ENVIRONMENTAL monitor

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APPLICATION AND TECHNOLOGY NEWS FOR ENVIRONMENTAL PROFESSIONALS

# PROTECTING BIODIVERSITY THROUGH MONITORING

## The Coevolutionary Arms Race
Fungus-Growing Ants and Social Parasites

## Endangered Species
Native Freshwater Mussels

## Coral Resilience
The Fate of Coral in a Changing Climate

# Welcome...

Welcome to the Winter 2023 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 and protecting biodiversity in a variety of ecosystems.

From endangered freshwater mussels across the U.S. to vegetation in the Amazon Rainforest, this latest edition highlights species of all sizes. Through monitoring various parameters, researchers spent the year gathering data and constructing management plans to protect these valuable species.

Our writers also sought out science professionals that are dedicated to protecting nature's most vulnerable through traditional and more contemporary methods. Featuring stories from a corporate project manager of an environmental dredging company, a coastal restoration scientist in Rhode Island and researchers from across the world, this edition showcases multiple approaches to understanding and protecting biodiversity.

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## ON THE COVER

Front: Big Bay outside of Eagle Mine early in the morning prior to sampling that day. Photo by Dylan Friisvall.
(See Pg. 42)
Back: Dr. Durelle Scott and two of his students on the New River in Blacksburg, Virginia. Photo by Sam Dean.

## CONTENTS

Contents Photo Credits (Left to Right):
Tim Mooney; David Girbino; Jen Bowman

## IN THE NEXT EDITION

Subscribe to read the next edition of the Environmental Monitor, focusing on climate emergencies and natural disasters. Stories will feature stormwater management, disaster risk reduction and remediation efforts.

# Contents


03. On the Web
04. Coastal Restoration in RI
08. Featured Photo: Amazon
10. Product Innovation
12. Ants and Social Parasites
16. Monitoring Riparian Zones
22. Freshwater Mussel Surveys
30. Biodiversity and Land Use
34. Infographic: Soil Food Web
36. Polar Night
40. Anguish of the Amazon
42. Keweenaw Bay Pollution
46. Coral Resilience
48. Ohio's Orange Streams
52. Environmental Dredging
56. Caring for Chesapeake
60. Special Offers




# On the Web

Searching for more quality environmental news? Find more at **fondriest.com/news**.

## So Far Yet So Close: Remote Sensing at Everett

Kerry Lyste, Faculty member at Geography at Everett Community College in Washington State and Tribal Historic Preservation Officer at Stillaguamish Tribe of Indians, believes in the importance of undergraduate research. His education specialty is remote sensing. He has spent many years transferring his enthusiasm to his undergraduate students. For 21 locations across Puget Sound, Lyste's class gathers data on water quality, pH, dissolved oxygen, salinity and conductivity. The collected data is expected to help answer the question of how Puget Sound is being affected by human development and changes in the environment, such as ocean acidification.

## Treating Harmful Algal Blooms: A Natural Progression

For Tom Johengen, Research Scientist for Cooperative Institute for Great Lakes Research (CIGLR) and Director of Michigan Sea Grant, choosing to study Harmful Algal Blooms (HABs) was "a natural progression" from his days as a grad student investigating best management practices for controlling nonpoint source nutrient pollution. As far as what kinds of data were collected on HABs, Johengen and colleagues focused on nutrient dynamics and used a variety of limnological approaches to understand how the blooms responded to their physical and chemical environment.

## Aquatic Systems Connectivity: Finding Relationships Between Waters

Determining how the land impacts water quality, is complex. There must be an understanding of the flow of materials, organisms and energy within our waters and how they are connected, or even whether they are connected. Enter the emerging field of aquatic systems connectivity. Nate Jones, assistant professor of ecohydrology at the University of Alabama and his colleagues explain in a recent paper that aquatic systems connectivity involves interdisciplinary researchers of the aquatic science community collectively working to improve and understand the connectivity of the physical, chemical and biological functions of aquatic systems.

# Coastal Restoration in Rhode Island

Anyone who has spent a significant amount of time in nature can likely relate to feeling connected and defensive toward protecting the environment. Heather Kinney, a coastal restoration scientist with The Nature Conservancy in Rhode Island, knows this feeling well, having felt a deep connection to nature her entire life. "I have always had a deep love for nature and the environment, particularly being out on the water and being drawn to the ocean, as cliché as that sounds," says Kinney.

Being so close to nature her entire life led Kinney to pursue a career in conservation and restoration. "You want to protect what you love, and I think that once I fell in love with it- it was something that I wanted to be able to pursue professionally," she explains.

Kinney focuses most on coastal and marine environments because of how vulnerable the habitat is. She adds, "So much of the marine environment from specific organisms to marine habitats are threatened by our current way of life. Because I studied marine biology, I got interested in learning about them and then interested in protecting them."

Kinney's work with TNC focuses most on restoring rocky shorelines, oyster reefs and oyster habitats, but she works throughout Rhode Island, particularly on the Providence River and the surrounding wetlands. Kinney helps facilitate TNC's fish and oyster surveys as well as the restoration plans that accompany these initiatives.

Kinney has spent the past 5 years working with TNC, maintaining equipment, conducting research and leading projects throughout Narragansett Bay. Most of her work involves overseeing and checking in with all the projects occurring within the Rhode Island chapter of TNC. Many of the longer-running TNC programs and projects rely on continuous monitoring to ensure that these initiatives succeed in their goals. Some of this continued monitoring entails monthly fish trapping to analyze population and species disbursement. The fish traps allow scientists like Kinney to ID and measure the species before releasing them to learn more about the species and ecosystem needs.

*Photos: Tim Mooney/ TNC. Illustration: Emma Jones/ Fondriest Environmental*

## MONITORING EQUIPMENT

Fish trapping began as a part of a fish habitat enhancement survey intended to assess whether an area is ready for habitat enhancement. "It's a multifaceted project that uses fish trapping and benthic video monitoring to look at different sites along the Providence River estuary and see what areas might be ready for fish habitat enhancement; particularly since the Providence River was highly degraded for many years, but has recently begun showing signs of some improvement over the last 20 or so," explains Kinney.

The study focuses primarily on sport fish because it's a sport fish restoration-funded project, but it has also helped to identify general improvement within the ecosystem. The larger fish traps allow researchers "to see the adult stages of the fish when they come into the bay, how many there are, their health as well as the water quality when we catch them," shares Kinney.

Beach seines and eel pots are also used along the shoreline, which turns up smaller species and juvenile sport fish. The shallow-water traps and nets allow for the true biodiversity of the Providence River to be seen. "We get a lot more diversity in the traps placed along the shoreline because it's shallower water and safer for the small critters," says Kinney. The traps also help indicate which habitats are best for species by comparing an artificial reef site with controlled sampling at a rocky and sandy-bottom shoreline.

While most research is conducted from the safety of a boat, sometimes snorkeling and diving are needed to obtain additional information. Kinney and her team measure salinity, dissolved oxygen (DO), temperature, conductivity and other parameters but these data points may still fall short of explaining catch data. For example, if water quality data reveals ideal conditions for fish but no fish are turning up in traps, divers may need to enter the water to see where the fish may be nesting instead. Diving is also particularly helpful during oyster surveys, as not everything can be seen from the surface or water quality data.

Kinney explains the phenomenon by saying, "If you have low DO levels and no fish, then that makes sense. If the water quality is good, but we're not catching anything then that may tell us something else about species distributions." For example, if an artificial reef has been installed in the area recently, fish are unlikely to turn up in fish traps because they use the reef for shelter and are less drawn to the traps. Even when there are no catches, Kinney explains that "No data is data. Having zeros is good information." If dive monitoring reveals that reefs are being used, causing fish to avoid traps, then the zeros suggest that the artificial reef is working.

## HABITAT ENHANCEMENT, RESTORATION AND MONITORING

TNC invests a great deal of time and money into these enhancement and restoration projects and in ensuring that the best and most sound methods are being used. When a project begins, program leaders look at all of the previously gathered data to determine what method would be best for that site specifically. Salt marshes, artificial reefs and other green infrastructure options may individually or collectively work for a specific location.

Complex structures called Reef Balls can be installed along shorelines lacking complex structures. Reef Balls also help with wave attenuation, breaking waves up before they have a chance to collide with the shoreline, preventing erosion. Building oyster reefs is another enhancement method that enhances both ecosystem services and fish habitats as it creates complex structures and access to food. Oysters are also filter feeders meaning that their presence in the ecosystem improves general water quality for the betterment of the habitat.

*(Left) In 2019, TNC and RI DEM installed 64 Reef Balls to enhance fish habitat off Sabin Point in East Providence, RI. It was the first artificial reef to be constructed in upper Narragansett Bay.*

*(Right) Heather conducting an oyster survey at India Point Park Providence.*


"Monitoring is super important because we spend lots of time and money on building these projects and we want to make sure that what we're doing is actually having a beneficial impact on the system," Kinney explains. "The only way to do that is to monitor it. I think sometimes, the funding goes towards creating a project and not enough to monitoring after the fact and so you have a lot of projects that get on the ground but we don't really get a sense of how much they're positively impacting the system because the funding doesn't normally reach for 5 or 10 years down the line," she continues.

## INFORMING MANAGEMENT DECISIONS

The data collected by groups like TNC inform state and local environmental initiatives within and outside Rhode Island. Locally, TNC works alongside the Rhode Island Department of Environmental Management, helping to "directly inform management decisions for the state of Rhode Island," shares Kinney. She expands to say, "TNC is an inter-state organization—it isn't just in Rhode Island. It's in every single state so being able to compare that data across a larger geography and learn from each other and just contributing to that science is impactful."

Not surprisingly, Rhode Island, like the rest of the U.S., suffers from various impacts of climate change, making it, and the other variables it introduces, a major concern for the region. For coastal states like Rhode Island, "We talk a lot about sea level rise and developing some infrastructure to deal with flooding in our areas," explains Kinney. Wave attenuation, flooding, frequent large storms, eroding shorelines and preparing local towns and people for these events are all major concerns for TNC Rhode Island.

TNC works closely with the Rhode Island Municipal Resilience Program, facilitating conversations with local municipalities to determine the area's greatest concerns that they want to improve. Once a plan is established, TNC helps organize grant applications to secure project funding. An example of one of these projects is Rose Larisa Park in East Providence on the Providence River. The bluff at Rose Larisa Park is eroding and falling down a cliff due to increased wave action resulting from rising waters. Additionally, coastal erosion and unhealthy vegetation that cannot hold everything together have caused the bluff to deteriorate further.

The city has a lot of coastal restoration options in situations like Rose Larisa Park. "One of them is to put in a structure like a Reef Ball which acts as a barrier to any wave action coming in. The waves, instead of hitting the shore are going to hit that hard structure first and then get slowed down before it hits the shore, slowing erosion," Kinney shares. She continues, "Another great option are salt marshes which are great wave attenuators." For that particular project, TNC worked with the RI Coastal Resources Management Council and an organization called Save the Bay to install "a small, experimental salt marsh in two different locations on the beach."

Salt marshes and Reef Balls are good alternatives to a hardened shoreline. Hardened shorelines are commonly installed to repair or prevent erosion; however, they often end up being more destructive in the long run. For this specific project, salt marsh grasses were planted along the shoreline. "It's actually doing pretty well. Initially we had some geese eat a lot of it, but now the salt marsh is doing pretty well. We also installed a coir log system that is a combination of biomaterial, coconut fiber and some smaller rock, as a combination of hard and soft structures," says Kinney. Both installations are helping prevent the bluff from falling or eroding anymore and have helped to flatten the bluff out.

*Photos: Tim Mooney/ TNC*

## PROTECTING BIODIVERSITY

Due to climate change, aquatic ecosystems worldwide have been facing climbing water temperatures, and Rhode Island is no exception. As a result, Rhode Island has seen a great deal of species migration in the region. "For example, we're seeing a lot more black sea bass, which are typically mid-Atlantic species. However, a lot more are being found in the Providence River estuary than in the past," says Kinney. A similar occurrence has been noted in blue crab populations in the areas. The population change will undoubtedly impact the ecosystem and fishing industry, though monitoring will determine the extent of these changes.

The artificial reefs that TNC installs help provide habitats and food for species in the area, keeping populations steady and protecting habitats. Some of these reefs are close to recreational fishing areas, which helps raise awareness for the species in the area. Oyster habitats work similarly to artificial reefs but have the added benefit of contributing to ecosystem productivity. Much like artificial reefs can help break waves up, oyster reefs can do the same while providing food to fish and preventing shore erosion.

Living along the coast and being near such rich pockets of biodiversity is a gift that should be appreciated and treasured. Part of that appreciation is through the responsible use of natural resources. "It's not about keeping people out, we want people to enjoy and love nature," Kinney says. Kinney elaborates, "I think a lot of times with conservation, it feels like what we were trying to do is keep people away from things, but I want people to know that nature is for us—this is for people too and we're a part of it."

Sharing that love and stewardship with others is one of the best parts of Kinney's work. "We have a lot of folks come up to us while we're in the field and ask what we are doing and being able to share that with them and see people, not necessarily change their mind, but not know what's two feet from them when they're on the beach is really cool because trying to foster that love of the natural environment means that more people will want to protect it," she says. SB

*(Left Page, Left) TNC's fisheries surveys provide hands on learning opportunities for summer interns from Brown University.*

*(Left Page, Right) Pat Barrett with the RI Division of Marine Fisheries prepares to deploy a fish trap in the Providence River, near Warwick, RI.*

*(Top) Reef Ball post installation at Sabin Point in East Providence RI.*

*(Middle) Savanna Olsen, an intern from the Rocky Hill School, holds an adult tautog, an important sport fish for recreational anglers in Rhode Island.*

*(Bottom) Experimental "living shoreline" project aimed at stabilizing the bluff at Rose Larisa Park, East Providence, RI.*

*Photo and Caption: Marcia Macedo*

## AMAZONIAN RESERVOIR

This small reservoir in Mato Grosso state sits in the heart of Brazil's agricultural frontier in the southeastern Amazon. It is one of thousands constructed throughout the region as forests were replaced by cattle ranching beginning in the 1980s. Today, the region is a major exporter of commodity crops such as soybeans, maize, and cotton, yet these reservoirs persist in the landscape.

Reservoirs fundamentally change the hydrology, temperature, and connectivity of sensitive headwater streams. Small streams that were once shaded and free-flowing are transformed into still, open-water lakes like this one. These novel ecosystems are productive, with algae and aquatic plants such as the ones blooming in this photo, but they may also produce greenhouse gases such as methane. Scientists at Woodwell Climate Research Center are studying these reservoirs to better understand their cumulative effects on freshwater ecosystems and the global carbon cycle.

(See "The Art of Sustainable Development: Monitoring Riparian Zones in the Amazon," Pg. 16)

# Proteus Multiprobe

The Proteus multi-parameter sonde is a unique, scientifically-proven multi-sensor platform that uses both fluorescence and patented algorithms to monitor biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), dissolved organic carbon (DOC) and total coliforms, fecal coliforms and E. coli coliforms in real-time. The instrument is designed for use in drinking water, wastewater, industrial, process, recreational swimming areas, aquaculture and food & beverage applications.

The platform can be fitted with up to 12 different sensors to output over 30 parameters on a single instrument. Sensor options include temperature, conductivity, pH, ORP, dissolved oxygen, turbidity, CDOM, tryptophan, chlorophyll, blue-green algae, depth and more. A central wiper on the turbidity sensor cleans the optical sensors prior to each measurement, reducing the maintenance requirements when continuously deployed. The probe can also be outfitted with a cabled Bluetooth battery pack for spot sampling with any Android/iOS device.

Included with the purchase is the Proteus base unit with temperature sensor, calibration cup, sensor guard, guard weight, USB PC cable, digital manual and Proteus software manager. Both SDI-12 and RS-485 Modbus RTU are standard outputs for interfacing with environmental data loggers and PLC's. Pair the multi-parameter probe with the NexSens X-Series data loggers and CB-Series buoys for cloud-based data in remote locations via WQData Data LIVE and cellular or satellite telemetry.


## Proteus Multiprobe Features

- Built-in wiper cleans optical sensors prior to each measurement
- Optional internal battery pack for standalone deployments
- SDI-12 and RS-485 Modbus output for integration with data loggers & PLC's


*(Left) Exposed sensor-end of the Proteus multi-parameter probe. (Right) Side profile of the Proteus multi-parameter probe with the sensor guard attached.*

# The Coevolutionary Arms Race:
## Fungus-Growing Ants and Social Parasites

Despite the negative stereotypes surrounding social parasites, Rachelle Adams, Assistant Professor at The Ohio State University, knows just how important host-parasite relationships are to evolution. Like many ecologists, Adams, Assistant Professor at The Ohio State University, found her passion for nature in childhood. "It began when I was a kid. I had this general interest of nature, and I loved to spend time in the forest, exploring," she recalls. Her desire to work with wildlife was solidified in college. "I didn't know exactly what direction I was going to head in but the ecology and evolution classes I took were really central to shifting my perspective on 'what is biology.' It opened my eyes to seeing nature in a different way," she explains.

Adams' interests zoned in during her undergraduate research focusing on species interactions and social behavior. And while insects may not be the first social creature that comes to mind, Adams saw just how important communication was to insect behaviors and interactions. She elaborates, "That hands-on research experience really impacted the direction that I went."

Even still, insects might not seem like the most obvious research subject. "I started as an undergraduate researcher studying honeybees and—I've always loved animals, but I'd never thought about insects until I got to college. So, I'm not an example of somebody who loved ants when they were a kid, instead my interest in insects and behavior were formed as a result of my research on honey bees," explains Adams.

The buzzing social lives of the bees she observed during her undergraduate years charmed Adams into pursuing a career studying bugs. During her time in the honey bee lab, Adams realized that "insects have amazing, complex social behaviors—they're also really fuzzy and cute," making her future career as a researcher clear.

The journey from bees to fungus-growing ants was an easy transition made during her time as a research technician at the Smithsonian and the University of Maryland, wherein her research focused on ant evolution. It was during this time that she connected evolution with the social behaviors that she'd found so fascinating when observed in bees. "The ants have interesting, complex social behaviors, but also have a mutualistic relationship with their fungus garden," she explains.

From an evolutionary perspective, it's interesting to observe how ants have adapted to their habitat and coevolved in symbiotic relationships. The fungus garden relies on the ants for growth as much as the ants rely on the garden for food. This relationship becomes more complicated when observing the interjection of social parasites and how they have coevolved alongside the fungus garden and its caretakers.

### ANTS AND THE ECOSYSTEM

Small, but mighty, ants may not seem like an important variable in ecosystems, but due to their colony size, speciation and strength, the presence of an ant colony can totally change an environment. "Generally speaking, ants are known to be ecosystem engineers, because a single colony can move large amounts of soil and reshape environments," shares Adams. She continues, "They're also incredible predators that clean up a forest rather quickly with a high number of individuals."

There are over 16,000 ant species, and each of them serve a unique role and function in their habitat. Some may be less noticeable, marked only by a tiny anthill, while others can have astronomical impacts. "When we think of ecosystem engineers, we might think about leafcutter colonies, because these fungus-growing colonies have hundreds of garden chambers underground, and the nest itself is several meters in diameter—some colonies are so large they can be seen from space," Adams explains.

While there are certainly many impressive examples found within the Formicidae family, there are also many smaller species still working hard as members of an ecosystem. Cleaning up dead organisms or preying on other insects that also shape the ecosystem is just as important, even if their area of influence appears smaller than larger colonies.

Adams' research focuses mostly on fungus-growing ants and understanding how these species are a central component of symbiotic networks. She elaborates, "You have the farmer ants that tend the fungus garden and associated microbes; fungi and bacteria that are helping or harming the garden or the ants; and then there are other ant species that are attacking the farmer ants." She continues, "It just builds out from there. And so when I think about how fungus-growing ants are impacting ecosystems, I think about how they're building a network of interacting species."

*Sericomyrmex amabilis farmer ant worker atop her fungus garden.This species is host to guest ant social parasite, Megalomyrmex symmetochus. (Credit: Anders Illum)*

## SOCIAL PARASITES

One type of ant species that attacks fungus-growing ants are *Megalomyrmex* parasites. *Megalomyrmex* ants are known as social parasites due to their social structure and the unique strategies they use to access the fungus-growing ants' resources.

"Chemical communication is important for understanding how species are connected in an ecosystem. Similarly, chemical communication is central to the complex organization in a social insect colony," explains Adams. She expands to say, "Understanding the chemical code of communication among species tell us a lot about why we see different species associated together."

Across the two ant lineages, the farmers and the parasites are often found living together. "I often think about how many *Megalomyrmex* social parasite types there are and why they parasitize fungus-growing ants," says Adams.

Three main parasite types infiltrate ant colonies, guest ants, thief ants and agro-predator raiders. Though all species manipulate their host to some degree, the host's reliance on chemical communication can leave a colony vulnerable to social parasites. While some social parasites try to match their host's nestmate recognition code, other species rely on chemical stealth to infiltrate and integrate into the host nest.

All social parasites are armed with chemical weaponry. The guest ants live with the farmer ant colony for many years, eating its food, the fungus and some of its brood, much like other parasites do, but at a slower rate. Thief ants will invade the host colony by neutralizing host ant aggression with toxic alkaloidal venom, rendering nestmate recognition irrelevant. Thief ants eat quickly, steal some larvae and then retreat back to their nest.

In contrast, agro-predator raider ants usurp the entire fungus garden. "They chase away the host ants, eat all the brood, eat all the fungus garden and then move on to the next colony," explains Adams. These hostile interactions can begin with a queen-to-queen fight or parasite workers can invade mature host colonies, depending on the parasite type. Regardless, the chemical code of communication plays an important role in these species interactions. The host must tolerate the presence of the parasite in order to survive the interaction and preserve a future for their colony.

*Mycetomoellerius mikromelanos farmer ant host queen with Megalomyrmex adamsae guest ant parasite queen on fungus garden.The parasite invades the host colony when only a queen is*

*Photo: Alexander T. Baugh*

Adams summarized current knowledge of social parasites saying, "So far, we know that all *Megalomyrmex* social parasites are using some type of alkaloid-based chemical weaponry. How toxic it is and how it impacts the host varies." Sometimes this weaponry is used to warn the host away from the parasite, and other times it is used to poison the host. In one species, the social parasites have a muted chemical profile which may allow the guest ants to blend in with the host colony more easily. "The hypothesis is that if the parasite has a muted nestmate recognition profile, then they can sneak into the host nest undetected," describes Adams.

## WHY FUNGUS-GROWING ANTS ARE PARASITICIZED

Understanding why *Megalomyrmex* ants target fungus-growing ants requires closer observation of both host and parasite—and a new perspective. "I've studied the fungus-growing ants for many years and always wondered how parasites invade the colonies" Adams shares. She continues, "There are almost 250 farmer ant species and, *Megalomyrmex* parasitize many different species across that lineage. So that leads to the question, why are they so vulnerable?"

The reason? "Most fungus-growing ants are wimps," answers Adams with a laugh. "They have an interesting defense strategy—which is to play dead. They curl up in a ball and play dead if they're attacked. That leaves them very susceptible to colony invasions," she further expands. While insects may not be known for playing dead, fungus-growing ants and even fire ants are known for this defensive behavior. "At first you wonder, `how can this even exist in nature', but as an evolutionary biologists it makes sense that this strategy has worked for the ants for millions of years." Adams explains.

Most fungus-growing ant species don't have soldiers or much of any way of fighting back against parasites since they have a vestigial sting and weak mandibles. Unlike leafcutter ants, who have evolved to cut leaves and therefore have large muscle-filled head capsules powering their mandibles, the majority of fungus-growing ant species feign death in hopes of being spared by invaders.

## IS THIS SPECIES WHAT I THINK IT IS?

Throughout her research, Adams questions, "Is this species what I think it is?" This question is important to consider both for scientific identification and to consider the species' function. For example, "Early on in my research, I was finding what I thought was a single species parasitizing different hosts. So, because of my interest in that symbiotic interactions, it's important for me to know: are they a specialist parasite? Meaning, are they only parasitizing one species? Or are they parasitizing many? That's a fundamental question for understanding symbiotic interactions," Adams says.

One species parasitizing many species has different ecological consequences than a single parasite species targeting one host species. Upon closer observation, Adams found that the parasites she had discovered were not the same but were instead two different species. "At the time, the taxonomy, the keys that allow us to differentiate species, did not tell us that they were different lineages. But the molecular and venom alkaloid studies that I was doing at the time suggested they were different," Adams elaborates. And so, a new species was named and the taxonomy was updated. This is not unusual in the world of ants, as many species remain to be discovered.

While it is easy to think of these social parasites as inherently bad, they serve an ecological function in the same way that any other species does. Hosts and parasites have evolved side-by-side, leading to favorable traits in both species as they try to combat the opposing strategies. Adams refers to this mad-dash toward improved characteristics as "the co-evolutionary arms race between the hosts and the parasites." She explains, "In nature, symbiotic networks have many interacting species tugging at each other and understanding how they impact one another helps us appreciate how all species are connected in an ecosystem."

## ANT OUTREACH

Much like complex insect social structures are interconnected, Adams has found a similar connection with humans over a shared interest in ants. For Adams, the best part of her work is doing research she loves with students that share her passion. "I get to have an immediate impact on young researchers, which is a real joy and, connected to that, is a broader impact. My lab group loves outreach and talking with the public about our scientific research," she explains.

**"THERE IS A LOT WE CAN LEARN FROM PARASITES. THEY'RE DRIVERS OF SELECTION, PARASITES ARE SHAPING POPULATIONS."**

Hoping to connect the public and ants more, Adams is in the process of creating two outreach programs that will highlight the importance of ants in ecosystems. One of these programs is called Bug Bio Badges, which is directed toward kids who can earn a badge by completing an activity. Adams plans to make the program multilingual and accessible online, so anyone can earn a badge. "This was inspired by all of us being restricted to exploring only in our backyards for many, many months," says Adams.

Another program involves a series of ant workshops running every other year throughout Ohio. Much like nest ants are connected through a shared chemical code, Ohio has an incredible community of ant enthusiasts connected online through a forum. Adams describes the group by saying, "They're discovering important and unique things about ants across Ohio, sharing what they've learned, and trading queens and colonies."

*Photos: David Girbino*

*Graduate students Mathew Boot (far left) and Victoria Sadowski (far right) with Dr. Rachelle Adams collecting an ant colony in Panama.*

Adams hopes to have these workshops all across Ohio as a means of connecting with both the ant enthusiast community and professional naturalists that are interested in preserving nature in parks and protected areas.

Naturalists and ant enthusiasts are both invested in preserving biodiversity, and Adams hopes to study Ohio parasite populations in the future. In particular, their risk of extinction, which hasn't been done since the 80s.
Adams' work in the Panama Canal region, is focused on a regional assessment of a parasite species that is listed as vulnerable by the IUCN. She plans to apply similar methods to Ohio ant species.

In the end, parasites and their hosts are equally important to the ecosystem surrounding them. Even if one were to remove a parasite from the ecosystem or expunge it from the host, the host wouldn't necessarily be better off in the long run. "I teach a course on fungus-growing ants where I talk about *Megalomyrmex* ants, and I have students who tell me how to eradicate parasites because they think all parasites are bad, but I disagree—there is a lot we can learn from parasites. They're drivers of selection, parasites are shaping populations," Adams explains.

Many species are parasites and all organisms have at least one parasite that relies on them. Adams encourages individuals to consider, "what happens to selective pressures when you remove a parasite?" The relationship between host and parasite is a tale old as time and a lifestyle that has evolved in all organisms and interspecies relationships, meaning parasites are just as important to biodiversity and the health of an ecosystem as their host. SB

THE ART OF SUSTAINABLE DEVELOPMENT:

# MONITORING RIPARIAN ZONES IN THE AMAZON

As concerns for the planet's future rise to the front pages of newspapers across the globe, so has the demand for science-based solutions to preserve and protect the earth and its resources. Sustainable development focuses on balancing the necessary harms of land use for global needs with environmental conservation. Marcia Macedo, an ecosystem ecologist and Director of the Water Program at the Woodwell Climate Research Center, understands how complicated sustainability can be.

While it is clear that the world is consuming resources at an unsustainable rate, understanding the full scope of the problem and developing solutions is challenging, particularly in a globalized world. Macedo has spent her career at the land-water interface studying how deforestation and land use change impact water flows in the tropics. She has spent over 15 years working with farmers in the Amazon and Cerrado biomes to help develop management strategies that allow continued crop production while minimizing harm to local watersheds. "We are trying to understand the main drivers of land use change in tropical regions, as well as the impacts of those changes on tropical watersheds," says Macedo.

## DRIVERS AND IMPACTS OF LAND USE

The expansion of export-oriented crops and cattle ranching have been the two leading causes of deforestation in the Amazon-Cerrado region. These resulting land use changes have profoundly impacted the ecological functions of native forests and savannas, as well as the freshwater ecosystems draining those landscapes.

The southeastern Amazon, where Macedo has worked since 2007, has experienced particularly rapid changes over the last two decades.

"There's a tight relationship between forests and the hydrological cycle," notes Macedo. Understanding those interactions and how strains on either system can affect the other is one of the fundamental goals of Woodwell's work in the Amazon. Macedo and her colleagues – including atmospheric scientist and Director of the Tropics Program, Michael Coe – have spent years studying these connections from local to global scales.

Their results underscore the close connection between the fate of native forests and the hydrological cycle. Tropical trees are massive, with deep roots that return about three-quarters of rainfall back to the atmosphere through evapotranspiration. The resulting water vapor helps form rain clouds, providing essential rainfall downwind and helping to cool the land surface. "Tropical forests essentially act like big air conditioners for the ecosystem and surrounding areas," explains Macedo.

It is no surprise, then, that removing those forests changes everything. Macedo elaborates, "It greatly reduces evapotranspiration, which not only reduces the amount of water recycled back to the atmosphere but also warms the land surface and increases stream discharge." These local impacts on the hydrology of small watersheds are often compounded by other disturbances, many of which have unintended consequences and large cumulative effects at the landscape scale.

*Photo: Marcia Macedo*

One such unsustainable practice is the construction of small earthen dams in sensitive headwater streams. These reservoirs – reminiscent of the small lakes formed by beaver dams or the mill dams commonly found in the northeastern US a century ago – can provide drinking water for cattle, irrigation, fish farming, or other recreational purposes. Although small, these impoundments stay in the landscape for decades and have proliferated throughout the Amazon-Cerrado agricultural region. Macedo and colleagues mapped thousands of these reservoirs in the headwaters of the Xingu River Basin in Mato Grosso, Brazil. A single farm where Macedo works contained over 50 of these reservoirs in an area roughly the size of Cape Cod, Massachusetts.

These water bodies represent a big change compared to undisturbed headwater streams, which are typically shaded by overhanging riparian forests and fed by groundwater that keeps stream temperatures at a steady 24°C. Once deforested or dammed, the hot tropical sun can reach streams and reservoirs, causing dramatic changes in water temperature. Macedo's team showed that one small reservoir can increase water temperature by 5°C from the inlet to the outlet. Once re-entering the stream, it takes over a kilometer for that temperature to recover to its natural background level. In many cases, additional downstream reservoirs keep the temperature from recovering at all.

"Here's a practice that makes sense at one scale, but not when you add it up. We mapped 10,000 of these in the upper Xingu River Basin, which covers 186,000 square kilometers. That's roughly one for every 7km of stream length," says Macedo.

"What does that mean for fish? Unlike humans, fish can't regulate their body temperature relative to their environment. If they evolved in stream environments with constant 24°C water temperature and suddenly they're experiencing high variability and 31°C water, that will directly affect their metabolism – and with it their ability to grow and thrive in the new environment."

The reservoirs only worsen the harm caused by riparian forest degradation and deforestation as streams and rivers have less tree cover to shade them from sunlight and contribute food and nutrients to the aquatic ecosystem below. They may also create hotspots of methane, a powerful greenhouse gas produced by bacteria living in the low-oxygen sediments along reservoir bottoms.

Macedo's ongoing research is focused on measuring methane emissions from these small reservoirs – a critical step for understanding how they impact carbon cycling, ensuring these often-overlooked greenhouse gas emissions are accounted for, and devising strategies to minimize those emissions.

*Submerged tree trunks in a small reservoir in Mato Grosso, Brazil. Building dams floods a large area upstream, killing most standing trees as a result. Mauritia palm trees are a notable exception: they are well-adapted to wetland areas and can be found scattered throughout some reservoirs in the region.*

## THE IMPORTANCE OF SUSTAINABLE DEVELOPMENT

The principles of sustainability often seem at odds with present-day notions of productivity. "It's counterintuitive at times – kind of the reverse logic of economics. In the context of agricultural production, we may actually need to discount present-day production and profits to ensure a resilient system that can sustain production over the long term. It's a hard problem to solve," states Macedo. Even so, many governments across the globe have tried to strike a balance by recommending practices that mitigate damages and incentivize sustainability.

Producing commodity crops on tropical soils requires a great deal of inputs, including additions of lime to correct soil acidity and nutrients such as nitrogen and phosphorus to increase soil fertility. Where Macedo works, these inputs are applied with great precision such that crops get exactly what they need and runoff is minimized. Nevertheless, these practices may not be sustainable over the long-term; phosphorous, for example, is a finite resource that will run out eventually.

Likewise, growing vast expanses of crop monocultures requires many herbicides and pesticides to outcompete ever-evolving diseases and crop pests. "Soon, we'll have to have a global conversation about our food systems and what to do over the long term. I don't think this mode of production can be sustained for very long, particularly in the face of a rapidly changing climate," Macedo states.

As for right now, the best option is to protect and sustain what one can. Macedo explains, "Sustainability can include small actions to minimize negative impacts now, but it also connects to ethics and broader social systems. We have a moral obligation to minimize impacts on Indigenous people downstream, for example, and to ensure fair, healthy, and equitable workplaces for the people working on these farms, not to mention considering the rights of future generations."

## SITE-SPECIFIC SUSTAINABILITY

Today, tropical land use changes occur largely to meet the global demand for plant and animal products. Macedo states, "I don't blame farmers who are supplying a global market for soybeans for doing what they're doing. I think revealing these underlying market connections – and understanding the unintended consequences associated with large-scale production – must be part of the solution."

To ensure that the impacts of land use are considered from various perspectives, Macedo works with a large team of researchers, farmers, and representatives from the Amazon Environmental Research Institute (IPAM), a Brazilian non-profit organization working at the intersection of science and policy. After identifying the source of the problem and its impacts, this team works to translate the science and communicate how these practices may impact regional climate, local biodiversity, and global climate changes.

*Photos: (Top) Marcia Macedo, (Bottom) Paul Lefebvre*

The solutions aren't necessarily large, sweeping policy changes or restrictions. Sometimes they amount to practical alternatives that help optimize fertilizer applications, repair degradation caused by land use changes, and minimize impacts when possible. Having worked in the same region for so long, Macedo explains, "It's been really gratifying to be in the same place for so long because there's a relationship of trust between the farmers and researchers. We've been able to ask some questions together on how to accomplish what they need to do while also minimizing environmental impacts."

Another important aspect of crafting sustainable development plans is moving away from "one-size-fits-all" solutions by working to understand regional differences – how each system works and what it needs. For example, much of the early scientific literature about the effects of deforestation and agricultural production came from temperate regions, where agricultural practices, rainfall, and soil characteristics often lead to surface runoff that carries nutrients and sediments into streams and lakes. Without careful management, these processes may lead to persistent water quality problems (e.g., eutrophication) that degrade freshwater systems. When they began studying tropical regions growing the same crops with similar approaches, Macedo and her colleagues expected to find similar processes at work, but their results surprised them.

Watersheds in the Amazon and Cerrado are quite different environments compared to the temperate zone. Soils are old and highly weathered, meaning they are deep – often 10 meters or more – and have a high infiltration capacity. Instead of running over land, rainwater carrying nutrients has time to percolate through the soil column. From there, the water and nutrients work their way throughout the watershed, so by the time they reach the stream, most nutrients have been trapped in the soil or taken up by plants, preventing the nutrient loading and high turbidity seen in many temperate case studies.

In this case, the "common knowledge" afforded by the literature did not apply to the tropical landscape where they worked. While they are still looking into other dimensions of environmental changes in these landscapes, these findings are a good reminder that management strategies must be tailored for different places and contexts. Macedo notes, "I think sustainability means different things in different landscapes and at different scales."

*(Top Left) A herd of cattle drinking water from a roadside reservoir in the southeastern Amazon. Many reservoirs now found in areas of mechanized agriculture are associated with the long history of cattle ranching, which pre-dated crop production in the region.*

*(Bottom Left) Dr. Marcia Macedo collecting a sample to measure greenhouse gases (methane and carbon dioxide) dissolved in water downstream of a reservoir in Mato Grosso, Brazil. Samples are collected in the field for later laboratory analysis at Woodwell Climate Research Center.*

*Photo: Paulo Brando, IPAM*

*Aerial photo of a headwater stream in the Amazon-Cerrado agricultural frontier (Mato Grosso, Brazil). Most streams in agricultural watersheds are fragmented by a series of agricultural impoundments much like the one pictured here.*

## STUDYING SYSTEMS

Understanding these different scales requires an in-depth understanding of the systems involved, including forests and water systems. Macedo's team relies on several Fondriest Environmental products to closely examine how the removal of forests impacts water systems in these landscapes. For example, the health of riparian forests along the stream, fish communities, and water quality can all be affected by changes to the systems they rely on.

With all the ways her work overlaps with other systems, Macedo's field work looks a bit different than other researchers. Macedo utilizes devices like a YSI EXO Sonde and other devices/systems to monitor water quality parameters like turbidity, discharge, water level, and temperature. They also examine system behaviors like water flows in and out of the forest or agriculture field, how much the forest exchanges carbon dioxide and oxygen, and how much water is recycled by evapotranspiration. This data provides a baseline for understanding how the system is faring overall, and how forested watersheds compare with agricultural watersheds, which helps inform future decisions and practices.

When measuring streams and reservoirs is not possible with a sonde, the team has to get a bit more creative. Measuring methane emissions from reservoirs, for example, whether released via bubbles formed in the sediments or by diffusion at the reservoir surface, presents its own challenges.

Still, the data is important for understanding their greenhouse gas contributions. To do this, the team pairs water quality measurements using a YSI meter with measurements from floating gas chambers and bubble traps constructed from readily available materials such as water jugs, pool noodles, funnels used for oil changes, and 60-mL syringes. These contraptions help Macedo and her team trap bubbles and diffuse gas emissions to measure how much methane and carbon dioxide are emitted.

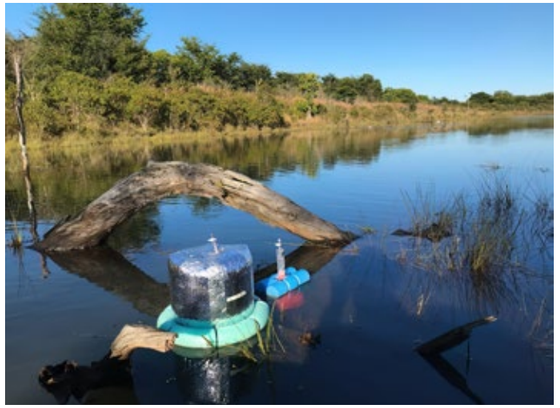
Understanding the health and functioning of the forests that border streams and reservoirs is another significant part of Macedo's work. Despite being near water, riparian forests are quite vulnerable to degradation. Where Macedo works, these forests are often small strips of land, surrounded by big soybean fields and exposed to stressors such as windthrow, fires, herbicides, and drying from the hotter landscape after deforestation. While they are protected by law, frequent disturbances and other edge effects may cause riparian forests to degrade over time.

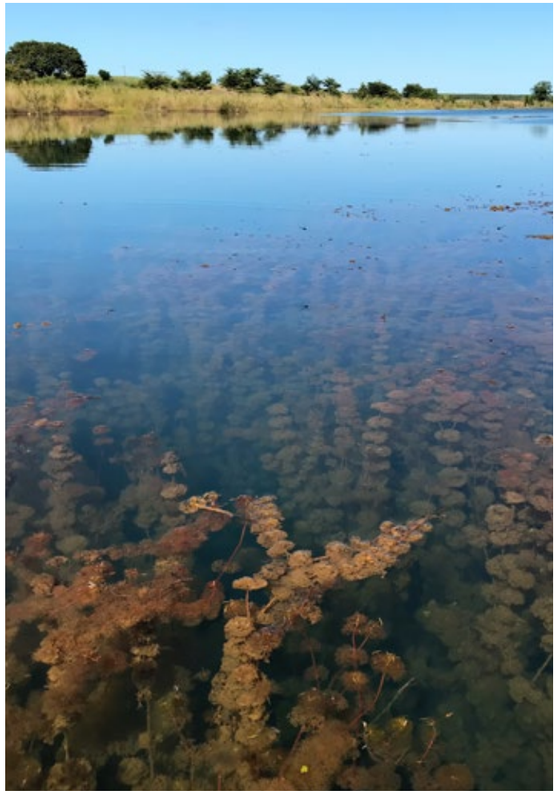
**"I THINK SUSTAINABILITY MEANS DIFFERENT THINGS IN DIFFERENT LANDSCAPES AND AT DIFFERENT SCALES."**

**- MARCIA MACEDO**

*Late afternoon light bathes a reservoir once connected to a small turbine used to produce power for a handful of houses on a farm in Mato Grosso, Brazil.*

*Photos: Marcia Macedo*





*Photos: (Top Left) Karinna Matozinhos, IPAM, (Bottom Left) Marcia Macedo, Woodwell Climate, (Right) Marcia Macedo*

Monitoring these forests to see how they're doing over time and where restoration efforts should be directed is, thus, a large part of the equation. Fortunately, about 80 percent of riparian zone species persist despite evidence of degradation. The forests also serve essential functions in terms of being a corridor for wildlife, filtering pollutants coming off the landscape into streams, shading streams and keeping them cool, and dropping leaves and insects that form the base of stream food webs.

Protecting and preserving these environments also helps protect the people, cultures, and ecological functions of the Amazon. But for Macedo this work is also deeply personal. She explains, "I'm Brazilian – a first generation immigrant to the US – so I've always had a strong connection to this landscape and these issues. It's really gratifying for me to be able to maintain that connection by going back to Brazil often to learn about these systems and, hopefully, to contribute to their conservation."

Thanks to growing discussions surrounding the climate and responsible resource use, Macedo is hopeful for the future. She attributes a lot of that potential success to science-based policies, as well as ongoing changes in business practices and individual choices. Macedo explains, "I think the world is waking up to the reality of climate change for one, and also to the interconnectedness of these markets."

Global negotiations have shined a light on many practices that were previously hidden. It's increasingly hard to ignore the data and public desire for more sustainable options. Companies and individual consumers have started to listen to the science behind sustainability as they look toward the future. Macedo states, "There's been a revolution in the data available to help us understand the world. Having that information at our fingertips makes it a lot easier to make more informed decisions and think more systemically about what we're doing to the planet." SB

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*(Top Left) Macedo transfers a gas sample collected from a reservoir to a preevacuated vial for later laboratory analysis.*

*(Bottom Left) A floating chamber (left) and bubble trap (right) deployed in a small reservoir in Mato Grosso, Brazil. These low-cost instruments were constructed from readily available materials, enabling scientists to measure greenhouse gas emissions from the surface and sediments of reservoirs.*

*(Right) Surface of a small reservoir in Mato Grosso, Brazil on a calm day. These man-made wetlands receive sufficient nutrients and light from the surrounding landscape to sustain aquatic macrophytes like those pictured here.*

## ENDANGERED SPECIES:

# NATIVE FRESHWATER MUSSELS

Though few people pay any mind to the occasional "clam" shell spotted along a river bank or lake, these small but mighty creatures are deeply important to water systems across the United States, and many of them are federally and state endangered. Greg Zimmerman of EnviroScience, Inc. shares, "We have about 300 species of mussels in the U.S., compared to other regions of the world like Europe that have under 20 species."

Zimmerman spent his life around water and always knew he wanted to return to help protect aquatic ecosystems. "I've always had a love of water, since I was 2. I grew up on an island in Buckeye Lake in Ohio." He further recalls, "I essentially grew up on boats—motorboats, sailboats—all summer I was around water and fishing."

Biology was an easy choice when he arrived at Hiram College for his undergraduate career. However, he found that the program was too focused on pre-med student needs and crafted his own major focusing on biology and water ecology, "I love fishing and biology so being around water was always my passion."

## WHY FRESHWATER MUSSELS MATTER

"When I'm working on a project and I hear locals say, 'Why do I care about mussels in my backyard? Why is money being spent on these mussels? Why does it matter?' I tell people, that mussels being there means that the place you live in is a good place," Zimmerman responds. "Mussels are bio indicators of long-term water quality—really long term. These things can live over 100 years. If your area hasn't been disturbed in a long time and the water is clean, then you'll find mussels there, and that means you want to live there, and that really equates to better property values."

More than their ability to indicate water quality, "They're important because they've been around for a while—dinosaurs were crunching these guys under their feet," says Zimmerman.

*(Left) Assorted Freshwater Mussels*
*(Right Page) Andrew Zimmerman, EnviroScience Biologist and crew navigating cold water and some challenging access while completing a mussel survey in the Great Smokies National Park, TN*

*Photo: Becca Winterringer / EnviroScience, Inc.*

*Photo: EnviroScience, Inc.*

Zimmerman reports, "They've been around for millions of years, and they've diversified over millions of years." The diverse assemblage of freshwater mussels in the U.S. gives conservationists and ecologists something to appreciate, but their niches also often conflict with human-driven environmental changes.

Mussels often become casualties from construction projects and largescale habitat changes (i.e., bridges, dams, dredging, land use changes, stormwater runoff and climate change). Various environmental disturbances, such as poor water quality, abnormal water temperatures and many other stressors have led to population losses for native mussels.

Unfortunately, human development and landscape changes within North America have and will continue to overlap with the highest diversity of freshwater mussels. According to Zimmerman, "You look where endangered mussel species are in regard to the human population and projected growth, and there is a lot of overlap—wherever cities and agricultural uses grow, mussels often disappear due to habitat changes, water quality degradation and competition for resources like the amount of water flowing downstream."

## HOW MUSSELS IMPACT ECOSYSTEMS

Native freshwater mussels are often considered "Ecosystem Engineers" and function as filtration devices in ecosystems. They are so efficient and effective that if placed in a tank of murky water, a cluster of mussels can clear the cloudiness within a few minutes. "They filter out food and particulates and after they process it, a lot of the material is still alive and just swims away. The other materials are put into more types of nutrients that are available for productivity—like invertebrates." explains Zimmerman.

"In a really densely populated mussel stream at low flow, the flow of the river might be filtered through a mussel 3 or 4 times the discharge rate of the stream," shares Zimmerman. While native freshwater mussels filter efficiently and help their ecosystem, invasive zebra and quagga mussels over-filtrate water and create many other problems.

Unfortunately, over-filtration harms ecosystems by enabling increased algal blooms and shifting the entire food web. While native mussels often release living organisms after digesting them, zebra mussels release their digested material in a mucus sac which kills anything trapped inside and covers the native substrates in sludge. The released materials also sink and accumulate heavy metals in the sediment.

For example, the introduction of zebra/quagga mussels in the Great Lakes killed off most of the native mussels (hence why many Midwest species became endangered). Zebra/quagga mussels changed the food web from productivity primarily being in plankton and algae in the water column to the bottom of the lake with aquatic plants and invasive/undesirable algae – and the hard substrates became covered with zebra mussels.

Then, the introduced round goby feed almost exclusively on zebra/quagga mussels that filter water laced with contaminated sediments at the bottom. Those are, in turn, eaten by smallmouth bass and other sport fish, adding problematic contamination in fish that are important for human consumption.

Essentially, "Zebra mussels are making a big sludge bed at the bottom of the lake that is loaded with heavy metals. Conversely, freshwater mussels are mixing the sediments up in the stream bed and actually making everything more suitable for macroinvertebrates, creating better water quality for themselves and increasing fish populations," Zimmerman clarifies.

## THE ENDANGERED SPECIES ACT

Some mussels are protected federally under the Endangered Species Act (ESA), while others are protected state-by-state. The ESA requires very specific expectations and guidelines for construction and other activities with a federal nexus in areas where endangered species may be impacted. Then the action has to be evaluated by the federal government, typically the U.S. Department of the Interior/U.S. Fish and Wildlife Service (USFWS), as to if the project is likely to have an adverse effect or jeopardize the continued existence of the species.

> **"THEY'RE IMPORTANT BECAUSE THEY'VE BEEN AROUND FOR A WHILE—DINOSAURS WERE CRUNCHING THESE GUYS UNDER THEIR FEET."**

Zimmerman explains that navigating the Endangered Species Act can often be confusing and complicated—making EnviroScience's work all that more important. "We try to help make everything as efficient as possible because it can be frustrating when somebody has a project that is delayed for a year or more if a client isn't prepared for the process and what pieces of information may be needed."

The ESA protects endangered species while allowing for projects to proceed as long as they have the right combination of avoidance and conservation measures. Unfortunately, the practical implementation of these standards is a bit more complicated. Furthermore, the process can become more complex depending on the state the activity is occurring in. "The endangered species act is a powerful piece of legislation and we work with our clients to help them navigate through the process because, even though it is a federal regulation, it depends on the state USFWS field offices that are administering it," Zimmerman elaborates.

## MORE THAN MUSSELS

Zimmerman's work extends far beyond the Endangered Species Act and can be very time-sensitive. Every project is a challenge, and Zimmerman's work involves people as much as it does endangered species. "We've had some things be related to emergency-response or a deadline—meeting that and having the client and the resource agencies be happy makes it challenging and rewarding."

According to Zimmerman, regardless of time constraints, complex resource management, or high-pressure situations, delivering on everything makes environmental conservation worthwhile. "I love the challenge of a big project." Protecting native freshwater mussels and working around water is the perfect challenge for biologists like Zimmerman.

With over 300 endangered mussel species in the United States, environmental agencies like EnviroScience rise to the challenge of protecting these vital species.

When new construction sites are determined, the Endangered Species Act steps in to protect any endangered wildlife within the impacted area. Unfortunately, the protocols surrounding these protections can be complex and difficult to understand, making the work of scientists like Greg Zimmerman, Corporate Vice President for EnviroScience and an endangered mussel surveyor, vital to protecting biodiversity.

## WHY ARE ENDANGERED MUSSEL SURVEYS CONDUCTED?

Depending on the state, they may have their own list of protected mussels or rely on the list of federally protected mussels to guide their environmental policies, and it's often a combination of both. For example, Ohio protects all native freshwater mussels, whereas other states only regulate federally and state-listed mussels, but not all species. Regardless of the referenced list, each state has an agency or multiple agencies tasked with managing environmental reviews that impact mussels.

Endangered mussel surveys are a necessary step in project planning because the distribution of mussels and species assemblage relative to a planned project is critical to completing the required environmental documentation.

In Ohio, the ODNR and USFWS are typically responsible for reviewing project plans and environmental reviews to ensure that protected species are considered. These agencies have classified all of Ohio's major waterways into areas known to have mussels and the potential for federally listed species within these reaches.

A Group 1 stream means a small to medium stream where mussels may be present, but it's not known to have federally listed species. A Group 2 stream is a small to medium stream where federally listed species are known to exist. Little Darby Creek is both a Group 1 and Group 2 stream, depending on the location.

*(Left) A bag of federally endangered Northern Riffleshell being held for processing at Hunter Station, PA.*
*(Right) A tray of federally endangered Clubshellbeing held while PIT tag epoxy cures at Hunter Station, PA.*

*Photos: EnviroScience, Inc.*

*Dive crew preparing for a mussel survey on a navigable river.*

Similarly, a Group 3 stream is a large river where mussels are present but no known federally listed species, and a Group 4 stream is a large river where endangered mussels may be present, like some sections of the Ohio River and the Muskingum River.

Having clear guidelines and boundaries makes urban planning easier. EnviroScience works closely with its clients and the respective state agencies. "That's the kind of work that we do. We work as an intermediary between the project owner and the agency in finding the most efficient way to get everything done," says Zimmerman.

Mussels are endemic to specific areas, and project impacts can disturb or kill the native population. Unlike fish that can move away from construction areas, mussels don't move. Often when the project cannot be moved, a mussel salvage (relocation) may occur to preserve the population. Divers and biologists enter the water and move the mussels away from the area of direct impact, but it can be a very labor-intensive process.

"Often you move them out of the way before the project because they live a long time—they don't repopulate immediately, similar to an old-growth forest, it's not something that's going to come back immediately," Zimmerman emphasizes. Because the population cannot quickly repopulate, surveys and relocations help prevent species and ecological function loss.

The procedures for conducting a mussel survey vary widely from state to state, and most states also have strict and specific guidance on who can perform mussel surveys, as they are very difficult to identify, and a relatively high level of experience is needed to perform and report the fieldwork to meet agency expectations.

Previously, mussel survey methods were proposed project-by-project, but this is no longer the case. Most states have basic survey protocols, which may need to be modified based on the project type and site conditions. Knowing when modifications may make sense rather than following the survey "recipe" is another reason most project owners know to utilize experienced surveyors and salvagers like EnviroScience.

Mussel surveys and relocations typically begin with defining the Area of Direct Impact (ADI). The ADI is typically where mussels are usually relatively certain to be killed or severely impacted by construction, scour, water quality, temperature, etc. Then survey limits are defined around the ADI in terms of how far upstream, laterally and downstream a survey should occur.

In some states, a "Recon" survey may be performed ahead of time at the site to determine if mussels and mussel habitats exist before conducting a formal survey.

## "WE HAVE THE RAINFOREST OF MOLLUSK DIVERSITY IN THE WORLD."

**- GREG ZIMMERMAN OF ENVIROSCIENCE, INC.**

After establishing the survey boundaries, the team of surveyors, often through a combination of methods including hand searches by wading, snorkeling and diving, are deployed to meticulously search for mussels.

### SEARCH METHODS AND FINDING ENDANGERED MUSSELS

Specific search methods include time searches in cells (sections of the survey limits divided into squares like a checkerboard), transect searches (essentially underwater measuring tapes), quadrats and moving transects. If endangered mussels are detected, the mussels collected in the field are put back where they were found.

Additionally, if endangered mussels are found, a project typically cannot move forward without informal coordination with federal and state agencies to avoid project impacts. If impacts can't be avoided, the development of a Biological Assessment (BA) is typically required to be submitted to USFWS for review.

The Biological Assessment is then approved via a Biological Opinion (BO) which can allow some impacts to endangered species so long as their existence is not in jeopardy.

The BO will also call for certain conservation measures, such as construction site best management practices like monitoring water quality and relocating mussels out of the ADI before construction.

"The worst case for a project owner is when we detect an endangered mussel during a relocation project in an area where endangered mussels were not expected. Then you have a situation where a project is likely about to go to construction, contractors can charge the owner fees for delays, and the project can't happen until we get environmental clearance and things turn into an emergency. These events can happen and I think EnviroScience has the best record out there for working through these issues," says Zimmerman

*Photo: Greg Zimmerman / EnviroScience, Inc.*

Zimmerman notes this is why doing a survey correctly up front, anticipating impacts and pushing for a mussel relocation scheduled as far ahead as practical in areas of uncertainty in terms of endangered species is important.

In cases where no endangered mussels are detected, or none are expected like in certain stream classifications, mussel surveys can sometimes move directly from survey mode to relocation mode where only non-listed mussels are relocated, or in some cases, no relocation may be required at all depending on the state/location.

### SURVEY EQUIPMENT USED

"We often use transects, which are weighted lines that we'll stretch across the river bottom and are marked out, so we know where the mussels were collected and where the divers are," says Zimmerman.

Transects can also be used to create a cell grid on the stream bottom, like a checkerboard, with each square receiving a specific level of search time (effort). The weighted line allows the divers to be more easily tracked in the water.

EnviroScience also uses specialized boats and diving equipment. The standard method of diving in rivers uses surface-supplied air hardhat diving, including video and communications for safety and efficiency. Because of its life support equipment, a very high level of training and equipment protocols and maintenance is required.

Zimmerman, who received a degree in Environmental Biology from Hiram with a heavy concentration in art, initially used his skills to create maps of the project area and the location of the mussels living there relative to the impacts. His diverse experience and educational background in biology and art have helped EnviroScience and its services stand out.

"One of the things that I think led to our success was being able to graphically display data in relation to a project in a way that is easier to understand," he adds. "Creating maps in GIS was my art outlet, I loved taking our field data and the engineering information and combining these things to create that 'a picture says 1,000 words.' Now we have an entire GIS/CAD department and they've done an amazing job to streamline the process, but I see the foundation of my original maps in our work products which is fun."

In particular, mussel relocations completed under a BO are very technical. "You work through the substrate like underwater archaeology—you work your way through one way, pull the mussels out and repeat over the same area continuing the process until you reach an established threshold where the agencies can be confident most of the mussels are cleared," Zimmerman outlines. Easier said than done, Zimmerman adds, "A lot of times in freshwater, you can't see, so you have to go by feel—it's a very resource-intensive process."

"The simplest equipment we use is a quadrat, which is just a square usually made out of rebar or PVC and a scoop," explains Zimmerman.

For detailed mussel population studies, often required for endangered mussels, the quadrats are disbursed throughout the area in a grid pattern with sometimes 100s of samples, and divers systematically search each box for mussels. The number of quadrat samples required is often based on statistical models developed by the USGS.

*Photos: EnviroScience, Inc.*

*(Left Page) Diver collecting freshwater mussels in the Apalachicola River Basin, Fl.*

*(Top Right) Remotely Operated Vehicle (ROV) used for habitat assessments, Allegheny River, Pennsylvania.*

*(Bottom Right) Phil Mathias, EnviroScience Malacologist and crew processing salvaged mussels and affixing PIT tags and Hallprint glue-on tags at a large utility crossing in the Kankakee River, IL.*

**"LOOK WHERE ENDANGERED MUSSEL SPECIES ARE IN REGARD TO THE HUMAN POPULATION, AND THERE IS A LOT OF OVERLAP—WHEREVER CITIES AND AGRICULTURAL USES GROW, MUSSELS OFTEN DISAPPEAR."**

## MONITORING AFTER CONSTRUCTION

During and after projects that impact endangered mussels, monitoring the species often continues. EnviroScience uses turbidity sensors to track water quality before, during and after construction for things like turbidity and pH from concrete work and Passive Integrated Transponders (PIT tags) by BioMark/Merek to track mussels that were relocated.

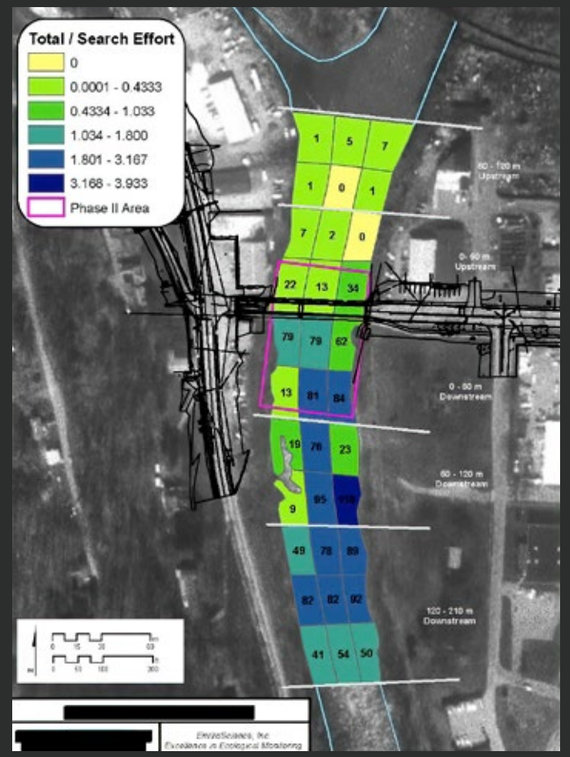
One of EnviroScience's biggest projects that continues to require monitoring is the PennDOT Hunter Station Bridge. "For the Hunter Station Bridge we used EXO 2s upstream, nearfield and far field from the bridge site during construction to monitor and ensure that when they're doing concrete pours or there is runoff from rain events, we can track how it relates to mussels," Zimmerman adds.

The Hunter Station Bridge in Pennsylvania was the largest relocation of endangered mussels ever completed in the U.S. According to Zimmerman, the bridge has a very large population of endangered mussels in the area, including directly underneath. Due to the population size and the potential impacts, the project took over 10 years to plan and complete. Over 190,000 mussels were moved to different streams and rivers in various states over 2 years, earning PennDOT District 1-0 the Pennsylvania Governor's Award.

"Usually, you just move them upstream to a suitable habitat near the bridge; it's pretty rare where you move mussels to different locations even within the same river, let alone 6 states and the Seneca Nation of Indians," Zimmerman says. However, "The Hunter Station project was so big that it could have actually jeopardized the existence of the two species that would have been impacted without these conservation measures."

Though unconventional, relocation was necessary considering the potential species loss and the large number of mussels present in the area. "It was a really big deal because there were so many mussels there, but there was nowhere else to put the bridge—it had to be fixed," explains Zimmerman. "Locals were looking at a 50-mile detour, and it was a critical route for emergency services. The design and construction teams were able to keep the bridge open through most of the replacement, which was another huge win considering the endangered mussel resources nearby."

Completing the project took years, but the time was well-spent. Zimmerman expands to say, "We have the rainforest of mollusk diversity in the world." Losing even two species of mussels could lead to further ecosystem instability as native freshwater mussels naturally improve their ecosystem. SB




*(Above) Photograph of Greg Zimmerman, Corporate Vice President and endangered mussel surveyor at EnviroScience, Inc.*

*(Right) Chart made by Greg Zimmerman showing "Phase I: Total Mussel (All Species) Distribution Results."*

*Images: Greg Zimmerman / EnviroScience, Inc.*

# BALANCING FOREST BIODIVERSITY AND LAND USE BENEFITS

A new study by Fangyuan Hua, Assistant Professor at Peking University's Institute of Ecology, compiles data showing that restoring native forests results in better biodiversity, greater carbon storage and more soil conservation and water provisioning benefits. However, the data also indicates that tree plantations are better at providing wood.

The benefits and downsides of each forest type lead to tradeoffs in land management practices. In their paper, Hua and colleagues explore the advantages and disadvantages of different forest types, hoping to point the way toward better forest restoration practices. They hope to encourage practices that balance environmental goals with wood production needs.

"Overall, we used a range of native forests – including pre-existing as well as restored ones – as our baselines," said Hua. "We compared several types of plantation tree covers against these baselines to assess their relative merits at supporting forest biodiversity, storing carbon in aboveground biomass, preventing soil erosion, providing water and producing wood."

## RELYING ON DECADES OF DATA

Hua's paper was a synthesis paper that pulled together findings from many other studies. Hua and colleagues researched and compiled all the data into a meta-analysis.

"Many authors collected the original data; they have produced all the data which we synthesized in one place, a compilation of 264 studies," says Hua. Data went back to the 1970s, and the researchers covered as much data as they could locate in the study.

Several plantation-versus-native-forest comparisons were examined in the paper. The paper compared: tree plantations vs. native forests that have not been deforested before, including old-growth forests, as well as plantations vs. restored native forests. In both cases, the study differentiated among different types of plantations, including monocultures (plantations with one tree species), mixed-cultures (plantations consisting of several tree species) and abandoned plantations for which active management has stopped.

*Experimental trial at Bertioga, São Paulo state. (Credit: Paulo Molin)*

*Experimental trial at the Forestry Station of the University of São Paulo.*

## OLD-GROWTH AND GENERIC NATIVE FORESTS

In terms of restored native forests, secondary forests are those that naturally recover, whereas actively restored forests are those people have deliberately worked with to bring back to their previous state. People are actively pioneering ways to get native forests to grow back, and one way is by using a tree-planting range that mimics natural trees.

For forest biodiversity, the study used population abundance - the number of individuals for a given study species – as the metric. Such data generally come from field research in which researchers used methods appropriate to the study species to quantify their abundance. For example, abundance data on birds are usually obtained by counting birds by sound and visual cues. In contrast, for insects, researchers typically relied on collecting insect samples with traps for subsequent count and identification.

## CARBON SEQUESTRATION IN FORESTS

The study represented carbon storage with aboveground biomass, the weight of living materials in aboveground vegetation and a major form in which carbon is stored in a forest ecosystem.

"Ideally, the carbon storage benefit of forests should best be gauged on the whole ecosystem level, including not only aboveground, but also belowground vegetation and the carbon stored in soils," said Hua. "But such data are highly limited. So we resorted to just one component, the carbon stored in aboveground vegetation, which has the greatest amount of available data."

Field studies reporting such data typically lay out a study plot to measure the diameter at breast height (DBH) of individual trees, sometimes also how tall they are. These measurements are then plugged into allometric equations, which combine information on wood volume and density to calculate the weight (mass) of living materials in vegetation.

## SOIL EROSION CONTROL

Prevention of soil erosion was another aspect compared between plantations and native forests. Data the study compiled on this aspect typically took form in the number of soil sediments displaced by surface runoff in a forest.

Field studies reporting such data rely on establishing "erosion plots" – typically on slopes – in the woods being studied to collect and measure runoff water-carrying sediments.

*Photo: Paulo Molin*

These sediment measurements are inversely related to measurements of how well a given forest cover is capable of retaining soil from erosion.

The amount of water provided by forests was determined by standard measurement of water yield. How much rain had fallen, how much water was already present and evapotranspiration all needed to be known to estimate such data. Water data was gathered by Professor Sampurno Bruijnzeel of the King's College of London, who has decades of expertise in forest ecohydrology.

## USING DATA TO INFORM POLICIES AND LAND USE

The meta-synthesis of all this data performed by Hua and colleagues pointed to a few possible policies and land use suggestions that might balance the environmental and wood production benefits of forest restoration.

"The benefit space must be considered," says Hua. "If a plantation-dominated restoration is done, especially one using monoculture that will not result in much biodiversity benefits. Plantation-dominated land tends to have fewer different tree species, which means less biodiversity supported overall. Instead, restoring native forests would be a good path forward, and our study shows that this would also bring greater benefits for aboveground carbon storage, soil erosion control and water provisioning."

Some programs already tried in China, such as the "Grain-for-Green" program in 1999 that gave farmers grain if they planted trees on otherwise farmed mountain slopes, have been effective at reestablishing forest cover.

"However, the prominent goal of many forest restoration programs like the Grain-for-Green Program is typically not biodiversity, it's carbon, water and wood," says Hua. "But are plantation forests really the best? We have not found that for biodiversity. We must then ask when and how and where can we put biodiversity back into this benefit space."

Hua had three critical points:

1) If the policy focuses on environmental benefits (carbon, water, soil, biodiversity), then restoring native forests is best.

2) But, plantations have an advantage over restored native forests in producing wood.

3) To achieve a balance, we must navigate around environmental vs. production needs.

## POTENTIAL SOLUTIONS

One technique may be that of sparing land. Suppose that a given piece of land can be used for high-yielding plantations. In that case, this can take on the burden of producing wood from existing, potentially environmentally more beneficial native forests elsewhere, including old-growth forests.

This strategy would require integrating plantations into land use planning.

## "BIODIVERSITY GOES DEEPER THAN PRACTICAL MATTERS. IT IS A SOUL QUESTION"

Abandoned tree plantations no longer intended for production functions should be actively intervened to mimic more native-forest-like conditions.

"This would allow them to provide much greater environmental benefits on multiple dimensions as our study showed," said Hua.

## FUTURE CONSIDERATIONS TO RESTORE FORESTS

In the future, Hua sees many areas to consider. "We are looking at how humans should balance wood production and biodiversity. In the future we must reduce the carbon footprint, but wood demand is also expected to go up. Even selective logging can hurt biodiversity."

Land sharing vs. land sparing is likely to be an important consideration. "We think if you can produce wood on one piece of land, at least in theory, it can potentially spare wood on other land."

Sharing land between production and forest biodiversity means a larger piece of land may be needed for production.

"How should we allocate our land into different uses? This is an important question. In China, our research team is already testing how different forest management techniques could meet wood production but minimize biodiversity costs," Hua mentions.

## INFLUENCING POLICIES, PLANS AND PRACTICES

In the end, preserving forest biodiversity is not just a trivial question. "Biodiversity goes deeper than practical matters. It is a soul question," says Hua. "Many people already agree that a ladybug has value in and of itself, an intrinsic value, and that biodiversity has an intrinsic value too. But for people who do not necessarily share that view, there is increasing evidence that biodiversity is valuable to good human health, carbon storage and pollination. For example, bees and flies are critical pollinators. Coffee plantations are protected from bugs by birds, etc."

Hua goes on to say, "These benefits and services that provide a healthy, vibrant ecosystem to humans – for free – are called ecosystem services. And there is increasing evidence for a strong link between biodiversity and the amount of ecosystem services delivered," explains Hua. "As an example, among all the other benefits, we know there is a huge potential for finding new medicines in nature, due to the wild gene pool. Wild nature provides immeasurable benefits for people."

Hua emphasizes, "We have a responsibility to conserve biodiversity." LB

# THE SOIL FOOD WEB


## THERE ARE MORE LIVING THINGS IN ONE TEASPOON OF SOIL THAN THERE ARE PEOPLE ON THE PLANET

### Members of the Soil Food Web

1. Plants
2. Nematodes (Root-Feeders)
3. Bacteria
4. Fungi
5. Organic Matter
6. Nematodes (Fungal-Bacterial Feeders)
7. Protozoa
8. Nematodes (Predators)
9. Arthropods (Shredders)
10. Arthropods (Predators)
11. Animals
12. Birds

*All Graphics: Emma Jones/ Fondriest Environmental*

The soil food web begins with the expulsion of active organic matter from the roots of plants or decomposing plant matter. This matter contains sugars, protein and carbohydrates available for the bacteria and fungi living near the root system. Depending on the plant, the exudate it releases may vary in order to attract specific species of fungi and bacteria.

These fungi and bacteria produce enzymes that help break down aggregates, making dirt into soil. As these aggregates break down, the bacteria and fungi consume a host of micronutrients like calcium, boron and magnesium. In order for the nutrient to become available to the plants, protozoa, nematodes, shredder arthropods and other microorganisms, prey on and eat the fungi and bacteria. The fungi and bacteria are highly concentrated with nutrients—so much so that when the preying microorganism consumes them, the excess nutrients are excreted. The excrement is nutrient-rich and plant-available, creating a mutually beneficial cycle in the web.

These smaller organisms are then consumed by large predators, like arthropods which tap into the nutrients consumed by the microorganisms. Eventually, the arthropods are consumed by birds or terrestrial animals, who consume the nutrients, returning to the soil as waste later. This organic matter will decompose into humus—the nutrient-rich matter will then enter back into the soil food web after being consumed by the local fungi and bacteria.

*Sources:*
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# NOT SO QUIET POLAR NIGHT

## ARCTIC CREATURES FOUND TO BE ACTIVE DURING DARK PART OF THE YEAR

Most people need little more than a comfortable pillow, a blanket and a dark room to drift off into a multi-hour snooze. Many researchers assumed that once plunged into darkness for about half the year during the polar night, most polar creatures would do the same: fall asleep and take a big nap for as long as the darkness lasted. But Jon Cohen, associate professor at the School of Marine Science and Policy, in the College of Earth, Ocean and the Environment at the University of Delaware, wondered if that was true.

Despite the technical challenges of monitoring biota in very low light conditions, Cohen and his team were determined to find out if krill, copepods and other creatures were dozing off in the dark or seeking out prey, light and each other.

"The polar research has an interesting starting point: I got to thinking about how light affects animal physiology, and I became drawn to deep ocean work, where light is so limited animals produce their own: bioluminescence," Cohen reflects. "For me, investigating low light conditions naturally led to research at the poles, focusing on the arctic."

### MEASURING THE POLAR NIGHT

For half the year in the arctic, the sun is under the horizon, and low light reigns—this phenomenon is referred to as the polar night. The other half of the year, the sun is above the horizon, and the sunlight bathes the land and water all day during spring and summer.

"Measuring light during the sunny part of the year is not too difficult," says Cohen. "Measuring light during the polar night—the period of the year we were interested in—is much harder technically. There weren't a lot of commercial solutions available for us, so we had to devise our own. A lot of the sensors that were available didn't work very well in really low light."

Measuring light and determining how much light was present was a technical challenge, but there were many other challenges as well. For example, if light is detected, there has to be a method that shows that the organisms can detect the light also.

There is also the issue of artificial light vs. natural atmospheric light. "People don't always think about this, but artificial light from buildings, ships, towers, and even in our case, research vessels, can be significant for biota, especially in low light environments," says Cohen. "We can see creatures swimming away from…or towards…our research vessel, for example, as they react to the light it's giving off. Their reactions to the artificial light will influence which of these creatures we see and how many." Cohen and his team had to factor this behavior in their estimations of biota numbers.

They also had to come up with ways to modify sensors or create other sensors to be able to measure light and light reactions of biota in polar night conditions.

"To get a good picture of light in the polar night environment, we had to modify our light sensors. We had to be able to capture the photons that animals were actually using to perceive light," Cohen explains.

Basic questions Cohen's team asked in their research included:

1) How much light is there?

2) How much can animals perceive?

3) How does that change over time?

*Graduate student Heather Cronin deploying a bathyphotometer to measure bioluminescence.*

*Photos: (Left) Jan Sivert Hauglid, (Right) Geir Johnsen*

Cohen's team wanted to get a holistic sense of the biological dynamics of various biota, even when the sun they get is under polar night conditions.

Cohen and his team were surprised to find that, not only was arctic life not dormant during the polar night, but were instead detecting each other, predators were finding prey, and the small amount of light available during the polar night was nevertheless sufficient to regulate the biological clocks of the marine biota studied.

Cohen also emphasizes that both natural and artificial light affect biota in the middle of the food web (which Cohen's team focused on), such as krill, copepods and fish. "Natural light includes things like moonlight or sunlight, and light the creatures generate themselves, namely bioluminescence," says Cohen. "Artificial light is anything the creatures are coming into contact with that is human-generated, such as light from street lamps, buildings, ships and even research vessels. While it may not occur to most people, a research vessel casts a pretty large shadow, but lights can be coming from the cabin or deck. All of these things can impact the creatures we're trying to study, especially in such low light conditions. So we need to be aware of all the possible light influences on the creatures."

Cohen's major findings are that, yes, the polar night has measurable light detectable by humans, fish, zooplankton and other marine creatures. Not only can these creatures detect it, but it also is biologically relevant light and acts to set their biological clocks. Cohen mentions, "Interestingly, we found the organisms we studied had a rhythmic biology with the sun, even when the sun was below the horizon."

### MONITORING EQUIPMENT

Cohen's team used autonomous vehicles to study water acoustics surrounding the creatures. The researchers used acoustic Doppler profilers. Moorings were used for some instrumentation to keep it in place.

"Light measurements apply to other organisms, too, not just the middle of the food web biota," Cohen notes. "We could potentially collaborate with other research groups studying other biota. We could learn to understand how light applies to terrestrial organisms and to other types of marine organisms not yet included in our research, such as macro algae and kelp."

Cohen took a wide range of data, including spectroradiometric data and data using PAR sensors. In some cases, commercial spectroradiometers were used with the added improvement of light measurements being taken off a reflective plate, which improved the sensitivity of the instrument in such low light conditions.

"For that data, sky light comes down and bounces off the reflective plate, and a photometer picks that up," Cohen explains.

*Light during polar night in Svalbard, including light from the sun below the horizon, moonlight, aurora borealis, and artificial light.*

In order to utilize all available light for their measurements, radiometrically-calibrated cameras were used to gather all sky light (wide field image) and incorporate it into PAR measurements. In addition to getting a good picture of what light is present, they obtained a picture of organisms' positions and reactions to the light they pick up.

"We ultimately get a picture of the distribution of the organisms in space and time," says Cohen. "We collect them and expose them to light under electrophysiological conditions where we can see changes in their eyes. We capture the wavelengths and intensities we see in their retinal cells, and that tells us their response to light."

The biota are collected with nets or tracked using acoustic Doppler profilers and broadband acoustics.

"We look for the biota reaction to the light. We look for them either swimming towards or away from light," says Cohen. For some experiments, locomotor activity monitors were used–printed circuit boards with infrared emitters and detectors (weatherproofed for seawater). For those experiments, the organisms are in test tubes, and whenever they move towards or away from the light they are exposed to in the test tube, the infrared light path will be broken, and the computer will detect it. "That's how we detect organism movement in the laboratory," says Cohen.

Cohen and his team used a variety of approaches to determine how active the animals are at day and night.

"We were also able to detect and track their natural bioluminescence when applicable," says Cohen. "The bioluminescence readings were recorded by bathyphotometer, which basically sucks in organisms, causes them to glow, and spits them out the other end of the instrument."

## RESULTS

Generally, in terms of overarching goals, Cohen and his team are pleased with the progress they've made technically, and Cohen believes they have done well at measuring light during the polar night by coming up with innovative ways to measure very low amounts of light and biota's ability to detect it.

Next, Cohen hopes to understand autumn and spring better, where light is abundant. He also wants to understand what's happening across years of polar nights and how climate change affects biota dynamics.

"International researchers I worked with, and honestly, my own team, we all thought all the biota would go to sleep during the polar night but that doesn't happen: in spring we have algal blooms. We see that fish and krill and copepods haven't been sleeping, they actually have been making themselves poised, and ready to take advantage of the abundance of food in spring," Cohen says.

In terms of polar biology research trends, Cohen says researchers are curious about how polar night systems will be altered by climate change. "We expect these changes to be complex," notes Cohen. "With less sea ice, biota could get more light, or they could get less. So what ultimately will be the effect of losing sea ice? These are questions that exist at the intersection of light and biology."

Studying the effects of artificial light at night on biota is another emerging field of study. "The LEDs emit strongly at wavelengths that organisms can detect, and we need to know how this impacts them and does it impact them enough to disrupt normal behavior," Cohen mentions.

In the future, Cohen hopes that low light detection sensors and analysis technology will continue to develop, making data collection and handling easier. He also hopes to see more connections between marine and terrestrial research in polar biology.

"I think this is already happening," he says. "We've already made some great strides. Just the fact that we know now that biota are active during the polar night, not dormant like we thought, is a part of a big step forward in our understanding. Next will be linking marine and terrestrial knowledge of the polar night." LB

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*(Left) Jonathan Cohen preparing sensor for light detection away from a research vessel.*

*(Right) Jonathan Cohen measuring light on Svalbard during polar night.*

*Photos: (Left) Randall Hyman, (Right) Geir Johnsen*

# ANGUISH OF THE AMAZON

## Climate Tipping Points and the Loss of Rainforest Resilience

When considering the health of sensitive environments such as the Amazon rainforest, Chris Boulton, Research Fellow at the Global Systems Institute at the University of Exeter, emphasizes that appearances can be deceiving. "I became interested in the research because of the idea of climate tipping points. In other words, a system under duress, like the Amazon rainforest, can seem fine, but it can undergo rapid decline in a short period of time."

The research Boulton and his colleagues are doing involves finding the characteristics that show a movement towards a climate tipping point and then hopefully ameliorating or stopping that movement before it is too late and the tipping point for the system has already passed. "Our goal is to quantify the movement towards a climate tipping point, measured as a loss of resilience in the system. Resilience is essentially how quickly a system recovers from perturbations, in this case droughts for example." says Boulton.

### THE AMAZONIAN CLIMATE TIPPING POINT

The data Boulton and colleagues used to measure changes in Amazon resilience came from satellite images. Vegetation Optical Depth (VOD) was used to estimate monthly vegetation water content, while Normalized Difference Vegetation Index (NDVI), a different vegetation index measuring the greenness of the plants, was used for comparison.

Great care must be taken in interpreting the images, as an increase in greenness does not necessarily mean the forest has recovered. Sometimes green, i.e., photosynthetic activity, does not indicate a healthy forest but instead suggests that there has been grass growth in its place.

As far as what exactly in the images translated into a meaningful loss of resilience, Boulton said that each pixel or location has a VOD or NDVI value each month, from which a time series can be created and analyzed. The team measured 'lag 1 autocorrelation' or AR(1), a correlation between values that are one month apart. "Measuring this AR(1) over time and seeing an increase in it suggests that the system is becoming more sluggish in its response to perturbations and, as such, losing resilience," says Boulton.

Although the Amazon still appears to recover when exposed to dramatic changes in rainfall and/or temperature, it takes longer to return to equilibrium. "In the last 20 years, we have been seeing more droughts, and we have seen that the Amazon is restoring itself more slowly than it used to," says Boulton.

*(Right) The Amazon River is pictured from the International Space Station as it orbited 260 miles above Brazil in South America.*

*Photos: NASA*



*In the south, extensive land-cover change can be seen where forest is being harvested and turned into agricultural land, typically soybean or cattle pasture. Here, the green forest gives way to tan land, often with remnant stripes of green marking small stands of timber yet to be cut. Ultimately, the deforestation in these areas will be complete. In some areas, red hotspots mark fires, typically used to burn debris and stumps.*

### THREATS TO VEGETATIVE BIODIVERSITY

While Boulton and his team did not investigate whether certain tree species in the Amazon are being affected by logging, drought, fire and other stressors more than other species, they did investigate the forest makeup and compared it to terrain primarily covered by grasses. Boulton's study only looked at pixels that had more than 80% broad leaf cover. "Our impression is drought-resilient plants may start taking over, but this depends on how fast the resilience is being lost and whether or not the forest can 'keep up,'" says Boulton.

Looking at the satellite data from 2005 and 2010, researchers previously found that the NDVI sprung back faster than in some other years, but they were disappointed to find that the green growth was primarily grasses, not trees. "Trees react more slowly," notes Boulton. "During heat waves, grasses may die faster but they also come back faster than trees."

Boulton and his team aren't the only ones who are tracking changes in the Amazon with growing alarm. While it is important to document the changes and try to understand them, studying them at this point may seem like an exercise in futility. However, Boulton believes that, despite the unrelenting stresses on the Amazon, people can do more than merely chronicle its demise.

"Studying the individual areas and their changes over time, we've found that it's the urban areas and fields that are losing resilience faster," he says. "These are also the areas where people interfere with natural processes the most, where biodiversity is being threatened. These areas are where trees are being cut down, where evapotranspiration processes are getting altered because of the trees being eliminated. Fires are also affecting these areas severely."

### AMAZON LOGGING

Boulton and his team are looking at local, regional, and global actions that could possibly be performed and would help the Amazon, even now. "We're seeing that the Amazon forest is not taking in as much carbon as it was in the past. This is because trees are being cut down, so there aren't enough trees to contribute to the carbon sink." Meanwhile, the drier climate means fires are more frequent and severe. "Logging heavily contributes to resilience loss in the Amazon," Boulton emphasizes. "Any reduction in logging would help, even now. It would help restore the carbon sink function and slow down or maybe even stop the loss of diversity."

In the near future, Boulton hopes to look into machine learning capabilities and how they could assist in detecting an Amazonian climate tipping point. "We want to see if we can detect something different or if the machine learning data can give us a different perspective," he says. "Ultimately, I'm a mathematician, and I got into climate change because the math interested me. I wanted to do something useful with maths and statistics. This study, and adding the machine learning aspect, would help me accomplish that."

Boulton adds that, even though doom and gloom pervade social media on the topic of climate change and the Amazon, the situation is not as hopeless as it may seem. "This is an early warning, we still have a chance to do something," he emphasizes. "So even though you see doom and gloom on social media, it's positive in a way, because people are paying attention to it, and people haven't given up yet. It's not over, we can still change course." LB

Keweenaw Bay Indian Community

# KEEPING KEWEENAW BAY POLLUTION-FREE

As much as climate change and pollution impact current generations and present environmental conditions, the compounding damages will continue to wreak havoc against generations to come if no actions are taken. This idea is central for scientists who focus their research on monitoring, analyzing and responding to environmental data.

Researchers like Dylan Friisvall, the water quality technician for the Keweenaw Bay Indian Community (KBIC) Natural Resources Department (NRD), have dedicated their careers to monitoring pollution and water quality in order to protect resources for the future. "One of the best parts of my job is just being outdoors, it makes my day go by faster because I get to enjoy the fresh air, and help do my part in protecting the environment," says Friisvall.

Friisvall states that it's difficult to pin down a single primary responsibility considering there are so many factors at play. Still, he highlights, "I think the primary responsibility for me as a water quality tech would be preservation for generations to come." He continues, "In the area I work in—I'm lucky enough to have such a pristine area where it's almost not really touched by the pollution of humans and that, I would say, is the goal and responsibility—keeping it as natural and pure as possible."

Friisvall works within the KBIC'S NRD, which shares its mission with many other Natural Resource Departments, "Making sure nature is as pollutant-free as possible for the next generation to enjoy."

It's easy to take advantage of water if you live in a community that consistently has access to clean water, but water pollution can make pure water toxic. Water pollution is not a niche concern of scientists but should instead be a concern for all people, regardless of proximity to water.

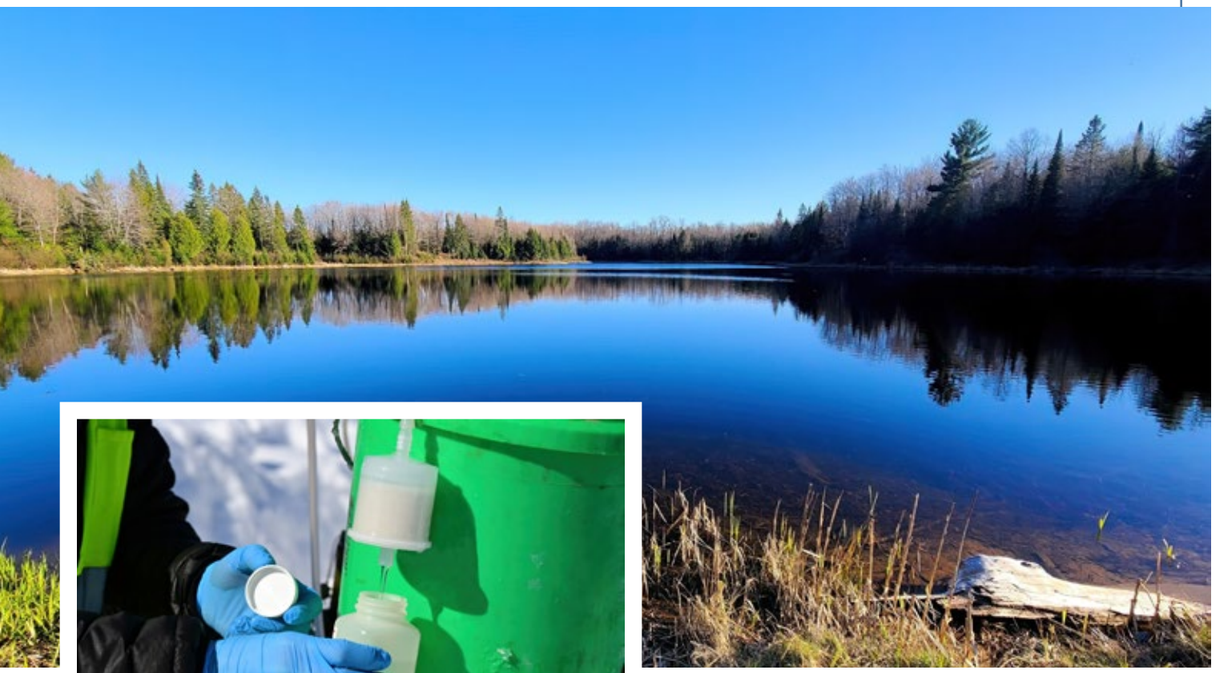
Friisvall explains, "Everything needs water and not just any water, pollutant/contaminant-free water to thrive. Even if we think about ourselves and wanting to make sure the water is clean and pure, as it is supposed to be, it helps out the whole ecosystem because not only do we consume the water, nature does so as well."

Water pollution is a problem because everything needs water. Water pollution contaminates drinking water, negatively impacts plant and animal biodiversity and can permanently change an environment's ecology.

The repercussions of water pollution are not isolated to aquatic organisms and instead ripples out from the site of contamination. The KBIC relies on both residential wells and Lake Superior for their water, and if groundwater is contaminated, the entire community's health may be at risk.

Friisvall and other water quality technicians sample groundwater to ensure the well water is contaminant-free. The data gathered is then supplied to residents, followed by recommendations on how to treat their wells so that residents have a healthy drinking water supply.

*< Crew packing up sampling equipment into field bags (Credit: Lindsay Bean)*





If water quality is compromised, the entire community could be negatively impacted. "For compromised water quality, we would resample the site to double check our findings and check field notes to see what was going on in the area that day of sampling, since we note weather from prior days as that makes a difference in our results, and then investigate the area and find out what could have happened," says Friisvall. He elaborates further, "For example, if it happens to be a flood event we would look upstream to see what could cause it and find the responsible party to see if it was intentional or accidental."

One such incident in 2016 was a flooding event at a textile factory that created a white film that flooded the surrounding waterways.

Thanks to the continuous sampling done through the Surface Water Monitoring (SWM) project, Friisvall explains, "We tested the site and streams as best we could and the incident created no harm or lasting effects, but it easily could have if it was anything else."

Pollution can enter ecosystems in a multitude of ways and in various forms. Chemicals like mercury and PCBs enter water often in a liquid state as a form of runoff from industrial sites; plastic debris has plagued waterways and every stretch of the ocean for years; mining waste can also enter the water in solid forms.

Friisvall has spent a lot of time studying the impacts of mercury and its influence on groundwater. In particular, how mercury contamination resulting from the copper mining boom in the Keweenaw Peninsula has impacted groundwater health. Toxins like mercury can harm fish health, increase mortality rates, and lower the production of an ecosystem. PCBs, mercury, and other harmful chemicals that are often a result of industrial runoff make fish sick, and chemicals traverse up through the food chain to humans that rely on fish as a resource.

Friisvall warns, "The mercury levels bio-accumulate which messes with the entire food web and gets built up as it goes up the food chain  and when we finally consume the fish, we could be consuming a dangerous amount of mercury."

For the KBIC, stamp sands, a solid form of pollution, started washing up on the shore in the 50s and have only multiplied in size. The copper found on the Keweenaw Peninsula was mined through a stamping method that led to the expulsion of the stamped material into Michigan's waterways, impacting ecosystems like Buffalo Reef and communities residing along the shore.

*(Left) Pulling a Groundwater sample with a filter on as turbidity was above 3.0 NTU.*

*(Right Page) Big Bay outside of Eagle Mine early in the morning prior to sampling that day.*

*Photos: Lindsay Bean*

The debris is sharp, black, and contains contaminants that quickly disbursed across the peninsula. The stamp sands are a particular problem for surrounding ecosystems. Friisvall explains, "Most plants cannot grow on it as it's either too hot from the sun or too sharp it destroys the roots."

Living right along the shoreline, monitoring water pollution is essential for the KBIC NRD. As such, the tribe has put into place several years-long monitoring projects to keep watch for changes in water quality.

The oldest project, the SWM project, began in 2001 and continues to this day. Friisvall began his work as a water quality technician in 2015 and continues to be a part of the project now. Friisvall states that positions like his exist to keep the SWM project operational by sampling "local lakes & rivers for contaminations as well as other parameters."

Friisvall explains that the project's goal is to "help determine the health of the water system and if there is any pollution." The program has been ongoing since 2001, and the long history of the project allows technicians to have "a pretty good guess on how a water system may be or is supposed to be in its natural state—before humans."

The KBIC NRD is also interested in examining water temperature and depth trends for fish stocking purposes. Friisvall uses Onset Level Loggers in streams during the spring, summer, and fall to measure these parameters.

Climate change has led to unexpected temperature variability, which harms wildlife. Stocking cold water fish in a habitat that is too warm destroys population-stabilizing efforts. Recognizing the high and low points of the stream is important to note when stocking fish and can impact other critical water quality parameters.

Friisvall also states that they've been able to detect trends that reflect how the environment has shifted over time in the eyes of the community. He recalls, "In recent years, there's been more of a drought going on and water levels have been going down in the streams that I sample at, especially when I compare them to memories of my childhood growing up and fishing. Now, some of them seem to not have really any water in them when comparing them to the stories of my father's childhood and his fathers."

To track some of these parameters, Friisvall uses the YSI EXO1 Multi-parameter Water Quality Sonde to gather data in the field. Water quality sampling technology has changed a lot over the years, and equipment that allow for out-of-lab analysis are best for technicians like Friisvall. "I feel that the more I can use tech to get results than having to bring it to a lab then the fewer chances of human error and cross-contamination," he explains.

**WATER POLLUTION IS AN ENVIRONMENTAL FACTOR THAT CANNOT BE IGNORED.**

Water pollution is an environmental factor that cannot be ignored. There is no escaping the necessity of access to water for all life, and monitoring and controlling pollution is one of the many ways of protecting a future for the planet. "The importance of monitoring is to protect and preserve for the future generations, not just for people but for all of nature," Friisvall emphasizes.

For Friisvall, the best part of his job is being able to educate people on water quality and the dangers of pollution. He explains, "When people ask me questions and I can educate them and spread awareness—then, I hope it means they are more cautious when littering or learn to recycle more." He further warns that "pollution is a global problem not just a local problem, so we all have to pitch in to do our part." The ties between urbanization and water pollution are well-examined and proven, and current practices must shift in order to protect the future. SB

*Photo: Dylan Friisvall*

# CORAL RESILIENCE

## DETERMINING THE FATE OF CORAL IN A CHANGING CLIMATE

It's no secret that the Great Barrier Reef is dying, as are many beautiful reefs created by coral all over the world. Excessive heat and ocean acidification have taken their toll. But Andréa Grottoli, distinguished professor of earth sciences at The Ohio State University, President of the International Coral Reef Society, Director of the Coral Bleaching Research Coordination Network, and a Fulbright Fellow, believes that all is not lost. Grottoli has found that the fate of coral is tied to one characteristic: its resilience.

"In my 20s, I decided I wanted to work on a problem to improve the world," she recalls. Since coral support so many other marine species and ultimately humans too, she felt like coral resilience was just the kind of important problem she wanted to spend her life working on. "I wanted to work on coral resilience from a problem-solving perspective, trying to understand why some corals are resilient, and seeing how we can help coral resilience," she says. "In the short term, it looks like there is still a lot we can do."

### CORAL DIVERSITY

Grottoli's work encompasses all sorts of corals: plating, mounding and branching corals. Grottoli and her team have also studied corals from all over the world, including Hawaii, Panama, Mexico, Guam, the Pacific, the Caribbean and the Mediterranean.

Field measurements include dissolved oxygen, buoyant weight, respiration and how much zooplankton the corals can consume. Lab measurements include chlorophyll and coral lipids. YSI sensors are used for the oxygen measurements, a microscope and known concentrations of brine shrimp are used for the zooplankton consumption measurements, and a spectrophotometer is used for the chlorophyll. Coral lipids information is extracted using organic chemistry.

One of the major goals of Grottoli's coral resilience study is to answer the question: can corals acclimatize? Can they adapt to the changes the environment is expected to undergo in the near and far future? In order to find out, Grottoli conducted a two-year Hawaiian study that exposed corals to end-of-century conditions. In the study, coral experienced elevated temperature and also elevated temperature along with lower pH. The acclimatization study did not include the effects of overfishing. All experiments were conducted with reef water. Reef water was heated and/or acidified to produce the desired treatment conditions. In the study, many coral died, but many survived.

Photo: I. Kuffner

*Dr. Andrea Grottoli snorkeling.*

"There is clearly resilience," said Grottoli. "Of the three species we tested, *Montipora capitata* had the worst survival rate, but *Porites compressa* and *Porites lobata* seemed to survive and thrive even in the more severe conditions. It's also possible that *M. capitata* may have had better survivorship had we provided them with more zooplankton." While coral can usually rely on both algae symbionts that use photosynthesis to make food and also zooplankton, under conditions of severe stress, the symbionts are ejected, leaving zooplankton as the only food source.

### ATTRACTING ZOOPLANKTON WITH LIGHT

In a related effort, a fall 2022 project by Grottoli involves enhancing resilience on a coral reef by building underwater lights by the reef that attract zooplankton, which would increase coral feeding, even under conditions of stress, hopefully enhancing coral resilience.

Adding underwater lights to reef environments is just one approach to enhancing coral resilience. "Current trends in coral resilience research include selective breeding—taking corals that are resilient to heat stress, for example, and producing 'super offspring,' says Grottoli. "Another trend is gene manipulation, namely coral genes that enhance resilience. Yet another technique is moving corals to better areas so they can recover."

Grottoli hopes that the impacts of climate change will be mitigated. Climate change mitigation would help corals the most. Locally, stopping overfishing and addressing pollution would also help retain the most reef.

"There is some reason for optimism," says Grottoli. "I didn't expect 50% of the coral in my study to survive. Model predictions said 10-30% would survive. This still means we've lost a lot of coral since 1850, which was the start of the warming trend since the Industrial Revolution. We had a much higher abundance back then. Oceans are still becoming warmer and acidifying at the same time, but I think we can still help the coral we have left."

In fact, the International Coral Reef Society has a list of 12 things everyone can do to help.

In closing, Grottoli suggests reducing local stressors and mitigating global climate change would help coral the most, though restoration and conservation are also helpful. "Coral resilience is out there," she emphasizes, "and we must harness it." LB

## TWELVE ACTIONS TO SAVE CORAL REEFS

- VOTE FOR CONSERVATION-BASED POLICIES & REDUCING GREEN HOUSE GAS EMISSIONS
- ADVOCATE FOR SCIENCE-BASED DECISIONS & REEF PROTECTION
- COMMUNICATE YOUR PRIORITIES WITH POLICY-MAKERS
- REFUSE SINGLE-USE PLASTICS
- EAT SUSTAINABLY & LOCALLY SOURCED
- LIMIT CHEMICAL & PRODUCT USE
- CUT CARBON EMISSIONS: WALK, BIKE, CARPOOL, DRIVE ELECTRIC
- REDUCE ENERGY CONSUMPTION
- PURCHASE CARBON OFFSET CREDITS
- PARTICIPATE IN LOCAL ACTION LIKE FUNDRAISERS & BEACH CLEAN-UPS
- EDUCATE YOURSELF & OTHERS; DONATE TO CORAL REEF RESEARCH
- SHARE THIS PLEDGE WITH EDUCATORS & THE PUBLIC

*Information retrieved from: http://coralreefs.org/pledge-4-reefs/*

# OHIO'S ORANGE STREAMS

## MONITORING ACID MINE DRAINAGE AND WATERSHED HEALTH

Not many young people pondering careers come up with the words "acid mine drainage." But Jen Bowman, Director of Environmental Programs at the Voinovich School at Ohio University, could not help but be fascinated by what she saw during her days as an Ohio University student collecting field samples.

"My interest in acid mine drainage, and how it affects watersheds, goes way back to my undergraduate days," she explains. "We saw firsthand how streams could be impacted by drainage from abandoned mines. Sometimes streams had such severe problems they turned orange. It was hard not to be struck by that. I was drawn in to the many associated challenges, keeping watersheds clean and improving stream health."

Bowman remembers spending a summer at Raccoon Creek in Athens, Ohio, with Dr. Mary Stoertz as her undergraduate advisor. In coordination with the Athens Soil and Water Conservation District and Wayne National Forest, she and three other students monitored the water quality at about 100 sites in the late 1990s.

*Photo: Darcy Holdorf / Ohio University*

"Some sections of Raccoon Creek were nice, others were impaired, so the Raccoon Creek project was continued," Bowman recalls. "Acid mine drainage, a legacy from when the mines fueled the Industrial Revolution back in the 1800s coal mining, was still having effects.

Coal mining, $H_2SO_4$ production, and coal rich in iron pyrite were a few of the things that were affecting water quality in the Raccoon Creek areas we studied. We were seeing very acidic pH levels, as low as 2 and 3. Our findings inspired the Ohio Division of Natural Resources Division of Mineral Resources Management and the Office of Surface Mining Clean Streams program to continue the Raccoon Creek cleanup."

*Jen Bowman, Ohio University, measures discharge in Hewett Fork an acid mine drainage impacted stream in the Raccoon Creek Watershed.*

### ACID MINE DRAINAGE MONITORING EQUIPMENT

Bowman and her team collect many types of watershed data. Data is used in part to assess the continuing impact of the coal mining once conducted in the area. Data collected includes laboratory water quality samples and field parameters such as pH and conductivity. SonTek Flow Tracker equipment is used to measure stream discharge. Some of the equipment used for stream data-gathering includes YSI data sondes, an EXO3, and a Myron Ultrameter.

Equipment is used to measure total dissolved solids, turbidity, temperature, pH, conductivity, and dissolved oxygen. The Myron Ultrameter is used for oxidation-reduction potential, temperature, pH, conductivity, and total dissolved solids. The acid mine drainage research is done in coordination with the ODNR Division of Mineral Resources Management.

Stream restoration data collected includes information on flood plain connectivity, water level with Onset HOBO data loggers, field water quality parameters using a YSI multi-parameter meter, sediment samples and salt tracing data (salt solution release based on stream size and measured conductivity allows for a formula to be used to account for interstitial flow).

Erosion is also measured using erosion bank pins. These data measure soil loss by measuring centimeters of exposed spray-painted rebar and utilizing metal detectors to find them. In this way, it is possible to quantify how much soil is lost. HOBO data loggers are also used to measure the depth and temperature of a stream, and these are installed directly into the stream with fence posts, PVC pipes and/or cinder blocks.

Bowman also collects data on the height of water in the water column. Water column data is taken in 5-minute intervals. Sediment data is gathered for streams using a rack, much like a dishwasher tray with open bottles attached. The open bottles in the tray are anchored with zip ties.

Alloway Laboratory analyzes the resulting bottled sediment. Additional analysis conducted at Ohio University includes dry weight and grain size using sieve analysis methods.

In terms of watershed data collection goals, Bowman and her team have many. "There are lots of environmental projects. However, our projects are defined by our partner's needs," she says. "I am happy to say they have been, and still are, committed to long-term projects at Raccoon Creek and across Appalachian watersheds."

### LONG-TERM MONITORING IN RACCOON CREEK

One of the long-term Raccoon Creek projects is monitoring for acid mine drainage in terms of a suite of parameters such as acidity, metals, and pH. About $17 million in funding has been used for restoration, including passive and active treatment systems.

Passive treatment means using natural means such as wetlands for restoration. Active treatment means using calcium oxide released from a doser system.

Active treatment for acid mine drainage involves continuously releasing calcium oxide powder into the water at a specific dose, creating an alkaline solution that treats acid mine drainage sources.

The goal is to maintain appropriate pH, alkalinity and metal levels. In addition, it is also the goal of Bowman's programs to align with funders' quality objectives. Measurements are taken before and after both passive and active treatment to assess best management practices. Some of the data collected is used to monitor treatment systems that inform maintenance and repair.

Bowman's team has many aquatic environmental improvement goals, some dating back to 2010. "Back then, one goal was to reduce acid mine drainage by 20%, and another goal was to restore streams to warm water habitats," Bowman recalls. "Back in the 1970s and 80s, these goals were not being met." A big goal was to restore the main stem of Raccoon Creek: Bowman and her team have achieved that goal as of 2022. Bowman credits Amy Mackey as a major partner in this achievement.

Bowman advises, however, that some headwater sections of the creek will always be treatment zones. Currently, the Ohio EPA's total maximum daily load report shows much improvement in Raccoon Creek. "The new report has been a great way to highlight how monitoring and partnerships work together to achieve big water quality improvements," Bowman notes. Furthermore, the Ohio Watershed Data program allows the public access to acid mine drainage abatement and treatment plans, says Bowman. There is also a citizen science program called "My Backyard Stream," which allows kids to gather data and share it publicly.

Bowman and her team also have a lot of plans for the future. They are currently hard at work creating a plan for Rush Creek, Western Pennsylvania stream restoration and floodplain reconnection, as well as plans for Licking County's Bloody Run Swamp. In addition to those projects, there are plans for riparian corridor efforts and tree planting work, and the gathering of monitoring data will continue.

Bowman mentions that there are many ways students and other citizens can help with the highly beneficial stream work they are doing. "There are lots of internships and volunteering opportunities," she emphasizes. "I always tell people to volunteer even if there are no internships available yet…there are lots of watershed job positions open right now, it's a good time to start a career in protecting and restoring waterways." LB

*(Top) Filling a sample bottle for laboratory analysis in Raccoon Creek Watershed.*

*(Bottom) Ohio University student, Nichole Mazzone, installing an Onset HOBO data logger in an agricultural stream in Licking County, Ohio.*

*Photos: (Top) Darcy Holdorf / Ohio University, (Bottom) Jen Bowman / Ohio University*

# ENVIRONMENTAL DREDGING REMEDIAL CONSTRUCTION

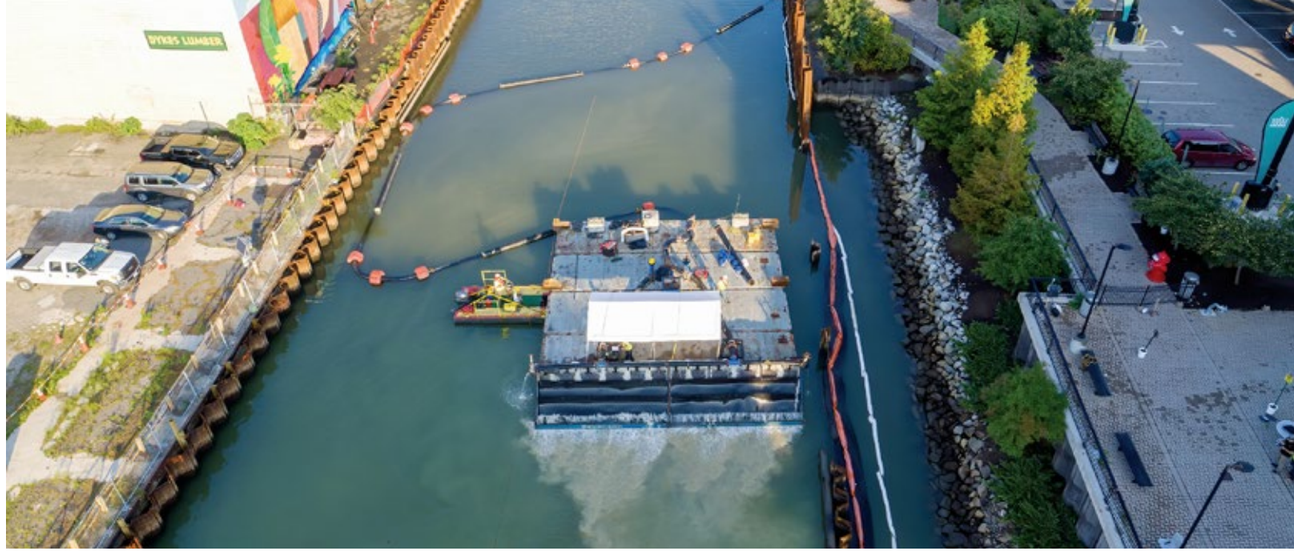
Though dredging is often painted in a negative light, dredging initiatives and projects are often conducted to improve environments, begin recovery periods for water beds contaminated with toxins, and reinvigorate ecological systems and habitats. Many of the technicians and engineers who plan and execute dredging projects are dedicated to balancing the economic benefits of dredging with protecting the environment.

Sevenson Environmental Services Inc. provides sediment remediation as one of many key services offered to help restore natural environments. Steven Shaw spent more than a decade working as an engineer on various dredging projects before finding his way to Sevenson eight years ago.

The work of companies like Sevenson has become increasingly more important as pollutants impact wildlife and communities living near and far from water. Toxic material can settle at the bottom of waterways like rivers, lakes, and ponds traveling through ecosystems and making environments unsafe. Lakes that were previously hospitable to a host of animal and vegetative life are no longer safe for swimming or fishing with declining aquatic populations.

Shaw explains, "Sevenson executes some of the most challenging environmental remediation projects around the country." Shaw works as the Corporate Project Manager/ Estimator for Sevenson and, as such, is tasked with completing estimates, designing constructability reviews, leading marketing initiatives and overseeing projects. Above all, Sevenson and Shaw prioritize the safety of people in all of their projects.






"Our sediment projects reduce risks to human health and the environment, often leading to the reopening of natural features of our country to recreational activities, such as swimming, boating and fishing, plus rejuvenating habitat for many plants and wildlife needed in our communities," says Shaw.

## ENVIRONMENTAL DREDGING

One example of the positives of environmental dredging is Onondaga Lake in New York State. The lake suffered greatly from the expulsion of mercury and other chemicals in the 1900s, which led to a build-up of toxic sediment in the lake bed that sat untouched for several decades until cleanup began in 2012.

The environmental dredging that followed helped begin a period of recovery for the lake's ecosystem. Shaw explains, "Environmental dredging is the precision (or surgical-like) removal of contaminated sediments from water bodies to reduce risk to human health and the environment."

Sevenson was part of the design and construction team and, after supporting dredging and capping treatability studies, deployed several dredges onto the lake to safely remove the contaminated sediment. The removal was successful and followed by a sediment cap that stabilized cleanup efforts. Sevenson's work and the success of these remediation projects are evident as the lake is now open to swimming and recreational fishing.

Environmental dredging and remediation projects are "infinitely more complex than only the removal of sediments." Shaw continues, "Projects typically also include water quality control, environmental monitoring, temporary wastewater treatment, sediment processing, transport and disposal, upland civil construction such as driving sheet pile for bank stabilization, emission and odor control, and a myriad of other issues."

## SEDIMENT REMEDIATION

Sediment remediation includes environmental dredging and the following care taken during projects. Shaw expands, "Sediment remediation reduces risks associated with impacted and contaminated sediments, but also includes monitored/ enhanced natural recovery, capping, in-situ stabilization/ treatment, and hybrid approaches which may include several of these methods."

Sediment remediation projects typically begin when a "governing environmental agency determines that contaminant levels in a water body pose a significant risk to human health and/or the environment." The reasons to begin a remediation project coincide directly with Sevenson's prioritization of safety and restoration.

Without the work of companies like Sevenson, contaminated water would be lost to pollution. Shaw reminds that recovery is possible—he explains, "Sediment remediation is important to our communities in helping the associated habitats and waterways recover and be restored to productive use." He continues, "Often, there is a ripple effect on the communities impacted by contaminated sediment and waterways, which can negatively influence the communities' financial health and the well-being of its citizens."

One can see the positive effects environmental dredging can provide simply by looking at the recovery of Onondaga Lake. Once impacted to the point where swimming and fishing were restricted, the community has now seen habitat revitalized, recreational fishing and swimming reestablished and the redevelopment of shoreline properties, such as the Lake Amphitheater, occur.

## DREDGING EQUIPMENT AND PROCESSES

Once the need for a sediment remediation project is established, Sevenson begins the long and diligent process of planning and executing the work. While much of the work relies on equipment and time, there are two primary factors that must be considered.

*Photos: Sevenson*

The first objective is safety. Shaw states, "Remedial construction (particularly marine work) poses significant safety concerns and risk. Sevenson is fully committed to fulfilling our responsibility to protect the health and safety of company personnel, and the public, continually working to improve the corporate safety and health program."

Most remediation projects entail the removal of toxic material, meaning that the dredging project must be attentive to properly managing contaminated dredged materials and avoid causing further damage to the environment or the surrounding community.

Shaw expands, "In remedial construction, contractors are tasked with removing or confining contaminants which pose a risk to humans and or the environment – we certainly don't want the 'cure' to cause additional 'injury'."

With decades of experience behind them, Sevenson's dredging capabilities and experience include:

- Dry Excavation
- Mechanical Dredging
- Hydraulic Dredging
- Horizontal Auger Cutterhead Dredging
- Hybrid Precision Mechanical with Hydraulic Slurry
- Diver Assisted Dredging

Sevenson implements a variety of Best Management Practices (BMPs) for its precision sediment excavation and dredging, focused on minimizing over-excavation. In order to avoid over-excavation, Sevenson completes a detailed review of project specifications and site conditions to ensure proper selection of sediment removal methodology and equipment; deploys the use of Sevenson key operators with over 10 years of environmental sediment excavation and dredging experience; ensures the implementation of machine control (GPS) on all excavators and dredges; conducts regular surveying to monitor progress, update machine guidance systems, and ensure grades and tolerances are being maintained; and executes a daily quality control plan to ensure machines are properly calibrated.

As the need for remedial construction continues, so will the evolution of the industry; for Shaw, this is the best part of the job. He shares, "Perhaps it is a little cliché, but the best part of my job is the people and relationships. The remedial construction industry is continually evolving, with new challenges, changing regulations, advancement in technology and tough competitors in the space."

Sevenson is an excellent example of how a rapidly changing industry can lead to innovation and change in its participants. Shaw recalls, "Sevenson was founded in 1917 as a general building contractor and, after WWII, diversified into civil, highway, industrial, and commercial construction."

Everything changed in 1979 when "Sevenson served as the principal contractor for remedial work at the Love Canal, which was our entry into remedial construction," according to Shaw. An earlier project that involved dewatering the U.S. side of Niagara Falls in 1969 due to safety issues associated with the park system allowed Sevenson to make a name for itself in the remedial construction world, followed by many other projects throughout the 1980s.

Regardless, it was involvement in the Love Canal project that solidified the company as a leading provider of self-performed remedial action services. Shaw believes that Sevenson's ability to adapt to the market led to the company's success today. He adds, "It was innovation that yielded our entry into remedial construction, maintained our industry position and reputation over the past 40-plus years, and continues to shape our future." SB

*Photo: Sevenson*

# CARING FOR THE CHESAPEAKE

## SUPPORTING THE ICONIC BAY STARTS WITH GOOD MONITORING DATA


*Photos: Chesapeake Bay Program/Will Parsons*

"I FELL IN LOVE WITH THE BAY AND WATER QUALITY DUE TO ITS INTERSECTION BETWEEN SCIENCE, DATA, AND THE NATURAL WORLD."
- DAVE PARRISH

The Chesapeake Bay is enormous: the Bay and its tidal tributaries have 11,684 miles of shoreline—more than the entire U.S. west coast. It is the largest of more than 100 estuaries in the United States and the third largest in the world. The Bay itself is about 200 miles long, stretching from Havre de Grace, Maryland, to Virginia Beach, Virginia.

But the Chesapeake Bay isn't just enormous—it's enormously important. The Chesapeake Bay Program reports that its watershed covers about 64,000 square miles and is home to more than 18 million people, 10 million of which live along or near the Bay's shores. The Bay supports over 3,600 species of plants and animals, including 348 species of finfish, 173 species of shellfish, over 2,700 plant species and more than 16 species of underwater grasses. Not only that, the Bay produces about 500 million pounds of seafood per year.

### MONITORING THE CHESAPEAKE BAY

An area as large and important as the Chesapeake Bay requires a lot of data to track, understand and maintain its health. That is where Dave Parrish and Liz Chudoba come in. Parrish works as the Environmental Data Center Manager at the Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERR-VA) and the Virginia Institute of Marine Science (VIMS). Chudoba is the Water Quality Monitoring Initiative Director at The Alliance for the Chesapeake Bay, where she manages the Alliance's water quality monitoring projects, including the Chesapeake Monitoring Cooperative (CMC).

Parrish's interest in monitoring dates back to graduate school, where he studied resource management. After graduate school, he began working at VIMS in the water quality monitoring program conducted by CBNERR-VA. While approaching the Bay from a data perspective, Parrish says, "I fell in love with the Bay and water quality due to its intersection between science, data and the natural world."

*Blue Water Baltimore conducting monthly water quality monitoring at Jones Falls in Baltimore.*

*Alliance for the Chesapeake Bay leads a training session for students at Bowie State University along Horsepen Branch, a tributary of the Patuxent River.*

Chudoba's background, on the other hand, comes from the perspective of both science and policy, having a master's degree in marine science and environmental law and policy. Chudoba states, "My job involves both degrees. I facilitate the collection of scientific data through our projects like RiverTrends, and work with partners to bring together volunteer-collected data across the watershed into a centralized place through the CMC, which enables broader scale use at the local, state and federal levels."

### COMPLETING DATA WITH PUBLIC OUTREACH

The CMC was formed in 2015 by the Chesapeake Bay Program (CBP) with the goal of integrating volunteer and community-based monitoring data into the Chesapeake Bay Program partnership. As Chudoba says, "Although the CBP has a tidal and nontidal monitoring network that covers a large portion of the watershed, significant spatial and temporal gaps exist in the network with some compromise due to site access. Volunteer data, on the other hand, tends to focus on smaller tributaries and headwaters (what's coming into the Bay) where some of the largest data gaps exist and includes additional sampling locations on private property." Chudoba suggests "putting these two datasets together can give us a more complete picture of the Bay."

The CMC is comprised of a network of volunteer and community-based monitoring groups collecting benthic macroinvertebrate data and many chemical, physical and biological water quality indicators. All data are organized into three tiers, using the CMC's Tiered Framework in order to make data comparable across the watershed regardless of what specific equipment is used to take a measurement.

*Photo: Chesapeake Monitoring Cooperative*

*The CMC team conducting benthic macroinvertebrate monitoring at a small stream near Berkeley Springs, WV.*

**"WE NEED ALL THE DATA WE CAN GET TO MOVE FORWARD AND ASSESS OUR PROGRESS TOWARDS BAY RESTORATION GOALS."**
**- LIZ CHUDOBA**

All data can be accessed online through the Chesapeake Data Explorer, which offers a homepage to visualize data and a query feature to download data and associated metadata. The Data Explorer is a robust data management tool, which provides a unifying structure to the diverse monitoring groups working across the watershed by qualifying data based on the parameter, tier and equipment used.

Parrish explains, "Our database has over 200 parameters. Each parameter has unique identifiers that document the methodologies used to collect each measurement. For example, we have 15 different methods for monitoring pH documented in the database." This system creates flexibility for each group to collect data through methods that meet their individual goals while maintaining a consistent structure to make it easy for end users to utilize the data.

With over 650,000 water quality samples in the Data Explorer, and some datasets dating back to the 90s, there is great potential to utilize the data to identify data trends. In 2020 the CMC partnered with Booz Allen Hamilton to host a hack-a-thon, called Hack the Bay. The event was divided into four challenges; each challenge tackled a different question about Bay health, and data scientists came together to create open-source tools to answer those questions.

While this experience did not yield groundbreaking results, it was the first time volunteer data was utilized together on a regional scale and opened the door to additional analyses. "Now we have an idea of the data potential and can continue to build on that in the future," Chudoba adds.

In the future, having high-quality, plentiful data will only become more important as researchers, policymakers, and the general public hope to assess and protect the Chesapeake Bay and its watershed properly.

As Parrish says, "The data gathered through the CMC helps fill gaps in our understanding of the Bay. By centralizing community science monitoring efforts, documenting the sampling methodologies, and making these data accessible to a variety of data users, we can increase public engagement, help inform management decisions, and contribute to the science needed to better understand the issues that surround the Chesapeake Bay and its habitats."

Chudoba adds, "We need all the data we can get to move forward and assess our progress towards Bay restoration goals." LB

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