zooplankton in lakes, and changes in their populations. Fascinated by the ocean, I wanted to study it, but in Ohio, the ocean is, of course, out of reach. So I turned to study abroad in Puerto Rico, collecting samples of plankton and bacteria. After taking a microbial ecology class in 2017, I got interested in microplastics."

Microplastics, defined as plastics 5 mm or smaller in size, were all over the environment, she learned. "Even in the deepest parts of the ocean, we've found microplastics. We've not only found that microplastics get transported everywhere, but they also act as transportation for other organisms. They act like tiny cars that take hitchhiking organisms on rides to faraway places."

While plastics are so common in our environment, we might be tempted to assume they're benign and ignore them; Wilkins says we should not be so hasty. "Bacteria can colonize microplastics and get carried all over the world, over our entire environment. This has consequences we are only beginning to study and understand," she mentions.

After finishing her master's at Miami University (Oxford, OH) and going to Australia in an exchange program with Southern Cross University, Wilkins sought to explore the question of how exactly she wanted to study microplastics. After working with corals and discovering they could ingest microplastics, her course of advanced study was finally set.

"I decided to study the effect of microplastics on corals, combining two big interests of mine. I also found there was very little research out there on how microplastics affected corals. It was a perfect topic for my doctoral research," she recalled.

Microplastics are an emerging area of study, but they have been in the environment for a long time. Some are primary, meaning they started out as microplastics–for example, microbeads in makeup–that passed directly into the environment. Others are secondary, meaning they started out as larger plastics, such as plastic bags, that were gradually broken down by the environment into microplastics. Lots of plastics of both types end up in the ocean.

"Microplastics themselves aren't the only concern," Wilkins noted. "There are also chemicals we need to add to microplastics to make them work and chemicals already in the environment which attach to microplastics. We don't know what effects those chemicals are having on the environment either, or whether they are safe."

Photo: Keiko Wilkins

Another aspect of Wilkins' research is geographical: she needed to determine which corals should be studied to look at the way microplastics affect them. "We've found that every environment has microplastics in it, so that means all corals are likely being affected," says Wilkins. "We already know something about how microplastics affect other marine life. We know seabirds have innards full of microplastics. We know even plankton can ingest microplastics. We suspect microplastics are traveling up the food chain right now, and we may be getting microplastics from the fish we eat. Whenever you drink water from a plastic bottle, you're likely ingesting microplastics. We've also been able to find microplastics in lakes."

However, the research on microplastics in coral is scant, making it ripe for a dissertation study by Wilkins and others. The first stage of her dissertation research will be field and lab coral collection in Oahu and Maui. "We want to look at the coral skeletons and coral polyps (mouths) and see the different ways they ingest microplastics. We also want to get a sense of where microplastics are collecting in the water column. We want to look at what coral characteristics influence microplastic ingestion," says Wilkins.

Types of microplastics found will also be explored, as well as related chemicals, especially those known to cause reproductive harm. Different concentrations and sizes of microplastics will be examined.

"We plan on doing the coral survey first. We also plan on looking at a species of butterfly fish that commonly feeds on corals to see if we can detect any microplastics transferring from the coral to the fish," Wilkins mentions.

"Right now, we don't know what types of microplastics we will find, or how much we will find," she adds.

Given the size and scope of microplastic distribution and effects all over the globe, studying microplastics in Hawaiian corals will be an extremely valuable step in beginning to understand what microplastics are doing to wildlife and human life.

"This study is the first of its kind," Wilkins emphasizes. "It's a very exciting time to be doing research." LB

IN THE RIGHT PLACE **ALL THE TIME**

GREENHOUSE GAS RESEARCH AND NTL-LTER

While researchers all over the globe have been studying greenhouse gases, there are still some areas in the field that have not received as much attention as they deserve. Emily Stanley, professor in the department of integrative biology at the University of Wisconsin and principal investigator for North Temperate Lakes Long Term Ecological Research (NTL-LTER), has spent a significant part of her career exploring a few of them.

"Clearly we have a problem with greenhouse gases. What people may not realize is that streams and lakes are hotspots of global methane and CO2. Understanding greenhouse gas dynamics in these systems is important because they are vents all over the world and they are not insignificant," said Stanley. North Temperate Lakes Long Term Ecological Research is one of 28 programs around the U.S. and beyond that form a rigorous research network.

While many long-term research programs are thought of in terms of two or three years of research, five if they are lucky--the NTL-LTR program has been going since 1981.

"We hope to be going another 40 years," Stanley said. "We collect biological, chemical, and physical data. This data is influenced by human responses and actions as well…we can't separate humans from the environment."

Stanley notes that while humans are not the source of all greenhouse gases, humans have exacerbated greenhouse gas issues.

Two significant effects humans have on streams and lakes are: 1) "turning them green," that is, creating conditions that encourage algal blooms, and 2) building dams. These human effects make emissions worse. In terms of methane, the more ephemeral gas and CO2, the bigger problem.

Stanley and her team have noticed that some greenhouse dynamics in lakes and streams are the effects of agricultural activities, low gradient landscapes, and topsoil ending up in lakes. While lakes handle nitrates, they produce methane, which bubbles up to the surface of the lake.

Undergraduate researcher Nick Gubbins measuring greenhouse gas fluxes from a northern Wisconsin stream.

Photo: Luke Loken

Photo: Emily Stanley

"The bubbling, or ebullition, is hard to measure, but it is important because lots of methane leaves lakes that way," said Stanley. "We will need about 10 to 20 years of that data to get some picture of the real processes and their impact. We are building a global database on these types of processes in streams. The conventional view has been that there's not much methane in lakes and streams, but we already know with the data we have that that is not true."

In addition to getting a handle on the methane and CO2 impact of lakes and streams, North Temperate Lakes Long Term Ecological Research has some overarching goals. Some goals are: to understand how the lakes work short and long term, what factors affect their ecology, and to what degree each factor has ecological influence. NTL-LTER is also designed to be a source of information for policymakers. It is also training the next generation of aquatic scientists and interacting with the general public. A NTL-LTER program called "Schoolyard LTER" teaches 3rd and 7th graders about area lakes. Open houses, lake trips for schools, and environmental training such as plankton sampling are all done by NTL-LTER.

Data collection is a fundamental activity for North Temperate Lakes Long Term Ecological Research, as is sharing data. Lake core sampling is performed every couple of weeks, with the exception of winter, where lake core samples are collected monthly. Recently, high-frequency data collected by instrumented buoys has become a valuable research resource as well. Core lake data stretches back to the early 1800s. Routine limnological data is taken.

The NTL-LTER contains 11 study lakes, but many other lakes have been included in their research efforts. Whether these lakes are a good representation of regional patterns is a topic that is being explored. Four southern lakes are also being studied, and one of the lakes, Lake Mendota, is considered the "best-studied lake in the world," said Stanley, as the university is right on the lake. Data goes back to the early 20th century. Sampling is seasonal.

NTL-LTER has made some interesting, sometimes surprising observations.

"People have said of us, 'You were in the right place at the right time," Stanley recalled. "I think we are in the right place all the time," Stanley noted. She mentioned, as an example, their strategy of placing data gathering devices under ice, which led to their observation that water starts stratifying before ice appears. "That's not what the textbooks said," elaborated Stanley. Another observation they have made due to their unique research setup is that groundwater levels in the area are rising, with new ponds showing up. They have especially seen this trend over the past five years.

"We know people who have had to abandon their lake houses," Stanley said. Despite the striking nature of this change, the cause is not yet clear, but a current hypothesis being considered focuses on land use. "What we are seeing could be a slow land response to usage change from prairies to agriculture," Stanley noted.

Ph.D. student Mike Spear (in wetsuit) sharing his research findings on zebra mussel invasions of Lake Mendota with a group of visitors.

Ultimately, the NTL-LTER has two main goals in researching greenhouse gas dynamics in lakes and streams: 1) building a data set for use as a data resource for the scientific community and, in collaboration with colleagues at Yale, to generate a reliable global estimate of methane emissions from world streams and rivers; and 2) to study aquatic gas dynamics as a means of understanding overall processes of lakes and streams. "We want to use methane as lens for viewing these ecosystems," Stanley said.

To Stanley, understanding the role of methane is key to understanding aquatic greenhouse gas dynamics. "Methane is such an interesting gas, which is something I became aware of when I was a postdoc studying wetlands, and my advisor was doing a methane project. I also had a chance to return to this topic through two of my graduate students who studied carbon dioxide and methane in streams as part of a collaboration with the USGS," she noted.

Stanley plans on continuing methane research and gaining more knowledge of how greenhouse gas processes function in lakes and streams. She concluded, "The incredible importance of having long term research can't be overstated. Understanding can only be gained over a long time scale. Too often, people think in terms of only one to three years. Being able to be in the right place all the time, as we have with NTL-LTER, makes it possible to actually get a grasp of real changes." LB

ESTUARIES: BALANCING LAND AND SEA

Throughout history, people and animals have flocked to where the rivers meet the sea. Whether it be part of complex and deeply ingrained migration patterns or the natural habitat of flora and fauna, estuaries are hubs of rich biodiversity.

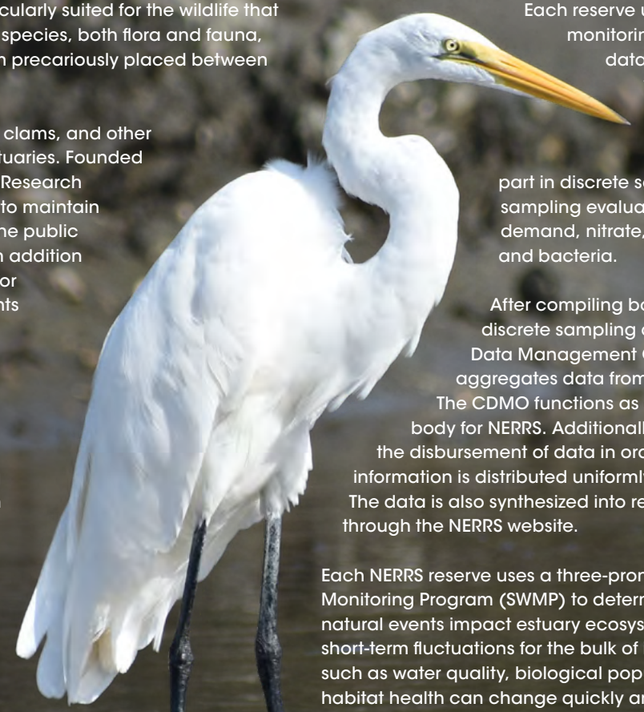
Unfortunately, if changes to the source waters occur, then estuaries may fall out of balance. The brackish waters of estuaries are unique and particularly suited for the wildlife that call them home. Thousands of species, both flora and fauna, rely on estuaries, an ecosystem precariously placed between land and sea.

Catfish, shrimp, crabs, oysters, clams, and other species depend on healthy estuaries. Founded in 1972, the National Estuarine Research Reserve System (NERRS) works to maintain estuarine ecosystems so that the public may continue to enjoy them. In addition to stabilizing the environment for public use, NERRS also highlights the environment as a learning opportunity for the public.

The National Oceanic and Atmospheric Administration (NOAA) partnered with nearly 30 coastal states participating in NERRS to foster conservation efforts locally. NERRS is a network of reserve sites located along the U.S. coast that promote stewardship, research, training, and education, all in order to help preserve estuaries. NERRS was established through the Coastal Zone Management Act to foster partnerships and conservation.

NOAA ensures that the coastal sites receive appropriate funding and serves as national guidance in public efforts. The sites are managed daily by a lead state agency or local partners. NERRS focuses on nonpoint source pollution, resilient communities, habitat restoration, and invasive species.

With public interest in mind, all of the reserves within NERRS are publically accessible. Access extends beyond locals and includes those who wish to observe estuaries as an educational resource. Furthermore, the biological variances found in estuaries make them an ideal living laboratory for researchers.



Each reserve utilizes real-time monitoring probes to transmit data to the cloud, which is then made available online. Most of the reserves within the systems also take part in discrete sampling. The manual sampling evaluates biochemical oxygen demand, nitrate, nitrite concentrations, and bacteria.

After compiling both the real-time and discrete sampling data, the Centralized Data Management Office (CDMO) aggregates data from all the reserves. The CDMO functions as a quality-assurance body for NERRS. Additionally, the CDMO controls the disbursement of data in order to ensure that all information is distributed uniformly throughout the system. The data is also synthesized into reports published online through the NERRS website.

Each NERRS reserve uses a three-pronged System-Wide Monitoring Program (SWMP) to determine how human and natural events impact estuary ecosystems. SWMP focuses on short-term fluctuations for the bulk of its surveys. Variables such as water quality, biological populations, and watershed habitat health can change quickly and impact the ecosystem. SWMP focuses on collecting data on abiotic conditions like dissolved oxygen, pH, sediments, organic contaminants, and tidal range within the water quality surveys. The brackish waters found in estuaries make surveying the water a bit more difficult but is nonetheless essential.

"Nutrients may come in [to the estuary] in one form and transition into a completely different form that may not be available for organisms," said Ralph Garono, the previous reserve manager for the Lake Superior Reserve in Superior, Wisconsin.

Photos: Emma Jones

The second prong of SWMP, biological monitoring, focuses on surveying species present in an estuary, particularly how those species may be bio-indicators of a change in the environment. Within the biological monitoring, researchers also look at population characteristics and habitats. Finally, landscape is the third focus which includes looking at how the watershed and coastal area change over time. As estuarine lands continue to become casualties of pollution and development, the landscape surveys also note how the land is being used.

SWMP is a key component of the Integrated Ocean Observing System. The newer system functions as an information source that provides oceanic and coastal data for environmental protection purposes and some industrial uses. Weather forecasters, fishery managers and transportation services rely on the data collected by NERRS.

From its inception, the NERRS program has been dedicated to serving the public and continues to do so today in many forms. One of which is through employment and academic opportunities. For example, NOAA's Margaret A. Davidson Fellowship program provides opportunities for graduate students to conduct collaborative research at one of the 30 national estuarine research reserves. Fellows address key reserve management needs to help scientists and communities understand coastal challenges that may influence future policy and management strategies, while building their own network and career in coastal sciences.

NERRS attracts researchers from everywhere in the country by providing a stipend and state-of-the-art equipment. The program also benefits local school systems by using collected data to teach students about estuaries and environmental stewardship. Further public outreach is also available through estuary training. In hopes of expanding knowledge and instituting change, materials and data are provided to city councils and coastal planners who hold power to make environmental change.

Many people move to the coast specifically for the view from a shoreside home but do not always realize the delicately balanced environments they are moving into. Their backyards are hubs of biodiversity, and human activities impact those ecosystems. NERRS data reflects the changes that estuaries undergo, and some of those changes can be traced back to human activity in these fragile coastal areas.

"We must forge science in people's minds, so they understand the consequences of their actions," Garono said. SB

This is an updated article from a previous edition. Learn more about the Lake Superior Reserve at https://lakesuperiornerr.org/

(Left) Great Egret

(Right; Top to Bottom) Juvenile White Ibis and Tricolored Heron; Group of Fiddler Crabs; Wood Stork; and Snowy Egret in Anastasia State Park, St. Augustine, FL

Special Offer

NexSens CB-25

The CB-25 is a compact and lightweight (18" diameter and 30lbs) data buoy. Designed for drifting or tethering, the buoy is a versatile platform for many projects with easy integration of wave, position, water quality and atmospheric measurements.

Powered by either alkalines or a rechargeable battery with solar charging, the NexSens buoy collects data and transmits it to the cloud. Wireless communication options include 4G cellular or Iridium satellite. Data is accessible at WQData LIVE.

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Special Offer

YSI ProDSS

The YSI ProDSS (digital sampling system) is arguably the most convenient instrument on the market for the simultaneous measurement of temperature, conductivity, pH, ORP, dissolved oxygen and turbidity in sampling applications. It is YSI's premium multi-parameter water quality meter with a 3-year meter warranty and 2-year cable/sensor warranty. The digital instrument supports up to 4 smart sensors that store calibration information and are auto-recognized by the instrument. Options are available for integrated GPS, depth sensor, up to 100m cable length, and more.

Price includes YSI ProDSS meter, 4m cable assembly with conductivity/temperature, dissolved oxygen, pH/ORP & turbidity sensors, and soft-sided carrying case.

~~$7525.75~~ **$7149.46***

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