Coral Reef Early Warning System
Central Caribbean Marine Institute

The Shark Lab
California State University

How Lake Erie Buoys Measure It All
Regional Science Consortium
Welcome to the Spring 2020 edition of the Environmental Monitor, a collection of the best of our online news publication. In this issue, we showcase a broad range of offshore monitoring applications.

This edition includes methods and equipment utilized by researchers from various organizations that focus on monitoring offshore environments. You will read about data buoys monitoring water quality in marine protected areas, research along the Californian coast by a shark lab, and how meteotsunamis are more common than once thought. New technology featured in this issue may have applications in the fight against climate-driven impacts on water quality.

Other topics include collaborations with national organizations such as the Great Lakes Observing System and the National Oceanic and Atmospheric Association as well as other programs.

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WELCOME...

The Coral Reef Early Warning Station (CREWS) at Monks Head in Antigua Barbuda, one of five funded under the United States Agency for International Development (USAID) Climate Change Adaptation Program (CCAP) for being implemented by the Caribbean Community Climate Change Centre (CCCCC) in the Eastern and Southern Caribbean.

Photo Credit: CCCCC
Extreme Wave Heights, Ocean Winds Increasing Globally

Around the world, extreme wave heights and ocean winds are increasing. The greatest increase is happening in the Southern Ocean, according to recent research from the University of Melbourne, as described by Dr. Ian Young. “Our main interest is ocean waves, and we are interested in wind because it generates waves,” explains Dr. Young. “Ocean waves are important for the design of coastal and offshore structures, the erosion of beaches and coastal flooding, and the safety of shipping.” Waves also have a role in determining how much heat, energy and gas can be trapped in the ocean.

In order to determine how wind speed and wave heights might be changing over time, the team looked at data collected between 1985-2018 by 31 satellites—about 4 billion observations. Then, the team compared those observations to measurements taken by over 80 data buoys deployed around the world. Moving forward and trying to answer these questions, Dr. Young sees the value of a longer-term dataset.


"WireWall" Measuring Flood Risk in Real Time

This past winter, physical oceanographer Jenny Brown and her team at the National Oceanography Centre (NOC), United Kingdom, were trialling a new concept: "WireWall" with colleagues at HR Wallingford. This new system for measuring wave hazard at sea walls allows managers to understand flood risk for existing coastal structures better. "Traditional sensors don’t work in spray conditions,” explains Dr. Brown. “We’ve got a lot of ocean-going sensors that measure currents, water depths, all sorts of information, but the second you put them on land and out of solid water, they don’t work, often because they’re acoustic systems.”

Finally, using WireWall, the team can generate a picture of the volume of water overtopping the wall to calibrate overtopping prediction tools to prove the concept. Obviously, such a system needs to be calibrated initially, but Dr. Brown’s team has confirmed the system’s performance in a wave flume at HR Wallingford. Next steps for the team? Opening up the system for use by more people and acquiring more data.


Learning With the Student Drifter Program

The mission of the Student Drifter Program, initiated by the National Oceanic and Atmospheric Administration (NOAA) and now administered by the Gulf of Maine Lobster Foundation (GOMLF), is “to establish scientific partnerships between schools around the region and engage students in activities and communication about ocean climate science.” NOAA oceanographer James P. Manning. The drifters, typically made with an aluminum (or bamboo) frame and cloth sails, flow primarily underwater with a transmitter above the waterline to send data on its location via satellite every few hours. They stay active with battery power for several months. The students follow the track online using a website where they can see the path of their drifter. As they send data back to students, they can record where the currents carry their instrument.

Depending on what the teams hope to measure, there are different drifters they might deploy. Sharing the data with other scientists helps students understand the value of the long-term fieldwork they are helping conduct.


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IN THE NEWS

UC Davis Bodega Marine Lab: Performing A Multitude of Environmental Monitoring Programs

A couple of University of California, Davis Bodega Marine Lab programs have been featured in previous Environmental Monitor articles, but there are many more in progress.

Professor John Largier, Coastal and Marine Sciences Institute Associate Director for International Programs, for example, is heavily involved in the oceanographic monitoring project. "Our oceanographic monitoring program incorporates classical water quality monitoring, which is part of the CoNCCOS system. We do this monitoring at the mouth of San Francisco Bay. We monitor water temperature, salinity, dissolved oxygen and pH," Largier says.

Special collaborative sites also do pH and atmospheric CO2. The Seabird stable of equipment is used for this monitoring, as well as ADCP, telemetry buoys, and monthly CTD lines monitoring project. "Our oceanographic monitoring program incorporates classical water quality monitoring, which is part of the CoNCCOS system. We do this monitoring at the mouth of San Francisco Bay. We monitor water temperature, salinity, dissolved oxygen and pH," Largier says.

Robotic Fish May Reduce Live Fish Testing Near Hydroelectric Plants

Each year in Germany, as many as 450,000 living fish undergo live animal experiments to test how fish-friendly hydroelectric power plants in the country are. The idea is to discover how readily the fish can move through hydroelectric turbine installations in order to ultimately reduce mortality rates.

Of course, subjecting live fish to a potentially deadly test to save others is a bitter irony. And it’s one that a team of scientists from the RETERO research project hopes to eventually mitigate with a robotic fish for testing. Oliver Cleynen and Stefan Hoerner from the University of Magdeburg discuss the complex conditions that set the parameters for the project.

One objective of the RETERO project is to better understand and predict how fish overcome certain conditions when they swim up or down through these installations. The project is scheduled to research and influence the current state-of-the-art of fish passability testing for the next three years, and the team will be updating the public on progress online.

Custom ROV Helps Protect Rockfish in Puget Sound

Washington Department of Fish and Wildlife (WDFW) scientists are using a custom ROV called the Soled-Seaeye Falcon on a critical conservation study of threatened and imperiled rockfish. Dr. Dayv Lowry, a Senior Marine Fish Research Scientist, discusses using the ROV to facilitate rockfish conservation and recovery in the Puget Sound.

"With species where mortality is a concern, your goal is to document but not disturb or kill," Dr. Lowry describes. "There are many options for counting fish, such as dragging a net across the bottom or hook and line sampling, for which the mortality rate can be considerable. The typical way to document where fish are, how big they are, and how many there are, is to catch them. Cameras allow us to count and observe fish in their natural habitat, without actually catching, killing, or injuring them."

Next up for the team: continuing to use bottom trawls on deep, muddy habitats, ROVs in deep, rocky habitats, scuba diving in shallow rocky habitats, and combining beach seins, dipped nets, mid-water trawls, and other methods to attempt to discern where these fish are and how many there are.

Utah’s Canyonlands Research Center

Canyonlands Research Center (CRC) is situated at The Nature Conservancy’s Dugout Ranch, over 5,200 private acres of research study area. One of CRC’s primary roles is to facilitate research and monitoring work of university and federal researchers. CRC also partners with many organizations to identify the most pressing research needs in this region.

“One of the key types of research done at CRC is drought monitoring,” says Nichole Barger, Research Director of CRC and Associate Professor at the University of Colorado at Boulder. Drought is simulated to investigate how it impacts these ecosystems with a particular interest in grassland communities.

In addition to acting as a site for drought research, CRC also functions as a working ranch. There are about 500 cattle in the herd today. CRC has future plans for its working ranch.

While CRC is on private land, it is meant for people to do research. CRC continues to welcome many types of research and researchers into its unique facility.

A Conversation with Mika McKinnon, Freelance Scientist

So much of what many field scientists and engineers do hinges upon their ability to communicate the value of their work. Geophysicist Mika McKinnon details her work as a freelance scientist, and what it’s like to do work that touches on science communication in so many areas.

“Thinking about it, my ultimate motivation is I need to feel like my work has made the world a better place,” details Ms. McKinnon. “I need to feel like the end result of what I have done has made the world less terrible. And that turn out to be disaster work.”

The goal became to better understand how disasters happen, how people interact with them, and how to communicate that information to decision-makers. “A lot of people say things like, ‘I don’t like math, or I’m not good at science,’ or ‘I hate school,’” remarks Ms. McKinnon. “Those are popular sentiments, but people enjoy stories. In fact, most of how we learn is through stories. So if you can have plausible, good science in entertainment, not only does it support the story by creating a more plausible worldview that doesn’t break our suspension of disbelief, but it also acts as a form of subversive education, where people can learn through the stories they consume.”

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Photo: Lobsang Wangdu, UC NRS (left), Jana Dünnhaupt / University of Magdeburg (center), Dr. Dayv Lowry, WDFW (right)

Photo: Nichole Barger (left), Mika McKinnon (right)

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ENVIRONMENTAL MONITOR
The purpose of CREWS, which is overseen by the National Oceanic and Atmospheric Administration (NOAA), is to provide a global network of instrument buoys that can track and understand global oceanic trends, thereby leading to early warnings of potential destructive trends allowing managers to adapt to the changing needs of our environment.

The new buoy also has a significantly smaller physical footprint, so it is easier to maintain, deploy and retrieve and is, therefore, less demanding on the resources and easier to handle,” comments Clamp. “Data is collected and displayed using updated real-time technology via smartphone, which is more responsive and user-friendly.

The smartphone app is available to the general public and is already used by interested stakeholders such as dive shops, sailors and fishermen,” confirms Clamp. “The website is available to resource managers, scientists and entities interested in long-term trends and historical records.”

Part of the aim of this tech and its implementation is to find innovative ways to restore coral reefs. The team also hopes that they’ll someday be using the technology to answer questions they haven’t yet conceived.

“The idea is to incubate potential strategies to help coral reefs to develop resilience and to identify coral species that can adjust to the potential environmental changes that we are witnessing now,” concludes Clamp. “This equipment can help understand the many different parameters that stress coral species. The data output has led to experimenting with how some corals survive in differing depths, locations and temperature exposure. We are also spearheading projects involving multiple species. Ultimately, though, the CREWS allows scientists to ask more in-depth questions due to the refinement of specific data.”

CCMI invites readers to watch for new developments on their website: https://reefresearch.org/
Mobile HAB Lab | Scientists Building Awareness

Yosemite or Yellowstone - the RSC must test sites almost along the entire Lake Erie shoreline in Pennsylvania.

“We just launched the HAB Citizen Scientists program this year,” explains the Regional Science Consortium (RSC) Executive Director Schnars. “It helps us work with people, especially people who spend time at marinas frequently, that are out there all season long.”

The blooms come fast and can disappear just as quickly. Because the water shifts the bacteria around the lake, the RSC relies on the public to help them monitor. “They’ve also been trained, so they can warn others about keeping their dogs out.”

HAB LAB AND WATER QUALITY

Ultimately, the HAB Lab team’s goal is to help people see connections between recreation, water quality, and health. “When we monitor, we look at the concentration of the cyanotoxin,” Schnars says. “We have different thresholds, including a level that is safe for dogs, a human advisory recreational level and a human level where it’s no contact.”

Schnars said they have exceeded the threshold set for dogs, so advisory signs are often displayed at sampling locations. Part of the purpose of the HAB Lab is to educate people about the particulars of these and other advisory notes, in hopes of increasing scientific literacy.

“What is toxic algae? What are HABs? We received an environmental education grant from the Pennsylvania Department of Environmental Protection to create the Mobile HAB Lab,” helping to answer these questions.

First and foremost, the HAB Lab itself isn’t there to scare anyone. It’s an awareness campaign focused on teaching the public about blue-green algae and the conditions that create algal blooms. That could be nutrient runoff dynamics or how blooms move.

But what RSC emphasizes is the need to raise public awareness while not fear-mongering.

“We even experience that with some property managers,” commented Schnars. “They didn’t want to scare tourists or visitors away from popular sites for boating, fishing and swimming. We completely agree. Educational HAB signage uses a popular tagline “If in Doubt, Stay Out”. And we continue to educate the public that HABs are produced from a naturally occurring cyanobacteria, however the bloom phenomenon is a product of how humans treat the land and excess nutrient runoff.”

HAB LAB AND WATER QUALITY

Ultimately, the HAB Lab team’s goal is to help people see connections between recreation, water quality, and health. Despite Lake Erie’s role as a primary source of drinking water and recreation, it has historically struggled with heavy metal or PCB contamination. Since algal blooms started creating bigger issues for residents and visitors, the RSC has worked to teach the importance of having clean water. One of the results is the training of citizen scientists to report their observational data through the RSC’s website.

“It’s actually providing a lot of good additional data for us that we wouldn’t have without all those eyes watching what’s going on with the water,” states Schnars. “They’ve also been trained, so they can warn others about keeping their dogs out.”

If the HAB Lab isn’t near an already posted sign, the HAB lab might make appearances near citizen scientists’ observations.

Right now a lot of the focus is on Lake Erie because of the intense blooms experienced in the western basin,” Schnars said. “A mobile display unit allows us to travel and talk to people recreating in these areas. The mobile HAB Lab also attends seasonal events for pet owners, festivals, and school groups.”

With multiple reports of animals getting sick and alerts regarding toxic pollution in Lake Erie, one Pennsylvania group has deployed a mobile educational tool to help people understand algal blooms.

CanoeMobile | A Floating Classroom

In the summer of 2019, a new way to learn about water recreation and environmental stewardship paddled into Ohio. With the help of the Environmental Protection Agency’s (EPA) Urban Waters Program, the Toledo Metropolitan Area Council of Governments (TMACOG) brought the Wilderness Inquiry (WI) CanoeMobile “floating classroom” to Toledo for a few days.

Sara Guihre, a Water Quality Planner with TMACOG, said they started designing the program after a representative from the US EPA called in August 2018. TMACOG has a 30-year history of water quality education through the Student Watershed Watch, which provides water quality testing supplies to local classrooms.

“We received funding through the Urban Waters Program to bring programming to the area focused on urban water resources,” said Guihre. “The park that we talked to from US EPA suggested CanoeMobile, which we had never heard of. As soon as we heard some details, we said, ‘how soon can you be here?’ Because it just sounded awesome.”

The CanoeMobile Program brings 24-foot, 10-person Voyageur canoes to various waterways for on-water paddling experiences. Based out of Minneapolis, Minnesota, WI brought seven staff, seven or canoeing, one serving as captain for each canoe.

With so many first-timers on the water, safety is a priority for the WI team.

“They give a safety talk about water safety before time and fit each person with a life jacket,” Guihre said. “Each of the nine passengers in the canoe helps paddle, so they instruct them on how to properly paddle and choose, how to hold your paddle so you get the least amount of resistance. That way when the passengers get out there, they already have the vocabulary to steer, paddle and stop a boat so that they can listen to their captain and work as a team.”

WATER QUALITY COMMUNITY DAYS

The TMACOG and WI community engagement event lasted four days and offered two different types of programming.

“Three of the days were for youth engagement,” Guihre details. “We had groups of kids and programming focused for people in underserved communities, both urban and rural, who don’t nec- essarily have regular or easy access to things like paddle sports or canoeing. We reached out to those communities specifically and provided transportation if needed.”

The recreation, although valuable in itself, is typically designed to work in tandem with onshore educational events. With the help of 14 community partners, educational activity stations were available for youth attending the event.

“We had a water footprint activity for food you might eat. We did water quality testing. We had an aquatic ecologist talk, and we explored different soil types in different land covers and how that can affect the way that water runs off. There were also tables that featured different animals you might find in or around rivers in the area. So they got a really great educational experience in addition to the paddling experience,” said Guihre.

During the four days of programming, 158 people made it out on the water and there were about 300 participants overall. The last day was a Watershed Festival open to all ages.

“I would say at least half of the paddlers had never been on the water at all before,” remarks Guihre. “We have some photos of people who were a little hesitant, maybe a little bit nervous at first. But the CanoeMobile staff is so great; they really put them at ease.”

With every first try, there were always potential challenges that didn’t pose risks. For TMACOG, it was creating enough exposure and community awareness. Because Guihre wanted to boost engagement among young people, that meant reaching out to elementary and high school students.

MORE CHANCES FOR OUTREACH AND IMPACT

The team predicts more success signing kids up for youth days in the future, now that locals know what CanoeMobile is.

“That is our shared goal between the CanoeMobile, US EPA Urban Waters and Student Watershed Watch programs: connecting people, especially young people, with their urban water resources that they don’t have an appreciation for yet. Trying to foster that appreciation and then, hopefully, stewardship.”

Although the youth teams don’t sample from the canoes, the connection between scientific monitoring, health of the water, and their own recreational adventures is not lost to them.

“We’re really glad that we were able to reach so many, especially young people, to be able to help them realize that rivers and water aren’t scary as long as you are safe,” remarks Guihre. “To see them learn about things on land that impact the water, I think that just helps to bring together everything that we already do with Student Watershed Watch and our partners.”

Guihre and her team think more trips with the CanoeMobile program could be beneficial moving forward. Particularly for people who live in urban areas, water in rivers or lakes may look or seem dirty, but still be teeming with healthy aquatic life.”

Photo: Mary Pat McCarthy, TMACOG

Photo: Sara Guihre, WI
New for 2020, NexSens Technology has released another data buoy in their growing line of CB-Series platforms. The model CB-1850 is a 1.5m (60") diameter platform intended specifically for coastal and offshore marine deployments. This latest platform maintains the well-regarded features of the CB-Series buoys such as lightweight yet robust construction, sealed center data well, and autonomous solar charging. This allows NexSens data loggers, sensor mounts, and other accessories to maintain cross-compatibility across buoy platforms. Some features new to the CB-1850 platform include optional wet-mateable sensor connectors, user-replaceable solar panels, and reinforced bottom frame.

“We listen closely to the feedback of our customers and try to incorporate those changes into the line,” explains Tyler Fondriest, mechanical engineer with NexSens. “We’re really excited about these new features and plan to incorporate these changes into the full line of CB-Series data buoys over time.”

While customers have the option to integrate their own electronics on any CB-Series data buoy, the CB-1850 data buoy is optimized for use with NexSens X2-CB data loggers. Wireless telemetry options include Wi-Fi, spread spectrum radio, cellular and Iridium satellite. Compatible instruments include wave sensors, met sensors, Doppler current profilers, water quality sondes, and more.

The CB-1850 buoy hull is constructed with a closed-cell, U.S. Coast Guard approved polyethylene foam. A tough polyurea skin covers all exposed foam, and the metal frame is constructed with Type 316 stainless steel to mitigate corrosion in saltwater deployments. Bolt-on sacrificial zinc anodes are also available, and anti-fouling paint can be applied to the submerged components for added protection. A tough polyurea skin covers all exposed foam, and the metal frame is constructed with Type 316 stainless steel to mitigate corrosion in saltwater deployments. Bolt-on sacrificial zinc anodes are also available, and anti-fouling paint can be applied to the submerged components for added protection.
For as long as scientists have been studying the ocean, they have been limited by a lack of power. However, new technologies offering promising ways to harvest energy from waves at sea and put this to work to study the ocean. Brian Polagye, an associate professor of mechanical engineering at the University of Washington, has spearheaded research studying how wave energy could power one of their Adaptive Monitoring Packages (AMP) over the past ten years. “Our work in this area has really been ongoing since 2012,” explains Polagye. “We put our first prototype AMP in the water back in 2012. Since then, it’s been quite a journey to develop sensors, various on-board processors.”

The team behind AMP, a package of integrated oceanographic sensors, in generations. The first one incorporated a cable sensor. The second, the current version, has the ability to process and transmit data in real-time.

Polagye directs the Pacific Marine Energy Center (PMEC), among the largest marine energy research centers in the world, a collaboration between the University of Washington, Oregon State University, and the University of Alaska. PMEC is an umbrella organization that unifies marine energy research and development, education, and testing going on across the three institutions.

“Prioritizing and Pricing AMP”

For many researchers, the cost of simply doing business under water is among the biggest obstacles. That’s beginning to change with systems like AMP. Researchers often use off-the-shelf, consumer-grade microprocessors to run them. BeagleBone, Raspberry Pi, and Arduinos are all inexpensive options. Blue Robotics has made ROV components available to the masses as well.

Polagye said they deployed their AMP system with the intention of satisfying specific priorities. First, make observations without disturbing marine life, then, make sure all rare events are recorded, finally record those events in the most efficient manner possible.

Prioritization matters because of how quickly data can build up when the equipment is always on. Instead, AMP would only record the rare events that help researchers understand animal behavior, and ignore all the rest. But all that information needs to be operated appropriately, as to avoid biasing the behavior of the animal.

“The AMP is really targeted to do all three of those things in that order of priority,” Polagye describes. “To do that, you need to have the hardware to bring all the sensors together. Then you also need the software to blend and use all the data streams in real-time, to not bias animal behavior, and to make sure that you’re actually capturing rare events.”

Sensing the Right Events

Originally, the team started developing the AMP system specifically to monitor marine renewable energy applications, like tidal turbines. For example, there continue to be concerns over the potential for marine mammals or fish to collide with the blades. Other issues like sea turtles or whales getting entangled in mooring lines were also possible.

“These are low probability events, but if they occur, they can have significant outcomes,” explains Polagye. “The AMP system was really designed to try to capture that sort of interaction.”

However, the trick with trying to capture these kinds of rare events is that it’s almost impossible with just one sensor. But with more sensors means more data—sometimes too much. “You end up dealing with sonar, optical cameras and passive acoustics at these sorts of events to actually make sure you capture them and really understand them,” remarks Polagye. “The trouble is, when you throw all those sensors at the problem, it’s unworkable to transfer and query the data.”

Polagye said his team found it all sensors ran continuously and logged all the data by years and they would have filled a “metric ton of hard drives.”

However, if researchers could increase the number of sensors but turn them to only record the significant events, it could solve their space problem.

“A Revolution in Ocean Sensing”

The work of the Ocean Observatories Initiative has allowed scientists to deploy higher bandwidth sensors in some of the ocean’s deepest places that had previously been unexplored. Polagye believes this may lead to major breakthroughs for marine researchers, but these require cables back to shore.

“There is a real revolution coming in ocean sensing,” he remarks. “One of the revolutions that are going on in marine energy right now is this thought that, right now, marine energy generation may be well suited to basically provide power in the oceans in places that we don’t have power currently.”

From October of 2018 through February of 2019, Polagye’s team powered a version of the AMP with a wave converter (a Fred. Olsen Bolt-class Lifesaver) that was being tested off the coast of Hawaii. With the two systems working in tandem, the team was able to make observations as if they were connected to shore via cable, but without that connection.

“We’ve had something north of 80% uptime on the system since it was deployed,” reports Polagye. “It’s basically like a small microgrid. The load is our sensor system; the supply is wave energy.”

In fact, offshore wave energy presents a host of market opportunities, the grid only being the most obvious. Had Polagye’s team tried running their AMP off of batteries, it would have consumed the equivalent of approximately 800 lead-acid car batteries over its deployment.

This highlights the perennial problem faced by anyone trying to get data from the surface to shore. Cables do the job, but when that’s not an option, researchers become power starved when they rely on batteries.

“When you’re an oceanographer and you’re dealing with batteries alone, it’s like, ‘Okay, how do I get a sensor that has the absolute minimum sensor power draw I need to even get close to the observation I want?’” said Polagye.

Detailed in a report by the US Department of Energy’s Water Power Technology Office, wave energy could unlock new and interesting oceanographic applications, from offshore aquaculture to recovery of rare earth elements from seawater yet to be discovered.

Polagye estimates with even a kilowatt of power from wave energy could provide continuous power for autonomous underwater vehicles (AUVs).

A good example for understanding what this could mean is the Malaysian Airlines flight that went down over the Indian Ocean. An 18-month search for the wreckage from man-controlled vessels yielded little results. Had officials air-dropped AUVs and wave recharge stations, it could have dramatically improved the likelihood of finding the plane.

It’s not just underwater discovery that could be incorporated, but search and rescue efforts as well. Instead of mobilising ships after a natural disaster, officials could just use vehicles that draw energy from the waves.
Say the word “tsunami” and images of tremendous waves engulfing homes or masses of debris might come to mind. Tsunamis that are triggered by massive landslides and earthquakes are at that scale. But weather can trigger more localized “meteotsunamis” as well and new research shows just how common these are along the East Coast of the United States. National Oceanic and Atmospheric Administration (NOAA) Physical Oceanographer Gregory Dusek of the National Ocean Service in Silver Spring, Maryland says since a 2013 event they reported on, they’ve been wondering how often they happen.

“At that point, there really hadn’t been any significant work in the US looking at a long data record and trying to determine how often meteotsunamis happen,” said Dusek.

As the team that operates the tide gauges, the Tides and Currents office at NOAA is uniquely positioned to know what data is available and how to best use it.

“Initially, I think people generally thought meteotsunamis were quite rare, at least in the US,” details Dusek. “There’s a lot of work in the Mediterranean, where they are perhaps a little more destructive and meteotsunamis are a little more common, but quite rare, at least in the US,” details Dusek. “There’s a lot of work in the Mediterranean, where they are perhaps a little more destructive and meteotsunamis are a little more common, but quite rare, at least in the US.”

Tide Gauge Data Reveal Meteotsunamis

Noting that much of the previous literature focused primarily on which meteorological conditions tend to drive tsunamis, Dusek’s team worked to identify those conditions in water level data. The goal was to see if watching meteorological conditions can be a reliably predictive measure of meteotsunamis.

SIMILAR RESULTS, DIFFERENT COASTS

Around the same time Dusek’s team was working on this problem, other NOAA and academic colleagues working on the Great Lakes and in the Gulf of Mexico published papers with similar findings.

“We found that instead of watching meteorological data, we should be looking at the water level data for the signal we know to expect,” Dusek describes. “Then we can confirm whether the meteorological data supports what we’re seeing in the water level data. Approaching it that way makes the process much more efficient, despite high amounts of data.”

That was news to Dusek. Until recently, information on the topic had been scant. Before 1996, NOAA tide gauges did not collect six-minute water level data, instead they collected data every hour. Researchers can’t resolve a meteotsunami with so little information, however, with 23 years of data, Dusek said they could start doing research.

When the team first developed and tested the algorithm using the 2013 meteotsunami event, they already knew of another event from that year. Surprises came when they discovered even more events.

“We knew we had two events that we needed to get right and detect, but when we first ran through the data, we found many events in 2013,” remarks Dusek. “I didn’t expect to see that many. I can’t remember the precise number now but in the teens, I think.”

Once the researchers felt comfortable with how the algorithm was working, they applied it to the data from a greater number of years.

“I started seeing 20 to 30 events every year,” comments Dusek. “I thought, wait, is that right? That seemed crazy, you know, that we’d see that many. We did extensive validation and sure enough, we’re seeing many events, but I think the catch is that the vast majority of them are quite small.”

So small in fact that without the data, Dusek doesn’t think anyone would know they’re happening - a reason why more aren’t reported. He estimates most are under a foot or a foot-and-a-half.

After that original study, other papers from the Great Lakes and the Gulf used the same water level data, finding similar results. “So it turns out these things happen frequently in all these places across the US, which confirmed what we were seeing,” adds Dr. Dusek.

WARNING OF METEOTSUNAMI HAZARDS

Even with so many smaller events, it’s rare to see larger ones that exceed two feet. One could go five years before seeing one if the conditions are just right. Dusek estimates about one larger event occurs each year along the east coast.

“Large ones might not be occurring frequently, but they’re occurring frequently enough that we want to make sure we better understand why they’re happening and better provide warnings if we need to,” he said.

The team’s goal became determining exactly which meteorological conditions lead to meteotsunamis.

“We aimed to associate meteotsunamis and whichever their concurrent meteorological conditions might be,” details Dusek. “We could then develop a better research strategy for unraveling why specific conditions lead to meteotsunamis more often.

The better those conditions are understood, the more prepared researchers can be about warning people when they need to be worried or should expect an impact, which is why Dusek’s next task is employing their algorithm in real time.

“There’s a bit of a lag because you have to have enough data before you can establish that you see a wave, so it wouldn’t necessarily give you warning before it’s arrived on shore,” Dusek describes. “It might at least give people some notice away from the initial location though.”

For example, in 2013, the meteotsunami arrived in New Jersey first, but then several hours passed before it arrived further south along the coast.

“One possibility is trying to implement our approach in a real-time manner to give people additional information in situations like that,” adds Dusek. “That’s something the National Weather Service is interested in. The NWS houses the tsunami warning center notification network for seismic tsunamis. In the ocean service here of NOAA, we’re exploring whether we can treat these similarly, notifying people right away that there potentially could be a hazard when we detect something somewhere that looks like an event.”

The NOAA team will also be exploring the possibility of applying other types of instrumentation such as high-frequency radar to the problem.

“These instruments can also detect meteotsunamis because they’re looking at the surface of the ocean. Now that we have this catalog of events, we can better pinpoint how well these systems are picking up the events, and we may also see additional information that could potentially be coupled with the tide gauge data.”

Another future point for research that Dusek wants to explore is the connection between tropical storms, nor’easters and meteotsunamis. However, due to the severity of storm surges and large waves, meteotsunamis may not be the biggest priority during those events.

However, an extra meter or so of water atop storm surge can worsen flooding and inundation.

“We discussed modeling some of these specific events to better understand why they are occurring during tropical storms or nor’easters, and whether we can parse out how much they might contribute to inundation,” Dusek says. “Is this something we need to be concerned about in some cases with those types of events? That’s something else we’re looking into with some of our partners.”

Right now, the team is prioritizing warning people and a better understanding of whether meteorological conditions are involved.

“Particularly in the summer months, where storm surges and Derechos tend to lead to meteotsunamis, the question is, do these meteorological conditions always lead to meteotsunamis?” Dusek queries. “And what is the threshold, so when the weather service sees these specific conditions, they can be ready.”

All Photos: NOAA
In the summer of 2018, scientists deployed new buoys in Lake Michigan—smaller, smarter buoys that record and provide data in real time. Ethan Theuerkauf, an Assistant Professor in the Department of Geography, Environment, and Spatial Sciences at Michigan State University, along with LimnoTech project engineer Ed Verhamme detail this development.

**SMARTER MONITORING ON LAKE MICHIGAN**

Buoys monitoring conditions in the Great Lakes are not a new phenomenon, but Lake Michigan, in particular, was due for some attention at the time of this recent deployment.

> “A network of buoys exists in the Great Lakes, but there were only a few in Lake Michigan,” comments Theuerkauf. “The few that were in Lake Michigan were far apart, which meant that in some locations, there were no real-time observations. In order to conduct scientific studies of beach erosion along coastal Illinois, we need real-time observations of waves and currents.”

The buoys, funded by a grant from the National Oceanic and Atmospheric Administration, awarded to the Illinois Department of Natural Resources, collect data on a variety of parameters. The data is available publicly on the Great Lakes Observing System website.

> “These buoys are monitoring wave height, wave period, wave direction, current speed and direction, air and water temperature and wind direction,” explains Theuerkauf. “They also have a webcam that shows hourly images of lake conditions.”

Ease of deployment was one of the principal reasons for selecting these particular buoys.

> “These buoys were chosen because they are smaller, lighter and easier to deploy than the other types of smart buoys deployed on Lake Michigan,” remarks Ed Verhamme of LimnoTech. “We’ve been building and deploying smart buoys on Lake Michigan for ten years, and we’re continually evaluating new technology and buoys to make them cheaper and easier to deploy.”

The team selected the locations for the buoys carefully, based on holes in existing data due to a lack of in-situ observations along the Northeastern shore of coastal Illinois.

> “The Winthrop Harbor buoy was placed right at the Illinois/Wisconsin state line in order to gather observations of potential sediment transport across the state line,” states Theuerkauf. “These data are important for developing accurate sediment budgets for southwestern Lake Michigan. The Waukegan Harbor buoy was placed to understand how wave conditions and currents change around that harbor.”

The buoys have nearshore placements designed to help study coastal erosion and deeper installations in water depths that range from 50 to 90 feet.

> “We wanted to get the buoys as close to shore as safely possible to accurately capture what wave and current conditions are impacting upon the shoreline,” details Dr. Theuerkauf. “Waves and currents are altered as they approach the shore from offshore, and we wanted to get in-situ observations of nearshore conditions, which are driving patterns of erosion and accretion.”

**SMALLER, FASTER, MORE DATA**

There is a notable range of features that make these buoys the smartest on the lake.

> “These buoys are all of the latest technology, including sensors that use sound waves to measure wind speeds and water currents, ultra-low power motion sensors to measure every wave passing by, high definition webcams about the size of your thumb, the latest cell phone modem technology to transmit buoy and video data, and a matchbox size satellite tracking device,” explains Verhamme. “No other buoy on the Great Lakes has this much technology packed into it and can be lifted up by two people.”

The buoys that are deployed in the middle of Lake Michigan are 10 feet across, weigh over 2,000 pounds, and require a fully staffed, 225-foot US Coast Guard ship to deploy and retrieve. The design of the new buoys has greatly improved the way that users are able to construct their projects. The Illinois State Geological Survey at the University of Illinois Urbana-Champaign manages the buoys in coordination with LimnoTech.

> “These new buoys monitor the same things, but can be deployed by two people and a 23-foot boat in a few hours,” states Verhamme. “We’re continually pushing the boundary and testing how small we can make each component in the buoy and still collect quality observations. The real cost associated with these buoys will be deploying and retrieving them each season to prevent damage from ice, and the smaller and lighter we can make the buoys, the easier they are to deploy. This, in turn, allows us to deploy more buoys to serve more people across the Great Lakes.”

Deploying buoys for the long-term is one of the “big picture” goals for this team, and they take it seriously.

> “Considering the full life-cycle cost of acquiring and maintaining environmental monitoring equipment was extremely important to our project team, as we strive to keep these stations operational indefinitely,” adds Verhamme. “This meant carefully navigating options related to cost, size, serviceability and reliability.”

**SMARTER BUOYS, BETTER SCIENCE**

Getting lake conditions in real-time has real scientific value for the team, not to mention importance for the public.

> “From a scientific perspective, it is important to understand in real-time what conditions are occurring so that we can plan data collection efforts,” Theuerkauf describes. “From a public perspective, it is important for boaters, beachgoers, search and rescue personnel, weather forecasters and others to have up-to-date observations of on-water conditions to enjoy the lake safely.”

Parsing out which erosion effects are the result of natural forces and which have to do with development is very difficult. The team hopes that these buoys will shed light on this issue.

> “This is a major component of my lab group’s research,” comments Theuerkauf. “We are tackling this issue in a couple of ways. By analysing past data, such as aerial photographs, we can get a sense of the interplay between natural and anthropogenic forces. We are also gathering erosion and accretion data in response to storms and high water events to isolate the impacts of natural processes versus human impacts.”

The buoys have their own specific research questions to help answer, but of course they may prove useful for other kinds of research as well.

> “My group is utilizing this data to unravel the processes leading to beach and nearshore geomorphic change,” states Theuerkauf. “However, this data could be used for a variety of research studies in such fields as biology, chemistry, physics and ecology.”

> Of course, information from the buoys is also relevant to boaters and other recreational users for safety reasons, as well as commercial fishermen. This is partly why the public has access to the data and visuals, which also helps build support for lake management.

> “The primary reason for public access is so that everyone can enjoy the benefits of having real-time wave and current observations in this region that has never had those data before,” remarks Theuerkauf. “We’ve partnered with a non-profit organization, called the Great Lakes Observation System (GLOS), that has expanded public access to buoy data across the Great Lakes. They made it easy for us to add a cell phone modem to our buoys and then use their website and data system to make that data available to everyone.”

> “One other aspect that guided this project from the beginning was involving the public in as many aspects of the project as possible,” adds Verhamme. “While sharing the data with the public didn’t meet any specific scientific goals, it allowed us to connect directly to a wider audience for support of the project and will lead to a smarter and better-informed public.” 🌋
Framed by a glacier, Jordan Pond is among Maine’s clearest, most beautiful bodies of water. It’s also a critical freshwater resource, and watchful eyes are protecting it.

Dr. Rachel Fowler, Friends of Acadia’s aquatic scientist, monitors Jordan Pond. A post-doctoral research scientist at the University of Maine, she is a member of a partnership among the National Park Service, the University of Maine Climate Change Institute and Friends of Acadia that began deploying the Jordan Pond buoy in 2013. Canon provided the initial support for the project. Friends of Acadia is a nonprofit organization that supports different projects in the park. Bill Gawley and Shannon Wiggin of the Acadia National Park Air and Water Quality Monitoring Program support the project from the National Park Service side of the collaborative. Dr. Jasmine Saros is a professor of aquatic ecology at the University of Maine who studies how lakes respond to environmental change over time. As part of her post-doctoral work, Dr. Fowler works with the Jordan Pond buoy and its data.

“I started working on this project in 2016 while I was a PhD student at the University of Maine,” explains Fowler. “My interests lie at the intersection of natural and human systems and how they respond and adapt to environmental change and climate change. I specifically study lake ecology and carbon cycling and how they are affected by climate change. Acadia National Park is the perfect place to work because there is a strong connection of people to the landscape, which includes lots of lakes.”

“In this position I help deploy the buoy in the spring, facilitate its data collection throughout the entire ice-free season, work with the team to pack up the buoy in the fall and then I do what I’m working on right now: analyzing the data and trends that we saw over this season,” details Fowler. “Also, now that we have seven seasons of data, we’re doing some year-to-year comparisons.”

“It’s a massive data set because we have over 30 parameters that get measured every 15 minutes,” remarks Fowler. “We have thousands of sampling events throughout the season, compared to pre-buoy monitoring, when the lake was sampled once a month from May to October. We’re taking 16,000 sampling events as opposed to six, so the buoy data really helps us fill in the gaps about what’s going on in the lake.”

**FILLING IN THE GAPS WITH DATA**

Among the trends that the team was most interested in monitoring were changing water clarity and dissolved organic matter (DOM) in the water.

“Since the 1980s, the National Park Service (NPS) staff has been sampling Jordan Pond and other lakes in Acadia National Park monthly during the open water season, monitoring parameters like water clarity and DOM,” Fowler describes. “From 1995 to 2010, they found that water clarity was actually declining a bit in the lakes while DOM was going up. When the data revealed that lakes in the park were not quite as clear as they had been in the past, we wanted to know what was going on.”

Jordan Pond, a crown jewel of Acadia National Park, is often described as the clearest lake in Maine, so it is a well-suited study site for changes in water clarity and DOM. It’s an important tourist draw, and numerous people recreate on the lake. It’s also a municipal drinking water source.

“It’s not necessarily a bad thing that the water is a little less clear than it used to be, because it may signify a return to pre-acidification conditions, a recovery that happened because of the Clean Air Act Amendments of 1990,” states Fowler. “Because of this successful piece of legislation, there’s less acidic atmospheric deposition, and that lowers the ionic strength of soils in the watershed. The soil can more readily give up the DOM that it holds, and it gets washed into the lake, making it a little less clear. That’s a piece of what we think may be going on.”

The team also thinks that trends associated with climate change are influencing Jordan Pond water quality.

“We think that climate is playing a role in what’s going on in the lake because, after 2010, that trend in water clarity decline wasn’t as well-defined,” says Fowler. “In fact, water clarity has been more variable since 2010. We think that’s because the lake has recovered from acidification, and the changes that we’re seeing now in DOM and water clarity are related to changes in climate, particularly more severe precipitation events.”
IDENTIFYING NEW TRENDS
The team has the buoy paired with a weather station on the Jordan Pond House, a restaurant located at the southern end of the lake. The weather station tells them about rainfall amounts, air temperature, wind conditions, and related parameters.

“It’s really helpful for us to have them working together,” comments Fowler. “We can look to episodic events, such as precipitation events, and we can see how those impact parameters like DOM and water clarity in the lake.”

The difference in data resolution now that the buoy is in place is striking—and it opens up many new opportunities for the team.

“In previous years, before the buoy, when the National Park Service staff sampled the lake once a month, we might not have had any idea how a big storm could affect water quality in Jordan Pond, and on what timescale. Now, sensors on the buoy are continuously recording water quality data during and after the storm,” explains Fowler. “The buoy is helping us to learn more about the effects of precipitation on the lake, which is useful because precipitation events in Maine are getting more severe.”

It’s a complicated research problem to crack because there’s really no way to predict exactly how climate change will affect one particular lake system. Although there are trends, each lake is unique.

Fortunately, there is a tremendous amount of local buy-in behind taking action to preserve the resource that Jordan Pond is to the region.

“I wouldn’t say people are worried about water quality in Jordan Pond, but we do have many people asking about it, and we are trying our best to do outreach and inform as many people as possible,” explains Fowler. “We have an interactive digital display at the Jordan Pond House to explain the purpose of the buoy in the lake and to share water quality findings. Fifty percent of park visitors come to see Jordan Pond and we want to ensure that they keep appreciating its aesthetic beauty.”

Of course, the team also watches parameters involved in sustaining Jordan Pond’s excellent water quality. This is critical for the local municipalities that use the water for drinking.

“Another great thing about the buoy is that the sampling intervals are so frequent,” adds Fowler. “If something unusual were to show up in the data, we could immediately flag it and either go out on the water and take samples, do an experiment or work with park staff to perform some kind of management action. We can respond very quickly now.”

In addition to high-resolution monitoring, Jordan Pond is “doubly protected” from threats by point-source pollution—and this is also partly why the changes to the water have, thus far, mostly been benign.

Its entire watershed is within the Acadia National Park boundary, and it’s also a drinking water source, so people can go out and kayak on the lake, but there’s no skin contact allowed,” remarks Fowler. “It’s very well protected, so instead of threats from local pollutants, we are more concerned about bigger picture threats from climate change and atmospheric deposition.”

Having just finished their seventh year, the team is excited to get close to a decade worth of high-resolution data they can compare with park data from years past.

“We have just started the long-term comparisons, but we can say that in just the past two years of having the buoy in the water, we’ve gained new insights,” states Fowler. “For example, the temperature profile of the water column and timing of thermal stratification are variable year-to-year. In 2018, thermal stratification happened at the beginning of June and then the thermocline quickly dropped to 10 meters. In 2019, thermal stratification did not occur until mid-June, and then throughout the whole summer, the depth of the thermocline was shallower; about eight meters.”

The researchers hope to learn more about these types of changes year-to-year and what that means for the ecology of the lake.

“Importantly for our project, Acadia National Park has a decades-long legacy of water quality monitoring. Previous monitoring consisted of monthly snapshots,” remarks Fowler. “Now we have high-resolution data that can enhance these snapshots and fill in all the blanks, and we’d like to continue to expand the project. Jordan Pond is the lowest-nutrient, clearest lake in Acadia National Park, but there are many different types of lakes in the park. We’re interested in putting sensor instrumentation in lakes that might not be as clear or low-nutrient as Jordan Pond to get a better idea of how the range of lakes in Acadia National Park might be responding to environmental change.”

The team is also exploring ways to monitor what’s happening in the park when the lakes are iced over.

“We have data from the buoy in Jordan Pond from May through November, but we don’t have a very solid idea about what’s going on in the winter,” Fowler adds. “Last year we put out some exploratory instrumentation in the winter, including temperature and light sensors, and this year we’d like to expand on that. This will give us an idea of what’s going on under the ice, and how that might affect water conditions going into the spring season.”
The region’s water clarity is defined by a long list of environmental factors, ranging from native oyster populations and seagrass health to the ratio of fresh to saltwater populating the riverways, and weather events that alter local conditions.

When all of these factors sync up, they create what Dr. Michael Parsons of the Vester Field Station calls ‘sweet spots.’ When they don’t sync up, the ecological balance is disrupted and organisms stress. Somewhere along the way, property values also decline.

“We’ve played a big role in monitoring the ecological conditions so when they (policymakers) are managing water flow, these sweet spots should be targets for when water is released and when water should be held back,” said Parsons.

“So we’ve really helped the process by providing the data looking for these sweet spots,” he added.

The Vester Field Station at Florida Gulf Coast University isn’t just at the scientific center of this environmental monitoring, but the geographical one as well. Built on Lake Okeechobee, the freshwater basin at the end of these estuary waterways, the field station is constantly measuring the region’s water flow and the environmental impacts that stem from it.

Estuaries are dynamic ecological phenomena and the amount of salt and fresh water mixing is always changing. When the dry season peaks, there isn’t enough freshwater in the system, which can dehydrate species. When hurricanes barrel into the coast and flood the region, too much freshwater can have a similar, but opposite effect, diluting saltwater and stressing species.

“In both cases, too much hydration, or not enough hydration – it can really throw off your electrolyte balances, your metabolism,” Parsons said. “It can be stressful (on the species). Similar things happen with temperatures, heatstroke, hypothermia.”

When the balance is thrown off, organisms can’t reach their fullest potential, their growth is stymied, and they become more susceptible to predation. Parsons says it can impede an animal’s fitness.

For the Vester Field Station, two of the more significant species they monitor for fitness are the oysters and seagrass.

A HAPPY OYSTER IS A HAPPY TOURIST

The report was explicit about how important the environment is to demand. That fact was cemented in 2015 after a Florida Realtor’s report tied hundreds of millions of property values to the Scechi disk depth of the surrounding water.

Policy makers and the public would benefit from research into the possible effects of Everglades restoration on water quality in the estuaries of Martin and Lee Counties,” concluded the report.

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Policy makers and the public would benefit from research into the possible effects of Everglades restoration on water quality in the estuaries of Martin and Lee Counties,” concluded the report.
Thirty years ago, white shark sightings near California’s beaches almost never happened. For Chris Lowe, who was a graduate student at California State University’s Shark Lab at the time, spying a dorsal fin from one of the ocean’s top predators was very rare.

Prior to the mid-’90s, an expensive commercial fishing operation and the loss of marine animals decimated white shark populations. If their food wasn’t being hunted, sharks were getting caught in gill nets. At that point, they would be killed anyways before getting brought to the market to be sold.

Then in 1994, California residents approved propositions that banned gillnets in state waters and enacted protections for the white shark. Scientists don’t really know how far the population’s numbers fell, too. But what scientists and Lowe, who currently runs that same shark lab he was a student of, now know is that juvenile white shark sightings have increased, sighting as many as 12 at a beach at the same time.

“They are coming back. It was a shock because they were in trouble for a while. When we started to look at why that is possible, a lot of things made sense,” Lowe said. “These are all juveniles. One of the things we’ve learned - juvenile white sharks use beach habitats and beach lagoons. They spend more time in those areas.

Whether because the water is warmer or it’s shallower or the food is easier to catch, juvenile white sharks use the California coastline to develop and grow. That wasn’t something scientists understood years ago.

In fact, scientists still don’t know nearly as much as they’d like to know about sharks.

“The challenge has never been public interest. It was always there, but we never had the right technology to answer the best questions posed for 80 years,” said Christopher Lowe. “Now, we have those tools, but not the money.”

Unless proposals for grant funding meet the criteria of “Do we eat it?” or “Is it endangered?” financial support from state and federal governments are scant.

But white sharks are returning to California. And while their return is praised as a win for the ecosystem and habitat balance, it also means sharks and people are coming into contact with one another. This means the demand for understanding the behavior and physiology of sharks at all breeds has increased in recent years.

**SHARK LAB ORIGINS**

Most of the Shark Lab’s work can be split into two categories - documenting and studying sharks, and developing technology that will aid those studies. That’s partly why the lab was started in the first place.

“The Shark Lab was founded in 1966 by Dr. Don Nelson, a renowned shark behavior expert. Our goal has always been to find the best ways to study shark behavior and make it available to the public,” said Lowe.

Research that was conducted in its early years was based on developing shark repellents - something the Office of Naval Research was keen on learning more about. But in order to repel sharks, scientists needed to understand the creatures they were repelling.

However, just diving with sharks to observe and study their behavior was too limited, which is how the lab started developing its tools into the development industry - researching and building tools that could help them with their work.

That meant placing sensors on sharks that could transmit data wirelessly but also withstand the extreme pressures exhibited by the seas and oceans. And of course, all of it had to be waterproof.

“Anything that’s easy to do on land, the minute you put it in water it becomes so much harder. Saltwater makes it even worse,” Lowe said. “Depending on what it is you’re doing, it can be challenging. Animals can make dives down 1,000 meters.”

A lot of this technology has roots in the military. It should come as no surprise that sonar and telemetry, two tools often used in science, were first developed by the military. A lot of the technology that Shark Lab engineers and modify is hand-me-down military technology no longer considered classified.

Once in the hands of marine ecologists and engineers, the technology is adapted for biological applications.

“Basically, what we’ve been doing is taking existing technology and modifying that. The goal is to continue this concept of innovation so we can make giant strides,” Lowe said. “What we’ve learned in the last five years through new tech has exponentially improved upon what we’ve learned over the last 50 years.”

And innovate they did.

Scientists are now using autonomous underwater vehicles and drones to track sharks, people on the beach and how close the two parties are together. There’s the inertial measurement unit (IMU) that acts a little like a Fitbit™ but for sharks - tracking its motion, acceleration and calorie burn.

Then there are about 100 acoustic receivers that line the California coastline, constantly listening for any transmitters attached to sharks. When a tagged shark comes within a receiver’s range, the receiver logs the time, date and ID number of the transmitter.
"We’ve been doing all of that for a while now," Lowe said. "Thirty years ago, we had to build our own transmitters and put it on the animals to follow where it went. We’ve also added sensors to the tags that give us more context."

**WORK IN THE SHARK LAB**

All of this innovation is coming at the right time, too. The Shark Lab tracks all kinds of species, from leopard sharks to horn sharks, blue sharks and even the rare megamouth shark. But the lab also tracks local species that sharks feed on, like stingrays.

And understanding how these species interact with each other, their food webs and the changing environment around them will be key in predicting their behaviors for the future.

"Just knowing where animals are going to be isn’t good enough. We need to answer questions on how they make decisions," Lowe said. "to do that, we need environmental data as well."

One application for this data is how sharks might modify their behavior in a changing climate. While some species of white shark can control their body temperatures, they typically prefer cooler waters. As waters continue to warm, Lowe anticipates the sharks through a different lens. Looking through it as they are now, it is a Vemco VR2C acoustic monitoring receiver that can detect tagged animals in the water. The unit is also equipped with a GPS receiver for timing and positioning information, and a three axis accelerometer for measuring pitch and roll of the buoy. Additionally, there is a Vemco V9232 acoustic monitoring receiver that can detect tagged animals within 400 meters of the buoy. An underwater probe for monitoring temperature, salinity, dissolved oxygen, algae, and other water properties is also being incorporated into the design.

Shark Lab engineers have equipped the buoy with three computers, among them 2 Raspberry Pi 4s, and a custom-designed low power ST232 system monitoring computer. The Raspberry Pis are equipped with an on-board microcontroller that can communicate with the lab to monitor and process data from virtually any kind of sensor attached to the buoy.

The buoy can communicate with the lab under virtually any conditions because of its versatile radio array. It is equipped with cellular, satellite, HF, and VHF radios for transmitting data, and receiving control messages. The HF and VHF transmitters are extremely versatile because they are implemented as Software Defined Radios (SDR) on the Raspberry Pi computers.

The entire buoy project has been released to the public as open-source. Design details, schematics, source code, and mechanical drawings via GitHub for others to use as a base upon which they can build their own custom solutions.

These units require a diver go pick up the receivers from the sea-floor so it can be downloaded. Now they have buoys with added receivers that transmit data in real-time using cell modems, along with relevant environmental data - like temperature and depth.

"That’s the completely wrong way to think about sharks."

"All of this should be used as an educational tool. We can’t tag every shark, but if we tag a decent number and study their behavior, we start to understand their behavioral patterns, which ultimately will help us share the ocean with them."

Prior to the white shark’s resurgence, most people didn’t realize how much of the oceans they did share with them. It’s why so many people feared them. But younger generations are growing up more used to seeing sharks – and less scared of them.

"The time is right to do some of this work because the public sees the sharks through a different lens. Looking through it as they are now, it is a Vemco VR2C acoustic monitoring receiver that can detect tagged animals in the water. The unit is also equipped with a GPS receiver for timing and positioning information, and a three axis accelerometer for measuring pitch and roll of the buoy. Additionally, there is a Vemco V9232 acoustic monitoring receiver that can detect tagged animals within 400 meters of the buoy. An underwater probe for monitoring temperature, salinity, dissolved oxygen, algae, and other water properties is also being incorporated into the design.

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The entire buoy project has been released to the public as open-source. Design details, schematics, source code, and mechanical drawings via GitHub for others to use as a base upon which they can build their own custom solutions.

However, Lowe believes those that will benefit the most from better shark data is the public. But it has to be used appropriately. After the white shark population began to rebound in Australia, there were more reported cases of shark attacks. After the country started tracking shark locations and made that data public to everyone, beachgoers began to use the data like an early warning system, which creates all sorts of problems. Researchers certainly can’t tag every shark, but there were likely times when untagged sharks were close to beaches, but there was no alarm.

SHARK TRACKING BUOY

The Shark Lab’s buoy features an Airmar 200WX-IPX7 weather station that measures wind speed, humidity, temperature, and dew point. The unit is also equipped with a GPS receiver for timing and positioning information, and a three axis accelerometer for measuring pitch and roll of the buoy. Additionally, there is a Vemco V9232 acoustic monitoring receiver that can detect tagged animals within 400 meters of the buoy. An underwater probe for monitoring temperature, salinity, dissolved oxygen, algae, and other water properties is also being incorporated into the design.

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**PARAMETER**

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Graphic: Joshua Pene
**Battle of the Trout**

**How brook trout reclaim native waters**

The North Carolina Wildlife Resources Commission’s Inland Fisheries Division has been working to restore brook trout in the state. Coldwater research coordinator Jacob Rash, who works with the brook trout team technicians on this project, provided insight into the work.

“In North Carolina, brook trout are our only native trout species,” explains Rash. “With that, come biological and ecological considerations as well as cultural importance. A lot of folks here grew up fishing for brook trout with their relatives, so it’s an important species that we work to try to conserve. We’ve done quite a bit of work to figure out where those brook trout populations are and what they are, in terms of genetics.”

The teams capture brook trout using electrofishers and nets, and then measure them and collect samples of their DNA. This process is part of a greater ongoing effort. “Back in the late-1800s and early-1900s, there was intensive forestry across the landscape,” says Rash. “A lot of those methods utilize the streams to transport materials out of the forest. These are pretty intense landscape practices. Folks were realizing even by the early 1900s that they were not seeing all those pretty fish that were once the fish that they were here to try to bring those fish back.”

In North Carolina, not only were brook trout themselves stocked back in the waters, but also rainbow trout from the Western US and brown trout from Europe. Today, brook trout have lost 70 to 85% of their range. “Folks didn’t know this, but those cultured brook trout stocks trace their lineage back to the New England states,” details Rash. “Loss of habitat, loss of range, encroachment by brown trout and rainbow trout, and the introduction of genes that were not here traditionally all happened. So, there is influence by those brook trout streams across the landscape.”

This has led the researchers to ask several questions as they work to untangle the genetic picture that exists as multiple trout species now co-exist where brook trout once lived alone. For example: Are these the fish that were here? Have they in fact been influenced by stocking throughout history?

“That’s why genetic work is so critical,” remarks Rash. “It lets us answer that question and helps us figure out which fish we’re working with. And that has all sorts of implications, particularly when we’re looking to restore brook trout populations.”

This matters from a biological standpoint, not just because managers want to preserve this particular trout, but also because keeping them around and healthy is important to efficiently managing the local ecosystem.

“We can now go to donor streams and know, yes, these brook trout are the ones that should be here, and some of those adults may make excellent candidates for us to move to other streams to help establish populations,” Rash describes. “That’s a lot more effective and efficient than just randomly grabbing populations, because you may not know what they are. We’re able to really zero in and make the best decisions possible.”

**RESTORING NATIVE SPECIES AND WATER QUALITY**

Thriving brook trout—the only native trout—in the headwater systems also signals better water quality.

“When brook trout are present and thriving, that means that they’ve got the habitat suitable to maintain them,” states Rash. “If the water at the top of the watersheds are in good enough condition to support brook trout, that is a positive signal for the resources downstream to which these waters flow.”

Brook trout are sensitive. If the local aquatic ecosystem is supporting them, it is probably capable of supporting everything else that should be there.

“If you think about a sandrap falling on the top of a mountain, that’s going to go downhill,” remarks Rash. “If conditions start out well enough to support brook trout up top, chances are that whatever’s below them will have conditions that are better than they would be otherwise.”

Rash and his team see brook trout populations in North Carolina above 3,000 feet and below that, rainbow and/or brown trout. However, historically it’s likely that the brook trout would have been in some of the lower reaches that are currently occupied by rainbow and brown trout alone. These are just a few of the considerations the team weighs as they design a program like this.

“The work that we do is all part of a larger effort,” comments Rash. “There are multiple partners involved because we have our focus and other partners do, too. But the issues that impact a species like brook trout don’t understand administrative boundaries, so by working with partners, we are all able to work collaboratively to address the larger issues.”

For example, Rash’s team collaborates with numerous partners such as surrounding states (e.g., South Carolina, Georgia, Tennessee, Virginia), the US Forest Service, the National Park Service, the Eastern Band of Cherokee Indians, Trout Unlimited and the Eastern Brook Trout Joint Venture.

“We all work to share ideas about what we may be doing individually, and pull all of that together to address brook trout conservation as a whole,” remarks Rash. “At the end of the day, we’re all trying to get to the same goal. I think it takes folks working together, particularly when there are so many aspects to it. It’s a challenge, but it’s really exciting.”

Project goals might include deploying volunteers to collect water samples on an ongoing basis or conducting work to improve habitats.

“Planting riparian vegetation to increase shading, for example,” explains Rash. “The larger collaborative approach is focused on improving habitat across the range and improving fish passage so that they can have access to different reaches within the stream.”

Local history and culture fuel much of the work and care behind this fish restoration project.

“As the only native trout, for everyone from anglers to biologists like myself, these fish carry a sense of importance that makes them special,” adds Rash. “Native fishes should be here. Plus, these Brook Trout are so pretty. If you see one of these, they’re one of the more striking fish. When they get those colors that they do, particularly in the fall, it’s a special thing. So, yes, they do mean a lot to many people.”

Photo: J. Rash (left), Thomas Harvey (right)
Trans Adriatic Pipeline Construction Monitoring

Pipeline construction began in 2016 to transport natural gas from Greece via Albania and the Adriatic Sea to Italy. The total length of the Trans Adriatic Pipeline when completed will be 546 miles, and the offshore section will be laid at depths reaching up to 2,660 feet.

In fall 2019, Gravity Marine was contracted by RSK to conduct buoy-based monitoring of water quality, currents, and waves on the Adriatic Sea during construction, transmitting data to Italian authorities in real-time. Delivery time was critical for the monitoring aspect of the project, and the system was transmitting data in the Adriatic Sea less than 4 weeks after placing the initial order.

Equipment used for the project includes a NexSens CB-650 data buoy with Iridium satellite telemetry, Nortek AWAC bottom-mount current profiler, and YSI EXO3 water quality sonde with temperature, conductivity, dissolved oxygen, turbidity, chlorophyll, and phycoerythrin sensors. To date, the system has survived two major storms with up to 4-meter waves and continues to provide the project with critical data.

Photo: Shawn Hinz, Gravity Marine
There’s no expiration time on our buoy,” remarks Hovel. “We plan to keep it out and maintain it for as long as we can. The only real maintenance that’s required is to download the data and replace the membrane on the dissolved oxygen sensors twice a year. Other than that, it’s fairly self-sufficient, which is really attractive.”

For years, limnologists have been limited to studying lakes during the summer months. However, newer remote sensing technologies and materials are enabling data collection in colder temperatures and under the ice without damage to equipment. “There are many long-term monitoring buoys deployed worldwide, and many different models and methods for deploying them,” details Hovel. “Many buoys are really expensive and highly-parameterized. These are highly valuable, and we get a lot of good information out of them. But we have another model that can be deployed at smaller scales with lower budgets. This helps to fill a science and data gap, in that it can collect data throughout the whole year, and not just during the summer months.”

During the spring and fall seasons, lakes experience water column mixing and rapid temperature fluctuations, both of which strongly impact nutrient cycling and biological organisms. The buoy deployed in Wilson Lake actually freezes into the lake ice by design.

“Especially as we start to consider more winter ecology questions and the field starts to move more in that direction, I think this is a good potential avenue that’s not very burdensome from a resource standpoint,” adds Hovel. “A lot of the bigger buoys that some of our colleagues use have to be deployed and taken out using an operation that sometimes involves a crane on a large boat. This buoy is accessible for smaller projects, such as those a lake association would develop, as long as they have enough funding to pay for the sensor. It’s relatively inexpensive to set up.”

The Wilson Lake buoy monitors dissolved oxygen and temperature using a series of sensors positioned at approximately two-meter intervals and suspended from the buoy on a line. The line extends to the bottom of the lake, with the sensors recording information at specific points in the water column.

“We are thinking about lake stratification, which happens when the thermal environment in the lake changes, and you start to have a warm layer sitting on top of a colder layer,” Hovel describes. “How stratified a lake is and for how long that happens depends on the amount of sunlight, the temperature in any given year, water clarity, and wind dynamics. In cases of significant stratification, conditions at the bottom may be very different from those at the surface due to this lack of mixing, and surface waters may be too warm for some cold water species. There are so many dynamics that stratification can really influence.” Hovel says. “For example, long periods of stratification can result in dissolved oxygen depletion at the bottom of lakes and water column mixing can relieve those oxygen limitations by bringing well-oxygenated surface water to the benthic regions. Being able to capture those early spring and late fall periods in particular, when a lot of the larger monitoring buoys are out of the water, is a really important step to answering these questions.”

Among the things the team feels sure about: the winter dynamics of the temperate and boreal lakes they are studying are changing notably. “Winter is warming more rapidly than summer in many places,” adds Dr. Hovel. “The sorts of things that we see in ice duration, water temperature, snow cover over ice and what that could mean for under-ice productivity — I think there are just limitless questions that we can ask. And being able to understand what’s going on in the winter in these lakes, even a little bit, helps a lot in starting to understand how climate change impacts the lakes that we care about.”

SEASONS CHANGE, BUOY REMAINS

Since the summer of 2018, Wilson Lake in Maine has hosted a data buoy that contains a set of long-term environmental data loggers. The rugged buoy, designed for year-round use, monitors dissolved oxygen and temperature even when it’s locked in ice.

University of Maine, Farmington Biology Professor Rachel Hovel discusses the Wilson Lake buoy and her team’s work with its data. “The ability to generate a long-term data set and collect these data over the entire year is really useful, both in the classroom and for asking questions about what’s happening in this lake,” comments Hovel. Although the Wilson Lake buoy has been deployed for just over a year, these kinds of deployments have the potential to be very long-standing. Dr. Hovel and the team are working to get everything they can from the station’s consistent data collection across seasons and years.

“There’s no expiration time on our buoy,” remarks Hovel. “We plan to keep it out and maintain it for as long as we can. The only comments Hovel. “Many buoys are really expensive and highly-parameterized. These are highly valuable, and we get a lot of good information out of them. But we have another model that can be deployed at smaller scales with lower budgets. This helps to fill a science and data gap, in that it can collect data throughout the whole year, and not just during the summer months.”

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Advanced warning for tsunamis is among the many drives for organizations to research and apply monitoring techniques to better understand factors that contribute to the devastating effects.

**TSUNAMI BUOYS**

1. **BOTTOM PRESSURE RECORDER (BPR)**
   - The BPR records temperature and pressure every 15 seconds. It will send information to a data buoy through an acoustic modem.

2. **TSUNAMI BUOY**
   - The tsunami buoy acts as the link between the BPR and tsunami warning centers. It collects the data from the BPR and relays it to the satellite.

3. **IRIDIUM SATELLITE**
   - An iridium satellite allows for two-way communication between the tsunami warning centers, and the BPR. This allows for live diagnostics and troubleshooting of the systems.

4. **TSUNAMI WARNING CENTERS**
   - Tsunami warning centers are actively researching the patterns and signs of tsunamis to steer clear of the dangers tsunamis bring.

**RECENT TSUNAMIS MAXIMUM RUNUP HEIGHTS***

<table>
<thead>
<tr>
<th>Runup Height</th>
<th>Date</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>11.00 m</td>
<td>February 6, 2013</td>
<td>Solomon Islands</td>
</tr>
<tr>
<td>13.60 m</td>
<td>September 16, 2015</td>
<td>Central Chile</td>
</tr>
<tr>
<td>22.35 m</td>
<td>September 29, 2009</td>
<td>Samoa</td>
</tr>
<tr>
<td>29.00 m</td>
<td>February 27, 2010</td>
<td>Chile</td>
</tr>
<tr>
<td>39.26 m</td>
<td>March 11, 2011</td>
<td>Japan</td>
</tr>
</tbody>
</table>

*Runup height is the maximum height the wave reaches at the tsunami’s maximum inundation.

**DART GENERATION 4**

**INSTRUMENTS**
- The buoy is equipped with sensors measuring meteorological conditions.

**ANCHOR**
- An all-in-one mooring system consists of a cabled anchor that self-deploys when placed in the water.

**DATA BUOY**
- Strong, capable buoy able to withstand the harshest environments.

**FORMATION OF A TSUNAMI**

1. Earthquakes/techtonic plates cause the up thrust of water which forms massive waves.
2. Waves start slowly building up over time.
3. The waves reach the end of their buildup as they crash over the shore.

*https://www.ngdc.noaa.gov/hazard/recenttsunamis.shtml*  
*https://nctr.pmel.noaa.gov/Pdf/brochures/dart4G_Brochure.pdf*
It has oak-hickory forest and post-oak savanna with bluestem boids (dolomite glades). Its glades, a unique feature, are dominated by grasses and wildflowers, with five endemic species. It has a unique pond marsh with rare marina grass as well as rare and endangered species such as giant cane and running buffalo clover. Wildlife includes deer, wild turkeys, a large variety of cavity-dwelling birds, and even armadillos. The area also has alligators for snapping turtles, the greater roadrunner and many types of lizards and snakes. A federally listed endangered species that lives there is the gray myotis bat.

Janice Greene, director of Bull Shoals Field Station since 2002 and professor of biology at Missouri State, found a rewarding career awaited her at the field station.

“Some common summer birds we get here are Kentucky warblers, indigo buntings and red-eyed vireos,” Greene mentions. “There are also some bigger birds here that we see whose breeding range has expanded, like fish crows and black vultures.”

There are many factors that affect bird populations in general. These include invasive species such as cats and pesticides like neonicotinoids, which affect insects that many birds eat.

“Habitat loss and change may still be the biggest factor in the population losses in birds we have seen,” Greene suggests. “There have been big declines in some species, like the scarlet tanager and cerulean warbler.”

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ACCRETE encompasses multiple projects that all aim to better understand threats and restoration, and this includes better understanding threats to AMERICAN SAMOA’S coral reefs, with NOAA’s Atlantic Oceanographic and Meteorological Laboratory, Climate and Coral Reef Ecosystems Team at AOML.

The National Oceanic and Atmospheric Administration (NOAA) and the Pacific Islands Ocean Observing System (PacIOOS) at the University of Hawaii at Manoa, in collaboration with other partners, recently deployed a new ocean acidification (OA) monitoring site in Fagatele Bay National Marine Sanctuary, American Samoa. Derek Manzello, a coral ecologist with NOAA’s Atlantic Oceanographic and Meteorological Laboratory (AOML) in Florida, is the lead PI of ACCRETETE: the Acidification, Climate and Coral Reef Ecosystems Team at AOML.

“ACCRETETE encompasses multiple projects that all aim to better understand the response of coral reef ecosystems to climate change and/or ocean acidification,” explains Manzello. “We work to provide information to assist coral reef management and restoration, and this includes better understanding threats like OA.”

Much of these efforts focus on the in-situ climate change and OA monitoring work that takes place as part of the National Coral Reef Monitoring Program (NCRMP), co-funded by NOAA’s Coral Reef Conservation Program (CRCP) and Ocean Acidification Program (OAP).

NCRMP has a tiered monitoring approach whereby we are taking a lot of measurements across a large spatial area at a low temporal frequency, but are taking many high-resolution measurements at a high temporal frequency from select key sites,” details Manzello. “The NCRMP plan calls for three class III or ‘sentinel’ OA monitoring sites in the Atlantic and Pacific.” There are two operational sites in the Atlantic in La Parguera, Puerto Rico and Cheeca Rocks in the Florida Keys. Prior to the deployment of the buoy in American Samoa, there was only one sentinel site in the Pacific: in Kanoehe Bay, Oahu, Hawaii.

“I’ve managed the Cheeca Rocks buoy since 2012, while other partners manage the other buoys,” Manzello describes. “I led the installation of the buoy in Samoa because of my experience with the buoy in Florida, but the project will now be led by Chip Young at PacIOOS, which is based out of Hawaii.”

The OA monitoring of NCRMP has two paired components: physical monitoring and ecological response monitoring.

“First, it’s important that there are historical and ongoing long-term monitoring of benthic cover,” states Manzello. “It’s important to have a baseline by which to gauge future change, as well as to understand how things have changed in the past and responded to other stressors like coral bleaching.”

Benthic monitoring has been conducted in Fagatele Bay, part of the National Marine Sanctuary of American Samoa, since the 1970s. This long-term monitoring highlights a second key consideration Dr. Manzello points out—experts expect the effects of OA to be subtle over time, and manifest as declines in coral reef calcification, with simultaneous increases in coral reef bioerosion and dissolution.

“The OA monitoring work that takes place as part of the National Coral Reef Monitoring Program (OAP).”

Finally, the MAPCO2 buoy itself will require regular sampling, refurbishment, and maintenance—and available local resources to ensure that happens.

“There are several well-equipped partner agencies in American Samoa that made this project possible, including the National Marine Sanctuary, as well as the National Park of American Samoa, the Coral Reef Advisory Group of American Samoa, and the Department of Marine Wildlife and Resources of American Samoa,” Manzello says. “After PacIOOS takes over the management of the project, they will continue to work with us here at AOML, as well as NOAA’s Pacific Marine Environmental Laboratory in Seattle, and NOAA’s CRCP and OA.”

Initial deployment plans for the buoy were delayed two months in 2019 due to a government shutdown and engine trouble with the shipping vessel en route from Honolulu. Due to this, Manzello reports that the deployment was a logistical challenge thanks to seasonal. Thus, we still do not have a solid understanding of the rate and magnitude of OA in nearshore environments like coral reefs.

The team pairs this physical monitoring with ecological response monitoring.

“Monitoring is specifically designed to document the abundances of the important calcifying and bioeroding taxa, as well as their respective rates of calcification and bioerosion. This is done via landscape photomosaic monitoring, census-based calcium carbonate budget monitoring, bioerosion monitoring, and calcification monitoring by taking coral cores every five to 10 years and assessing recent rates of coral growth,” comments Manzello.

DEPLOYMENT FOR DATA

Fagatele Bay itself is a place more than 160 species of coral call home, as well as dolphins, many species of fish, giant clams and the critically endangered hawksbill sea turtle. The team selected the specific sentinel site for the buoy based on a range of factors.

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Initial deployment plans for the buoy were delayed two months in 2019 due to a government shutdown and engine trouble with the shipping vessel en route from Honolulu. Due to this, Manzello reports that the deployment was a logistical challenge thanks to
suboptimal weather and rough seas. However, with the help of local commercial divers and the efforts of partners Chip Young and PacIOOS, the deployment was successful.

“The Moored Autonomous pCO2 (MAPCO2) system is the gold standard for long-term, accurate, and reliable measurement of seawater CO2 in surface waters,” Manzello describes. “This buoy measures carbon dioxide in air and water, temperature, salinity, oxygen, turbidity, pH and air pressure.”

Partners in American Samoa led by National Marine Sanctuaries of American Samoa are also conducting bi-monthly bottle sampling, and the team is using the data from that sampling to calibrate and validate the data from the buoy.

“Also, we are able to measure total alkalinity and dissolved inorganic carbon, two variables that are not measured on the buoy but are part of the carbonate system,” adds Manzello.

Meanwhile, these data are reported to the public in real-time. This way, reef managers, scientists, and anyone else can follow CO2 trends and patterns through time, adding their insights.

“The seawater CO2 system of coral reefs can be highly variable from day-to-day and across seasons, so it’s necessary to take long-term, high-quality measurements with high accuracy and high precision at a high temporal frequency so that we are able to determine if coral reef environments are experiencing OA at the same rate and magnitude as what has been shown in the open ocean, where there is far less variability,” remarks Manzello.

The MAPCO2 buoy takes measurements every three hours and internally calibrates its reading, thus providing accurate data at a sufficient frequency. However, to truly understand the impact of OA on coral reefs, the physical monitoring that is provided by the MAPCO2 and ancillary environmental data must be paired with biological monitoring to understand the impact of changing chemistry on coral reef ecosystems. Otherwise, it’s just an expensive chemistry experiment.”

With 450 lbs of net buoyancy, the NexSens CB-450 is compact and light enough for deployment from small boats. Onboard batteries and solar panels provide adequate power.

Pass-through ports make it easy to deploy and retrieve underwater sensors, and topside mounts are available for weather sensors. Add a solar power marine beacon for nighttime navigational warning.

Communication options using the X2-CB data logger include Wi-Fi, radio-to-shore, cellular, and Iridium satellite. Data is available online. More at Nexsens.com.
We intended to use the project as a testing ground, learn about R
THE TROUBLE WITH TRACKING HARMFUL ALGAL BLOOMS
of fresh water shortage.

Relyea said in order to understand HABs, it’s key to understand
temperature, wind direction and wind speed. All three influence
the severity and proximity of bloom events.

“The world doesn’t really understand much more about how the
weather conditions play into harmful algal blooms,” she said.

Relyea said the project’s parameters has always been RPI’s intention since they
started creating new technology in Lake George in 2013.

“We always planned to expand once we hit a mature stage in
the project and bring our technology to other lakes. None of us
wanted a one-off proposition on Lake George,” explains Relyea.

“Lakes where you expect HABs have some sort of big source of
nutrients that are rapidly changing, because you only have snapshots
every couple of weeks,” said Relyea. “There are a lot of lakes
that do have some sensor technologies, but nothing to the
level of sophistication that we have on Lake George and have
brought to Lake Skaneateles.”

The monitoring package is rounded out by an acoustic Doppler
current profiler, which uses sound and Doppler technology
similar to a police radar gun to determine where and how fast
the water and the particles within are flowing.

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“Every meter, as you descend into the lake, it can record which
way the water is flowing and how fast,” remarks Relyea. “We
care about that because the direction the water flows is also
the direction that nutrients flow, and the direction of moving
heat in the lake.”

Now, this single, integrated unit has each of these instruments
in action as part of one big, floating platform on the water of
Skaneateles Lake.

“We have brought to Lake Skaneateles is a vertical profiler, a weather station on that profiler, and a current profiler built into it,”
Relyea describes. “Those three things provide three different sets of
data on the lake. We have gone beyond what is commercially available to make it a very flexible, integrated system.”

The vertical profiler is something the Jefferson Project has built at
RPI in collaboration with IBM.

“It’s akin to a computer-controlled winch that lowers a group of
sensors from the surface of the lake to its bottom, and those sensors measure chlorophyll, blue-gren algae, oxygen, pH,
temperature, pretty traditional parameters,” states Relyea. “It
goes up and down the water column, stopping about every half
meter and takes readings from top to bottom about every hour,
24/7, to provide the profile of the lake.”

The weather station sits atop the vertical profiler to provide infor-
mation on weather conditions.

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MONITORING SKANEATELES LAKE

When thinking about harmful algal blooms, Florida is probably
more likely to come to mind than upstate New York. In fact, Ska-
neateles Lake has traditionally been a source of drink water for
the city of Syracuse.

For this reason, Skaneateles Lake can seem a strange place for
these algal events—at least it was in the past.

“Lakes where you expect HABs have some sort of big source of
nutrients coming in. Those low nutrient lakes, by definition, don’t.
So no one expected Skaneateles Lake to ever have a harmful
algal bloom, and for decades and decades, it didn’t,” remarks
Relyea. “Until September, 2017, they had a big one. The ques-
tion is: why? And we don’t know the answer. No one knows the
answer.”

Finding the answer is crucial for people in the region, but also
for expanding our more general understanding of how HABs
develop in freshwater. Unfortunately, it’s not an easy answer to

“These harmful algal blooms in lakes typically happen in the late
summer or early fall when you have some source of nutrients
coming into the lake, or coming up from the mud in the lake through processes we call respiration,” Relyea says. “There’s also some
source of phosphorus and these blooms are pretty important, but so are unusually hot weather and a series of unusually calm
days. Those three things happen at a lot where you see a harmful algal bloom, and they seem to have happened in Skaneateles last fall.”

Although the bloom appeared during an unusually warm week in
September with no wind, the source of the extra nutrients that fueled the bloom remains unknown. Adding further to the
mystery of this first HAB was its size.

“It happened for the first time that anyone had ever seen and
it happened all over the lake,” details Relyea. “When the wind
picked up again, it blew all of this algae right near the surface
to the north end, which is right where the city of Syracuse draws
all of its water. So now you’ve got undrinkable water in a place
where most people would have bet a lot that you’d never see
a harmful algal bloom.”

But after the bloom event, Relyea’s team was asked to start a pilot program on the lake. The plan is to have the platform
on-site for about four months, and remove it before the lake gets
cy in November or December.

“At that point, we’ll have a look at all the data, and we’re looking at
the data already,” adds Relyea. “For example, there was a very
localized, small harmful algal bloom about four days after we
went on the lake. Nothing like we saw in 2017, but it was still
very fortuitous that we got there when we did. We got to collect
some data during an event and we’re looking at those data
right now.”

The next challenge the team faces is processing the massive
amounts of data they’ve collected.

“We’re talking about thousands of data points per day,” empha-
sizes Relyea. “If they are unfortunate enough to have another
localized or large harmful algal bloom, we’ll be there to measure
those conditions and hopefully have a much better sense of
what the early warning signs are if we can identify them.”

The grand challenge for the team is where and when the next
harmful algal bloom will occur in a particular lake.

“That’s really what drives us: to work with all of the folks who have
been doing research on Skaneateles Lake for decades before
we ever arrived, to partner with them, to put our heads together,
and from all the data we have from our sensors and other peo-
ple’s work, identify the best predictors of where and when the
next harmful algal bloom will happen,” Relyea says. “And that’s
really a tremendous challenge because that’s something that
people have not figured out for a couple of decades.”

Of course, experts also haven’t had the same kind of advanced
technologies that Relyea’s team is working with. And as the
demand for answers grows, their technologies and understand-
ing of how to deploy them will come in handy.

“Although we understand some of the basic things that are
associated with this, beyond that, every lake seems different,”
remarks Relyea. “That’s the frustrating part. There has to be
some commonality to all of these harmful algal blooms, what
drives them and why they’re becoming more common. But we
don’t have a great idea of what that commonality is yet and
we’re hoping that the technology, which gives us high-
frequency data, will help illuminate some of those answers.”

“If this were easy, we would have known the answer years ago,”
Relyea added. “It is not easy.”

ENVIRONMENTAL MONITOR
Measuring It All at Lake Erie

Since its population bottomed out, the federally-endangered Piping Plover in the Great Lakes has made a comeback for the ages.

A population that once measured approximately 17 pairs and rebounded, hitting 76 pairs in 2017. The same year that count was made, the plovers had also returned to Gull Point, a nesting location that hadn’t been used in more than 60 years.

In an effort to understand some of the conditions that have allowed this species to return to its habitat, researchers have directed their attention toward a curious instrument for help.

A buoy that floats off the coast of Presque Isle State Park, near where Gull Point is located.

“Wind speed and direction, as well as water height, are critical variables to the breeding success of plovers. In my experience, when wind acts as a predator, plovers get excited. The website’s gotten a lot of hits. This last year, it was off the charts,” said Schnars.

A subject that easily fits this template is harmful algae blooms - one of the better-known cyclical phenomenon that takes place in Lake Erie. Along with the consortium’s smaller beach buoy, the Nearshore buoy uses a Blue-green algae probe. When measuring their concentration in the water, the buoys can quantify the number of Blue-green algae cells present.

Due to Presque Isle’s popularity, Pennsylvania’s Department of Conservation and Natural Resources (DCNR) places special emphasis on beach upkeep and water quality standards. The RSC works with the Erie County Department of Health to monitor water quality for bacterial concentrations (E. coli), which determines swimming advisories at beaches. Since this monitoring process takes nearly 24 hours to obtain results, the RSC also works with the U.S. Geological Survey (USGS) and Mike Rutter, PhD (Penn State Erie) to predict bacterial concentrations at swimming beaches using real-time buoy data.

Like most environmental models, predicting what each day might bring from all the little variances and factors can be challenging, which is why researchers are usually satisfied with a 60% accuracy rate. But the consortium’s buoy models hover closer to 80% percent.

The buoy doesn’t just aid in day-to-day monitoring. Some data can inform longer-term preparatory decisions, like judging where on the peninsula sand nourishment needs to occur.

“All this becomes important because over $1 million is spent (annually) on sand nourishment.”

Through a grant from the PA Department of Environmental Protection (DEP)-Coastal Zone Management, the RSC collaborates with the USGS to collect data from a remote-controlled data logger and the deployed buoys to model water currents and determine the movement of eroding sand at Presque Isle State Park.

If the day-to-day reports and annual data assessments help boost statewide tourism, then trend data over time helps scientists paint a larger picture of what conditions are determining the output of the lake.

A subject that easily fits this template is harmful algae blooms - one of the better-known cyclical phenomenon that takes place in Lake Erie. Along with the consortium’s smaller beach buoy, the Nearshore buoy uses a Blue-green algae probe. When measuring their concentration in the water, the buoys can quantify the number of Blue-green algae cells present. The RSC is collaborating with the U.S. Geological Survey to create a predictive model using data from the buoy.

“The data is posted in real-time on the RSC’s website palaeriebuoy.com, which features each operational buoy, the data collected and a satellite map. Easy enough to comprehend, users now extend to boaters and fishermen preparing trips on Lake Erie. We use the data from the buoy to plan our sampling trips and to help prepare us for the conditions we will encounter when we leave the dock. Currently, we run a boat angler survey three days a week,”

Haffley added that the commission is even dissecting archived data to bulk up its harvest and catch-per-effort models, as well as better predicting lake conditions from past events.

As the diversity of uses for the data has grown, so has its popularity.

“We have noticed since launching the Near Shore Buoy, people have gotten excited. The website’s gotten a lot of hits. This last year, it was off the charts,” said Schnars. At its peak, the website was accruing 14,000 views a month, with 14,000 unique viewers returning to the website. And that doesn’t include everyone using the smartphone app. Many of those viewers range from members at the U.S. Geological Survey to state-funded agencies, granted funded research projects and prospective boaters and anglers.
**YSI ProSwap Digital Water Quality Meter**

The YSI ProSwap is a versatile water quality meter for single parameter sampling applications (conductivity, pH, DO, turbidity, algae, etc.) with optional integrated GPS and depth sensor.

**Juniper Mesa 3 Rugged Tablet Computers**

The Mesa 3 Rugged Tablet offers powerful new functionality, while retaining impressive features from the popular Mesa 2 Rugged Tablet.

**Kipp & Zonen SMP Series Smart Pyranometers**

The SMP series pyranometers are designed for measuring short-wave irradiance on a plane surface, which results from the sum of the direct solar radiation and the diffuse sky radiation incident from the hemisphere above the instrument.

**SonTek SL-Series Side-Looking Doppler Current Meters**

The SonTek SL Series side-looking Doppler current meters are an advanced instrument for water velocity measurement and flow calculations in streams, rivers, and other water bodies.

**Heron dipper-See H2GO Underwater Drop Camera**

The Heron dipper-See H2GO is a self-contained, high-powered, low-cost illuminated underwater inspection camera.

**SMP series pyranometers**

**Van Essen Diver-Link Cellular Telemetry System**

The Diver-Link is a durable and easy to install telemetry unit for AT&T/T-Mobile networks that can be used in a variety of borehole locations such as flush mount and stick-up wells.

**NexSens G2-EXO Water Quality Monitor**

The NexSens G2-EXO provides live data access to a YSI EXO multi-parameter sonde. Included solar power pack and integral cellular system provide real-time data and notifications.

**Geotech Portable Turbidity Meter**

Geotech’s Portable Turbidity Meter is designed to withstand the rigor of field analysis with laboratory precision and repeatability.
Keeping TABS
ON THE TEXAS GULF COAST

From extreme weather such as Hurricane Harvey to spills and other accidents, the Gulf Coast of Texas is no stranger to dangerous situations. This is where the data provided by the Texas Automated Buoy System (TABS) comes into the picture.

Among the nation’s most successful and longest-running coastal ocean-observing systems at the state level, the TABS real-time oceanographic buoy system monitors currents, waves, salinity, wind, and other parameters.

“TABS has been running now for 24 years,” explains Anthony Knap, director of the geochemical environmental research group at Texas A&M. “I came to Texas A&M six years ago with a backdrop in taking long-term, sustained measurements in the ocean, and being able to show the importance of that sort of effort.”

Strategies that scientists employ are shipboard measurements (poking a hole in the ocean by putting a wire down with various bottles on it) and collecting discrete samples at monitoring locations in specific places. These locations, based on physics, biology, or other factors, ensure repeatability of the same spot over time either with ships or other remote tools such as buoys, gliders, etc.

Knap elaborates on the value of monitoring parameters and over time, in the same locations.

“It’s a strategy that provides you with temporal changes, an incredibly powerful tool for trying to understand the ocean. There is a massive amount of variability in the ocean due to eddies, which are basically oceanographic storms—just as you have things like hurricanes and lows in the atmosphere or other forms of ocean currents,” he said.

Returning to the same spot to monitor over time provides a better sense of how the ocean is changing because it reduces variability and deepens knowledge of ocean mechanics.

“The location of the TABS sites were chosen very carefully, because they represent many of the physical oceanographic parameters that change on the Texas coast due to its bathymetry, the seasonal weather, and other factors,” details Knap. “We have eight locations which provide a good representation of what is happening off the Texas coast.”

To design the system and select the right sites, team members accounted for the physics of the Texas coast and modeled the problem, identifying the most sensitive locations. The physics of the coastlines largely control problems like storm surge and flooding.

“We put the buoys in the places that are sensitive to the overall circulation of the Texas coast.” Knap describes. “The symmetry and the bottom topography will create a storm surge in some places and not others. The main thing is to try to understand differences from place to place and make sure you have a representative model that can help predict change.”

Why Monitoring the Gulf Coast Matters

Predictive power is certainly among the reasons to monitor, but there are other applications.

“It’s important to know what the system is doing at a given time,” reminds Knap. “For example, if there’s an oil spill or a toxic algae bloom, the characteristics of the location determine the impact on that site and help predict where that event is going to go next.”

In a complex system such as the Gulf of Mexico, additional data from such “moments” allows for increased accuracy in predictions.

“The ocean water is responding to various forces anyway. In cases of contamination, such as an oil spill, it’s even more complex,” adds Knap. “Unless you have a baseline and a continual measurement at specific points, you’re sort of blind.”

Fortunately, the Texas General Land Office supports the TABS system and takes its work very seriously.

“The TABS system was developed specifically due to the real chance of an offshore spill contaminating Texas beaches,” Knap states. “When you’re responding to an oil spill, it’s all about which way the current is going and how intense it is. Those factors help you model where the oil is going to go on the beach. You must ensure that you have the best possible prediction so you can deploy assets to control the effect of the spill in the most precise way.”

The amount of the existing data GERG has for the existing conditions is fairly unique.

“The Texas coast is probably one of the most oceanographically complete measured systems in the United States,” remarks Knap. “We have our buoys, high-frequency radars, gliders and wave-powered surface vehicles that give us information on currents and other water column parameters. I think we pretty much have the Texas coast covered other than the Flower Garden Banks—further offshore.”

Physics, Climate Change, and Extreme Weather

The TABS team is keen on the holistic view, particularly with regard to climate variability. Whatever the causes of these changes, the team is committed to preparedness. Along the Texas coast, subsidence due to human activities and global sea level rise together generate more serious problems than they can alone.

“For example, subsidence can cause problems building roads, or affect the groundwater.” comments Knap. “Then a global sea level rise of three millimeters per year occurs.”

That is very small, but over the course of decades or even hundreds of years, the change is significant—and it is a growing threat that demands both mitigation and prevention.

“The fact is, if you’re sitting on the coast, the land is subsiding, and sea level is going up, most of that sea level rise has to do with the ocean getting warmer as it expands,” says Knap. “In the ocean, you can also see the effect of heat on the intensity of hurricanes.”

Knap recalls the 2005 hurricane season, which was the deadliest and costliest on record. However, ocean dynamics are changing fast.

“When I first got into the climate and hurricane world, everyone connected that surface temperature of the ocean being 26.5 degrees centigrade, that was more or less considered to be the minimum trigger for tropical cyclones,” adds Knap. “What we’ve learned is that it has an effect on the structure of the water above—remember the coolness and the temperature of the water below that surface of the ocean down to 75 meters or more. This represents a massive amount of energy, not just to start the storm, but to allow it to intensify and stay intensified by preventing it from cooling.”

To gather the right data underwater, the team uses automated gliders and other remote vehicles along with its buoy network to examine the thickness of upper ocean water.

“For example,” Knap says, “when Hurricane Harvey hit, you looked at a map of the upper ocean of the Gulf of Mexico, and everything was red hot: 31 degrees centigrade.”

“Yet underneath, one meter down, the water was very cool. That hurricane could not be sustained—and could not intensify due to the cooler water below which de-intensified the storm.”

Clearly, an understanding of the upper limits of heat is important. But before these new measurement technologies, much of this was essentially poorly quantified. With an understanding of some conditions on certain days at set points in time, experts were limited to using climatology data from several decades to predict the future—we have now learned that real-time data is an important addition to historical data.

“The problem is that it’s a very active and interactive process, so the upper ocean heat content during one storm may be completely different than the upper ocean heat content during another,” states Knap. “It’s decreased in intensity, as many hurricanes tend to de-intensify as they reach the coast, losing some characteristics as they approach landfall. However, recently, Harvey intensified as it approached land. Michael, last year, did the same thing.”

Protecting Our Coastlines

These increasingly intense storms highlight the importance of TABS.

“Think about all of those aspects of what these storms can do, right?” Knap comments. “They’re phenomenal, but it’s not just the damage to property; it’s the overall vulnerability of the population.”

By building larger cities on coastlines, we place more people and property in danger.

“We’re starting to build megacities in the way of storms,” explains Knap. “When Harvey arrived, there hadn’t been anything greater than a hurricane category three—making landfall in the US for 12 years. This was the longest drought of major hurricanes since 1860. Until Harvey in 2017, the last landfalling storm of Category 3 or greater was Wilma in 2005. In between that period, coastal development increased, putting more property in harm’s way.”

There is obviously no way to prevent the storms from coming. But monitoring and understanding ocean dynamics will help us better predict their paths, timing and intensity, helping to save lives and money.

“I think one of the key things for any coastal area is to have decent ocean observations,” confirms Knap. “Then, at least you can predict what may happen and make sure people go to higher ground when they can. A lot of people tend to just ride it out—without detailed knowledge of what actually could happen in a specific storm. And now we have the measure- ment and modeling is incredibly, incredibly important as it can inform prediction and save lives.”
The Oneida Lake ecosystem has been the subject of extensive data gathering, some of it going back 60 years. Data has been collected on everything from water quality and nutrients to fish abundance, diet and growth rates. Parasites on fish are also monitored. “We could not observe the changes we see without environmental data gathering,” says Rudstam. “The EPA research vessel ‘The Lake Guardian’ is used to gather and process data. These data are used to look for trends over time and to create indices for the status of lake ecosystems.”

Lake Oneida data shows differences in the Lake over time that indicate climate change. “We have seen an increase in temperature of about two degrees Celsius since the 1970s,” Rudstam indicates. “We also have less ice cover duration in the Lake than we used to, about a month less than it used to be.”

Lake Oneida’s behavior is partly influenced by the fact that it is a shallow lake that doesn’t stratify like the deeper lakes in the Great Lakes system. It is only 16 meters deep at most, averaging about only 7 meters deep. “Lake B. Clair is similar; it is shallow also and doesn’t stratify,” says Rudstam.

In Lakes Superior, Michigan, Huron, Ontario and Erie, researchers at the Field Station at Shackelton Point have been working with the EPA to monitor zooplankton, chlorophyll and bottom animals such as worms, insects, plants and mussels. Sampling is conducted in April and August, and sometimes at other times of the year as well. The EPA research vessel “The Lake Guardian” is used for these studies. This research is in collaboration with Buffalo State and employs graduate students and several technicians to gather and process data. These data are used to look for trends over time and to create indices for the status of lake ecosystems. “Blue-green algae is still a problem in the Great Lakes system, as it has been for many years,” says Rudstam. “But we have seen some progress with persistent contaminants PCB and DDT. They have been slowly going down. The numbers have definitely become lower since the 1970s.”

While he has had a great familiarity with Lake Oneida and the Great lakes ecosystems over the years, Rudstam has still been surprised by some observations that have been made. “I’ve been surprised by some effects of zebra mussels, which invaded the lakes many years ago. The mussels have cleared the water, and that has had all sorts of effects for the ecosystem. They are still spreading across North America. In Lake Oneida, they have simply become part of the ecosystem. Instead of trying to eradicate them, I think people have come to realize that we will just have to learn to live with them,” he says.

The Oneida Lake data has made it possible to understand many aspects of the lake ecosystem better, and the work on the Great Lakes is used to determine what the future might hold for the largest freshwater system in the world. “We could not observe the changes we see without environmental monitoring and good data sets,” Rudstam emphasizes. “They are critical to our understanding.”

The Oneida Lake data is some of the best data that has been collected for understanding species impacts and climate change effects.

Lars Rudstam, Professor of Aquatic Science at Cornell and Director of the Cornell University Biological Field Station at Shackelton Point, says that he has lived in an area of lakes in general, so naturally the Great Lakes, the largest freshwater lake system in the world, have held a fascination for him for many years. He also works on Oneida Lake, the largest lake wholly inside New York. Oneida Lake waters, traveling from the lake to the Oneida River, then to the Oswego River, ultimately flow into Lake Ontario. “In addition to lakes in general and the Great Lakes, I have been especially interested in the impressive data series that has been collected for Oneida Lake,” Rudstam notes. “Oneida Lake data is some of the best data that has been collected for understanding species impacts and climate change effects.”

The Oneida Lake ecosystem has been the subject of extensive data gathering, some of it going back 60 years. Data has been collected on everything from water quality and nutrients to fish and the birds that eat them. “We are interested in the whole lake,” says Rudstam. “We collect data on many aspects.”

Lake nutrient samples are collected weekly at Oneida Lake. A Hydrolab Datasonde unit is used to collect temperature, oxygen and pH information. Fluorometers are also used to collect information on algae. For those, German Moldaenke fluoroprobes are used. HCBO temperature loggers are also utilized in the field. The water quality data has been taken for 50 years.

Data on fish have also been taken for 50 years. Data includes fish abundance, diet and growth rates. Parasites on fish are also monitored. “We see parasitic copepods showing up in fish gills,” Rudstam mentions. “Invasive species are constantly coming into the system.”

Some of the common fish include walleye, yellow perch, smallmouth bass and largemouth bass. “We are also seeing round goby, which eats the eggs of some of the other fish. On the other hand, some of those other fish prey on the goby, and the goby does eat zebra mussels, an invasive species we’ve had for many years,” Rudstam mentions.

A large number of people fish on the public lake, as many of its fish are tasty game fish, such as the walleye. “The current limit is three walleye a day,” notes Rudstam. “The walleye population has increased in the past decade. About 50,000 walleye are harvested each year from the lake. We’ve also been seeing some increase in cormorants, which are fish-eating birds.” Sheepshead and carp also live in the lake but are not typically taken as game.

While no plants are specifically being threatened in the Oneida Lake system, European milfoil and story stonewort, a macroalgae, are considered to be invasive and have been affecting the ecosystem.
A focus on the Lake Okeechobee Watershed

The team is focused on the Lake Okeechobee Watershed for its newest project. Not only due to the watershed's significance as Florida's biggest lake, but also because of its wetland and sugar farm surroundings.

There's also the famed Everglades to the south and the coral reefs to the east, near where the university is located. Despite the freshwater habitats being different from Lopez's traditional focus, the same methods for characterizing microbes can be applied.

"We use genetic techniques because we can't culture a majority of bacteria that live in a habitat in any given ecosystem," remarks Dr. Lopez. "About 90 percent cannot be put on a petri dish. So the only way we can really study them and get a handle on what species are there and what they're doing is by reading what genes are there, what their genomes are, and what tRNA is expressed."

This is the reason for the team's heavy focus on molecular biology and molecular gene sequencing in the project.

"We're going to be looking at meta genomes and meta transcripts; these are the unculturable community that's there," Dr. Lopez elaborates. "Most habitats have a community of bacteria. We're looking across the whole consortium of species that might be living in the water, and we hypothesize on pivotal interactions there that may or may not be controlling the algae blooms."

"Cyanobacteria is the primary species that scientists know of that grows in Lake Okeechobee. The reason is the microcysts that popuate in the nearby waterways."

Okeechobee, Caloosahatchee River that feeds it, and in nearby waterways is Microcystis.

"Our primary focus has been on two different ideas," remarks Lopez. "One is a synthetic approach, using mesocosms on the Caloosahatchee River."

These are closed systems where the team can safely collect actual river water and add nutrients such as ammonium, phosphorus and nitrates to it in higher doses without environmental impact.

"The idea is to cause an artificial bloom in these mesocosms, which we've already started to do," states Lopez. "We can compare that with what's happening naturally in Lake Okeechobee. We've asked our partners to collect water samples from the lake and other parts of the watershed and we're going to profile the natural communities in those samples."

This team of collaborators boasts experts specializing in very different areas, which speaks to the complexity of the HAB problem. Any number of factors, such as winds or physical systems, nutrient run-off or temperature, could also be impacting these blooms.

"It is very complex, because first of all, it's a community in water, so you've got hundreds of species there," says Lopez. "We also know that there are nutrients getting into the waterway that have increased these changes in our water. We don't really know which ones might be driving the bloom, so that's why we've isolated a few to start with. We know those are probably being introduced from agriculture."

But there are also numerous human activities in this watershed that are probably having an impact. A rising population around the lake and in Florida means more septic tanks, which means higher nutrient loads. This can make it difficult to target one factor when so many are at play.

"...we're going to be able to tackle just a few of those parameters. We're going to try to do it systematically, and hypothesize about the specific nutrients that we think are in the water, based on the activity," said Lopez.

Perhapes the most interesting reveal from this work, however, will be the deeper profile of those bacterial communities—most of which remain unknown. Just knowing more about these interactions may help crack the HAB problem.

Using the latest genetic methods and algorithms, "I think we'll get an idea of how these species interact with each other," Lopez states. "We think that certain heterotrophic bacteria might be affecting the cyanobacteria. These are the consuming bac- teria that are also normally there, and they might not necessarily cause any problems. However, I think when the conditions are just right, something triggers the cyanobacteria to start choking, and they begin reproducing uncontrollably."

The toxins in cyanobacteria may not be as bad as the red tide, which causes respiratory ailments—but just having too much overgrowth of the blue-green algae still isn't good.

"It causes anoxia in the water, as they degrade, and overall it's an imbalance in the system," clarifies Lopez. "We're seeing more and more of a tipping point with more frequent blooms, and that's a sign to us that something is not normal. If we can deter- mine what those factors are, we'll work with local managers and agencies which monitor water quality to help improve it."

In fact, looking at genetic factors is a natural water quality study area, and a smart extension of the field, albeit a relatively new one. Still, today's problems demand the application.

"This is happening all over the world, there are blooms in Lake Erie, blooms in China, etc.," comments Dr. Lopez. "People are just not going to jump in the water with a mat of algae on top of it. So it's about time."
**ERIE**

Processes, jobs, products and other tasks are becoming “smarter” with the use of devices and machines. The Great Lakes are no exception with the Great Lakes Observing System’s new initiative, “Smart Great Lakes.” Goals of the pilot project include informing the public on water quality issues before more significant public health events unfold. Many collaborating researchers are involved with GLOS and work together to disseminate water quality data to the public. Another goal includes outfitting all of the Great Lakes with equipment that has proven reliable during times of distress, such as data buoys during the Toledo Water Crisis. Many organizations can benefit from real-time data on water parameters that contribute to water quality issues in areas that supply drinking water to so many. This project hopes to bring together researchers to work together toward one goal.


**HURON**

The Great Lakes have had their fair share of issues surrounding clarity, each lake hosting their own set of problems. Recent research by Michigan Technological University, the National Oceanic and Atmospheric Association, and the Thunder Bay National Marine Sanctuary sheds light on the recent increase in water clarity in Lake Huron. The new development comes from a recent spike in the exploration of shipwrecks in the lake. Thunder Bay National Marine Sanctuary is home to many shipwrecks that have been the site of various research initiatives lately. Among the wrecks, zebra mussels were found to have covered most of the wreckage sites, where in the past, they were absent. Water clarity has improved over the decades and the focus turned to zebra mussels, who are known to filter contaminants out of water.


**ONTARIO**

Where and how to monitor water quality is always a challenge, particularly in complex aquatic ecosystems. The new REASON Project from a team at Clarkson University is working to demonstrate the utility of using water quality instrumentation in dams on major rivers in the Great Lakes region. Michael Twiss, professor of biology, and his team are taking a new approach at the Moses-Saunders Power Dam across the St. Lawrence River, a main drainage outflow of the Lake Ontario watershed. Dr. Twiss found that much about this section of the river remained unknown, so the team began to conduct fundamental studies of how water changes when it flows out of the lake and downstream. The team’s first sensors were installed on the New York side of the power dam in 2014. The project is working to acquire a big picture for policy information so that decisions can be made more effectively locally, and municipalities can use better, scientifically-backed information for planning their own water quality monitoring.

**MICHIGAN**

Sometimes the scientific process makes for a great story, or many, like when discovering the relationship between lake levels and mercury levels in fish. Lake levels in the Great Lakes region rise and fall with some regularity. Peaks happen about every thirteen years. It’s a pattern supported by lake level data going back to the 1930s, it’s essentially region-wide, and it’s determined by what happens over half a continent away. Scientists begin to conduct fundamental studies of how water changes when it flows out of the lake and downstream. The team’s first sensors were installed on the New York side of the power dam in 2014. The project is working to acquire a big picture for policy information so that decisions can be made more effectively locally, and municipalities can use better, scientifically-backed information for planning their own water quality monitoring.

**SUPERIOR**

Over the summer, ecosystem ecologist Amy Marcocci taught a course for students titled “Lake Superior Exploration,” which revealed itself to be quite the journey. This course was designed to educate students about the many facets of the massive freshwater basin that lies so close to their campus. Not only do participants gain experience with field equipment and methods, they learn about ongoing research, culture and stories from different organizations across the basin. Students were able to record and visually observe temperature conditions on the lake in real-time, something that many students have never had the opportunity to experience. Guest scientists and speakers provided a glimpse into the real lives of working scientists. Nearly all of the students in the course have career goals that lie in the aquatic industry, and the experience provided valuable insight on what it takes to make an impact in the Great Lakes region.

**ERIE**


**HURON**


**ONTARIO**


**MICHIGAN**


**SUPERIOR**

EDUCATION AND RESEARCH AT DAUPHIN ISLAND SEA LAB

Named after French royalty, Dauphin Island sits on the Gulf of Mexico. It is an important stop for many migratory birds traveling from South America as well as many human visitors in search of beach scenery. It is also home to the Dauphin Island Sea Lab (DISL), which serves as the main educational and research center for marine science studies in Alabama. One of DISL’s most impressive gems is the Estuarium, a large aquarium where the public can view estuarine organisms native to Alabama, which includes a 12,500 square foot exhibit hall. Aquatic Life from the Mobile-Tensaw River Delta, Mobile Bay, the Barrier Islands and the Northern Gulf of Mexico are featured. Outside the aquarium is the Living Marsh Boardwalk, which looks over Mobile Bay.

The Mobile-Tensaw River Delta is Alabama’s largest wetland and is home to turtles, geese and American alligators. Mobile Bay has brackish water and is a habitat for blue crabs, stone crabs, horseshoe crabs, oysters, and flounder. Barrier Islands sports hermit crabs, and the Northern Gulf of Mexico supports octopi, lobsters, eels, seahorses, sharks, jellyfish and many others. The Rays of the Bay, an Estuarium exhibit opened in the mid-2000s, features indigenous Northern Gulf of Mexico and Mobile Bay skates and rays, including the Cow nose ray and Southern stingray. The newest exhibit is Windows to the Sea, added to the exhibit hall space in 2018.

“Windows to the Sea features a video wall for the public to explore a sargassum community and learn about changes in Earth’s history,” says Angela Levins, public relations director of Dauphin Island Sea Lab. “Windows to the Sea also provides visitors with educational videos of programs on campus, research happenings on campus and topics of interest in the world of marine science. The exhibit gives the public a view of the sea outside of the four habitat focus areas.”

DISL also features a dolphin, manatee and whale standing research facility, the Marine Mammal Research Center.

“The Alabama Marine Mammal Stranding Network (ALMMSN) uses the center for necropsies and research. There is also the Manatee Sighting Network (MSN) on campus. Both programs are projects of Ruth Carmichael. The Manatee Sighting Network has a great focus in giving us a better understanding of manatee travel. There was a time it was believed that manatees were out of place in Alabama, however, through the manatee sightings we’ve discovered that manatees migrate to our area in warmer weather and then head back to Florida when the water cools down. MSN has used satellite tagging and citizen visuals,” says Levins. “A great paper just came out relating to a portion of this.”

Satellite tagging of manatees and public reports of manatee sightings can be found at https://manatee.dsi.org.

“Constant water monitoring is a central feature of Dauphin Island research,” added Levins. Dauphin Island monitoring data provides many benefits, including a permanent record of changes in environmental indicators over time, support for research activities through the availability of consistent, high-quality data and potential for the public to track and learn about water quality status. Monitoring informa-
**HANDHELD CYANOTOXIN DETECTION**

Combating harmful algal blooms (HABs) is no easy task. While conducting tests in a timely fashion is key to mitigating damages, the laboratory equipment needed for those tests can cost a lot.

Qingshan Wei, an assistant professor at North Carolina State University saw that problem, and sought out a solution by developing low-cost sensors, which can monitor the cyanobacteria that generates HABs.

“They have very severe health implications such as brain damage. So far, the standard detection methods still rely on laboratory technology, such as using mass spectrometry to quantify the cyanobacteria,“ explains Wei.

Those methods are very accurate and sensitive, but it takes both a laboratory setting, qualified personnel and expensive equipment to conduct them.

“We thought, maybe people will appreciate a portable technology that enables onsite detection so they can immediately evaluate that quality of the water in the environment and try to guide their daily activities,“ Wei describes. “For example, a test to determine whether you can swim or fish. That was our motivation.“

The sensors perform well under ideal conditions, but how they perform in the field remains a question Wei’s team is looking to answer.

The team also plans to push the technology out to the broader scientific and water management communities to gauge interest.

“That way we can also potentially achieve more collaborations, further improve this technology and perhaps get more funding support to develop new technologies,“ adds Wei.

**DETECTING CYANOTOXINS WITH A CELL PHONE**

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**ALGAE-TRACKING SAILBOAT**

Scientists from Florida Atlantic University Harbor Branch Oceanographic Institute (HBOI) recently trialed a solar-powered, algae-tracking sailboat developed by Navocean, Inc.

“This boat is so amazing when you see it in action,“ remarks Jordan Beckler of Florida Atlantic University (FAU), director of HBOI’s Geochemistry and Geochemical Sensing Lab.

After being contacted by Navocean and conducting a pilot test in December 2017, the team sent the boat out in December 2018 off the coast of Sanibel, Florida, coinciding with the beginning of the Florida Red Tide Bloom (Karenia brevis) that lasted until February 2019.

Beckler is now at the Indian River Lagoon, where severe algal blooms occur. Due to the small size of the algae-tracking sailboat, Beckler believes it could be the “perfect platform” for monitoring these phenomena.

The boat also offers a mobile monitoring platform for users, requires less technical training or support, more affordable and can be deployed by one person.

Target users include research scientists, water quality monitoring officials, anyone studying Lake Erie algae blooms - anyone interested in real-time data from remote locations.

“We’re trying to make this system turnkey so that people can simply send the boat out and keep recording a series of waypoints for weeks, or even months at a time and get real-time data on chlorophyll, at least from a fluorescent sensor,“ comments Beckler.

Once calibrated, the boat can be deployed for extended periods of time, partly due to its solar panels. Beckler said they use a sheet of tinted, frosted purple plexiglass material, which makes for a solid fluorescent reference signal when held against a fluorometer.

That single data point from the fluorometer can be used for calibrating the sensors, or at least provide clues about which groups may be present.

“The other sensor we used for Lake Okeechobee is a Wetlabs backscatter meter (BB3),“ explains Beckler. “We have three channels of RGB backscatter to detect particulate material. Combined with the chlorophyll data, these sensors can potentially be used in tandem for resolving functional groups of phytoplankton, or at least provide clues about which groups may be present."

The team is now preparing to deploy the boat alongside a NASA-funded project called SeaPRISM in Lake Okeechobee.

Beckler’s Navocean vehicle circled the platform and would take backscatter data.

Data could improve algorithms the SeaPRISM uses to deconvolute the backscatter signal acquired by the lake reflectance.

“The easiest things to customize are the channels on a fluorometer,“ states Beckler. “They aren’t the most definitive instruments, meaning there will always be a question of signal interpretation, but they’re versatile with lots of sensor options. You can look at hydrocarbons, for instance, so now you can search around for oil slicks."

The team seeks out natural extensions of what these fluorometers can do to find new applications for the boat. They’ve worked with the Mote Marine lab in an effort to measure colored-dissolved organic matter (CDOM), as well as red tide. This is done by integrating a Programmable Hyperspectral Seawater Scanner on the sailboat.

“By using a long-pathlength spectrophotometer, spatial measurements of CDOM could be obtained even in the open ocean, yielding data useful for many biogeochemical applications and improving our understanding of light availability, photochemistry and biology, heat transfer, and trace metal availability."

When the team deployed the boat in Sanibel, they measured chlorophyll a, CDOM, and turbidity.

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Rental equipment is available to minimize downtime and cover equipment needs when projects expand.

**Arrow Gold GNSS Receiver**
The Arrow Gold is the first high-accuracy iOS, Android and Windows Bluetooth GNSS receiver to implement all four global constellations, three frequencies, and satellite-based RTK augmentation.
- Full GNSS: GPS/GLONASS/Galileo/BeiDou/QZSS
- 100% Android, iOS, Windows compatible
- SafeRTK maintains RTK-level accuracy in spotty cellular coverage

**SonTek CastAway-CTD**
The CastAway-CTD is a lightweight, easy to use instrument designed for quick and accurate conductivity, temperature, and depth profiles.
- Can be used for sensor verification, speed of sound profiles, thermocline profiling, and more
- Sampling rate and sensor response of 5 Hz with 1m per second free fall design
- Designed for CTD profiling down to 100m

**EXO2 Water Quality Sonde**
The YSI EXO represents the next generation of water quality instruments from YSI. The EXO2 sonde includes six sensor ports and a central anti-fouling wiper option.
- 2 spare ports for adding Total Algae and/or fDOM sensors
- Internal battery pack for unattended logging
- Central wiper prevents fouling and extends deployment

**CB-50 Cellular Data Buoy**
The CB-50 Data Buoy is designed for quick deployment in emergency response situations including industrial spills and natural disasters.
- Design accommodates X2-SDL data loggers and is compatible with many environmental sensors
- Cellular, Iridium satellite, and radio-to-shore telemetry options available
- Lightweight system can be deployed by a single person

**Cyclops-7 Rhodamine Dye Logger**
The Cyclops-7 Rhodamine Dye Logger is ideal for time of travel studies, dispersion and mixing studies, circulation, and stormwater retention studies.
- Includes Cyclops-7 rhodamine dye sensor
- Internal battery pack for unattended logging
- Log as fast as 1-minute for up to 28,000 samples

**Signature 1000 ADCP**
The Signature 1000 ADCP is the optimal tool for turbulence measurements.
- Five beams for mean currents and turbulence
- Wave height and direction
- Very small size and weight