

# ENVIRONMENTAL monitor

SPRING 2024

APPLICATION AND TECHNOLOGY NEWS FOR ENVIRONMENTAL PROFESSIONALS

## CLIMATE EMERGENCIES & NATURAL DISASTERS



### **Water Sharing in Bangladesh**

Solving the Largest Mass Poisoning in History

### **Marine Cold Spells**

The Flip Side of Global Warming

### **Sustainable Data Collection**

Climate Monitoring in the Caribbean

# Welcome...

Welcome to the Spring 2024 edition of the Environmental Monitor, a collection of the best of our online news publications. In this issue, we showcase researchers from across the globe and the importance of monitoring natural disasters and the various symptoms of climate emergencies.

Tracking the impacts of wildfires in Canada to air pollution in New York, this latest edition showcases how the influence of climate change and natural disasters transfers across state and country lines. Researchers spent the year gathering data, predicting disasters, and monitoring as a means of managing and understanding natural disasters.

Our writers sought out environmental professionals dedicated to protecting human health, minimizing the impacts of natural disasters and creating monitoring systems. Featuring stories from a supervisory electronics technician with the Hawaiian Volcano Observatory, president of the North American Lake Management Society, and other experts, this edition highlights the many ways that natural disasters and climate emergencies impact the planet.

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## ON THE COVER

Front: At approximately 4:44 a.m. HST on June 7, 2023, an eruption began in Kīlauea's summit caldera, within Hawai'i Volcanoes National Park. Photo taken by USGS (See Pg. 30)

Back: A NexSens datalogger sits on the open lid of its metal housing attached to Langley Bridge overlooking the Neosho River downstream of Pensacola Dam. Photo taken by Sarah Dexter

## IN THE NEXT EDITION

Subscribe to read the next edition of the Environmental Monitor, focusing on data-informed resource management. Stories will feature and highlight strategies and projects from resource managers.

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Contents Photos (Left to Right): © 2024 Robert Kurkjian, Chemists without Borders, K. Lynn / USGS, Kiyoko Yokota



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# On the Web

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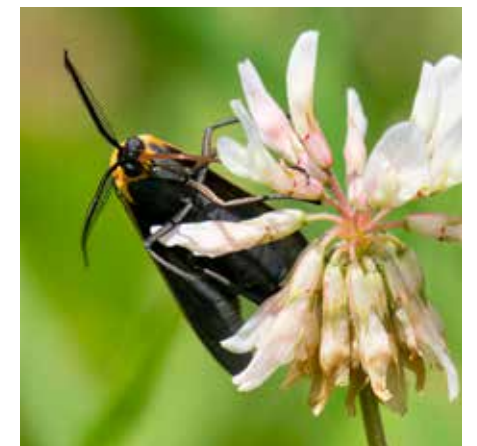


## From the Tap: Source Water Monitoring for Public Health

In regions with historically secure access to clean drinking water, few think about the work that goes into ensuring that the water they fill their cups with is safe. In reality, millions of dollars are invested in the infrastructure, equipment and teams involved in converting source water into drinking water. While all the work that goes into providing clean water often goes unnoticed, analysts like Michele Gilkerson, a water research analyst with the City of Columbus Division of Water, know exactly how much goes into securing safe water for millions of people.

## The Birds and the Bees: Understanding the Diversity of Pollinators

Pollinators of all shapes and sizes are vital to ecosystems around the world. From the wide array of food people eat to the diversity of life around the planet, life would be very different without them. Pollinators are organisms that help carry pollen from one plant to another, and over 350,000 species can be found worldwide, according to The California Department of Fish and Wildlife. With the strong relationship between plants and pollinators, losing either would have detrimental impacts on ecosystems.



## Data in Action: Heidelberg's Nutrient Monitoring in Great Lakes Tributaries

In the early hours of the morning, when most people have yet to hit snooze for the first time, water sampling sites across Ohio are awake and actively collecting nutrient data. The samplers are active at noon, eight in the evening and four in the morning, but very few people would know or even think about the equipment. Included in those few is Jakob Boehler, field manager for the National Center for Water Quality Research (NCWQR) at Heidelberg University. For Boehler, these systems booting up every day represents valuable data points that will be used to educate the public, influence environmental policies and support future research.

# THE EASTERN HELLBENDER:

## NORTH AMERICA'S LARGEST SALAMANDER MAY BE IN TROUBLE



(Left) Illustration: Emma Jones/ Fondriest Environmental. (Right) Photo: Jordy Croffien

The eastern hellbender is a fully aquatic salamander species that inhabits the rivers and streams of the Appalachian region of the U.S. It is the largest salamander in North America, with an average length of 12-20 inches—however, they can grow up to 30 inches and weigh as much as 4 pounds. Eastern hellbenders are identifiable by their large, flattened head and small but widely separated eyes. They are often brown in color but can be gray, yellowish brown and even black.

Rebecca O'Brien, a Ph.D. candidate at Virginia Tech, did not originally plan on studying these amphibians for her doctorate. "I just saw this listing when I was looking for graduate positions. And I didn't know much about hellbenders at the time so I started looking into it. Evolutionarily, they're a really unique species," she explains. O'Brien learned that eastern hellbenders display unusual parental care behavior, which inspired her to learn more about this distinctive species.

### OBSERVING HELLBENDER PARENTAL CARE

Hellbenders are difficult to study during their reproductive season because they spend most of their time underwater and nestled under large rocks at the bottom of rivers and streams. What is known, however, is that male hellbenders will stake out and create nests under these large rocks. Afterward, females will lay eggs, and the males will fertilize the eggs and stay with them until the following spring, according to the Virginia Department of Wildlife Resources.

To get around the challenge of observing hellbenders during their mating cycle, O'Brien and her colleagues have been using artificial habitats to observe these amphibians in an environment that attempts to replicate their natural nests. "It's a square chamber with a long tunnel coming off one corner. So they have this easily defendable space where they can hang out."

O'Brien describes. "What I was working on was taking one of those shelters and making it much taller, and then putting a camera in the roof so that we could film the behaviors going on."

Although she initially worried that the hellbenders wouldn't like their new, larger dens, they responded well, and this allowed O'Brien to observe them like never before.

### DOES WATER QUALITY IMPACT EASTERN HELLBENDER EGG HEALTH?

O'Brien is observing eastern hellbenders during their reproductive cycles to understand how changes in water quality are influencing parental care behavior. According to O'Brien, one of the biggest threats to hellbenders is their declining recruitment, with parental care being vital to the recruitment of young hellbenders.

As water temperature rises, dissolved oxygen levels in that system decline, and because hellbender eggs rely on diffusion for their oxygen, this could cause problems for the eggs. O'Brien is interested in how male parental care behaviors influence this process.

(Right) The animals are brought to the bank to measure their size and assess their health three times during the breeding season.

## THE DECLINING POPULATION OF EASTERN HELLBENDERS OFFERS INSIGHT INTO HOW DECLINING WATER QUALITY CAN HAVE A SEVERE EFFECT ON THE POPULATIONS OF RIVER-DWELLING SPECIES.

"Hellbender dads have the potential to either compensate for the declining dissolved oxygen through their parental care behaviors, or to not do anything," O'Brien explains. "Maybe as dissolved oxygen levels get lower, they spend so much time taking care of themselves that they spend less time taking care of their eggs."

O'Brien described how eastern hellbender males are known to move their tails in a fanning motion to help buffer eggs against hypoxic conditions. However, it is possible that conditions become bad enough that the males may instead revert to behavior that pushes fresh water across their own skin, creating a positive feedback loop that will only provide less oxygen to the eggs.



## EASTERN HELLBENDER POPULATION CONCERNS

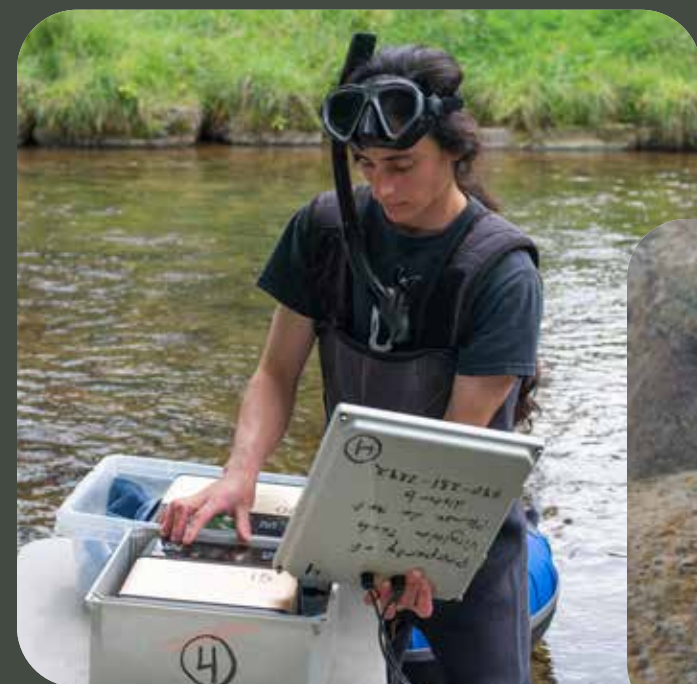
Although the explanation for less recruitment is still not certain, eastern hellbenders are still suffering. The eastern hellbender is listed as endangered in some states, such as Missouri, Ohio, and Alabama. With the difficulty that comes with studying eastern hellbenders in the wild, they are not yet listed as endangered in all states where their populations are thought to be declining, according to the New York Department of Environmental Conservation.

Along with low dissolved oxygen levels, another issue facing hellbenders in regard to water quality is siltation.

"Hellbender larvae depend on these really small spaces in between the gravel and small rocks on the bottom of the creek," says O'Brien. "So if you get a bunch of silt that comes in and fills in all those little spots, there's nowhere for them to go."

Clearing riparian zones along creeks and rivers can be a cause of both of these issues. O'Brien explains that the erosion caused by less vegetation can lead to increasing amounts of sediment entering the water from stormwater runoff. Moreover, reducing the amount of shade a creek receives only perpetuates rises in water temperature and a decline of dissolved oxygen.

"If you get enough siltation, even the big crevices that the adults depend on can get filled in, and then they don't have anywhere to hide," O'Brien explained, also adding, "These guys are so big, that they need high oxygen concentrations in their streams to survive."



## IMPLEMENTING DISCOVERIES

O'Brien believes that the public plays a large role in helping to drive progress in ecological conservation. Land managers, companies and everyday people can play a key role in the connection between scientific discovery and the implementation of that work in the real world.



"It's a lot of learning what people value and tapping into their local norms and learning either how to work within those norms to shift people's approaches towards how they manage their property or to figure out ways to shift those norms," says O'Brien. "Working on private lands enables more conservation work, but it's hard."

The declining population of eastern hellbenders offers insight into how declining water quality can have a severe effect on the populations of river-dwelling species. Small changes in aquatic ecosystems can have cascading effects, but work across the country is being done to monitor and improve water quality for the benefit of all the humans, plants and animals that need it to survive.

Despite the challenges facing conservation efforts, O'Brien remains optimistic about the future, "I think it's so important to pay attention to the success stories that are out there. Because they are out there. Everywhere." <sup>SN</sup>

(Above) Illustration of an Eastern Hellbender protecting eggs.

(Left) Every two days during filming the batteries and data storage devices in the cameras must be exchanged, and can be done without disturbing the animals.

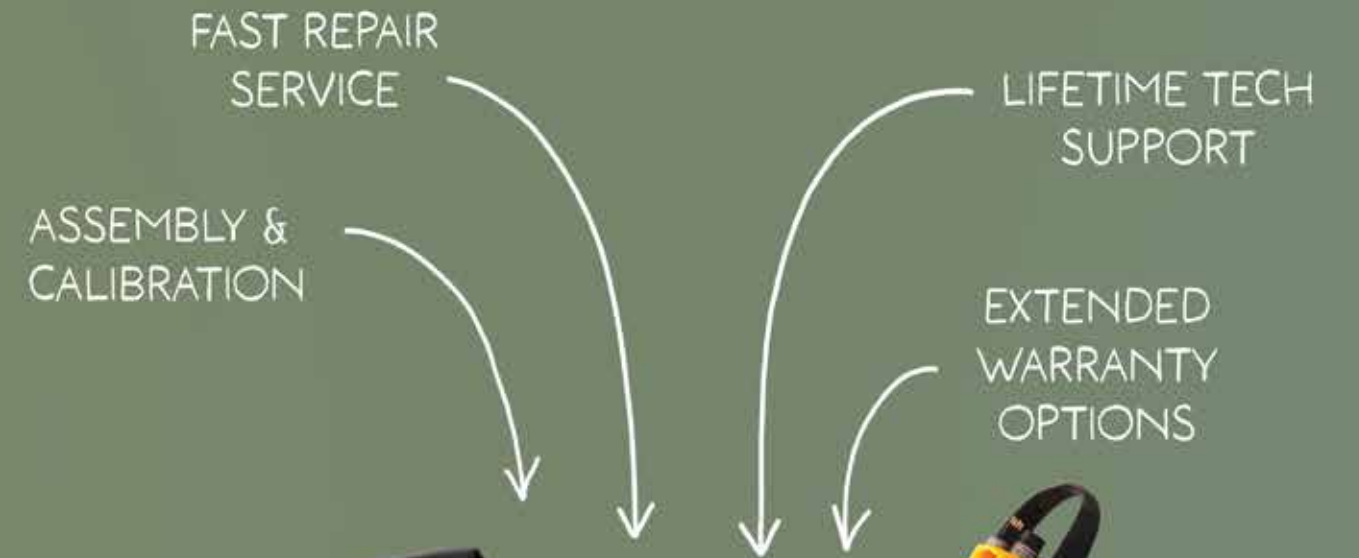
(Right) Eastern Hellbender in its natural habitat.



(Above) Illustration: Emma Jones/ Fondriest Environmental, (Left) Photo: Caleb O'Brien, (Right) Jordy Groffen

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## WILDFIRE SMOKE IN NEW YORK CITY

In the summer of 2023, wildfires in Canada engulfed the northern United States in smoke, blanketing urban and residential areas in the orange haze. Taken on June 7th from "The Top of the Rock," New York City's skyline is obscured by the smoke. Through the veil, the Empire State Building can be made out against the orange sky.

Scientists with the New York State Department of Environmental Conservation's Division of Air Resources spent the smoky weeks monitoring air quality and reporting particulate matter and other air quality conditions to the public. The weeks following the onset of smoke would see New Yorkers wearing masks and spending more time indoors to avoid exposure to the wildfire smoke.

(See "Clearing the Air: Insights into New York's Air Quality Monitoring Network and Strategies," Pg. 36)

# NexSens X3 Data Logger

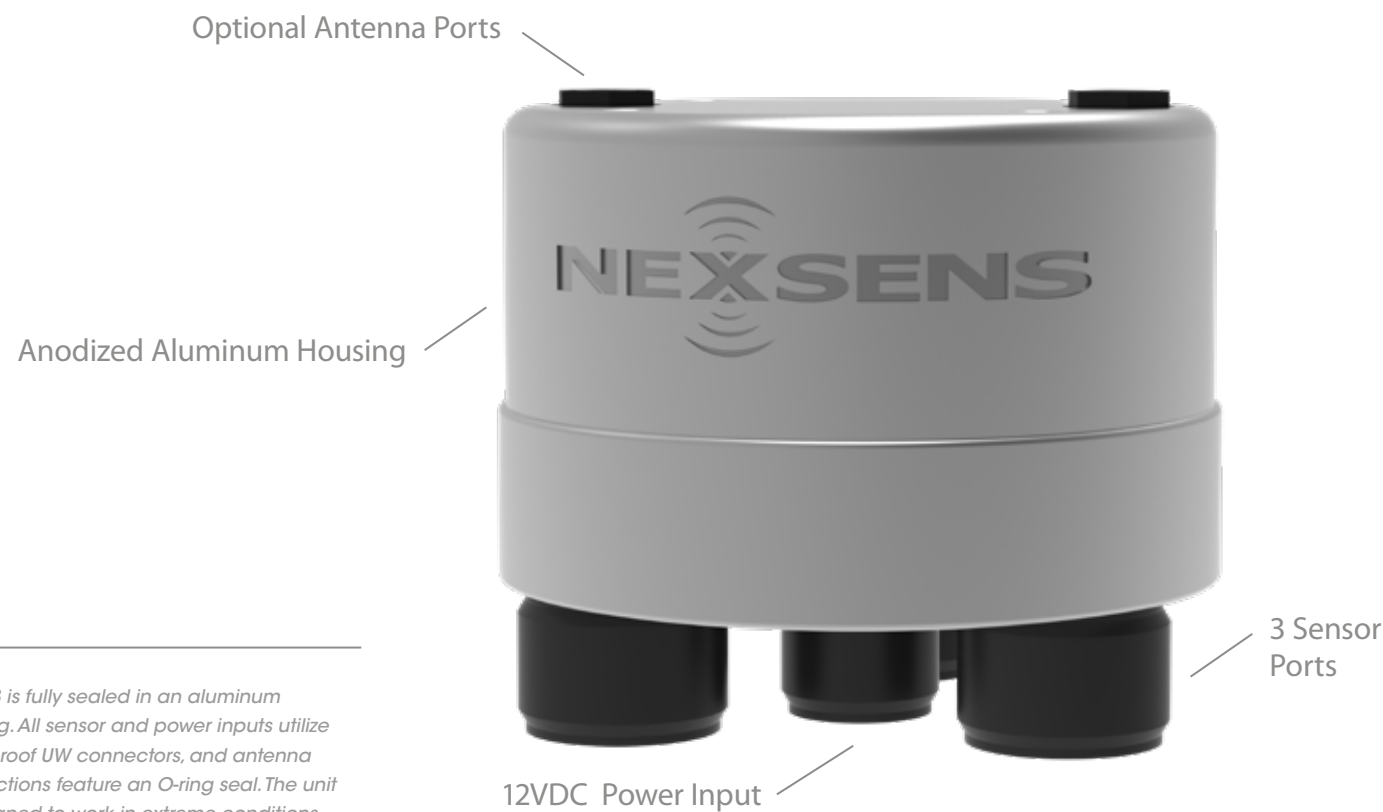
The X3 is an all-in-one environmental data logger designed for both pole/wall mount and buoy-based applications. Measuring only 4.9" (12.45cm) diameter x 4.15" (10.54cm), the palm-sized device is an all-in-one environmental data logger designed for both pole/wall mount and buoy-based applications. The three waterproof sensor ports are compatible with most environmental sensors, including multi-parameter sondes, water quality sensors, temperature strings, ADCPs, water level sensors, and weather stations.

All connections are made with a simple thread-in connector, and the built-in sensor library automatically facilitates setup and configuration. Data is stored on common or independent schedules. Power options include SP-Series Solar Power Packs, AC adapter, or external 12 VDC. Advanced power management combined with ultra-low sleep and run currents extend battery life and eliminate the need for multi-battery arrays or large solar charging systems.

The X3 monitors itself while collecting environmental data—internal temperature, humidity, voltages and currents are constantly recorded, and failure alerts can be sent automatically to a predefined list of contacts. Purchase includes the X3 environmental data logger, sensor port plugs, power port plug, maintenance kit, quick start guide, and wireless antenna (telemetry units only).

## X3 Data Logger Features

- 4G LTE cellular, Iridium satellite, or dual telemetry options
- Marine anodized waterproof housing for deployment in harsh environments
- Uses WQData LIVE web datacenter for instant data access from any web browser



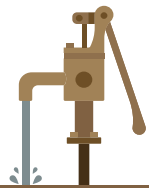
*The X3 is fully sealed in an aluminum housing. All sensor and power inputs utilize waterproof UW connectors, and antenna connections feature an O-ring seal. The unit is designed to work in extreme conditions, including underwater.*





# ESTABLISHING A WATER SHARING PROGRAM IN BANGLADESH

## Solving the Largest Mass Poisoning in History



People in rural communities across the world rely on wells, but not all contain safe drinking water. In Bangladesh, many of their shallow wells are contaminated with the poisonous metalloid, arsenic. Arsenic is tasteless, odorless, and colorless, and has contaminated many wells in SE Asia, particularly in rural Bangladesh. The result, according to the World Health Organization, is the largest mass poisoning in history.

For many years, the government of Bangladesh has been sampling the wells—however, the task is enormous, clean water has not universally been provided, and often awareness of the arsenic problem was not included in the testing/outreach program. In 2018, Robert Kurkjian traveled to Bangladesh as an international consultant and as a Board Member and Technical Advisor for Chemists Without Borders to help sample the wells and develop a solution.

During the 2020 visit, Kurkjian realized that the sampling needed to be updated to be more accurate and the solution needed to include educational initiatives, public investment and community programs built off the data they collect. When Kurkjian returned in 2023, he brought a long-time colleague, Matthew Karanian. As an attorney, policy advisor and Board Member of Environmental

Strategies International, Karanian provided policy and survey guidance in the initiative to establish a Water Sharing Program in Bangladesh. Their work was funded by Chemists Without Borders and a matching grant from DoTerra Healing Hands Foundation.

### ARSENIC CONTAMINATION IN BANGLADESH

Private citizens, international agencies and the government of Bangladesh installed millions of shallow tube wells to help provide water to rural areas while avoiding exposure to cholera in the surface water. Arsenic is naturally occurring in the groundwater of Bangladesh, so when these shallow wells were installed, the source water was already contaminated. The water from the hand-pumped wells was unsafe to drink from, and education surrounding the impacts of arsenic was limited.

A large part of Kurkjian and Karanian's work has been educating the public on the long-term effects of arsenic poisoning. Arsenic is clear, colorless, odorless and tasteless, meaning they had to convince citizens that something they couldn't see or taste was in the water. Beyond that, they had to convince people that exposure to arsenic could be deadly.

Kurkjian and Karanian both explain that a significant part of educating the public on arsenic poisoning is redefining the idea of what poison is. Poison is often thought to be fast-acting, but arsenic consumed at the levels found in the wells may take years to show an impact. Continued exposure to high concentrations of arsenic can lead to the development of conditions like keratosis or melatosis, as well as have adverse impacts on the cognitive function of children.

Kurkjian explains, "It can take decades for it to manifest itself into either cancer or cardiovascular disease." He continues, "They'll say, 'I've been drinking this for 10 years, and nothing's happened.' But we don't really know because the doctors don't diagnose arsenic poisoning. And if somebody dies of it, they have no idea what they actually died from."

### TESTING FOR ARSENIC IN THE WELLS

Prior to Chemists Without Borders, the Bangladesh Department of Public Health and Engineering had tested millions of wells, but they faced delays and obstructions as a result of the COVID-19 pandemic. Chemists Without Borders began testing well water in 2018 in a small community, which was then mapped for evaluation.

The group assisted with sampling wells in Terail, in the Chittagong region. They found that roughly two-thirds of Terail's wells exceeded Bangladesh's safe consumption threshold of 50 parts per billion (ppb). However, even these levels are not necessarily safe if chronically consumed, as arsenic is poisonous even in the lower ppb range to children, according to Kurkjian. Some of the samples revealed wells exceeding 100 ppb, as well as several concentrations of 160 ppb. Data from previous years revealed levels as high as 250 ppb. For comparison, the US Environmental Protection Agency's drinking water standard for arsenic in drinking water is 10 ppb.

*(Left to right) A Chemists Without Borders volunteer, wearing a bright orange scarf, takes a break from her work and washes at one of the many hand-pumped wells in the area.*

*A group of volunteers from Chemists Without Borders testing water samples collected from wells in Terail, Bangladesh, earlier this year.*

*Matthew Karanian (left) and Robert Kurkjian sit beside a man who is celebrating his wedding in the community of Terail.*

*The Chemists Without Borders team pauses for a group photograph at Terail High School in Bangladesh, during their work on the water sharing program. Robert Kurkjian (front row center, with floral shirt) is standing beside Matthew Karanian (blue shirt). Jasmine Nakahigashi, an intern with Chemists Without Borders (blue shawl) and Shahena Begum, project coordinator for Chemists Without Borders (purple burka), are standing in the front row, far right.*

*The Bangladeshi and Armenian flags fly above the courtyard of the Armenian Church of the Holy Resurrection, in Dhaka, Bangladesh.*

*A man sits on the sand at Cox's Bazaar, the world's longest natural sea beach, in Bangladesh.*

*The sun rises over a hazy sky in Dhaka, Bangladesh, during Kurkjian and Karanian's visit earlier this year.*

*Volunteers from Chemists Without Borders during a training session at Terail High School in Bangladesh. The volunteers conducted surveys of local residents, participated in focus groups of the local community, and tested wells for arsenic.*

*A resident of Terail is surveyed inside his home by volunteers of the Chemists Without Borders team, during a site visit earlier this year.*

*A young boy from the village of Terail stops to talk with a volunteer from Chemists Without Borders.*

Photos: Matthew Karanian, Robert Kurkjian, and Chemists Without Borders





The samples were tested using high-quality arsenic field test kits. Then, using data from the tests, the wells were designated as safe or not. Many of the wells they sampled were located inside homes or community areas. As a result, Kurkjian and Karanian were able to interact with the community every day.

During these interactions, the Chemists Without Borders Team, comprised of local college students, conducted surveys, asking local members of the community about their knowledge surrounding arsenic and their opinions on solutions. These surveys revealed critical information that would help advance the Water Sharing Program that Chemists Without Borders was developing.

### WATER SHARING IN BANGLADESH

The idea stems from a solution proposed more than 20 years ago by researchers, including members of the faculty at Columbia University. As the name implies, this program relies on households sharing clean water with their neighbors.

Sampling allows scientists like Kurkjian to identify which of the existing wells are safe. From there, the water distribution is in the community's hands. Investment from the local community will play a major role in the success of the Water Sharing Program, making the surveys Kurkjian and Karanian conducted vital to ensuring the program's success.

"Because if everybody said, 'No, we don't want to share water—this is ours.' We're not going to do it then because it wouldn't work," Kurkjian elaborates. The surveys revealed that 96 percent of respondents in Terail would freely share their water with their neighbor if they had clean water and their neighbor's was contaminated.

Karanian adds, "If we had unlimited resources, if money was no object, we could go and drill a deep water well, for every household in Bangladesh. But that's not an option. And so this water sharing program that Robert is talking about—that's the alternative that gets the cleanest, safest water to the most number of people."

There were limitations to people's willingness to participate. Kurkjian and Karanian documented, "One of the leading concerns of people receiving the water is that they prefer not to carry the water great distances, and typically not more than 100 meters."



Fortunately, Bangladesh's low water use makes water sharing a realistic solution, as citizens would not need to transport high volumes of water. The surveys revealed that the average household only uses about 10-15 liters per household per day. Kurkjian and Karanian note that this is a stark contrast to the United States, wherein residents of California may use as much as 400 liters of water per person per day, including water for irrigation of yards.

### THE ROLE OF PUBLIC INVESTMENT IN INFRASTRUCTURE

Investment from the community is critical to the success of this program. The surveys revealed that people were open to the idea of sharing resources, but Kurkjian and Karanian's confidence in the program was solidified by the success of the community meetings at the local High School that they began hosting on their 2023 visit.

The presence of young people and women at the town halls was one of the most gratifying parts of the process, as it affirmed that the community wanted to be a part of the solution. "They weren't eager to leave the classroom—they came up to us asking more questions, making more inquiries, asking how they could continue to work to improve their communities," states Karanian.

Young people have assisted over the years with the sampling necessary for the project. Kurkjian recalls seeing one young man assisting during the 2023 trip and realizing he had also been helping him during his 2020 trip. Karanian elaborates on the event, "He was a member of that community, a young person who just said 'I want to help make my community better.'"

One of the next steps for the program is to finish sampling and identifying existing safe wells, most of which are deep water (exceeding 100 meters in depth). Next, they will begin testing different areas as potential construction sites for deep water wells. Some of the variabilities they must consider are the location, so it is accessible to locals, and ensuring the source water is safe and plentiful.

*(Left) Volunteers test water samples collected from nearby wells in Terail.*

*(Right) A resident of Terail drinks water from one of the many tube wells in the community.*

Before beginning well installation, hydrogeologists will use electric pumps to evaluate the water supply. They'll assess the withdrawal rate, output volume, source level losses and then calculate how much can be safely extracted. While placing a well approximately every 100 meters may seem like the most accessible option, geological conditions change, and it may not always be possible.

They will need to build off of existing public investment in the program to ensure that these new wells are utilized and remain free for people to use. Kurkjian explains that in some cases, government wells that had been installed ended up with people building fences around them so that they became inaccessible to all of the public. So before building the wells, Kurkjian and his team will work with the public to develop a framework for water sharing.

Past failures of NGOs providing safe water include overlooking the nuances and complexities of rural communities. CWB emphasizes arsenic education and then allowing communities to develop their own system for water sharing based on kinship, social relations and cultural practices.

Kurkjian and Karanian also must consider how the changing climate will impact future conditions in Bangladesh. Climate change leads to the two extremes of flooding and drought—both of which can be detrimental to the water supply.

In rural parts of Bangladesh, there is insufficient sanitation infrastructure, which results in people defecating outside or in pit latrines as alternative options. If flooding occurs, waste can be carried to the wells, contaminating them with a host of bacteria and viruses that make previously clean water unsafe. On the other side of the extremes, long periods of drought lead to the reduction of groundwater levels, leaving less water and potentially higher concentrations of arsenic.

Understanding all of the compounding variables and the importance of civic engagement are necessary for ensuring the Water Sharing Program is successful. Over the past few years, they've learned a great deal about the community, their behaviors and the ways in which they will respond to improved access to clean water.

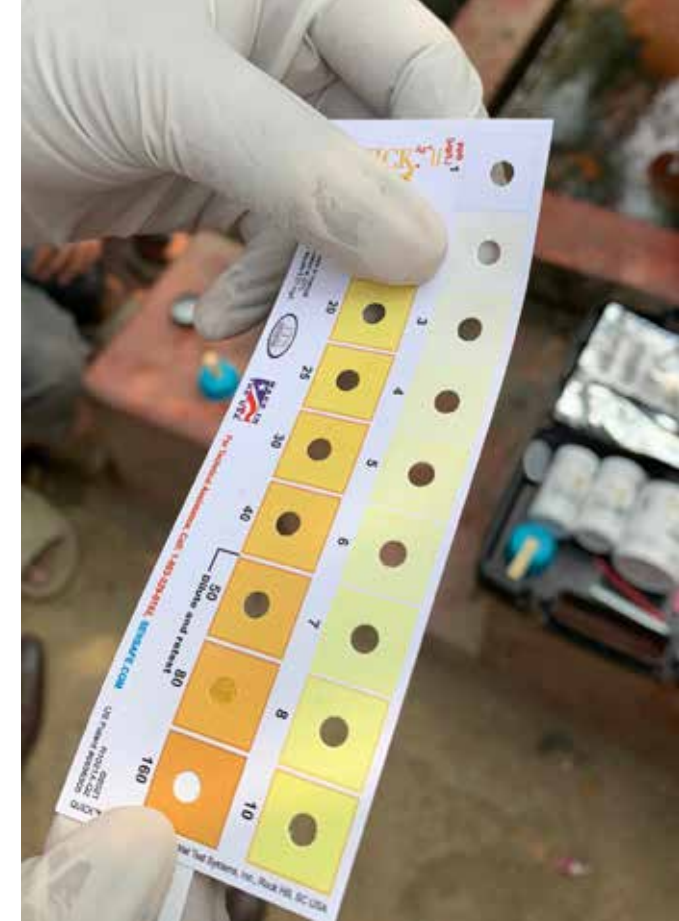
Kurkjian and Karanian are hopeful that they will be able to refine the program through their work in Bangladesh. If successful, the program could work in other parts of the world that are facing difficulties accessing clean water. Kurkjian explains, "The idea is to develop a model that can be replicated throughout the country and elsewhere in the world. That's the ultimate goal." <sup>SB</sup>

For more information, email [robert@environmentalstrategies.org](mailto:robert@environmentalstrategies.org) Or visit [chemistswithoutborders.org](http://chemistswithoutborders.org)

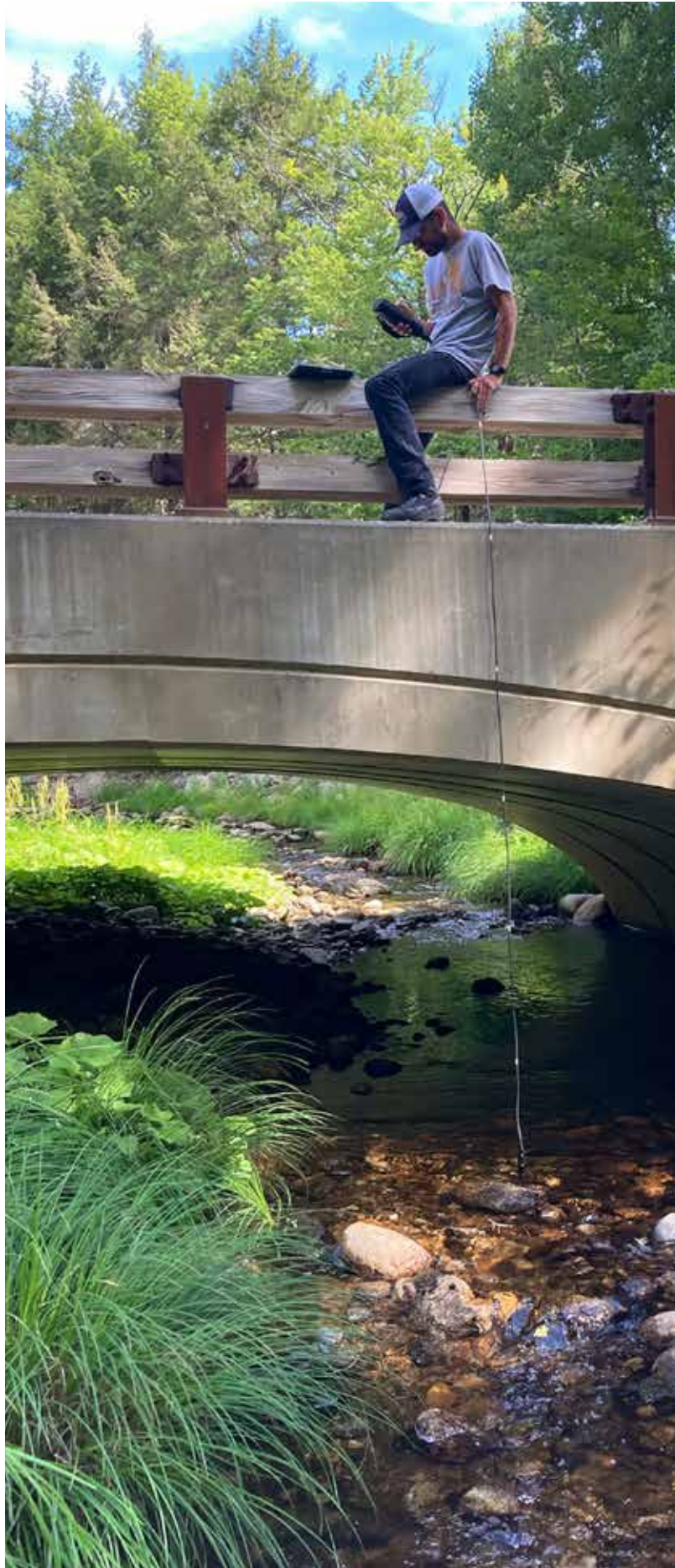
*(Top) A test strip helps volunteers determine the concentration of arsenic in a sample of water.*

*(Middle) A volunteer from Chemists Without Borders (right) meets with high school students in Terail during a public outreach program.*

*(Bottom) A group of children gather spontaneously while volunteers test water samples from their community.*



Photos: Matthew Karanian, Robert Kurkjian, and Chemists Without Borders



# SMALL-SCALE MONITORING FOR LARGE-SCALE IMPACTS:

## *Building Storm Resilience in the Newfound Lake Region*

As many resource managers and conservation groups can attest, their work serves both the environment and the surrounding communities. Dynamic and healthy ecosystems can become center points for towns, cities, and entire regions—such is the case in the Newfound Lake Region, located in central New Hampshire. The Newfound Lake Region Association (NLRA) knows just how critical the preservation of the lake and surrounding watershed is for all members of the region. Paul Pellissier, the NLRA’s Conservation Program Manager, considers everyone living near Newfound Lake to be connected to the water.

*"All conservation work needs to start from a place of education and getting people to come on board to what the mission of our organization is really about."*

– Paul Pellissier

He explains, "You don't have to be a million-dollar shorefront property owner be connected to the Lake. You could be working and living further out in the watershed, and your impacts are just as great as if you were living on the shore."

There's an obvious reason to include young people, as they are the future, but it's also about connecting the community to a resource that can be difficult to access. Newfound Lake has a large seasonal community, with many second homes along the shore and only a handful of public access points to the lake.

Keeping those impacts in mind is particularly important for relatively intact systems with high water quality like Newfound Lake. Fortunately, management doesn't have to focus so much on reviving the watershed; instead, the focus can be centered on small- and large-scale approaches to management that include the public. Pellissier states, "When I see what other lakes are having to do to manage invasives and claw back ecosystem function, I feel fortunate that our task, and large responsibility, is stewarding a relatively healthy ecosystem into the future."

"Getting folks that live in the watershed, especially kids, to experience Newfound Lake in order to better understand that what happens out in the watershed directly influences the health of the lake and is really important. Not only for stewarding the next generation of conservationists but also for the long-term protection of this shared resource," Pellissier states.

### PUBLIC OUTREACH IN THE NEWFOUND LAKE REGION

A large part of that stewardship involves citizen science and education initiatives that engage the local community. The NLRA works with people of all ages and backgrounds in their region.

Educational opportunities are vital for teaching the community about the importance of the system. Pellissier believes the human side of conservation to be critical, stating, "All conservation work needs to start from a place of education and getting people to come on board to what the mission of our organization is really about."

For the Newfound Lake Region, including the community in conservation means securing a future for the system. "You're talking to someone who works with a nonprofit. Public support is kind of our bread and butter. If it wasn't for the support of our community, we wouldn't be able to do our work nearly as effectively as we do," he says. "We're fortunate, our community is very supportive in that way," he continues.

### CONSERVATION APPROACHES

Community support and cooperation are vital for the success of any conservation efforts, no matter how big or small. Groups like the NLRA rely heavily on volunteers to help gather data and protect the environment. Residents of the region have stepped up in Newfound Lake's hour of need, and even those that consider Newfound their second home are invested in the ecosystem's health and preservation. Newfound is considered an oligotrophic lake, meaning it is deep, clear and cold with low nutrient levels.

*(Left) Monitoring Newfound Lake's tributaries allows the NLRA to better understand how these systems are changing and helps to quantify the impact that development is having on water quality in Newfound Lake.*

*(Top) In the steeply sloped Newfound Lake Watershed, mismanaged stormwater can quickly lead to big headaches for property owners and significant downstream environmental impacts.*

*(Bottom) AmeriCorps Watershed Steward, Anthony Jaster, works to maintain an infiltration trench at the Grey Rock Conservation Area. Small-scale stormwater installations protect water quality by slowing down, capturing, and directing runoff away from water bodies to areas where it can infiltrate into the ground.*

Photos: NLRA

As far as monitoring and conservation are concerned, Newfound's characteristics lead to a unique approach to common problems.

Two of the top concerns for Newfound Lake are invasive species, particularly aquatic plants, and pollution from stormwater runoff. In order to protect against both of these variables, the NLRA has spent years building programs and developing standing in the community. Much of the organization's work in defense against invasive species involves volunteer monitoring and prevention.

One of the major routes in which invasives are introduced is through hitchhiking. Boats traveling in nearby waterways may unintentionally stow invasive species on the exterior or interior parts of the boat. For that reason, the NLRA worked with statewide partner NH LAKES to bring the Lake Host program to Newfound. This program provides complimentary boat inspections and educates boaters on invasive species and proper boat care in between use. Since 2002, Lake Hosts have prevented 28 fragments of invasive plants from entering the ecosystem. While seemingly insignificant, the introduction of an invasive species like variable milfoil could harm the delicately balanced ecosystem already established. Milfoil is one of the greatest concerns for invasives in the region as it can be found in nearby lakes and rivers, explains Pellissier.

With that concern in mind, the NLRA also runs a Weed Watchers program and an annual Weed Stampede event. The Weed Watchers program is ongoing and trains volunteers to keep an eye out for variable milfoil and other aquatic invasive plants through monthly surveys. Similarly, the Weed Stampede program seeks out invasives by engaging residents in a two-day, lake-wide event. This past summer, the Weed Stampede program attracted 24 volunteers who paddled 78 miles and logged 81.5 hours of survey time looking for invasive species, Pellissier shares. Thanks to the hard work of volunteers this past summer, 94% of Newfound's near-shore area was able to be surveyed, and no invasive species were found.

Keeping invasives out of Newfound is one of the primary ways the NLRA protects the ecosystem. Keeping the watershed healthy and maintaining ecological function makes it more resilient in the face of a changing climate.

## STORMWATER RESPONSE

Mitigating stormwater and the inevitable nutrient loading that follows is vital for systems like Newfound. Oligotrophic systems like Newfound Lake have lower nutrient levels, and nutrient loading following storm events can throw the system out of balance. Even smaller events can have an impact on the watershed's health, which weakens it in the case of extreme weather events. Newfound Lake is surrounded by steep hills and mountains with highly erodible soil, meaning that in the case of snowmelt or rain, a great deal of sediments flood into the watershed below.

Pellissier explains, "When the soils are saturated, an inch of rain throughout the watershed can raise the level of the lake by as much as 12 inches."

With that in mind, the NLRA has created both small- and large-scale responses to stormwater threats. On the smaller side of things, the NLRA works to conduct stormwater assessments and propose some strategies that homeowners can use to protect the lake. Pellissier describes, "Part of the small-scale stormwater approach is looking at homeowner's property and developing a suite of landscaping practices to limit the concentration of stormwater and increase infiltration on their property."

When deciding how to proceed with a property, vegetative buffers on the shoreline or stream bank are first and foremost. After that, the property owner and the NLRA decide on the best approach to manage runoff on that piece of land specifically.

For example, when accessing the lake, creating a meandering path limits the amount of stormwater that reaches the lake as opposed to a straight path down a slope that funnels the water and causes erosion.

Pellissier highlights driveways, roads and roofs as some of the greatest sources of stormwater concentration. These contributors can be mitigated by ensuring that gutters are terminated into a dry well; ensuring driveways and roads are properly firmed, crowned, and maintained; and finally, ensuring infiltration trenches are deep enough to catch runoff. While the impacts of individuals may not have as large of an impact on the ecosystem as larger town-wide responses, individual actions help build the ecosystem's resistance to environmental stressors.

"By the numbers, it's a different scale but if people feel like they're engaged in protecting the watershed in their daily actions at home and that allows us to be more effective on the bigger stuff," Pellissier highlights.

As it turns out, the "bigger stuff" has become increasingly relevant as extreme weather events become more frequent. Rebecca Hanson, Executive Director of the NLRA, explains, "As we see an increase in development and an increase in high-intensity storms, this threat is expected to grow. Maintaining, and improving, water quality in the lake remains our biggest challenge and our overarching objective. A healthy lake means we have a resilient ecosystem and prosperous local economy."

These large- and small-scale management strategies work in tandem to build up the watershed's resilience to climate change and other environmental stressors. Hanson states, "By implementing stormwater management, we are actively encouraging water to infiltrate into the ground instead of running along the surface, picking up pollutants, causing more erosion, and depositing pollution into the lake."



(Left) NLRA Conservation Program Manager, Paul Pellissier, leads a Weed Watcher workshop—training volunteers in aquatic plant identification, survey techniques, and how to report suspected invasive plant material.

(Right) Twenty-four trained Weed Watcher volunteers took to Newfound Lake as part of the lake-wide Weed Stampede, surveying for invasive aquatic plants. During the two-day event, volunteers paddled 78.5 miles and surveyed over 60% of the lake's near-shore area.

This pollution can lead to nutrient loading in Newfound Lake and even algal blooms. A sudden increase in algal productivity in a system like Newfound would impact the availability of key nutrients and negatively affect native species. "We tackle stormwater both at the small scale—with homeowners and homeowner associations—and at the larger scale involving towns and state agencies," Hanson comments.

Working with both groups helps build the efficacy of the Newfound Lake Watershed Management Plan. Large-scale projects require intensive planning, heavy equipment, and coordinated effort—they also greatly impact the watershed's health.

One large-scale project currently underway began as a result of a major storm event in 2019. The event washed out a stream bank, and now every storm brings more sediment and nutrient pollution to the tributaries below. The NLRA responded to the emergency at the request of local officials and is now working with the Town of Groton and three state agencies to repair the damages and prevent further pollution. If successful, the amount of runoff that reaches the nearby tributary will be massively reduced.

The success of small- and large-scale stormwater management plans works not only to repair current conditions but also embolden future conservation efforts.

*"The watershed is a natural boundary. So many times we put our political boundaries on a map and they don't really mean anything in the context of nature, but we are all connected to each other through the water in the watershed."*


– Paul Pellissier

In regards to their current work in Groton, Hanson explains, "Careful and deliberate communication about this project also directs more folks towards our small-scale stormwater program. I believe it's empowering for homeowners to direct energy and stewardship activities to their own property."

Ultimately, Newfound Lake is a cornerstone of the surrounding community. In 2008 local students from Plymouth State University interviewed members of the community that grew up in the area. The stories were shared with NLRA and are available here. Many of the interviewees mentioned that Newfound Lake is a constant in their life, something that has always been there, never changing. And for a community-based organization like the NLRA, that sense of connection makes their work all that more significant.

Pellissier states, "The watershed is a natural boundary. So many times we put our political boundaries on a map and they don't really mean anything in the context of nature, but we are all connected to each other through the water in the watershed."

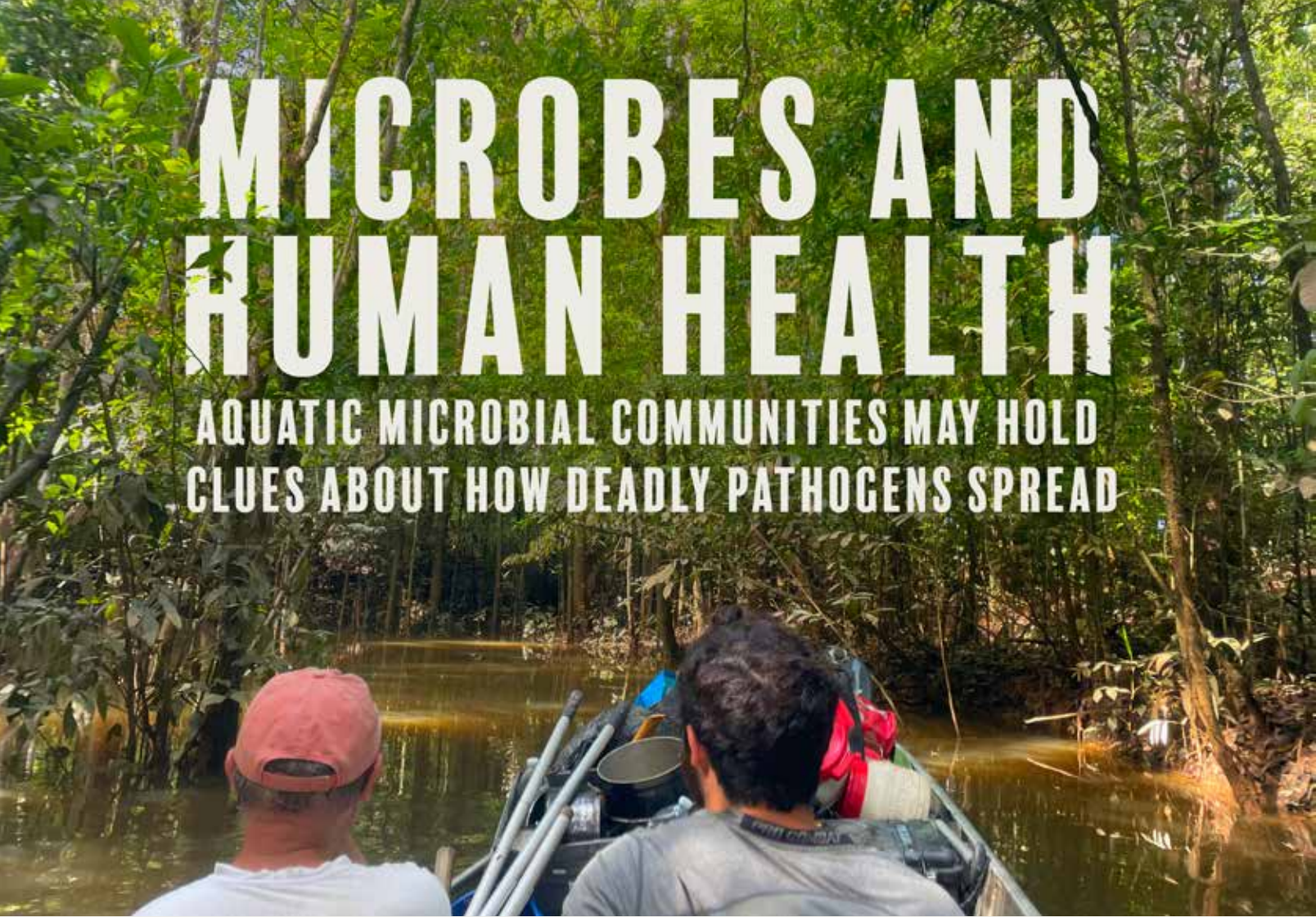
A strong sense of community and communal investment is vital for the work of groups like the NLRA to be successful. Fortunately, Newfound Lake has a large group of supporters who see the importance of protecting the resource. The NLRA works to bring people in by sharing monitoring data and prioritizing outreach. Pellissier explains, "Monitoring helps us communicate the importance and the impact of the work that we do. People often look at the clear water in the lake and assume that everything is good. Having a reliable record of water quality allows us to tell a more nuanced story and helps people understand a much-loved shared resource that much better."

Fortunately, New Hampshire's deep connection to its natural resources makes protecting the Newfound Lake Region easier. Pellissier states, "When I think of this area, I think of that proximity to the lake—that connection to the water is kind of a common identifier." New Hampshire is one of the most forested states in the country, and its ties to nature have run deep throughout the state's history. That investment in the region is what makes conservation so important and rewarding. 

Photos: NLRA

# MICROBES AND HUMAN HEALTH

## AQUATIC MICROBIAL COMMUNITIES MAY HOLD CLUES ABOUT HOW DEADLY PATHOGENS SPREAD



Aquatic ecosystems are incredibly complex, with many different biotic and abiotic factors constantly interacting. Microbial communities are a key part of aquatic ecosystems, involved in the constant flow of energy and recycling of organic matter, according to Science Direct. The true scope of microbial community impacts on aquatic ecosystems is still not entirely understood. Eric Benbow, a professor of community ecology at Michigan State University, is exploring how microbial communities and pathogens may be negatively impacting human health, and how a changing climate could worsen this problem.

### HOW DO PATHOGENS ARISE?

Benbow, along with his students and colleagues, are studying a realm of community ecology that is still relatively unknown. "We're really trying to bring in the microbes within that larger network of organisms," explains Benbow. "Because I think if you start looking at the literature, we're finding that microbes likely drive a lot of processes in ways that we never understood."

Benbow has done work around the world in countries such as Ghana, French Guiana, and others where unstable ecosystems have led to harmful disease outbreaks. Pathogens entering new ecosystems find varying degrees of success based on the conditions present when they arrive.

Benbow explains how microbes can enter a community and immediately become extinguished, may persist for a time but eventually disappear, or may stay around longer.

When non-indigenous pathogens stick around in an ecosystem, they have the opportunity to start negatively affecting its structure. This can occur through resource competition that leads to pathogens outcompeting native species. This harmful restructuring of aquatic ecosystems can cause pathogens to act as invasive species. Benbow hypothesizes that when pathogens become this abundant, humans may come in contact with them and contract diseases that otherwise would not have been found in these bodies of water.

(Above) Entering some of the riverine wetlands of the Sinnamary River that are only accessible by boat.

(Right page, Bottom) The research team doing a standardized sampling of fish, macroinvertebrates, suspended solids of the water column, sediments and water quality conditions.

(Right page, Top) Collecting macroinvertebrates in a small river of the Approuague River, French Guiana.

Photo: Eric Benbow

### CHANGING ABIOTIC CONDITIONS

When native macroinvertebrates and microbes exist in healthy aquatic ecosystems, they efficiently occupy their niche and often prevent invasive pathogens from entering the ecosystem. Benbow wants to know what is changing in these aquatic ecosystems that allow pathogens to take hold and increase sufficiently enough to harm human populations.

The answer, he hypothesizes, lies in the water's abiotic conditions. "The abiotic conditions of the water quality are the habitat template from which you have to start," explains Benbow. "If you understand how one water quality variable really changes the community, like dissolved oxygen, for instance, you can predict how that's going to affect which community members can be in a certain location."

Previous projects done by Benbow and his students have explored this question, manipulating the absence or presence of certain macroinvertebrate species and then observing how pathogens respond to these changes. However, they have taken this a step further, now comparing this absence and presence effect of the microbes of aquatic ecosystems to pathogen growth. Benbow believes there is a possibility that macroinvertebrates do not have a significant impact on pathogen presence—instead, microbial communities are reacting to changing abiotic conditions, which may open the door for pathogens to enter the ecosystem.

"So maybe it has nothing to do with the macroinvertebrate changes, but the microbes associated with plant biofilm, microbes associated with periphyton, or epilithic communities on rocks," Benbow states. "But the abiotic conditions are such that a community member is no longer there, or it's in reduced population numbers so that now this novel genome can get in and take hold and start to persist and start to replicate."

### THE EFFECTS OF A DEGRADING ENVIRONMENT

Environmental change can affect many abiotic factors, such as temperature, sunlight, soil, and nutrient availability. Benbow also believes that microbial communities may also play an important role in regulating ecosystems' health. "Microbes seem to have this unknown potential of importance to environmental condition," says Benbow. "We're in the process of figuring some of that out."




However, microbes can still be negatively impacted by changes in aquatic ecosystem health if they are severe enough. Benbow believes invasive pathogens are able to enter and stake a claim in aquatic ecosystems when certain organisms that are in decline open up the door, and that worsening environmental conditions around the world will only exacerbate this problem.

"I think there's little doubt that more extreme weather events are going to change ecosystems in ways that may allow certain species of human health importance to get in, persist and likely disperse," says Benbow.

Along with the indirect effects of global warming, such as extreme weather, direct human impacts also cause problems for aquatic environments. Pollution, especially when it contains nitrogen and phosphorus fertilizer, creates runoff that leads to eutrophication in bodies of water. "There are examples out there that show that extreme weather events and flooding, combined with pollution can provide the circumstances where you get increased potential pathogens in aquatic ecosystems," says Benbow.

Benbow gives the example of how in southern regions of the United States, where hurricanes lead to flooding, *Vibrio vulnificus*, a bacterial species that can transmit life-threatening diseases, may enter waterways and provide the means for infection in human populations that rely on those waterways. Studies have found that frequent flooding carries eutrophic waters, where *Vibrio vulnificus* thrives, closer to humans, and therefore increases the risk of infection.

The link between microbes, pathogens and environmental changes is still an area of study with many unknowns, but it's one that may provide key insights into preventing harmful diseases from spreading. A documentary has been made that highlights Benbow and others working to understand and solve this issue.

Anthropogenic impacts are intricately tied to ecosystem health and have a major impact on the ecosystem services that humanity relies on. It is a continual reminder of the need to ensure constant and quality monitoring of aquatic ecosystems due to their widespread impacts on human health. 

# The Water of Life

How Understanding Natural Hydrologic Processes in Aquatic Ecosystems Can Lead to a Sustainable Future

From watersheds that provide drinking water, the rain that nourishes plants, to the streams and rivers that help aquatic ecosystems flourish, water is an ever-present and ever-essential part of life. For those like Durrelle Scott, a professor of Biological Systems Engineering at Virginia Tech University, understanding the importance of these natural systems was always a part of life.

The desire to preserve the nation's aquatic resources stems from a childhood spent exploring the lakes and streams that surrounded him growing up in rural Pennsylvania. Now, as a teacher and a researcher, Scott makes it a priority to ensure that people now and in the future appreciate the enormous impact that aquatic ecosystems have on their lives.

"I would say that water connects us all. We all live downstream," remarks Scott. "What's in that water becomes really relevant to you and I as individuals and our human health, as well as how much taxpayer dollars are needed to clean that water up." Hazards and contaminants in aquatic ecosystems pose a huge risk to humans and the ecological system, and Scott is searching for ways to improve their health.

## SEARCHING FOR NEW SOLUTIONS

As humans continue to live, build and farm on new land, the systems and structures of that land change and the natural processes that once fueled the ecosystem are altered. Engineers have devised methods of controlling water flow and distribution, such as levees and dams, but these developments can add to land use pressure. In an effort to not only control water but also to promote sustainability, engineers have turned to "nature-based solutions."

In considering nature-based solutions, Scott states, "How can we harness the potential of biology? Exploring nature-based solutions has enormous potential to maximize human well-being and ecosystems."

In the floodplains that surround rivers, farmland has directed water away from supplying the river itself—instead being harnessed for irrigation and agriculture. Not only does this diminish the healthy supply of water and nutrients into a river, but the water that may eventually make its way downstream has the potential to be contaminated by chemicals used in fertilizers, pesticides and petroleum products that enter waterways via runoff. Runoff itself is caused by storms, irrigation and other disturbances to the landscape.

When so much has been built and altered across a landscape, sacrifices must be made to improve water quality downstream. Scott gives the example of reconnecting streams to rivers with the goal of improving the health and function of floodplains.

"Getting water back out onto a floodplain not only increases ecosystem services but also reduces land for farming. So there are cons but at the same time, it's good for ecosystem services, such as reducing flooding for downstream communities. There are always compromises," explains Scott.

## RESPONDING TO A CHANGING CLIMATE

It is within aquatic ecosystems that some of the most tangible effects of anthropogenic pollution and climate change can be observed. Algal blooms in Lake Erie and rivers have rendered areas unsuitable for recreational activities such as swimming and fishing. Scott added that across the world, rivers such as the Mekong River in Southeast Asia and the Amazon supply those living on them with their main food sources. Therefore, if areas upstream are suddenly contaminated, then people's immediate health and livelihood could be at risk.

Scott explains, "As we go through extended droughts or a very large, catastrophic flood, both disrupt the floodplain biodiversity and some of those services that we collectively all rely on." Understanding how material flows through aquatic ecosystems is important in understanding how it affects the plants, animals and humans who rely on it. This is why Scott and his students are continually learning more about these systems and devising solutions that will benefit both human and ecosystem health as society adapts to the changing climate.

## PUBLIC OUTREACH

Generating public interest and understanding water as a resource and a place to protect is an important step toward water sustainability. The goal of water sustainability ensures that water quality remains at or becomes a level safe for humans and the surrounding ecosystem in the future. "It's something not only just to protect, but it's valuable to us," says Scott. "If we didn't have the natural filtration that occurs in a floodplain or stream channel, we would be spending a lot more money on water treatment."

Tuning the public into why scientists do what they do can be hugely beneficial in garnering support for research and projects. "Use data to help tell the story and understand what's going on, then share that with people," explains Scott.

The students at Virginia Tech have proved to be an inspiration as well. Getting students involved in his research, doing their own and inspiring them to carry the same values and appreciation of hydrology into their careers has been hugely rewarding, says Scott. "I would say that the best part of my job is working with students," he explains. "Then seeing that light bulb moment turn on for the student is just simply fun."

Photos: Sam Dean

Another rewarding aspect of his work at Virginia Tech is seeing his, and his students' discoveries show up in the state legislature. Scott has worked with the Virginia Department of Environmental Quality and the Office of Water Supply, as well as seen his work appear in the State Water Resources plan. Scott remarked on how exciting it has been, restoration-wise, to see the work that he and his students have done in floodplains, and further noted how tangible results can provide great encouragement for future projects.

On campus in Blacksburg, Virginia, students and faculty alike can see the results of a stream restoration project. The StREAM Lab, led by Dr. Cully Hession, a professor in Biological Systems Engineering at Virginia Tech, allows students to participate in hands-on fieldwork near their homes and see the results with their own eyes.

Along with the classes being taught, Scott and his team of students have been able to conduct research in Stroubles Creek, where the StREAM Lab is located. Scott explains, "It's exciting to see both the change that has occurred over the last decade, but [also] how that's really galvanized a future generation of students to seeing the benefits of restoration."

**"How can we harness the potential of biology? Exploring nature-based solutions has enormous potential to maximize human well-being and ecosystems."**

- Durrelle Scott

Preserving watersheds and other natural systems is crucial to ensuring water sustainability in the future—but that is only half the battle. Equipping students with the tools to be future conservationists and innovators, as well as helping the public understand the importance of quality hydrological research and applications, will help lead to the greatest change within these valuable aquatic ecosystems.

Encouraging those around him to see the small victories has helped Scott garner enthusiasm from his students and colleagues.

"How do I share that the 1970s Clean Water Act has made an incredible difference? The small success stories that are happening with some of the sustainable development goals that the UN has, or different stories that help show that each of us can push and make a difference." Scott points out. "I think that's that one of my biggest proactive measures right now: to inspire hope." <sup>SN</sup>

Monitoring for nitrate, DO, and conductivity along the New River

# MARINE COLD SPELLS

## THE FLIP SIDE OF GLOBAL WARMING



(Left) Illustration: Emma Jones/ Fondriest Environmental, (Right) Image: Yuxin Wang

While many of her colleagues around the globe are studying marine heat waves and temperature rise effects related to global warming, Yuxin Wang's team focused on the opposite: global marine cold spells. Wang is a PhD student majoring in physical oceanography at the University of Tasmania.

"Many researchers are focused on the increase in marine heat waves as global warming occurs. Cold spells are receiving less attention," says Wang. "They are important because they can have large impacts on marine life too, even the same magnitude as the heat waves but in the opposite temperature direction."

A "marine cold spell" technically refers to an unusual spell of sea surface temperature, cooler than 90% of what it was previously in one spot the previous year, lasting at least five days. Satellite color degrade (¼ degree (i.e., 0.25 degree latitude x 0.25 degree longitude global grid)) and resolution of the satellite data were considered in the publically available NOAA data that Wang analyzed. Wang says their study shows that cold spells are useful because they can provide information that explains marine ecosystem phenomena.

For example, a previous study found that a severe 2010 cold-water event caused unprecedented mortality to corals of the Florida reef tract and reversed previous survivorship patterns. As a result of the cold spell, there was a shift in ecosystem structure in 2010. The marine cold spell caused 100 times the coral mortalities than a heat wave of similar magnitude.

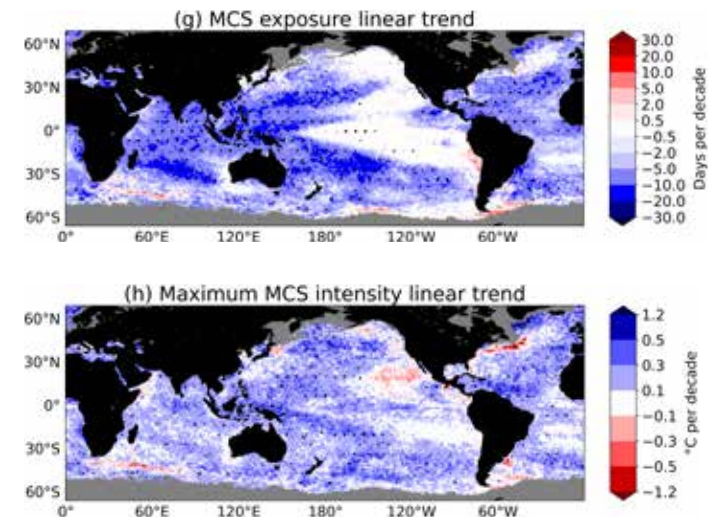
Similarly, a 2021 study examined several multi-year cold spells off the west coast of Australia and the effects they had on fisheries. The study showed that, between 2010 and 2011, there was an ecosystem shift along the coast of Western Australia, where a big heat wave caused a shift in species. However, in 2013 there was a cold spell that helped fish, crabs, and scallops recover.

So, while it may be tempting to say cold spells are harmful to marine life, it is not that simple. Cold spells can also counteract the effects of heat waves and help marine life. So the effects are dependent on the length and depth of the cold spell, other temperature effects going on at the same time, and species type.

Wang's methods included using the NOAA-Optimum Interpolation Sea Surface Temperature (NOAA-OISST), looking at annual satellite properties, changing rates of sea surface temperatures and using color degrade in latitude and longitude.

Wang elaborates, "We were using the NOAA-OISST (¼ degree), which is an observed ocean surface temperature data from satellites to detect marine cold spells. From those cold spells we detected, we calculated some annual properties of cold spells (annual oceanic cold spell days, annual marine cold spell intensity), and we fit trends on those properties to see the changing rate of cold spells.

To test whether it is global mean warming that causes the decrease in cold spells, we generated 500 artificial ocean temperature histories in each oceanic region, and those histories didn't include any long-term warming. Then, we manually added temperature warming trends to those artificial ocean temperature



Trends in marine heatwaves (MHW) and marine cold-spells (MCS) metrics as well as sea surface temperature (SST) properties in National Oceanic and Atmospheric Administration Optimal Interpretation SST over 1982–2020.

histories. If 95% of the histories are found to decrease in cold spells after manually adding the warming trend, then we can say that cold spell decreases are caused by ocean warming, in line with global warming," Wang continues to state, "It's a way of determining if the effects are coming from global warming or not."

Important questions Wang was trying to answer included: what was the global nature of marine cold spells, are their decreases much less than the global increases in heat, and what was the cause of the cold spell changes?

The three key findings of Wang's research were:

- 1) Marine cold spells have been decreasing in intensity and frequency over the globe, with only a quarter of cold spells occurring in recent years compared to those seen in the 1980s, in terms of the global average. This is largely due to global warming instead of internal temperature changes;
- 2) There are changing rates of heat waves and cold spells;
- 3) There are weakening rates of cold spells. These rates are not the same as the increasing rates of marine heat waves and changes in internal variability.

In summary, Wang says, "We expect continued ocean warming, and marine cold spells may disappear, based on what we have seen with the 1982-2020 satellite data. While creature losses from cold spells will decrease due to a loss in intensity, species that are helped by marine cold spells, such as Antarctic krill, are likely to lose their refugia."

# CRYSTAL CLEAR PROBLEMS

## Impacts of Water Transparency in Aquatic Ecosystems

From crystal clear alpine lakes to muddy rivers and boggy swamps, water transparency is an easily observable water quality parameter to anyone who takes a few moments to peer into the (sometimes) murky depths. Water transparency varies dramatically based on the location of bodies of water among different watershed environments, but it can also change quickly due to a variety of internal and external factors.

At Miami University (OH), the Global Change Limnology Lab explores the many ways that water transparency impacts aquatic ecosystems.

Operational for nearly 20 years, the lab trains undergraduate and graduate students and has conducted work from the midwest Great Lakes to Alaska, South America and New Zealand.

The Global Change Limnology Lab, headed by Dr. Craig Williamson, has carried out significant research in its time. Dr. Williamson maintains an extensive database on water transparency, with data from almost 400 lakes. He also served on the United Nations Environmental Effects Assessment Panel as an expert on the effects of UV on aquatic systems.

*(Left) PhD candidate Lauren Knose collects water from Maumee Bay in Lake Erie. Western Lake Erie is plagued by harmful algal blooms. Knose's research investigates the role of dissolved organic matter in controlling the frequency and toxicity of these blooms.*

*(Right) PhD candidate Nicole Berry measures water transparency using an underwater radiometer. The offshore regions of Lakes Michigan and Huron are increasing in transparency. This may expose the early life stages of fish to damaging ultraviolet radiation.*

The lab primarily looks at the factors that control water transparency and how fluctuations in transparency affect aquatic ecosystems. With many bodies of water worldwide facing declines in populations of fish and other organisms, the lab hopes to highlight how vital understanding the effects of water transparency is for protecting these ecosystems.

### EFFECTS OF WATER TRANSPARENCY

Biotic and abiotic factors are both affected by water transparency. Biota can be affected directly via UV radiation and indirectly due to changing abiotic conditions, which often arise externally.

"It's a structuring factor for a lot of things," says Erin Overholt, who received her Master of Science in Zoology from Miami University and is now the Global Change Limnology lab manager. Overholt went on to explain how water transparency influences how deep light penetrates in lakes, which in turn changes temperature, oxygen, and photosynthesis levels.

Light, temperature, and oxygen levels are all imperative to a productive aquatic ecosystem but are also extremely sensitive to changes in water transparency. "Water transparency, aside from being something that people can see and characterize as dirty or clean, also has those underlying water quality variables that it directly influences," says Overholt.

Overholt and students in the Global Change Limnology Lab focus, in part, on how dissolved organic matter within inland lakes impacts transparency. Dissolved organic matter (DOM) is different from sediment or algae, which are considered particulate matter. DOM consists primarily of carbon and other nutrients including nitrogen and phosphorus.

When DOM builds up it absorbs UV wavelengths and reduces UV transparency throughout the water column. "We're primarily interested in UV radiation, and dissolved organic matter selectively absorbs in that wavelength range," says Overholt. The lab has long focused on the effects of UV radiation on aquatic ecosystems and is now at the forefront of understanding the role that DOM plays in changing transparency levels.

### UV TRANSPARENCY AND FRESHWATER BIOTA

In the same way that we can get sunburn or DNA damage from spending too much time in the sun, aquatic organisms can also experience negative impacts from UV exposure, says Overholt. The effects of changing UV radiation levels on aquatic animals, especially in early life stages, are being explored by a student within the Global Change Limnology Lab.

Ph.D. candidate Nikki Berry, along with Overholt, is working on a project studying UV transparency effects on the early life stages of fish, specifically focusing on how UV affects recruitment in the egg and larval stages. Studies have already found that as lakes become clearer, fish are exposed to more UV-B (short wavelength) radiation. While the exact mechanisms causing these declines are still unknown, the Global Change Limnology Lab hypothesizes that the effects of increased UV radiation in the early stages play a significant role in the declining recruitment of some species of young fish.

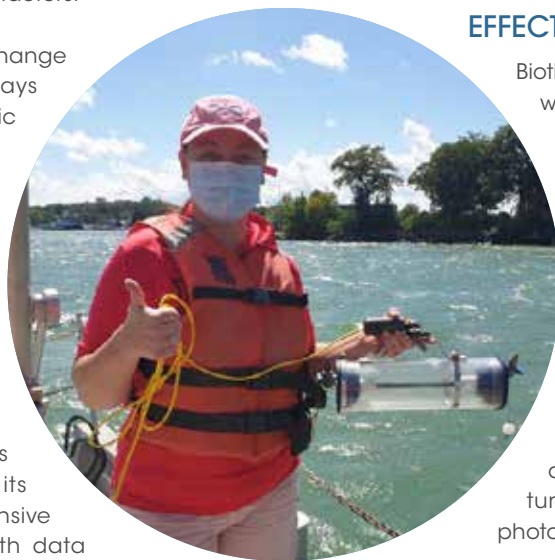
Overholt and Berry study fish found in the Great Lakes because some lakes such as Lakes Michigan and Huron are becoming more transparent to visible light, and may become more transparent to UV light as well. Overholt explains that this increase in transparency is due primarily to invasive zebra mussels that filter algae and nutrients.

While fish larvae may be directly harmed by increased water transparency, decreased transparency can indirectly harm other organisms by altering abiotic conditions. Overholt explains how increased dissolved organic matter could absorb light energy at the surface, limiting how much light travels deeper and heating the surface waters, which could provide ideal temperatures for toxic cyanobacteria.

Changes in the depth to which light penetrates also affect what can live there, what nutrients are released, and the distribution among organisms throughout the water column. When the light becomes limited at deeper depths, algae and cyanobacteria congregate at shallower depths and

produce more oxygen at the surface, but reduce the light that is necessary for photosynthesis to produce oxygen at deeper depths.

As the algae die they settle out, leading to hypoxic conditions deep in the lake. Overholt explains that many zooplankton and fish may be unable to tolerate these conditions and therefore move to shallower areas with higher levels of oxygen.



Photos: (Left) Lauren Knose; (Right) Nicole Berry



"Water transparency controls how much light is available within the water column," says Overholt. "Some organisms are able to detect and avoid harmful UV radiation, so they swim away to avoid damage." The largest migration on Earth occurs when zooplankton move from deeper water, where they spend their days, to shallower depths at night to feed. Light is a major driver of this daily migration. Similarly, algae are found where light is most optimal for photosynthesis.

An increased frequency of harmful algal blooms can also be tied to water transparency, which Overholt believes may be exacerbated by changes in dissolved organic matter. Although widely observed and known to be caused in part by excess nutrient runoff and other human activities, some of the factors that control the frequency and toxicity of these blooms are unknown.

"We're thinking about harmful algal blooms, and we don't know quite what controls them or what controls the toxin production that makes them harmful," says Overholt. "Our lab is at the forefront emphasizing that dissolved organic matter is something that we need to think more about."

### CLIMATE CHANGE AND HUMAN IMPACTS

As with many water quality problems facing the world today, anthropogenic impacts are often at the root of the problem. From climate change-induced droughts that can cause lakes to become clearer, to increased precipitation events that flush dissolved organic matter, fertilizer and pollutants into the water, human activity rapidly changes water transparency.

"There's a lot of ways that climate change interacts with the work that we do," says Overholt, citing the connection between dissolved organic matter and water transparency and how DOM transport within a watershed changes with precipitation levels.

While some may assume that clear lakes indicate a perfectly healthy ecosystem, the work being done by the Global Change Limnology Lab cautions people to think otherwise. "There's a lot



going on below the surface," says Overholt. "So what your initial reaction might be to that body of water might not fully explain what is going on."

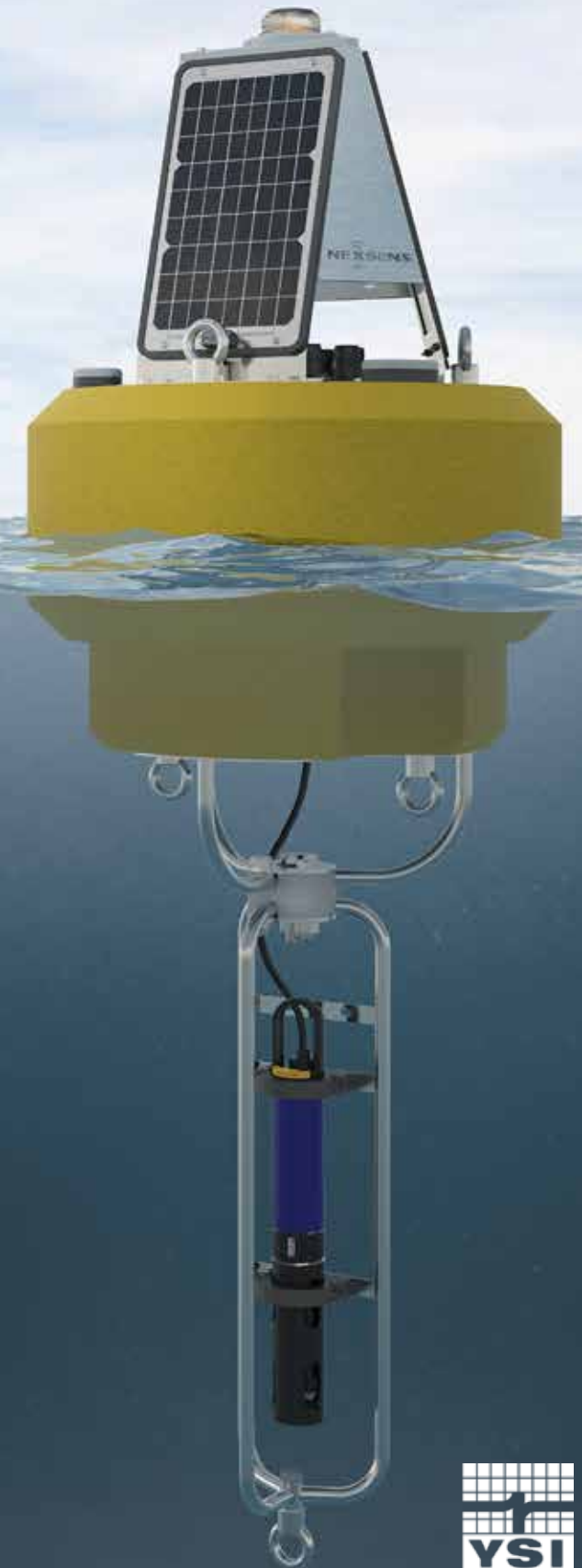
Despite the lab work shedding light on new problems facing aquatic ecosystems, Overholt is optimistic about the future and public understanding surrounding water transparency. Overholt emphasizes that by listening to the scientists, working in citizen science groups, and taking a moment to appreciate the nature around you, all can play a positive role in fostering healthy bodies of water. <sup>SN</sup>

*(Top) With funding from the Ohio Department of Higher Education's Harmful Algal Bloom Research Initiative, a team from Miami University is investigating the role of dissolved organic matter in controlling the frequency and toxicity of harmful algal blooms. Members of the research team sampled 24 mesocosms for eight weeks.*

*(Bottom) PhD candidate Nicole Berry samples under ice on Lake Huron. Many coregonine fish species lay eggs in the fall that will incubate under the ice through the winter.*

Photos: (Top) Erin Overholt; (Bottom) Nicole Berry

# NEXSENS & YSI: AN UNBEATABLE COMBINATION



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# MONITORING VOLCANIC ACTIVITY IN HAWAII



*Aerial image of fissure 3 erupting on the Northeast Rift Zone of Mauna Loa on December 8, 2022. The eruption has built up a cone around the vent, which was 98 feet (30 meters) tall on December 7, 2022.*

The eight main Hawaiian Islands are made up of 15 volcanoes, six of which are active as of 2023. Many locals live on or near an active volcano, making the monitoring and understanding of volcanic activity a core issue of public safety on the islands. Organizations like the Hawaiian Volcano Observatory (HVO) have spent decades monitoring the islands' volcanoes to protect the public, develop a deeper understanding of the islands' volcanos and forecast eruptions whenever possible.

Even those who live away from edifices like Mauna Loa often have connections to the people living near the volcano. It's the pursuit of knowledge and understanding the complexities of volcanic activity that drive the work of scientists like Kevan Kamibayashi, a supervisory electronics technician with the Hawaiian Volcano Observatory.

When Kamibayashi was in intermediate school, a program offered to Native Hawaiian children, Nā Pua No'eau, introduced him to the world of natural science. More specifically, Kamibayashi was enrolled in a program called Rock and Rolls, which was headed by two instructors, Jim Anderson, a professor at the University of Hawai'i at Hilo and Jim Kauchikaua, who was a geophysicist at HVO.

Students would be taken out into the field and taught various survey techniques for lava flow monitoring. "I kind of got hooked to this whole world of geology ever since then," explains Kamibayashi. His experience led him to pursue a geology degree at the University of Hawai'i at Hilo and his later employment at HVO in 1998.

## THE HISTORY OF VOLCANO MONITORING IN HAWAII

Before he became a supervisory electronics technician in 2010, Kamibayashi started working in the geodetic sector of the observatory. At the time, Kamibayashi worked with instruments like GPS, tilt meters, gravimeters, electronic distance measurements, level tilt and anything focused on geodetics and ground deformation. However, both sampling techniques and HVO have changed drastically over the decades.

At the time, the program was comprised of segregated networks that focused on various scientific disciplines. Within the observatory, there would be a group that monitored seismology, ground deformation, gas and geochemistry and a geology group—all of which were disconnected from one another.

Photo: USGS image by T. Oir

(Left) Aerial image of the lava channel issuing from fissure 3, erupting high on the Northeast Rift Zone of Mauna Loa. The reduced lava output at fissure 3 is evident in the low level of lava in the channel. Mauna Kea is visible in the background of the image.

(Right) Image of a webcam deployed to monitor the Northeast Rift Zone eruption of Mauna Loa.



Part of the reason behind this isolation in disciplines was the result of the limitations in technology at the time. "The old analog seismic systems didn't allow for adding additional data streams into the same telemetry network. And so when you expanded these networks to also include GPS, you'd essentially have to build out an entirely separate telemetry system for that type of instrument," explained Kamibayashi.

The organization of HVO changed drastically in 2009 as a result of the American Reinvestment and Recovery Act which allowed HVO to overhaul the monitoring network completely. HVO was able to digitize all of its monitoring capabilities which paved the way for today's monitoring network. Kamibayashi elaborates that you can essentially integrate any instrument with a digital communication capability into the new system.

### MAINTAINING THE HAWAIIAN VOLCANO OBSERVATORY NETWORK

The transition in 2009 allowed the field engineers to be consolidated into one team managed by Kamibayashi. Nowadays, monitoring looks different thanks to the integration of telemetric systems and the use of solar power to maintain the system and remotely receive data. Fieldwork is generally comprised of proactive or reactive maintenance.

Proactive maintenance keeps the network healthy and follows a general routine wherein about 20% of the monitoring network is serviced each year. Alternatively, reactive maintenance involves responding to random outages like premature failures.

A large percentage of the monitoring network is only accessible by helicopter, so researchers spend a lot of time in the air and off-roading to reach sites. Thanks to the integration of telemetry devices, the frequency of these trips has been limited. Kamibayashi explains, "I used to joke around about this and say, 'Well, you know, my job is to check emails and then respond to them.' And that's because we've established alarms and alerts for when there's issues. So when our automated systems see these, then we tend to them."

When fieldwork is necessary, the team prepares by researching and building out new instrumentation packages and monitoring systems in the shop and then preparing for deployment. The variety of the work creates unique challenges but also keeps team members and the advancement of the system from becoming stagnant.

### HOW THE HAWAIIAN VOLCANO OBSERVATORY MONITORS VOLCANIC ACTIVITY

HVO's network is spread out across Mauna Loa, Kīlauea, Hualālai, Kohala and Mauna Kea volcanoes. The 240-site network includes a diverse array of instrumentation and is solar-powered. Some of the devices used in the field include common environmental monitoring equipment like GNSS GPS receivers, tilt meters, gas monitoring instruments and cameras. Alternatively, some equipment is more specialized, like short-period seismometers, accelerometers, infrasound sensors, gravimeters, upward-looking UV spectrometers and a sulfur dioxide (SO<sub>2</sub>) camera.

While most of these sites are standalone instruments, some newer sites have a colocation. Kamibayashi provides an example of an array of 10 sites with upward-looking UV spectrometers that can work together as one system downwind of the volcanic plume and give SO<sub>2</sub> concentrations. For more remote and inaccessible sampling needs, HVO uses drones equipped with LiDARs or other equipment to reach the data they need.

A long-term monitoring system like the HVO network is vital for monitoring and understanding volcanoes. By gathering data over a long period, researchers and scientists can identify shifts and trends that deviate from expected ranges, which may indicate an eruption.

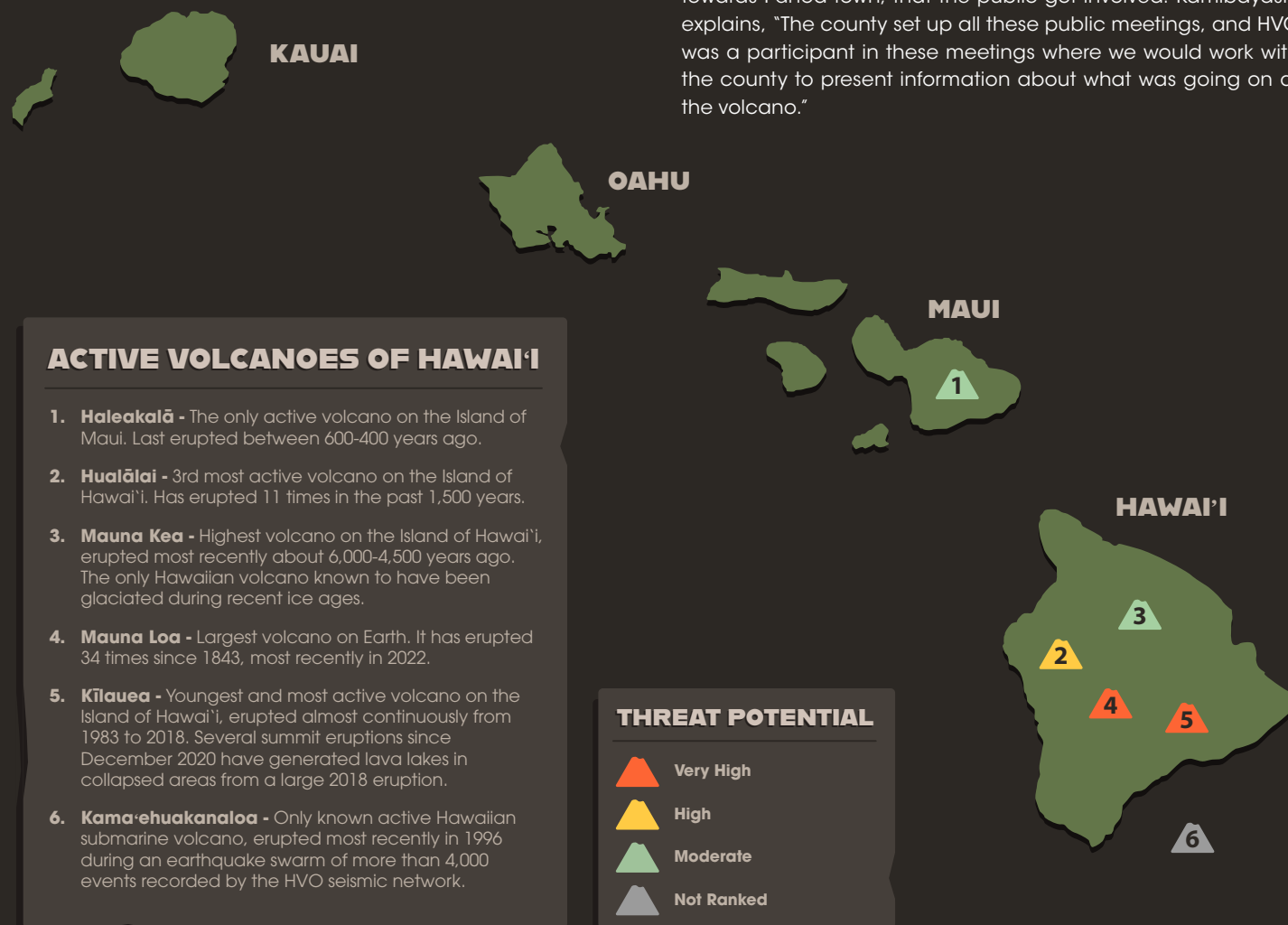
"As an example, Mauna Loa erupted last year at the end of November. Three months leading up to that, we started seeing strange signals and seismic energy, we also started seeing inflation of the volcanic edifice through our tilt meters and GPS stations," states Kamibayashi. "I'm always impressed by what they're able to do and how they're able to visualize what's going on volcanically through looking at essentially squiggly lines and numbers," he continues.

Having access to and being able to interpret the data gathered by the network is what allowed seismologists to confidently say that they could go from the current levels of activity to lava breaching the surface in less than a few hours. HVO then began raising awareness in the communities on the Island of Hawai'i by conducting public meetings and interviews.

### THE SIGNIFICANCE OF VOLCANO MONITORING


While HVO is now considered an authority on eruptions and other volcanic activity, the public was not always invested in the group's work. For many years, volcanic activity was confined within the National Park. It wasn't until 2014, when lava flows started heading towards Pāhoā town, that the public got involved. Kamibayashi explains, "The county set up all these public meetings, and HVO was a participant in these meetings where we would work with the county to present information about what was going on at the volcano."

Photos: (Left) P. Doherty / USGS; (Right) USGS; Infographic: Emma Jones / Fondriest Environmental; Infographic Content: USGS HVO



The Pāhoā community meetings were a major milestone in building relationships with the public, according to Kamibayashi. The flows had the potential of cutting off access to a big part of the island where people live, so the public was invested in learning about the volcanos and what HVO was observing. Kamibayashi says that these meetings were significant for the organization as well because the public was learning, and their interest paved the way for the outreach the observatory does today.

The strength of that relationship has been demonstrated in every major eruption since Pāhoā. The combined work of researchers, scientists and the public information department helped solidify the positive relationship reflected today. Those relationships are meaningful because people live on these volcanoes; having those connections makes minimizing and avoiding harm easier.

The power of outreach and reliability is evident from the success of Mauna Loa's disaster mitigation efforts. Thanks to the continued communication of HVO, no one was harmed in the 2022 eruption. While eruptions are never good, Kamibayashi explains, "It is rewarding to know that we were able to detect it, we were able to warn the public about it and as a result, no one was hurt or injured." He goes on to state, "I think it's one of the things that drives us—it's probably the reason people work too much!" 

*(Top) Webcam sentinels stand watch over the new eruption within Halema'uma'u Crater, at the summit of Kīlauea, in the early morning hours of January 6, 2023.*

*(Left) A Hawaiian Volcano Observatory technician replaces batteries on the Hualālai repeater station. The station, which relays monitoring signals from nearby stations back to the observatory, is powered by batteries that store energy generated by solar panels.*

*(Middle) A close up of the small lava fountain at the upwelling source of the eastern lava lake in Halema'uma'u, at the summit of Kīlauea. The fountain is adjacent to a small island of solidified lava.*

*(Right) The KWcam webcam, on the west rim of Kīlauea caldera, was upgraded on January 4, 2023, to a more advanced model, which provides a slightly wider view and higher image quality. This should provide an improved view of any future activity in Halema'uma'u. In this photo, an HVO scientist begins the process of the webcam swap.*

Photos: (Top) J.M. Chang, / USGS; (Left) M. Warren / USGS; (Middle & Right) M. Patrick / USGS

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# CLEARING THE AIR

## INSIGHTS INTO NEW YORK'S AIR QUALITY MONITORING NETWORK AND STRATEGIES

"AIR QUALITY ALERT" warnings dominate television screens across the U.S. as pollen counts climb and air pollution worsens. While stories cautioning against people going outside and increases in air contaminants skyrocket mostly during the summer, air quality monitoring occurs year-round and has been for decades.

Dirk Felton, a research scientist with the New York State Department of Environmental Conservation's Division of Air Resources, has been monitoring air quality and pollution since 1994. During his time with the NYSDEC, Felton has worked on the state's complex air quality monitoring network. The collection of systems assess particulate matter (PM-2.5 and PM-10), carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO<sub>2</sub>), ozone (O<sub>3</sub>), sulfur dioxide (SO<sub>2</sub>) and air toxics—all of which influence air quality and can be hazardous to human health.

### HOW AIR POLLUTION IS MONITORED

Air pollution is monitored through several EPA standards that are intended to not only protect the environment but also public health. Felton explains, "Every five years the EPA revises, reviews the current standard and decides if the current published literature regarding health effects of pollution warrant an increase, or a decrease in the current level, instrumentation or monitoring network design."

He continues, "When that's published as a final National Ambient Air Quality Standards (NAAQS) we have to respond accordingly, and either modify our monitoring network and the type of instruments that are approved for that network, and produce data that are acceptable, so that we know that the air quality is meeting standards for the people in New York."

The NYSDEC has 50 stations statewide that monitor air pollution, a dozen or so of which are part of the state's Air Toxics Program. Most of these systems are continuous and integrated with real-time technology, but half of the PM monitors are filter-based, requiring more frequent maintenance.

The live PM-2.5 and ozone data gathered by the system is used to create the air quality index and provide visibility to the public.

Felton explains, "Our network provides hourly data statewide from more than 40 of the sites and that data goes to our website, as well as to the EPA's AirNow database." Both resources are available to the public, and the AirNow database allows people to track the movement of pollution across the country.

Each station is comprised of different equipment depending on the needs of the surrounding area. The equipment and stations also depend on whether Federal Reference Methods (FRMs), Federal Equivalent Methods (FEMs) or a combination of the two are being used. Methods include the use of filter analysis, continuous PM analyzers, ozone monitoring, gas analyzers, ultra-fine particle counters, continuous formaldehyde monitoring and auto-system gas chromatography.

When air quality declines as a result of ozone episodes caused by photochemical reactions between volatile organic compounds and other emissions, including NO<sub>2</sub> in the atmosphere, or wildfire smoke, as was the case recently, there is little the NYSDEC can do to control the event once it's begun. Even with control strategies and various prevention strategies, air quality events may still occur, and according to Felton, "The one thing we can do is track it."

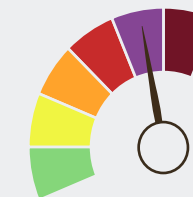
The sources of particulate matter can be speciated through specific equipment that measure things like black carbon. Looking for indicators of wildfire smoke and wood smoke can help provide more information on where the state can improve their control strategies as well as seeing how close they were to attainment, excluding the event.

### WHY MONITOR AIR QUALITY

Air pollution can have long- and short-term impacts on human health, making the live data gathered by the NYSDEC air quality monitoring system highly valuable for people hoping to protect themselves. Ozone primarily affects the lungs, while PM 2.5 can impact the lungs and cardiovascular system. The system allows the NYSDEC to forecast air quality and gives people a visual to help them decide when to go out and exercise during a certain time of the day or choose a different day.

The standards specified in the NAAQS exist in order to protect human health. As the impacts of pollution become better understood, the standards adjust to reflect the latest research. Organizations like the NYSDEC also adjust as time goes on, implementing newer and more precise monitoring equipment and control strategies to limit pollution.

When the PM-2.5 Program first began, levels exceeded EPA standards in parts of the state, but over time, air quality has improved. Statewide, New York meets the NAAQS threshold for PM-2.5, but potential reductions in



**"OUR NETWORK PROVIDES HOURLY DATA STATEWIDE FROM MORE THAN 40 OF THE SITES AND THAT DATA GOES TO OUR WEBSITE, AS WELL AS TO THE EPA'S AIRNOW DATABASE."**

**- DIRK FELTON**

acceptable levels may mean that the state will need to update its network and current control strategies. Parts of New York are not in attainment of the ozone NAAQS including New York City, Long Island and the lower Hudson Valley.

The attainment area New York is responsible for extends beyond the state's borders—"You can have an [ozone] episode that starts in Maryland and goes up through New Jersey and through New York City, and then head to Connecticut—because Connecticut is part of our ozone non-attainment area, we're responsible for those levels in Connecticut, because we're contributing to them," states Felton.

Pollution originating from other states or countries can also influence New York's attainment of NAAQS standards. The wildfire smoke that traveled from Canada and blanketed the region in smog will have an impact on the state's daily and annual levels despite the state being unable to control the pollutant.

The multi-state nature of the ozone problem makes it all the more difficult to solve. Felton elaborates, "It's not something that we can just figure out precisely what to control and put a stop to it. We have to work on strategies for a long time, and there's a lot of new research focusing on this particular problem."

As air quality monitoring programs become more advanced, the EPA seeks to optimize systems and unify data from across the country. Felton says that one of the major changes happening is that the EPA is working to create an algorithm that will be installed in the firmware of PM-2.5 instruments to make results more consistent from one instrument vendor to another.

For years, states may have had some bias in comparison to neighboring states due to differing instrumentation, making the direct comparison between state attainment levels difficult. "We're sort of in a new era where the EPA is looking at the warts of the system and saying, 'you know, we could improve upon this instrument,'" explains Felton.

"I think PM 2.5 is fascinating [ . . . ] It's important that they're responding to the health impacts of this—and they're saying that we need to continue to lower the standard to keep people healthy," states Felton. Since 1970, the PM NAAQS have been revised many times to reflect current research and knowledge surrounding health and air quality. PM-2.5 monitoring started in 1999 and the EPA is looking to update the current standards once again. <sup>SB</sup>



Felton working on a rooftop air monitoring site with DEC and DOH equipment.

(Right) PM-10 inlet

Photos: NYSDEC

# LAKE MALAWI

## A Treasure to Protect

Lake Malawi (also known as Lake Nyasa and Lake Niassa) doubles as a Rift Valley Lake and one of the seven African Great Lakes. Due to its unique biodiversity, it's a great place to conduct limnological studies. Harvey Bootsma is a professor for the School of Freshwater Sciences at the University of Wisconsin-Milwaukee and has had an interest in limnology ever since he was a kid.

Bootsma fondly recalls summer vacations to Georgian Bay, Ontario. "I probably spent as much time in the water as I did out of it." He continues, "I remember telling myself, 'I'm going to get a job where I can stay here all the time.'" While Harvey didn't end up working on Georgian Bay, he was offered a job working on Lake Malawi. He continued working there while completing his Ph.D. While studying Lake Malawi, Bootsma learned about its significance to the culture, health and wellness of surrounding communities.

### THE ROLE OF LAKE MALAWI

According to Bootsma, Lake Malawi is used as a mode of transportation, as parts of the massive lake are inaccessible by road due to the rugged, mountainous shoreline that comes with being a Rift Valley lake. The water is also used domestically by those living in the region for drinking, bathing, washing and recreation.



Agriculturally, the water is used to irrigate small local farms as well as larger industrial farms, such as sugar plantations. Additionally, the Shire River that flows out of Lake Malawi is "the primary source of electricity for that region," explains Bootsma. The electricity comes from hydroelectric dams that depend on the lake level remaining high enough to discharge water into the Shire River.

Lake Malawi also serves as a very important source of food and water. Usipa, or lake sardines, are just one example of an abundant fish that is harvested widely for food, as well as for income. Bootsma explains that "Lake Malawi has more species of fish than any other lake in the world," supplying the region with a wide variety of food and economic opportunities.

The biodiversity of the lake draws a great deal of global attention. In fact, Lake Malawi has been named a World Heritage Site by UNESCO due to its captivating beauty and remarkable aquatic biodiversity. Tourism helps to fuel Malawi's economy because it brings in foreign exchange currency needed for Malawi's trade in the global market.

### THREATS TO LAKE MALAWI

The natural world is frequently burdened by human impacts, such as intensive land use and global warming. Lake Malawi and the surrounding population face each of these threats; however, these disturbances can be reduced or even eradicated with water quality monitoring.

Unsustainable practices like overfishing are obvious problems because they threaten the natural biodiversity and productivity of the ecosystem. Agricultural land use also puts pressure on the lake because it can cause heavy soil erosion, which Bootsma explains can dramatically affect water clarity and bring harm to species that depend on visual cues for breeding and other biological processes. When female fish can no longer recognize males of the same species, it can negatively affect their reproductive rates and fecundity, and even result in hybridization and the loss of genetic diversity.

(Left Page, Top) Nearshore fish community.

(Left Page, Left) Vincent Chiwanda and Harvey looking at sonde data.

(Right Page, Left) Kids with usipa.

(Right Page, Right) Lakefly emergence from Lake Malawi.

Agriculture also increases the likelihood of nutrient loading in Lake Malawi, which can cause harmful algal blooms. While the lake's food web relies on algal production, excessive algal growth can lead to a loss of dissolved oxygen from the water once the algae dies and decomposes, restricting the areas where fish can live. Higher nutrient loads can also promote the growth of potentially toxic cyanobacteria, which can cause fish kills and affect human health.

As supported by several decades of data, climate change is undoubtedly warming Lake Malawi. Warmer lake temperatures impact the way the lake's surface water (the epilimnion) mixes with deeper, phosphorus-rich water (the hypolimnion).

Because phytoplankton growth in the epilimnion depends largely on the delivery of nutrients from the hypolimnion, any changes in the lake's mixing patterns will ultimately affect phytoplankton production in the lake, which will affect fish production and food supply. Warmer lake temperatures may also increase the likelihood of toxic cyanobacteria growth.

Climate change does not just mean warmer temperatures; it is also inspiring changes in rainfall patterns around the world. In Malawi, Bootsma explains that the frequency of cyclones and heavy rainfall events is expected to increase as climate change persists, which would generate even more soil erosion. Bootsma proceeds to explain, "Not only does the erosion negatively affect the lake's water quality; it also removes important nutrients from the land, reducing soil fertility and therefore negatively affecting crop production."

### HOW TO MITIGATE ENVIRONMENTAL STRESSORS

Bootsma believes that one step to identifying and alleviating these environmental stressors is through water quality monitoring. With proper equipment and expertise, Bootsma is confident that a better understanding of how Lake Malawi is responding to these disruptions will improve the ability to develop management strategies that can mitigate the damage caused by these stressors and provide human populations around the lake with the information needed to adapt to change.



Critical components of a water quality monitoring system include sensors on buoys and regular sampling to measure variables such as nutrient and plankton concentrations. The information gained from monitoring programs not only indicates how the lake has changed over time but can also be used to guide the development of numerical models that can help predict how the lake will respond to future stressors.

With initial support from a Fulbright Scholarship, Bootsma has been working with scientists in several Malawi government agencies to establish a monitoring program on Lake Malawi, but Malawi and the other two riparian countries (Mozambique and Tanzania) will need continued support from the international community if they are to develop and sustain an ongoing, effective monitoring program.

Due to the widespread dependence on this lake, local communities strongly support increased monitoring procedures. Bootsma explains that regional students and government scientists are passionate about the need for research and monitoring of Lake Malawi. They understand the importance of this lake and its astounding qualities better than anyone.

Implementing a continuous monitoring program in Lake Malawi could help predict scenarios that may negatively affect the lake and the services it provides. For example, if climate models suggest a period of low rainfall is coming, action could be taken to optimize hydroelectric dams and develop alternative energy sources.

Monitoring will also help to better understand changes that are already occurring in the lake. Bootsma points out that there have been multiple mass fish kills within the lake, and the specific cause is unknown. With an effective monitoring program in place, data could be gathered that may explain what is killing these fish.

Given that Lake Malawi serves millions of people and is home to Earth's most diverse community of freshwater fishes, protecting and restoring it deserves to be prioritized. The technology that is needed to establish an effective water quality monitoring program exists, but the expense and logistic challenges make it difficult for regional management agencies to realize. Bootsma's work in Malawi serves as an important reminder that monitoring is essential for the health and protection of regions across the world. 🌍

Photos: Harvey Bootsma & Melinda Bootsma



# MONITORING HEALING

## ENVIRONMENTAL CLEANUP & COMMUNITY RESILIENCE IN EAST PALESTINE

On February 3rd, 2023, East Palestine was devastated by a train derailment that led to the introduction of hazardous materials into the air, soil and waterways. Around 9:00 pm, an overheated wheel bearing led to the derailment of 38 Norfolk Southern rail cars, 11 of which contained hazardous materials.

Local hazmat groups were the first to respond to the emergency—one of whom was Kevin Clark, an on-scene coordinator with the EPA. The night Clark arrived, he was there in his volunteer hazmat capacity, and he knew that the cleanup would require EPA involvement. Mark Durno, EPA Region 5's Homeland Security Coordinator, summarized the call, "He called one of our phone duty officers and said, 'Hey, this is one of the biggest ones I've seen. You guys need to send the cavalry.'"

Following the call for help, the EPA mobilized teams from EPA Regions 3 and 5 to help respond. As soon as the teams arrived, they immediately started supporting Ohio EPA by setting up stationary and roving air monitoring systems. Over the week following the vent-and-burn event that occurred a few days after the EPA's arrival, the team realized the response would require significant time and effort from numerous parties.

While the EPA had originally planned to step back and leave the long-term cleanup project oversight remaining with the Ohio EPA, the ash and soot cloud, paired with other environmental impacts, raised the project's stakes. Durno explains, "We realized that there was no way the federal government was stepping back from the situation."



On February 21st, the EPA issued a unilateral administrative order to Norfolk Southern, effectively becoming the lead agency for this response. While the EPA took over as the lead agency, local groups have remained actively involved in the monitoring and cleanup process, as the effects of the derailment could spread and stay in the landscape for years.

### IMPACTS OF THE TRAIN DERAILMENT

These long and short-term effects originate from three primary chemicals of concern: vinyl chloride, n-butyl acrylate and 2-ethylhexyl acrylate. When the derailment occurred, fires resulting from the destroyed tankers led to concerns that the vinyl chloride could lead to an explosion. To prevent this, the railroad company, Norfolk Southern, controlled the release in a vent-and-burn event. The EPA closely monitored conditions before, after and during the event.

A significant butyl acrylate release along with some petroleum products contaminated Sulphur Run. The effects of this particular contamination could reach far beyond the boundaries of East Palestine. Sulphur Run flows through the town and then meets Leslie Run, which connects to a series of other creeks, like Little Beaver and Bull Creek, that link the Ohio River with the contaminants.

Following the spill, there was a substantial fish kill as well as the loss of many other aquatic organisms, totaling around 40,000 organisms. Thanks to the EPA's efforts, the region has seen the return of some native aquatic species. Endangered Eastern Hellbender Salamanders, small fish and minnows have returned to Little Beaver Creek.

While there have been great milestones of success over the past few months, there is still a great deal of work that must be done. "It's still a work in progress," says Durno.

The primary long-term concern is drinking water. While the cleanup plan is comprehensive, it is impossible to guarantee that the site will be entirely clean—"You can never guarantee that you're going to get every molecule of the contaminants out of the soil," states Durno.

Photos: EPA

Monitoring sources for drinking water will be managed by the Ohio EPA once the Unified Command has completed the initial cleanup. The Ohio EPA is establishing sentinel wells as an early warning system that will be monitored and help discover contaminants in groundwater.

Regarding short-term concerns, the EPA is most concerned with completing the cleanup of Leslie Run. At the same time, they are focused on following community concerns and monitoring the area. When necessary and possible, the EPA will conduct further assessments to help ease public concerns.

While the area directly below the tracks has been cleared, more sampling is still needed. North of the tracks, where the tankers were burned, the EPA plans to assess the area and determine what contaminants might still linger. The short-term plans for the project are to continue the cleanup process and conduct surveys to assess the health of the landscape.

### MONITORING CHEMICAL SPILLS

Air, water and soil monitoring have been cornerstones of the EPA's efforts following the derailment. The system combines telemetry, handhelds and roving stations that gather environmental data. Devices equipped with telemetry allow the team to transfer data from the field, making it accessible elsewhere.

(Left) Crash site recovery operations.

(Right) Norfolk Southern and EPA conducting soil sampling beneath the excavated rail track area.



**“REAL-TIME DATA COLLECTION ALLOWS FOR DECISIONS TO BE MADE IN REAL TIME”**

**- JAMES JUSTICE**

While some instruments deployed in East Palestine passively collect and send data to the cloud over time, manual sampling is regularly conducted as well. This mixture ensures the remote devices are working correctly. James Justice, an on-scene coordinator with the EPA, describes this partnership as a combination of monitoring and sampling.

In terms of air monitoring, the EPA utilizes five gas meters that include photoionization detector (PID) lamps. These lamps can measure a wide range of chemicals with ionization potentials within the range of the lamp. They also use Summa canisters to sample for a large list of compounds, and sorbent tubes and badges for specific chemicals. Following the initial vent-and-burn event, the EPA deployed several Single Point Monitor Flex Units to monitor for hydrogen chloride and phosgene—potential toxic byproducts of the burning of vinyl chloride.

As the cleanup project has stretched on, the monitoring has continued and gotten more advanced. Additional technology like the Trace Atmospheric Gas Analyzer (TAGA), a self-contained mobile mass spectrometer that can be tuned to monitor specific chemicals, has been deployed. The EPA also has a portable Gas Chromatography-Mass Spectrometry Unit, which is stationed wherever there are complaints of odors that may indicate contaminants. Norfolk Southern supplied a Proton Transfer Reaction Mass Spectrometry unit, a mobile laboratory similar to the TAGA but more precise, capable of monitoring single parts per billion.

Through the partnership of real-time and manual monitoring, the EPA has been able to better understand the spill's impacts on the region and how to move forward. Justice explains, "Real-time data collection allows for decisions to be made in real time,

like proper engineer controls, or even stopping work if we start seeing things on the air monitoring equipment.” He continues, “Air monitoring and sampling will continue until those other areas are all assessed and have been remediated as needed.”

## CLEAN UP AND HEALING FROM THE DERAILMENT

While derailments can be devastating to the local environment, they can also become traumatizing events for local people. Destroyed property, health issues connected to the disaster, fear of another incident and long-term anxiety surrounding the safety of drinking water and air quality are all common stressors following incidents like the East Palestine derailment. Monitoring and restoration efforts will help begin the long process of healing from this traumatic event.

The first step was removing the debris from the derailment, then clearing the streams and terrain. While the long-term cleanup strategy is still being discussed, Norfolk Southern is expected to remediate local waterways to residential standards and take on the responsibility and liability of funding the cleanup. Specifics on long-term surface water and sediment assessment are still in progress.

In the meantime, the EPA and Ohio EPA are overseeing Norfolk Southern’s efforts to address contamination in surface waters with the use of aeration systems and sediment washing. So far, their efforts have been successful in Leslie Run, which has shown significantly reduced contaminant loads. There is still much to be done, particularly in Sulphur Run, and the EPA is dedicated to ensuring they don’t leave contamination behind.

Community work is included in project management as the EPA tries to restore the environment and ease the public’s concerns. They publish a weekly newsletter and hold weekly public information sessions to help keep everyone informed on the

(Below) Aeration equipment deployed within Leslie Run.



cleanup as well as to connect with the public and learn what they can do to help people feel comfortable again. Durno states, “It’s important to recognize that it’s more than just the technical stuff; we’ve got a pretty strong community presence here as well.”

There are signs of healing everywhere in the community of East Palestine. On April 8th, the city held an Easter egg hunt, its first community event following the derailment. The hunt was held in City Park, an area that had been high on the list of locations to sample and monitor for contamination. Durno explains, “The city wanted to start the healing process by being able to identify some areas where there was no question that they were safe.”

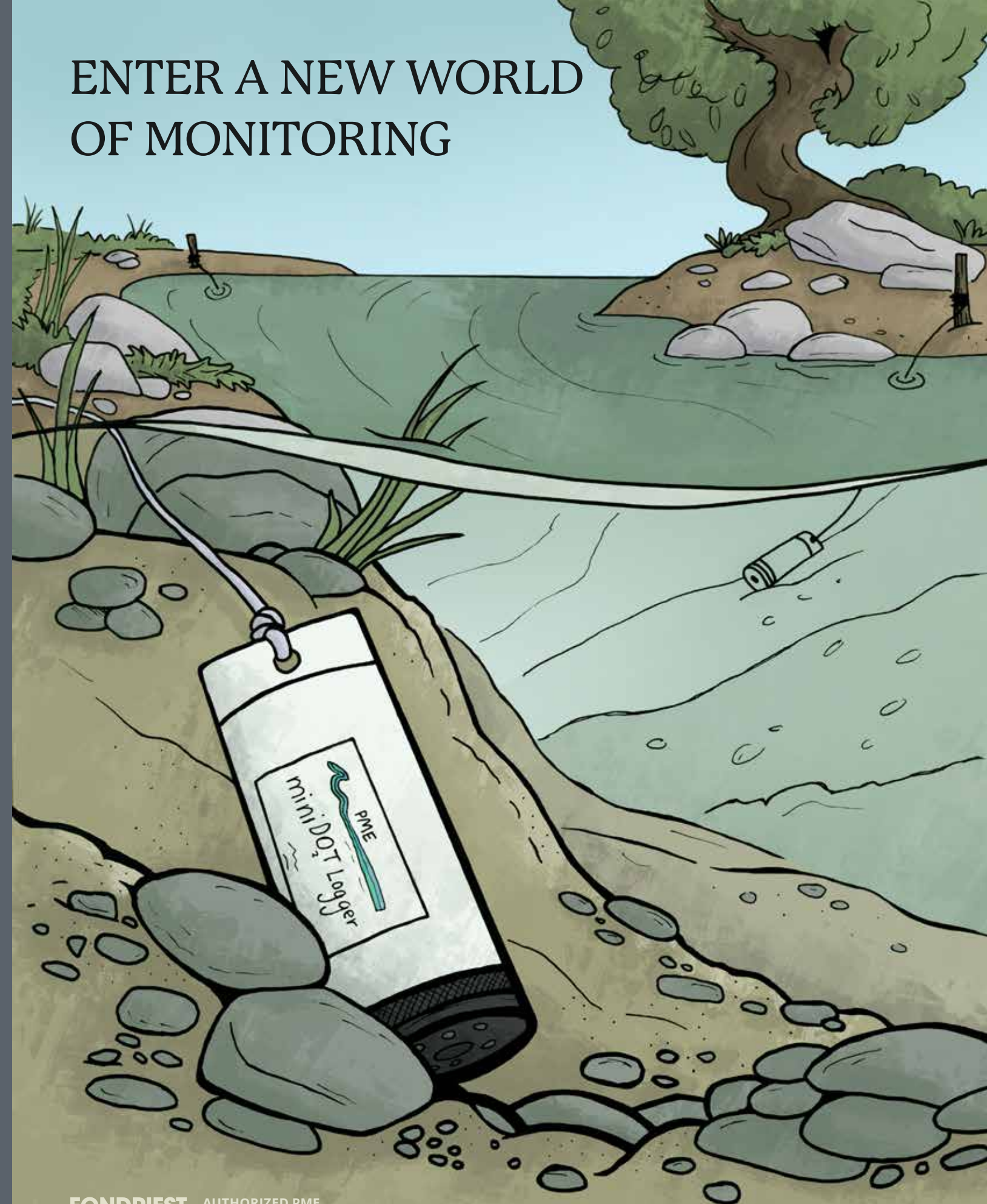
The results of the City Park assessments revealed levels at the lower end of normal for the compounds they were looking for. “To me, that was a significant milestone, just from my part in this seeing that community event being able to take place just two months after the derailment,” says Durno.

Other milestones are a testament to the gravity of this event. Over 50,000 tons of materials and over 19 million gallons of water have been shipped off-site so far, a reminder that this was not a small spill. Norfolk Southern removed 1900 feet of track on the north and south sides combined, and rebuilding of the tracks is finally set to begin in June. “Those are some of the things you can sit back and look at and say, ‘We’re making progress.’ It’s baby steps for making progress,” states Durno.

The fear and anxiety experienced by the public weigh heavily on hazmat responders like Justice and Durno, scientists who have worked countless derailments in the past and are familiar with the scars left behind as they’ve worked in various towns and cities over the years. Durno explains that it can take years for people to recover from traumatic events like this.

Still, community events like the Memorial Day Parade that took place May 29th, only about a mile away from the site, are essential parts of this process. “Just over a mile away from the site, they were able to get that sense of normalcy going again.” He continues, “Those little things are what will continue to help.” <sup>SB</sup>

# ENTER A NEW WORLD OF MONITORING



Photos: EPA

# PREDICTING & RESPONDING TO WILDFIRES

## Canada's Scientific Approach to Fire Management

High temperatures and prolonged dry spells lead to increased chances of wildfires sparking across the world. In order to combat fires, federal and local governments have developed fire management programs and policies to prevent and respond to wildland fires. Many of these policies and strategies are influenced by research emerging from scientists that study landscapes across the world.

In Canada, Marc-André Parisien, a research scientist for Natural Resources Canada (NRCan), spends his days surveying and sampling forests to help better understand wildfires and inform future management. Over the past 23 years, Parisien has worked to help compile and understand foundational data on wildland fires. He explains, "The better we understand them, the better we can live with wildfire."

Beyond fire research, NRCan works on a range of initiatives that support operations and help develop policies in provinces and territories. While research is conducted across the country, land management is relegated to the respective province and territories, not the federal government. As such, it is the responsibility of the Canadian Forest Service to guide and support local initiatives through research, funds and guidance.

### HOW CANADA MONITORS FORESTS & WILDFIRES

Canada monitors above and below the tree line to survey land and monitor fires. In terms of ground monitoring, forest inventory plots are used to sample vegetation and assess forest health. Vegetation sampling in these plots can explain the composition of the forest in terms of species and structure.

Parisien expands, "So how big are the trees? Is it an open forest? Is it a closed forest? Is there a big shrubby layer or it's just wall to wall, kind of like tall, thick trees? Those kinds of things. So it's fairly detailed measurements to get to the composition and structure of this forest."

(Left, Top) Sentinel-2 imagery of wildfires in Quebec.

(Left, Middle) Parisien conducting fieldwork in Wood Buffalo National Park, Alberta and the Northwest Territories.

(Left, Bottom) Map of the 2017 Kenow wildfire, Alberta.

(Right Page) NRCan researchers conducting fieldwork in Nahanni National Park Reserve, Northwest Territories.

Data gathered can be used to predict the likelihood and severity of fires—it all depends on what is being predicted. In some cases, ground monitoring may be necessary, while other circumstances may be better suited for monitoring from the sky. Satellites provide imagery of the environment from above and can capture much wider visualizations of fires and forests.

"It always depends what you're predicting, right? If you're predicting something that's supposed to happen tomorrow, then you can use very detailed weather data, weather forecasts, and things like that. If you're trying to predict a wildfire that may occur over the next 20 years you can use different types of information but it's all based on what drives wildland fires," states Parisien.

Weather monitoring is also a significant part of fire prediction as fire-conductive weather, like hot, dry and windy conditions, can create an ideal environment for a wildland fire. Once the fires have been ignited, flammable vegetation allows the fire to spread. Surveying and documenting the percentage of flammable vegetation, also known as fuels or the flammable portion of the biomass, is another way to study and predict wildfires. In hot and dry years, more vegetation is likely to be considered a fuel, allowing wildfires to spread further.

While the satellites help provide greater insight into how far-reaching everything is, they provide limited information on what's going on at the ground level. The combined use of satellite imagery and ground monitoring allows researchers to build a better understanding of forests.

"There is a variety of ways that we can measure what's going on in the forest and then evaluate the health of the forest or things like tree regeneration, how these forests progress through time and are affected by the various disturbances and changes in climate," says Parisien.

### CAUSES OF WILDFIRES & HOW TO PREVENT THEM

In a typical year, the majority of large wildfires are usually ignited by lightning strikes in remote areas, igniting available fuel sources. This year's fire season was unique in that a majority of the first wave of wildfires in the spring and early summer were presumed to be human-caused since there was no evidence of lightning strikes or links to a holdover fire.

"The warmer the atmosphere is, generally the greater the convective and lightning activity. So that makes a lot of sense. But then, in terms of human caused ignitions, many, many, many of these are preventable. And it's a little bit disappointing to see how many of these large fires we have at this stage," Parisien explains.

The responsibility of wildland fire response and prevention are both assigned to individual provinces and territories, but many of them include similar strategies as a result of the comprehensive wildfire information provided by NRCan. Management approaches like prescribed burns and sustainable land use are two strategies recommended by NRCan and often deployed locally in provinces.

To support these initiatives and contribute to the greater understanding of wildfires, NRCan monitors, maps and predicts



**"THE BETTER WE UNDERSTAND THEM, THE BETTER WE CAN LIVE WITH WILDFIRE."**

**- MARC-ANDRÉ PARISIEN**

wildfire occurrence—all of which is shared with the public through the Canadian Wildland Fire Information System.

The data gathered by researchers like Parisien helps provinces develop more comprehensive plans and increase public awareness. "The research is essential because it leads to tools that help the broader public to understand and map, wildland fire risk, those kinds of things," states Parisien.

Depending on characteristics and location, fires aren't always suppressed. Parisien explains, "Some wildland fires get full fire suppression treatments—so kind of hit them hard and hit them fast—and others that ignite in remote areas that are not a threat to communities are often not actioned."

If the isolated fires spread toward communities or other infrastructure, then the province will move to suppress them. Parisien continues, "There's a lot of priority setting that is going on when you have so many fires burning, as is the case right now."

Canada's fire season this year was particularly severe, with the greatest area burned on record since they started measuring wildfires. While the beginning of the season was largely connected to human-caused fires, a majority of the fires that occurred later were caused by lightning strikes.

Even though this season has been particularly active, Parisien notes that previous years demonstrate a trend of fewer human-ignited wildfires on average, contrasting the increasing trend in lightning-caused wildfires in some areas. While human-caused ignitions can hopefully be reduced through awareness and education, naturally caused fires are a result of environmental variables that will continue to change. <sup>59</sup>

Photos: NRCan, National Burned Area Composite, NRCan



# SYMPTOMS OF A CLIMATE EMERGENCY



Scientists across the world and international environmental institutions have warned about the severity and speed at which the climate is changing, with the United Nations Environment Programme declaring a climate emergency.

Symptoms of this crisis are evident in many of the natural disasters that have occurred in recent years at a rising rate. Wildfires, drought, extreme precipitation, storm events, harmful algal blooms (HABs), and volcanic eruptions are some of the many indicators of a climate emergency.

## WILDFIRES & DROUGHT CONDITIONS

One of the most well-known and recorded climate change indicators is temperature, which has been increasing globally. While some parts of the world experience a more intense rain and snow season, landlocked regions tend to experience drought and dry land conditions.

According to the *Center for Climate and Energy Solutions*, the hotter climate creates a cycle of enhanced evaporation, insufficient precipitation, and dry spells, making the region more susceptible to wildfires and water shortages. Additionally, storm events wherein lightning strikes hit already dry land and vegetation can be the catalyst for wildfires.

## EXTREME PRECIPITATION AND STORM EVENTS

Climbing air temperatures can also lead to increased precipitation rates—with more moisture in the air, extreme rain or snowfall is more likely. The *EPA* notes that extreme precipitation doesn't necessarily mean that annual rainfall has increased—instead, the severity of these precipitation events has risen. As a result, flood events throughout the year are common.

Coastal areas have experienced some of the more extreme impacts as their proximity to the ocean means a greater availability of water to evaporate, leading to more frequent and severe events. As *NASA* explains, warmer air temperatures can hold more water vapor, increasing the intensity of hurricanes and monsoons.

## HARMFUL ALGAL BLOOMS

Flooding resulting from extreme rainfall or snowmelt can lead to a surge of excess nutrients from the land entering nearby bodies of water. Excess nutrient loads are then consumed by phytoplankton communities, triggering algal growth.

Depending on water temperature, dissolved oxygen, and other water quality conditions, toxic bacteria may prosper more than harmless algae. The *Oregon Health Authority* reports that some harmful algal blooms can produce cyanotoxins, which can cause health problems in humans and kill pets and wildlife.

## VOLCANIC ERUPTIONS

In addition to precipitation changes, temperature changes can also lead to glacial loss—two conditions theorized to be connected to increases in volcanic and seismic activity.

According to the *Smithsonian Institution*, volcanic activity is on the rise and research may point to climate change as a possible contributing factor. The *Scientific American* reports that comparing the volcanic record with glacial coverage revealed that eruptions decreased as the climate cooled. In contrast, eruptions during ice-covered periods were less frequent and less severe than those recorded during periods with less ice cover.

*The Conversation* wrote in 2023 that researchers have long assumed a connection between rising rainfall rates and glacial melting, leading to increased seismic and volcanic activity. Flooding and glacial loss change surface conditions and destabilize the impacted area, increasing seismic event frequency. <sup>SB</sup>

United Nations Environment Programme — <https://www.unep.org/climate-emergency>

Center for Climate and Energy Solution — <https://www.c2es.org/content/drought-and-climate-change/>

Environmental Protection Agency (EPA) — <https://www.epa.gov/climate-indicators/climate-change-indicators-heavy-precipitation>

NASA — <https://climate.nasa.gov/news/3184/a-force-of-nature-hurricanes-in-a-changing-climate/>

Oregon Health Authority — <https://www.oregon.gov/oha/ph/healthyenvironments/recreation/harmfulalgaeblooms/pages/taqs.aspx>

Smithsonian Institution — <https://volcano.si.edu/taq/index.cfm?question=historicalactivity>

Scientific American — <https://www.scientificamerican.com/article/get-ready-for-more-volcanic-eruptions-as-the-planet-warms/>

The Conversation — <https://theconversation.com/how-climate-change-might-trigger-more-earthquakes-and-volcanic-eruptions-210841>

Illustration: Emma Jones/ Fondriest Environmental

# REDEFINING REMEDIATION

ECOSPEARS' GREEN SOLUTION FOR A CLEANER FUTURE



Co-founder and CEO of ecoSPEARS Sergie Albino is dedicated to restoring the health and vitality of the environment for all people.

An environmental remediation strategy that has the potential to remove PCBs, dioxins, PAHs, DDT and other persistent toxins permanently may sound too good to be true, but recent innovations introduce a solution that removes these chemicals from the environment forever. This potential to change the industry forever is what attracted ecoSPEARS CEO, Sergie Albino, to the industry in 2015.

ecoSPEARS offers a green decontamination strategy that is built off of the need to create a cleaner world for the future. Persistent toxins have saturated the environment, contaminating soils, sediment and water sources, all of which impact human and ecosystem health. Toxins enter the food chain through smaller organisms that are exposed and then eaten by larger species who continue to carry the toxins throughout the ecological chain.

**"WE WANT THAT TO ACTUALLY BE LOOKED UPON MORE AS—NOT A TYLENOL FIX, BUT MORE OF A HOLISTIC PROCESS OF ENVIRONMENTAL REMEDIATION [ . . . ] BUT LIKE KOBE ALWAYS SAYS, 'JOB'S NEVER DONE.'"**

- SERGIE ALBINO

## GREEN SOLUTIONS INSPIRED BY NASA SUSTAINABILITY

With a background in aerospace engineering at NASA and the Department of Defense, Albino found himself interested in how he could change the remediation sector and make it greener. "NASA is always in this sustainability model because every time we send stuff to space, what you send up there is what you're going to expose the astronauts to. They're going to breathe it in because it's a closed volume—it's not like you can open the window."

This sustainability model is what led to the first draft of the ecoSPEARS technology in 2012. Albino tells an elaborate tale of Dr. Jackie Quinn making the discovery as a result of a grant and request from the Navy to develop a solution that removes PCBs from waterways after it's entered the sediment. With the proposal in hand, the team of NASA scientists, Dr. Jackie Quinn, Dr. Bobby Devore and Dr. Jill Maloney, set out to find a solution.

Persistent toxins all share the similar characteristics of being hydrophobic as well as inorganic. "She basically said, 'Okay, like versus like, they attract—organic or non-organic.' So the legend goes that Dr. Quinn ran down to the Sonny's BBQ restaurant in the Operations & Checkout, or O&C, building at NASA and grabbed a bunch of straws," begins Albino.

Photos: ecoSPEARS

She took the straws back to her desk, where she used a hair-crimping iron to seal the straws, one of which was filled with green solvent. Albino continues, "And lo and behold, those were the first Sorbent Polymer Extraction And Remediation System (SPEARS). The plastic with green solvent allowed more absorption of chemical contamination because the green solvent expanded the plastic lattice and allowed for the contaminants to go into the green solvent, allowing the plastic to absorb more contamination."

The success of the technology inspired Albino to start ecoSPEARS with Dr. Quinn's technology as the leading solution for sediment remediation. The success of the SPEARS technology uniquely positioned the company in other avenues of environmental remediation, specifically in soils with their ecoAINA as well as wastewater treatment with the ecoCUBE.

## CRADLE-TO-CRADLE INNOVATION

The principle behind each of these solutions is to create something long-lasting that solves the problem forever, not just temporarily. Traditional soil remediation involves the removal of contaminated dirt, which is then shipped to a designated incineration site for burning. The removal site must then be restored by finding non-contaminated soil and filling in the empty space. Sediment treatment involves a similar process—historically involving the removal of contaminated sediments followed by a sediment capping procedure.

One of the main environmental concerns with these current solutions is how the transport of these contaminants impacts the environment. In particular, current solutions are largely inaccessible for islands like Hawaii and Guam, as well as other areas that do not have easy access to burn facilities. "It's not very cost effective, and it's not very sustainable either. You're essentially trading off clean water and clean soil for clean air at that point," states Albino.

Instead of removing the sediment to be shipped elsewhere, ecoAINA is an ex-situ soil washing remediation that involves removing the contaminated sediment and then washing it in a chamber nearby to separate contaminants from the soil. Once cleaned, the soil can be put back, meaning there is no transport to or from required.

The goal is to clean the soil enough to meet residential levels wherein the previously contaminated soil can be restored, saving the need to find clean fill soil. When residential levels cannot be achieved due to high levels of contamination, boundary caps can be installed to protect the public from being exposed. Albino expands, "We're probably battling close to 95% average of getting everything down below one part per million on soil remediation."

*(Image 1 and 3) Invented, patented, and validated by NASA scientists and engineers, ecoSPEARS' technologies exemplify scientific excellence and innovative solutions.*

*(Image 2 and 4) The ecoSPEARS team executed a year-long effort of cleaning up industrial chemical contamination, also known as "forever chemicals," from the Anacostia River near Washington D.C.*



In terms of sediment, ecoSPEARS are different from ecoAINA in that it is an in-situ solution—intended to remain in the environment until the source of the contaminant is resolved. “As long as we have our SPEARS in the ground, we know that it’s always going to be absorbed into the SPEARS and trapped in the SPEARS instead of going into the fish,” explains Albino. “We want that to actually be looked upon more as—not a Tylenol fix, but more of a holistic process of environmental remediation [ . . . ] But like Kobe always says, ‘Job’s never done.’”

The SPEARS are deployed in dynamic environments as a part of a long-term reconstructive program. The SPEARS can hold a large volume of contaminants, so they only need to be removed in the case of testing or when the project has been completed. The idea behind both solutions is that they are built to clean the environment without creating new problems for the next generation.

Albino and the rest of the ecoSPEARS team hold sustainable remediation as the most important factor to consider in development. “This is what I tell people that want to learn more about the environmental sector, ‘There is no happy ending.’ The contamination that we think, or things that we think are bettering our lives today, because they’re making our lives convenient—we find out later on that it’s harmful.”

Albino expands, “I think as a society, we just need to be mindful and start always thinking—instead of thinking about this cradle to grave mentality, we need to start thinking about cradle to cradle. What are we using today that our kids and our grandkids can utilize later? So they don’t have to deal with the health issues that we’ve caused to their generation for our convenience today.”

## INSTRUMENT OF CHANGE, HOPE FOR THE FUTURE

Moving forward, ecoSPEARS is dedicated to innovation and sustainability. While Albino is an aerospace engineer by trade and his co-founder and executive vice president, Ian Doromal, is a marketing and business-oriented individual, he believes that this makes ecoSPEARS different from other solutions.

Albino explains, “Just like in anything you do, when you become a subject matter expert, you become pigeon-holed to only what you know, and what you see. So we’re the guys that are like two-year-old kids that you typically will yell at, because they’re always asking why! Why is the sky blue? Why are you digging up that dirt? Why are you sending it to California? Why are you burning dirt? Isn’t it hard to burn dirt?”

Asking these questions led to the birth of ecoSPEARS’ solutions and will continue to drive the company and industry’s future. Moving forward, the company is interested in integrating the SPEARS with AI to better inform clients and regulators on how the waterway is improving. The eventual goal is to build sensor technology into each spike or each mat to report conditions in real-time rather than manually removing a spike each time.

Also on the list for future improvements is the development of a portal wherein the data can be available at different levels to the public, researchers and regulators. This portal would be powered by sensor technology and data buoys that can monitor other conditions in the waterways, all of which would build a more comprehensive picture of the environment’s health.

Ultimately, Albino believes that asking questions and pushing for things to change is what has to happen to change the future and achieve the larger goal of a cleaner planet. “We bring innovation. The biggest enemy to the sector is the lack of innovation—it’s not the people, and it’s not the contamination—the contamination is what helps our lives to be more convenient. But it’s a lack of innovation, to clean it up after we let it out to the environment.”

Being able to help people and clean up the world is what drives ecoSPEARS to continue innovating and growing. Albino explains that the company’s future is to continue to partner with other sectors dedicated to the same cause. As a team, ecoSPEARS is committed to doing things bigger than themselves and working to extend help and partner with groups across the globe. After all, “It’s a big world to clean up, and we want to work with like-minded folks,” states Albino. <sup>SB</sup>

*(Left) The ecoSPEARS team executed a year-long effort of cleaning up industrial chemical contamination, also known as “forever chemicals,” from the Anacostia River near Washington D.C.*

*(Right) ecoSPEARS’ in-situ sediment remediation technology, once deployed in rivers, waterways, and wetlands, serves as cleantech Active Monitoring Samplers (AMS) to monitor PCB, PFAS and other Persistent Organic Pollutant (POPs) samplers.*

Photos: ecoSPEARS



# BEFORE & AFTER HARMFUL ALGAL BLOOMS LONG-TERM MONITORING & MODELING IN OTSEGO LAKE



Throughout the years, harmful algal blooms (HABs) in the Laurentian Great Lakes have been meticulously documented and closely studied due to their annual appearance across the basin. While these blooms have become a recurrent issue in the Great Lakes region, many lakes worldwide are now facing harmful algal blooms for the very first time, with some causes still unknown.

Otsego Lake is one example of a lake that experienced its first harmful algal bloom in 2022, leaving state agencies and researchers to wonder what triggered the event. Kiyoko Yokota, an associate professor of biology with the State University of New York (SUNY) at Oneonta, is the lead researcher of the project.

Serving as the current president of the North American Lake Management Society, scientific advisor for the Otsego Lake Watershed Supervisory Committee and technical advisor for the Otsego Lake Association, Yokota is familiar with harmful algal blooms and the significance of Otsego Lake for the surrounding community.

On the southern end of Otsego Lake is the beautiful Village of Cooperstown, which houses the National Baseball Hall of Fame and Museum and welcomes numerous baseball fans from around the world, especially around the induction weekend in late July. Scattered around the lake are other cultural institutions, including Fenimore Art Museum, the Farmer's Museum, Glimmerglass Opera, and Hyde Hall.

Glimmerglass State Park is a full-service state park with a visitor center, trails, campgrounds, picnic areas, a swimming beach with a lifeguard, and canoe and kayak rental, providing affordable, family-friendly outdoor recreation opportunities for all. Bassett Medical Center in Cooperstown is the medical hub that serves the entire Otsego County and surrounding communities, and the natural and cultural resources around Otsego Lake facilitate the recruitment and retention of highly qualified professionals from around the world.

Yokota splits her time among teaching, office work, and fieldwork—a habit that runs in her family. "My father studied silviculture and forest management in college, and he split his time between fieldwork, teaching foresters techniques and management plans, and administrative work at the prefectural government office, which included regular business trips to Tokyo for meetings at the national forestry agency. He always seemed happier when he was working in the field," explains Yokota.

**“WORKING WITH COMMUNITY-MINDED RESEARCHERS WHO RESPECT THE GLEON MANTRA OF DATA SHARING & EQUITABLE COLLABORATION HAS BEEN EXTREMELY INSPIRING AND REWARDING”**

**- KIYOKO YOKOTA**

Fond memories of days spent fishing with her father and an interest in being able to protect nature are what drove Yokota to pursue a career focusing on lakes and estuaries. Most recently, Yokota has been working alongside the New York State Department of Environmental Conservation (NYSDEC) to develop the Nine Element Plan, a comprehensive lake and watershed management plan.

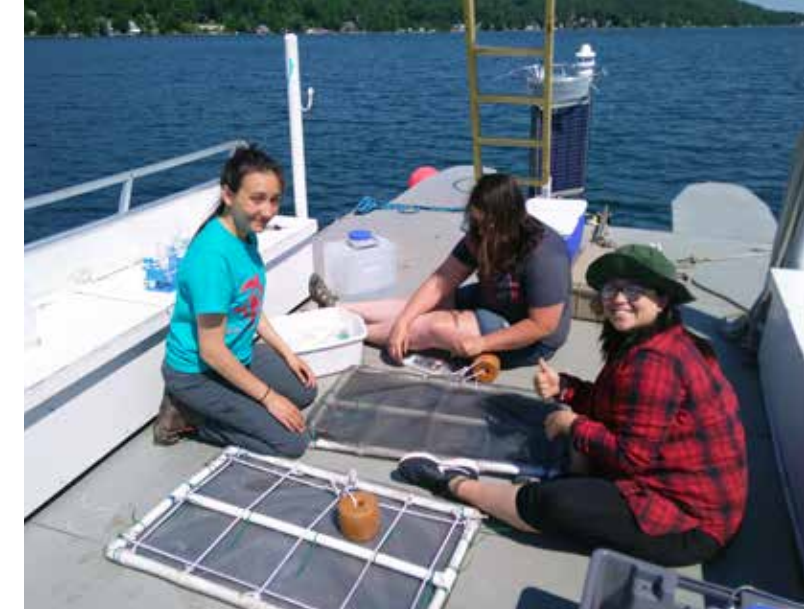
The program began in partial response to the cyanobacterial bloom on Otsego Lake in 2022 as the first HAB event led to others, with recurring toxigenic blooms that interfered with beach activities and overall ecosystem health. In response to the event, the NYSDEC and NYS Federation of Lake Associations (NYSFOLA) added Otsego Lake to their Citizens Statewide Lake Assessment Program (CSLAP) in order to help gather more data on the aquatic system.

SUNY Oneonta is a primarily undergraduate university, so Yokota's research team does not include postdocs, Ph.D. students or lab techs. Instead, the community aspect, involving both SUNY Oneonta students and local residents, becomes an important part of monitoring the lake. Yokota helps CSLAP volunteers collect water samples and assess water clarity with a Secchi disk and simultaneously collects water quality data with a sonde and measures underwater irradiance with a light sensor to make the most out of each sampling event.

*(Left Page) Data buoy in seemingly clean water, but the white foamy scum on the water surface contained high concentrations of cyanobacteria (Microcystis aeruginosa).*

*(Top) SUNY Oneonta students and an international summer intern setting up the microcosm experiment.*

*(Bottom) Data buoy winterization on 29 Oct 2022, Otsego Lake, NY, USA.*



In addition to the discrete sampling by students, volunteers and fellow researchers, Yokota uses NexSens Technology to gather real-time data on the lake. A grant funded by the National Science Foundation's Field Station and Marine Lab Program helped Yokota purchase a CB-950 data buoy for Otsego Lake, which supplemented the long-term biweekly manual sampling program by SUNY Oneonta Biological Field Station staff.

The buoy, equipped with an X2-CB data logger and two YSI EXO2 sondes daisy chained at two depths, collect water quality data to capture the annual establishment and disappearance of summer stratification of the water column—with warmer water at the surface (epilimnion) and cooler water at the bottom (hypolimnion). The buoy is also equipped with both a Lufft WS600 and an Airmar 200WX-IPX7 to gather weather data and develop a more comprehensive image of what is impacting the lake.



Photos: Kiyoko Yokota



The sondes are each equipped with a temperature, conductivity, dissolved oxygen and pH sensor. Due to the differences in light, only the top sonde is equipped with two additional sensors that measure total algae and fluorescent dissolved organic matter.

All of the data collected by the sensors is logged in the X2 and then transferred to the cloud, where it is accessible through WQData LIVE, making data analysis and monitoring easy for busy researchers like Yokota. Without having to leave campus, Yokota can sign onto WQData LIVE and see what is happening at the lake. The accessibility and long-term data capabilities the X2 provides came at the perfect time for the lake.

She explains, "When I first got the buoy, I was more or less like, 'Oh, long-term high-frequency data would be useful for various studies.' Because you can compare the background water quality and weather information from the buoy with whatever you might observe or manipulate. But now we have the long-term high-frequency data before and after the lake started to bloom."

## DATA-DRIVEN MANAGEMENT IN OTSEGO LAKE

When Yokota was first in the market for a data buoy in 2015, she knew that the system would have to be compatible with her busy teaching schedule as well as largely self-sufficient, as frequent trips to the buoy for system maintenance are not possible due to the distance between the main campus and the lake.

She explains, "My local Global Lake Ecological Observatory Network (GLEON) collaborators, who were also faculty at primarily undergraduate institutions (PUIs), spoke highly of

NexSens buoys that they had used. Also the combination of a stationary thermistor string and sondes was recommended as it involves fewer moving parts and therefore more manageable than vertical profiling buoys—a very important factor for researchers at PUIs who typically teach 3-4 courses per semester."

Yokota continues, "I was so excited when our proposal was funded, and Paul Nieberding helped me place the order and helped me keep track of different parts that came in separate shipments. Justin Walters has been super helpful—so many times he helped me over the phone while I was on a boat next to the buoy in the middle of the lake and gave me step-by-step guidance while he was able to check real-time data on his side. I have yet to meet Justin in person, but it feels like he is part of my lab!"

Having access to high-frequency water quality and weather data greatly facilitates lake modeling. NYSDEC's Nine Element Plan includes modeling of the Otsego Lake watershed and the lake itself, using the Chesapeake Assessment Scenario Tool (CAST) model by the Chesapeake Bay Program and a modified CE-QUAL-W2 model by the Upstate Freshwater Institute.

"CE-QUAL-W2 is a two-dimensional model originally developed by Portland State University. Once the nutrients and sediment come into a lake, do they move horizontally and flow out of the lake? Or are they going to settle to the bottom? The high-frequency water temperature and wind data from the buoy greatly assist the modelers with simulating the complex and weather-dependent movements of imaginary parcels of water within a lake, which also dictate the movement of nutrients and sediment in those parcels," explains Yokota.

Photos: Paul H. Lord, Alex Sessions, Kiyoko Yokota

She continues, "Then the model addresses how much of the nutrients are going to feed the phytoplankton, what kind of phytoplankters are likely to flourish (diatoms vs. cyanobacteria, for example) and by how much, and then how that affects light availability within the water column, and so on."

Combined, the CAST and CE-QUAL-W2 models will predict lake water quality resulting from various watershed management scenarios. This will allow local stakeholders to consider Otsego Lake and its watershed as a whole and evaluate various potential watershed and in-lake management strategies using the model predictions.

The modeling will also enable objective and consistent assessment of the effectiveness of the selected management actions by comparing the modeled vs. observed outcomes, an important element of all NYSDEC Nine Element Plans. Such assessment is essential for periodic revisions of the management plan to keep moving towards the lake and watershed management goal.

For example, a community may have funding for one watershed project but not two. The models will simulate how reductions in agricultural runoff vs. septic discharge affect the chlorophyll concentration in a lake. The community will then be able to prioritize projects based on the predicted chlorophyll concentrations.

After the nutrient load reduction is achieved, the actual chlorophyll concentrations will be compared to the predicted values to assess the effectiveness of the project. This model-based approach allows more comprehensive and data-driven protection of natural resources.

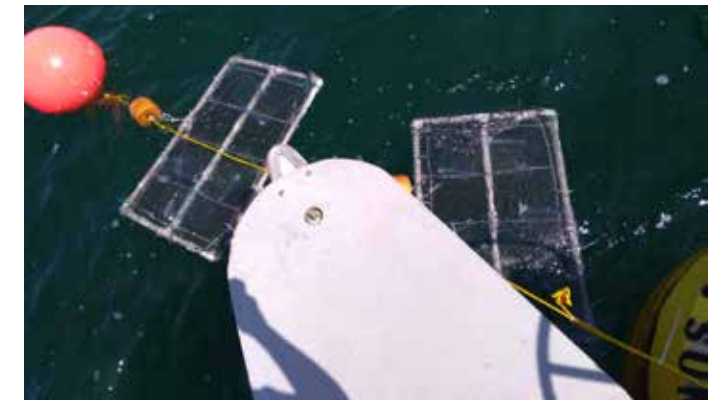
Local initiatives and regulations have led to declines in agricultural and septic runoff, though the lake is still impacted by a number of invasive species, including zebra and quagga mussels, which are reported to have contributed to cyanobacterial blooms in many temperate lakes in North America and Western Europe.

Both species are known to change food webs and system dynamics as they over-filter the water, increasing water clarity and light penetration, which disrupts native species and can promote

*(Left Page) Buoy maintenance and bird deterrent installation by SUNY Oneonta student SCUBA divers. Photo taken 17 July 2022, Otsego Lake, NY, USA.*

*(Top) A Biological Field Station Volunteer Dive Team Dive Master LiCol Paul H. Lord checking the underwater cables hanging from the data buoy.*

*(Bottom) A microcosm experiment in summer 2019 as part of a multi-lake nutrient limitation study through GLEON. The floating PVC frames housed 8 plastic bags that acted as microcosms (small experimental units incubated in the real lake environment).*



benthic growth of filamentous algae and/or cyanobacteria. "It's kind of deceiving because the lake looks cleaner than before, but then we start to have the harmful algal or cyanobacterial blooms," states Yokota.

In recent decades, Otsego Lake has gone from mesotrophic to oligotrophic, with medium to low productivity, while cyanobacterial blooms have long been treated as indicators of eutrophication and increased productivity.

Many lakes, including those in Upstate New York, such as Skaneateles Lake and Lake George, are affected by cyanobacterial blooms despite being oligotrophic. The overall nutrient input from the watershed has generally been stable or reduced over time. Because the exact cause of the harmful algal blooms in Otsego Lake is still unknown, continuous real-time monitoring will help to observe conditions over time and potentially conclude what is causing the harmful algal blooms.

Otsego Lake is a part of GLEON, and as such, the data collected by the buoy deployed there and the discrete measurements conducted by Yokota have been shared with a community of researchers. Likewise, she has the support of the network's data to support her research as well.

"Working with community-minded researchers who respect the GLEON mantra of data sharing and equitable collaboration has been extremely inspiring and rewarding," states Yokota.

Like many other lakes, Otsego Lake is one of many included in the list of lakes that have begun to experience algal blooms. Research gathered by the buoy-based system will not only improve NYSDEC's local Nine Element Plans, but the data can also help support limnological research elsewhere. <sup>54</sup>

# Sustainable Data Collection

## Climate Monitoring in the Caribbean



A CB-950 being pulled for deployment in Belize.

Environmental monitoring in the Caribbean may be essential, but it has also historically been placed on the back burner. Albert Jones, Instrumentation Officer for the Caribbean Community Climate Change Centre (CCCCC), explains, "Data collection itself is not what is considered one of those sexy activities where you can easily get funding."

Still, monitoring the water surrounding island nations is necessary to protect residents and the environment. The CCCCC works to establish environmental monitoring networks and systems in the Caribbean. One aspect of Jones' work centers around data buoy instrumentation and deployment—equipment that will be used to support Ecoforecasts for Coral Health Monitoring and to provide valuable environmental data to the public.

Most recently, Jones completed the last of four stations in Tobago, Barbados, the Bahamas and the barrier reef of Belize, funded by the European Union. Earlier partner projects with the USAID have allowed systems to be installed in St. Kitts and Nevis, Antigua and Barbuda, St. Lucia, Grenada, and St. Vincent and the Grenadines.

### MEETING DATA NEEDS IN THE CARIBBEAN

Working around the staff shortages and other logistical challenges presented by the COVID-19 pandemic introduced a series of problems for the CCCCC as these systems require maintenance. The systems also have to be easily accessible by

the locally responsible agency in the case of severe weather events so that they are able to move the systems to a safe storage location.

Despite the challenges, the CCCCC has been able to install hundreds of Environmental Data Collection Stations, Terrestrial and Marine, over the years. Not only has the CCCCC contributed to the installation and curation of these networks, but also to the yearly maintenance, which keeps these systems online.

Before the data from the marine stations can be used for ecoforecasting, a robust and accurate system must be developed in the Caribbean so that NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) can publish the findings to the greater public.

"We're asking them to be part of the information package that can guide marine park managers, coral health enthusiasts and operators on how to best protect the ailing barrier reefs across the Caribbean, as most of the islands have been experiencing quite a bit of bleaching," explains Jones.

Such trends come as no surprise to scientists like Jones, who have spent decades monitoring the climate, but up until recently, many of these concerns surrounding coral reefs failed to make waves with the public. A new report from the Intergovernmental Panel on Climate Change stated that July, August, and September have been the hottest they have ever been.

Jones expands, "We are all cognizant of the fact that our corals are at stress at this point in time due to these high water temperatures, so we are hoping that the information and data that we are gathering will provide the necessary guidance for decision making, as well as for better management of our natural resources, knowing that corals are not just a tourist attraction, but also an extremely important spawning grounds for many fish species out there."

In the wake of more climate-related research being published and international efforts focusing on environmental protections, monitoring has gotten a bit more attention. Coral reefs are critical habitats for thousands of species that humanity relies on for food. Protecting the reefs and spreading environmental data regarding the reefs works toward solving a major contributor to the region's food security issues.

### MONITORING CLIMATE CONDITIONS WITH DATA BUOYS

With a background of more than 35 years in the meteorological sphere, Jones transitioned to electronics in 1980, where he was tasked with building a network of environmental monitoring stations in Belize and ensuring that they met international meteorological monitoring guidelines. He also worked in related sectors to curate monitoring systems.

Jones explains, "We had a base network that included agrometeorological stations for the agriculture sector, climatic stations for folks that were monitoring for forest fires, as well as stations that contributed to the regular Weather Forecasting for the general public."

He continues, "We have quite a bit of interaction, not only from the Caribbean Sea itself, but we have a whole host of terrestrial microclimates, that need to be addressed for the different sectors. So that was something that spurred us into having a more dense network of environmental monitoring stations."

Early renditions of the coral reef early warning system used in the Caribbean utilized exceptionally larger monitoring buoys, which gathered the needed data but also created several logistical concerns. For example, these buoys were quite costly, often required more maintenance and were a burden on local agencies.

Additionally, anything above a category two hurricane could possibly cause the moorings for these large buoys to break, damage the attached instrumentation and possibly be a hazard for locals facing an influx of water and ocean debris. Moving these large buoys to a safe harbor was challenging due to the size of the buoys.

Photo: Albert Jones / CCCCC



In 2017, a colleague with NOAA's AOML recommended NexSens buoys as they'd had success with the systems in Florida. The NexSens CB-950 data buoy was less expensive, lighter-weight and durable, meeting everything Jones was looking for in the project.

"NexSens came in and gave us the opportunity not to have only four sites, but to have five sites, because of the lower acquisition cost. And it was a real one stop shop, where [NexSens] integrated the whole system for us. It was easy plug and play," states Jones.

He expands, "For us, the buoys are configured ready to be put out in the field, which is something that has made our lives a whole lot easier, where we don't have to go through a full programming course to actually deploy the system—like we did from the previous supplier. So those sorts of dependencies on a full integration that NexSens actually provided, gave us a lot more confidence in having a working system."

The network of CB-950 buoys and X2-CBMC provides continuous data, even while the systems are being deployed and years after being installed. Equipped with a Sea-bird CTD, and LI-COR LI-193 underwater PAR for the marine variables; and Airmar 200WX, Vaisala WXT536 and LI-COR LI-190 PAR for meteorological variables, the buoy and sensors are durable for marine conditions. The previous system observed a large variety of parameters, though not all of these were determined to be necessary for coral reef early warning information produced by the ecoforecast program.

"We made it a more manageable system where we collected what we needed, rather than have excess information that was practically just sitting there for future research. So we said, 'Let's

concentrate on what we can use as data for the information needed now,'" explains Jones.

The sensors gather a more narrow set of data, but this data is more relevant and higher quality thanks to the more manageable system. The X2-CB data logger transfers data via cellular transmission every 10 minutes to Jones even when he is elsewhere in the Caribbean.

The smaller system is also more manageable for the locals who are responsible for the system. Not only is Vaisala familiar to many in the Caribbean due to the company's presence in land monitoring systems, but the size of the buoys makes moving them in for storm events much more manageable. On the off chance that a buoy is displaced during a storm event, the Airmar complete weather station includes a GPS that allows for the buoy to be located.

## THE FUTURE OF CLIMATE MONITORING IN THE CARIBBEAN

Once the systems are well-established and functioning in the Caribbean, Jones hopes to make the data easily accessible to the public. The goal is for anyone with a cellphone to be able to view the data gathered by the data buoys, informing not only local officials but also citizens of current conditions.

The greatest challenge to continuing monitoring work in the Caribbean is that data collection isn't very popular with politicians who decide on the amount of money allocated to each public initiative. In every system he designs, Jones has to consider the short and long-term costs of the system.

Jones explains, "We always say that it's best to have no data than bad data, because bad data gives you the completely wrong picture of what is happening out there. So rather than giving wrong information, we prefer to not have that information to skew things in the wrong direction."

While a large number of systems equipped with a host of sensors may gather a larger quantity of data, the system must also be sustainable. More than the initial purchase, the networks require maintenance that must also be considered in the budget.

Unfortunately, data collection isn't something people campaign on and doesn't garner votes, putting it high on the list of activities that may lose funding. Public investment in data collection is finicky and can weigh heavily on professionals trying to protect natural resources. Despite this, Jones is hopeful and dedicated to protecting reefs in the Caribbean.

"I have a passion for data collection—I see the value of what data does for information. And the thing is, in our field, where we are trying to downscale global models to regional models, to national models, that can only be achieved with data—we cannot think that we can guess our way along," states Jones.

He continues, "[Data collection is] one of these things that they tend to say, 'let's see if we can do with less.' And then that becomes a problem—but, data collection has been my passion. I've been dealing with this for some 40 years. I enjoy what I'm doing, so as long as I get some support, I will keep pushing on." <sup>58</sup>

*(From left to right)*

*Mounting of Sensor to CB-950 Tower at Barbados Coast Guard Base under the supervision of the Barbados Coastal Zone Staff and the Buoy Mooring Team. (Credit: Kai Wulf / Saba Conservation Foundation, Mooring Consultant)*

*Data Logger final assembly before Tower and Sensor attachment in Barbados. (Credit: James Hendee / CCCCC Consultant)*

*A CB-950 being lifted by a crane for deployment at the Coast Guard Base in Barbados. (Credit: Albert Jones / CCCCC)*

*Albert Jones preparing CB-950 for deployment in Belize. (Credit: Kai Wulf / Saba Conservation Foundation, Mooring Consultant)*

*A CB-950 deployed in Belize. (Credit: Albert Jones / CCCCC)*

*Albert Jones and Shoneé Howell (Barbados Coastal Zone Office) setting up the CB-950 before deployment in Barbados. (Credit: James Hendee / CCCCC)*

*Terrestrial PAR Sensor attachment. (Credit: James Hendee / CCCCC Consultant)*

*Albert Jones preparing the CB-950 for deployment in Belize. (Credit: Kai Wulf / Saba Conservation Foundation)*

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