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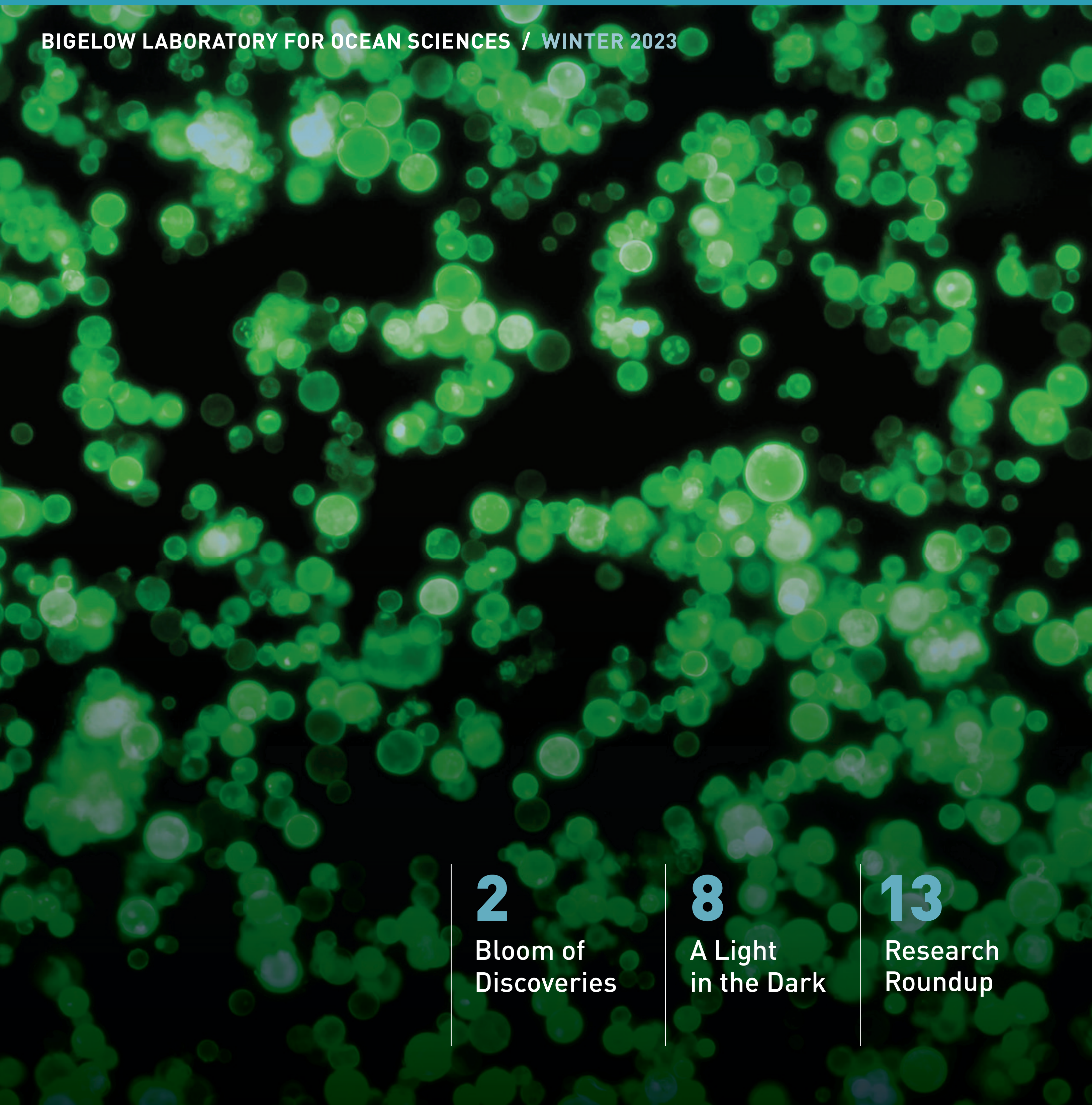
BIGELOW LABORATORY FOR OCEAN SCIENCES / WINTER 2023



Message from the President

Reasons to be optimistic about the future of our planet can often feel elusive, but I find new ones every time I walk the halls of Bigelow Laboratory. Our scientists are constantly advancing the understanding of the ocean and unlocking its potential, and I can't help but leave the laboratory each day with a renewed sense of hope.

It was so exciting to again open our doors this summer and share the possibilities our science is revealing with the public. A new sculpture of a vital marine microbe was installed outside our main entrance (see page 15), joining the two-story "Majestic Fragility" exhibit that continues to draw people to our laboratory. We held our first open house and in-person Café Sci series since 2019, and more than 1,000 people came out to learn the latest about our research around the world. Dozens of students, scientists, and educators also joined us at our laboratory for training with the latest scientific techniques.

One of our educational courses was an annual training we offer to professionals around the world on harmful algal blooms. HABs are a growing challenge for the planet, and a longstanding area of excellence at Bigelow Laboratory. For 30 years, I studied ocean nutrients that are closely connected to these harmful events. It's so encouraging to see the cutting-edge techniques our scientists are developing and applying to address HABs. I dreamed of having tools like this as a graduate student, and these much-needed resources are now becoming reality.

This work is so important because harmful algal blooms are an expanding threat to human health — and can cost billions of dollars in lost seafood and tourism revenues. However, the sporadic nature of these events has led to the underfunding of long-term research on them. The tools we're developing offer exciting new pathways to understanding, monitoring, and mitigating the impact of these devastating events. You can read about our efforts to advance this work and equip the affected communities on page 2.

Getting our science out of the lab and into the hands of the people who urgently need its insights is a critical component of our work. On page 8, you can also read about how we're helping ensure that the best available science is used in the development of international regulations about seafloor mining for rare metals and minerals. Global demand is driving the rapid emergence of industry in the deep sea — a region that is little understood but crucial to global ocean health.

Your support is vital to this work — and to all the discoveries we make, solutions we create, and people we inspire. Thank you for helping us work toward the bright future our science shows is possible. We can't do it without your help.

Deborah A. Bronk

DEBORAH A. BRONK, PhD

ON THE COVER

The parasite *Perkinsus marinus* causes deadly diseases in oysters, but it may be an unlikely ally for humans. Senior Research Scientist José Antonio Fernández Robledo studies parasites and the shellfish they infect to help solve pressing issues. Using cutting-edge techniques, such as genetic engineering, he unlocks tools to fight against infectious diseases in humans and protect shellfish aquaculture.

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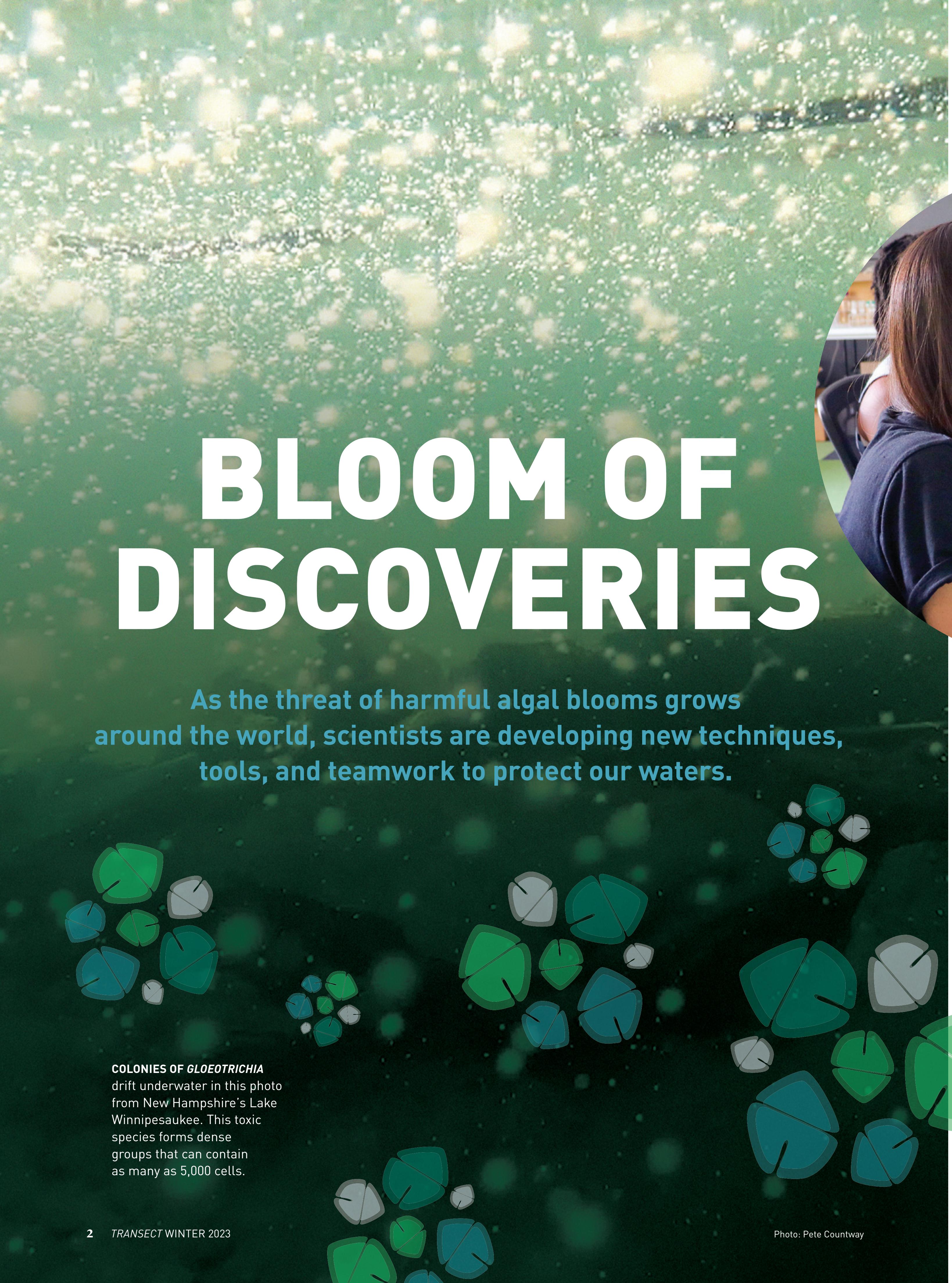
CONTENTS

ICY WATERS, low clouds, and sunlit mountains frame the Neumayer Channel in Antarctica. Senior Research Scientist David Fields went to Palmer Station this fall to study how krill respond to changes in water flow, scents, and light. The data he gathers will be used to determine how krill coordinate movement inside schools that can be composed of millions of individuals.
Photo: David Fields

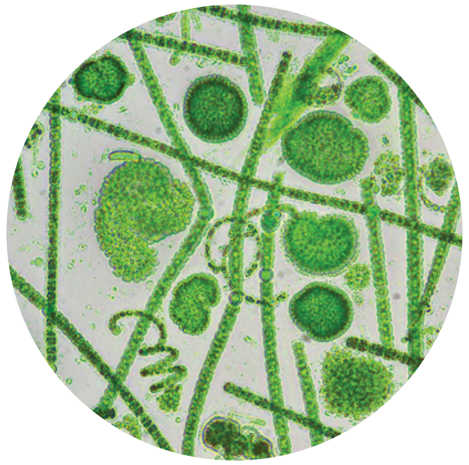


BLOOM OF DISCOVERIES

As the threat of harmful algal blooms grows around the world, scientists are developing new techniques, tools, and teamwork to protect our waters.

COLONIES OF *GLOEOTRICHIA* drift underwater in this photo from New Hampshire's Lake Winnipesaukee. This toxic species forms dense groups that can contain as many as 5,000 cells.

Photo: Pete Countway



LEFT Michelle Lepori-Bui, a marine water quality specialist from Washington Sea Grant, looks though a microscope during a Bigelow Laboratory course on how to identify harmful algal species. **TOP** A freshwater algal bloom changes the color of Sabattus Pond in Maine. **RIGHT** Cyanobacteria from Sabattus Pond float in a water sample on a microscope slide.

In the early 1500s, Spanish conquistador Álvar Núñez Cabeza de Vaca observed that indigenous people on the modern-day Texas coast would seasonally suspend shellfish harvest in response to widespread fish deaths. In 1648, a Franciscan monk in Mexico wrote of a ship from Spain that "encountered a mountain of dead fish near the coast."

These accounts are some of the earliest reports in North America of harmful algal blooms, or HABs — an increasing occurrence in Maine and coastlines around the world.

HABs pose serious risk to wildlife and waterfront communities, forcing the closure of beaches and fisheries each year. However, scientists do not fully understand what causes harmful algae species to quickly grow in great abundance or what causes such blooms to end.

Bigelow Laboratory researchers are working to answer these fundamental questions about HABs and determine the best ways to minimize their negative consequences. Teams are studying when and why the blooms occur and how science can empower government and community efforts to keep people and seafood safe.

"Harmful blooms are not just caused by one species and don't just cause one type of problem, which makes them really complicated to understand and address," said Senior Research Scientist Rachel Sipler, who has studied HABs from the Arctic to the Gulf of Mexico. "A HAB is any algal bloom that causes a negative impact, and there are many ways they can do that."

Some HAB species generate toxins. Some choke out competing organisms by using up oxygen. Others simply become problematically prolific — covering coastal surfaces, blocking light from marine organisms, and driving people from beaches. They can be found in oceans from pole to pole, and cyanobacteria cause similar events in lakes that can sicken people and kill pets.

Harmful algae species can exist in all bodies of water, but there is no one set of conditions that cause them to rapidly multiply to the point they are a problem. However, scientists believe increasing temperatures and nutrient pollution are key factors in their expanding influence.

"There's generally at least one potentially harmful species of algae in every liter of seawater," Sipler said. "However, we don't understand all the reasons that cause good algae to go bad. Sometimes, a HAB species doesn't produce a toxin and has no negative impact on the environment. Other times, that same species can be really toxic even in low concentrations."

Photos, top right and bottom: Pete Countway

‘If we can provide a reliable glimpse of what’s coming in the next week, month, or year, we can help people be proactive in decision-making.’

LEFT A bloom of the harmful algae *Karenia brevis* is visible off the coast of Sarasota, Florida, in August 2018. **MIDDLE** Intern Katie Baker, left, and UMaine doctoral student Sydney Greenlee, right, collect water samples from the Bigelow Laboratory dock to study *Pseudo-nitzschia*. **RIGHT** Nia Rene, an environmental scientist from NOAA’s National Centers for Coastal Ocean Science, examines an algal sample during Bigelow Laboratory’s weeklong harmful algae identification workshop.

BUILDING KNOWLEDGE

As HABs expand, there is increasing necessity to identify the species and understand the conditions that cause them to form blooms. One foundational part of building this knowledge is monitoring when and where they appear.

Bigelow Laboratory hosts specialists from across the country each summer for a weeklong course on how to identify and analyze harmful algae using microscopes. Participants include researchers as well as government scientists responsible for advising when to shut down an area due to a HAB.

“We train others to better understand the spread of harmful algae species,” Senior Research Scientist Mike Lomas said. “We know certain species are harmful. While they may not be producing toxins at the moment, knowing they are present is a big step toward preventing harm.”

Microscopy remains the primary method for monitoring HABs, but emerging DNA-based tools are providing promising new avenues for understanding and managing harmful algae.

Senior Research Scientist Pete Countway is part of the $20 million “Maine eDNA” project led by Bigelow Laboratory and the University of Maine, which uses DNA found in the environment to understand the ecosystems it is sampled from. Countway is particularly interested in using this approach to understand how harmful blooms occur.

All aquatic plants, animals, and microbes leave genetic traces wherever they go as a natural byproduct of their existence. Countway is using this environmental DNA to catalog potentially harmful organisms throughout the year, as well as the bacteria that live alongside them.

“Instead of just focusing on HABs, our approach is to find out what organisms are present and to see if certain members of the microbial community are somehow setting up conditions for a harmful bloom,” he said. “We’re also looking for environmental indicators for blooms. Maybe it has something to do with nutrients, or maybe it’s temperature or salinity. We don’t know yet, so we want to keep an open eye out for patterns we can connect.”

Research to understand how HABs start is critical, but scientists are equally interested in discovering why they end. Senior Research Scientist Joaquin Martínez Martínez studies marine viruses and believes they may be a significant part of the answer.

Last December, he and Postdoctoral Scientist Anne Booker traveled to the Gulf of Mexico to study a record bloom of *Karenia brevis*, the alga that causes red tide, which had been going on for 15 months. Two weeks before they set sail on the research cruise, the bloom suddenly disappeared.

“We went south, north, east, and west, but we didn’t find a single *Karenia* cell,” Martínez Martínez said. “How can this bloom be maintained for so long and then terminate out of the blue? We think that interactions with bacteria and viruses are important for bloom dynamics, but they have not yet been studied in detail.”

SENIOR RESEARCH SCIENTIST Joaquín Martínez Martínez studies marine viruses, which may play a key role in why harmful algal blooms come to an end.

Research has shown many algae depend on certain bacteria species for survival, and these bacteria may be susceptible to fatal viral infections. Martínez Martínez has also discovered a virus that naturally occurs in the Gulf of Mexico and can infect *Karenia brevis*. His findings have so far been solely based on samples that were cultured in the laboratory, but Martínez Martínez thinks they could help explain why blooms end in the Gulf of Mexico and beyond.

“If it happens in culture, it might happen in the environment,” he said. “One way or another, viruses seem to contribute to the termination of a bloom. That said, I don’t believe there’s one factor that determines every single outcome. It’s likely a combination of viruses and other processes.”

SAFEGUARDING SEAFOOD

In the Gulf of Mexico, warm waters and nutrient-rich runoff promote blooms of toxic algae every year. In the Gulf of Maine, where climate change is warming and acidifying the waters, conditions are becoming similarly fertile for harmful blooms. This shift is particularly detrimental to New England’s shellfish fisheries, such as oyster, mussels, and clams. HAB toxins build up inside these filter feeders and can harm people when consumed, complicating the management and harvest of seafood resources.

In 2016, a toxic bloom of *Pseudo-nitzschia* prompted the recall of more than 58,000 pounds of mussels and the closure of hundreds of miles of Maine coastline to shellfish harvesting. In 2017, the first *Karenia mikimotoi* bloom was identified in Maine waters and caused a clam die-off. Also in 2017, a *Pseudo-nitzschia* bloom closed Casco Bay to shellfish harvesters in December, when waters have historically been cold enough to inhibit such events.

In Maine, seafood consumers are protected from these toxins by robust toxin monitoring and rapid closures of affected regions. Maine Department of Marine Resources partners with Bigelow Laboratory on the regular testing of samples from all along the coast. The state then uses that data to inform their decisions about when to close and reopen specific harvest areas in response to toxin levels.

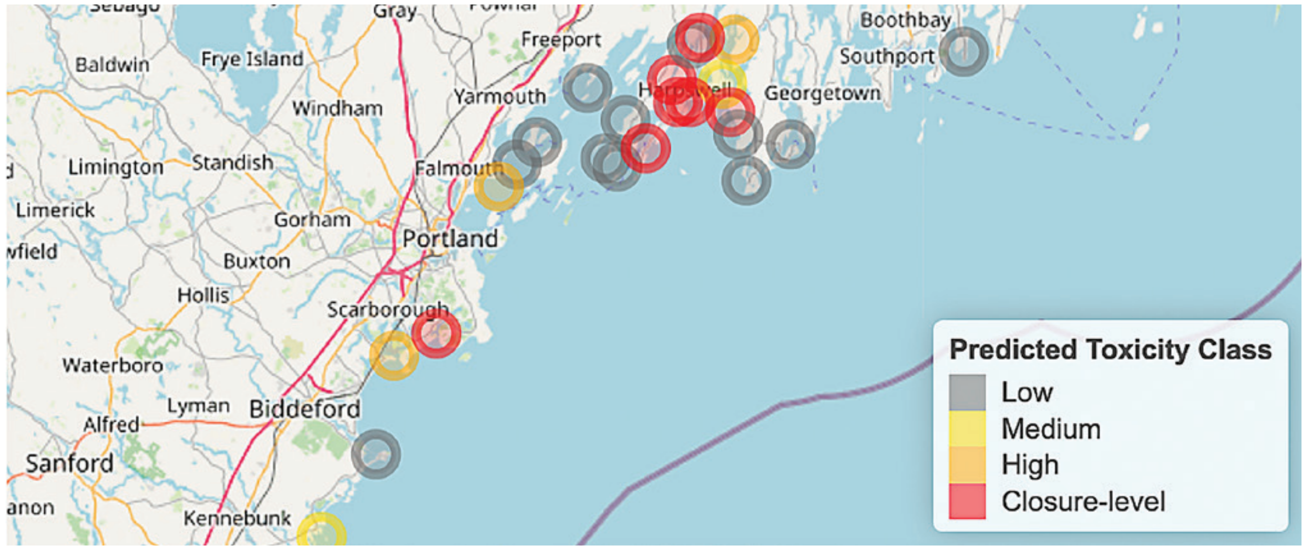
“It’s been an incredibly effective system,” said Senior Research Scientist Steve Archer, head of the team that conducts the analysis. “There hasn’t been a fatality since the system was put in place. That’s pretty incredible when you realize how toxic some of this stuff is.”

Since they started collaborating with the state government in 2014, Archer’s team has screened tens of thousands of shellfish samples for a dozen toxic compounds related to diarrhetic shellfish poisoning, amnesic shellfish poisoning, and paralytic shellfish poisoning. The collaboration has created a massive dataset of information on when and where toxins occur.

In 2018, Archer and Senior Research Scientist Nick Record started collaborating with Maine officials and shellfish farmers to develop a toxicity forecast. Applying artificial intelligence, they use the data from Bigelow Laboratory to predict fishery closures due to toxins a week ahead of time. The researchers started publishing the regular forecast two years ago, providing shellfish farmers and resource managers early warning of likely harmful algal blooms.

“This short-term forecasting is a climate adaptation tool,” Record said. “The environment is changing more rapidly and in more unexpected ways than ever before. If

ABOVE Research Associate Craig Burnell analyzes shellfish samples for toxins. **BELOW** The shellfish toxicity forecast being developed by Bigelow Laboratory can predict fishery closures due to toxic conditions a week out, providing shellfish farmers and resource managers early warning of likely harmful algal blooms.



Photo, top left: Vince Lovko, Mote Marine Laboratory

SENIOR RESEARCH SCIENTIST Pete Countway works to monitor and understand harmful algae in partnership with communities such as Colby College students (**LEFT**), Midcoast Conservancy members (**RIGHT**), and local residents in Wolfeboro, New Hampshire (**BOTTOM**).

'We can learn to better coexist and reduce harm once we understand what drives blooms and causes them to end.'

we can provide a reliable glimpse of what's coming in the next week, month, or year, we can help people be proactive in decision-making."

In addition to developing a computationally powered approach for Maine, Record recently started working on a United Nations-supported effort to build HAB early warning systems in countries without strong monitoring capabilities. This year, he and an international team of other forecasting experts began to partner with groups in Namibia and Morocco to assess local needs and co-develop a path forward.

GROWING COMMUNITIES

From Maine to Africa, HAB mitigation efforts highlight the importance of community involvement. Record said it would be easier to just use scientific data to create predictive models, but they'd likely be wasted efforts without factoring in the perspectives of those living and working in the region.

"A really important part of this research is stepping away from the lab and talking with people who are working in aquaculture or managing natural resources," Record said. "You have to ask what kind of forecast they could use, what kind of information they want, and what would actually help them."

In New England, Sipler and Countway also work with local groups, landowners, and governments to determine the needs that power their research. Maine has thousands of miles of waterfront and only a handful of researchers studying HABs. Through efforts like the Maine eDNA project and Bigelow Laboratory's Water Health and Humans Initiative, the researchers collaborate with communities to monitor local conditions.

"The number one way that we are able to identify harmful algal blooms is because someone sees a change in their environment and reports it," Sipler said. "Our goal is to give communities the power to monitor their own waters, and then we can be a resource to help interpret and utilize the information they're gathering."

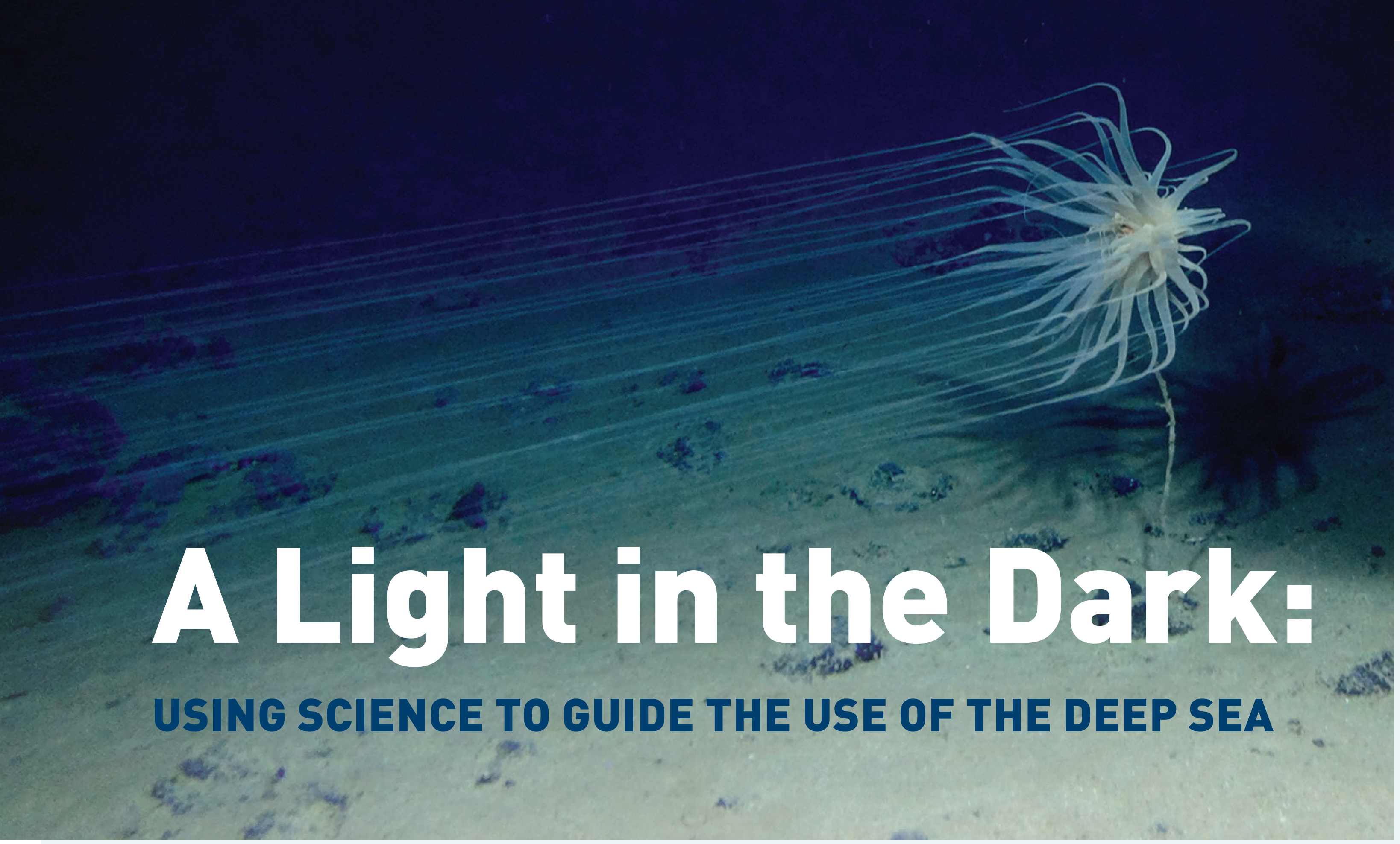
Some of these efforts are as simple as environmental journals or photo documentation. Others are more complex. Countway has been working to train communities on how to use genetic testing methods, similar to what he uses in the laboratory to identify organisms.

"Recently, the door has been flung wide open on access to DNA technology," Countway said. "The really cool thing is that we can take portable technology out to the field to work with community groups at the location that they care about. We can show them the tools they need to do some pretty advanced analysis, all on something as accessible as a smartphone."

Efforts to monitor for HABs and avoid their harmful impacts are increasing in tandem with the threat. This is providing scientists, communities, and resource managers with new suites of tools. However, as the earliest records show, these organisms have been around far longer than human society. Ultimately, people have to learn how to best live with them.

"Many of these organisms have been around for millions, if not billions, of years, and they're not just going to disappear," Countway said. "While avoidance is currently the best tactic, we can learn to better coexist and reduce their harm once we understand what drives their blooms and causes them to end."

Photos: Pete Countway, top right and bottom; Denise Bruesewitz, top left



A Light in the Dark:

USING SCIENCE TO GUIDE THE USE OF THE DEEP SEA

Senior Research Scientist Beth Orcutt leaned into her microphone. She had been preparing her next statement with her online team for the last half hour, translating complex scientific information into advice for shaping intergovernmental policy. As she spoke, hundreds of delegates from countries and organizations around the world listened.

Orcutt is an expert on the deep sea. She went to Kingston, Jamaica, to attend a meeting of the International Seabed Authority, the United Nations-mandated body in charge of regulating deep-sea mining in international waters. Representatives of countries and mining companies had gathered there to negotiate the emerging set of rules that will govern the possible extraction of valuable seafloor resources.

The deep sea is a prospective source of critical minerals and metals that are used in many modern electronics, such as smartphones and electric cars. The Clarion Clipperton Zone, a region that spans 1.7 million square miles in the central Pacific Ocean, is the area most aggressively being pursued for mining. It is also being eyed by industry and science groups for how it may serve as a guideline for other regions.

Scientists are an important part of the process that guides responsible use and conservation of these resources. In addition to her deep-sea research, Orcutt leads the Crustal Ocean Biosphere Research Accelerator. This five-year initiative was started in 2021 to expedite research of the deep sea and inform policy-making related to emerging human industries, such as deep-sea mining.

Orcutt was one of only a handful of scientists there in person, backed by dozens of international researchers who participated virtually. She and the other scientists were there to provide objective feedback and represent the current state of scientific understanding of deep-sea habitats and their ability to withstand human impacts.

"In the room of hundreds of people, the three of us were part of only a handful who have ever been on a deep-sea expedition or worked with deep-sea data," she said. "I think that experience really is essential to the success of this process."

If mining of the seafloor is mishandled, the consequences could be dire. The ecosystems there support life on the rest of the planet. Orcutt wants to help ensure the industry push for deep-sea mining does not get too far ahead of the science to understand its potential impacts.

TOP ROW Rocks at the ocean floor can be covered with crusts of valuable minerals and metals that are used in many modern electronics. **BOTTOM ROW** These same environments are also home to a rich collection of little-understood life that would be impacted by mining and other industrial uses of the seafloor.

"What's at stake here is the health of deep-sea ecosystems around the globe, and these are ecosystems that we barely know anything about," Orcutt said. "The amount of area this mining may impact is ten times more than all of the areas we bottom trawl for fish. Seafloor mining has the potential to severely affect a large fraction of deep-sea ecosystems on scales that are enormous compared to existing human impacts — and these impacts could last forever."

In 2021, the Pacific island nation of Nauru notified the United Nations of its plans to start deep-sea mining, setting off a two-year countdown for the International Seabed Authority to finalize regulations. These regulations must abide by the United Nations Convention on the Law of the Sea, which says human activities in the area need to both benefit all humankind and do no harm.

However, it is yet unclear what "harm" even means for these environments. While the deep seafloor covers two-thirds of Earth's surface area, it is still mostly unexplored and poorly understood. Scientific understanding of deep-sea ecosystems, as well as their ability to withstand human perturbation, is severely limited.

'What's at stake here is the health of deep sea ecosystems around the globe, and these are ecosystems that we barely know anything about.'

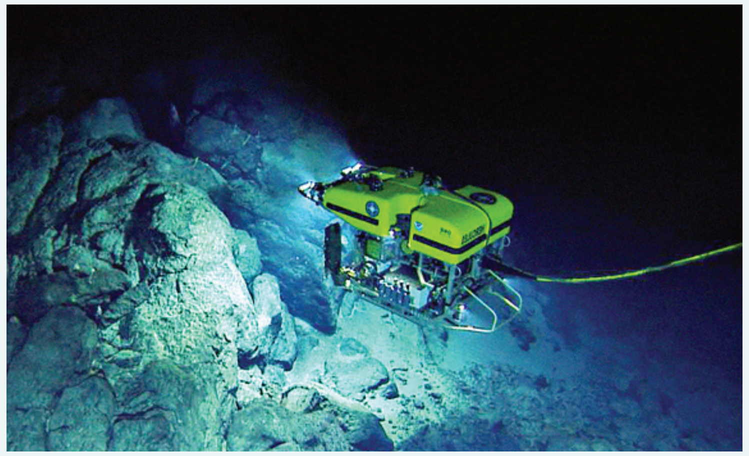
Humans have only studied a tiny fraction of the deep sea, but it has proven to offer a wealth of scientific discoveries. It is home to complex networks of organisms, from microbes to whales, that exist in sediment, underwater canyons, and volcanic mountain chains. Scientists are concerned human activity on the seafloor may fundamentally alter conditions that took millions of years to establish, the consequences of which could potentially dwarf the value of the extracted resources.

"The minerals we are talking about removing are generated on geologic timescales," Orcutt said. "We barely know anything about the ecosystems they are tied to. It's like saying that we're just going to mow down all of the forests of a continent before we've ever studied what trees and plants live there — or know if they will grow back."

Developing the rules to mine the seafloor is considerably more complex than on land. Not only is the area extremely remote and poorly understood, but the ecological processes are almost alien. On land, mining opera-

Photos: Craig Smith and Diva Amon, top; International Seabed Authority, bottom

Photos: NOAA Ocean Exploration, top left; Ocean Exploration Trust, top right; Woods Hole Oceanographic Institution, bottom left; NOAA Ocean Exploration, bottom right




TOP LEFT A remotely operated vehicle explores the deep sea near Hawaii. **TOP RIGHT, BOTTOM LEFT** Senior Research Scientist Beth Orcutt breaks off pieces of a deep-sea rock and grinds them down for laboratory analysis of the microbes they contain. **BOTTOM RIGHT** Orcutt monitors a remotely operated vehicle from aboard the E/V Nautilus during a deep sea expedition as lead scientist.

'It's like saying that we're just going to mow down all of the forests of a continent before we've ever studied what trees and plants live there.'

tions adhere to mitigation and remediation standards to undo any harm done. In the deep sea, there is not a baseline for what a healthy ecosystem looks like. Without scientific backing, policymakers can't develop accurate procedures to monitor, quantify, and repair harm.

Orcutt's research focus is the vast microbial life that exists in the deep sea. Scientists know these organisms drive most of the valuable processes that go on there, but the individual organisms and their contributions largely remain a mystery.

"A lot of what we depend on the deep sea for is actually driven by microbes," Orcutt said. "We don't know much about what causes harm to the deep-sea corals, fish, and other animals we can see, and we don't really even yet understand what 'harm' means for the diverse microbes we find on and below the seafloor."

What is really needed is more time. A misstep in the regulatory process could create a disaster for the planet, and it may take decades of intensive research to build the understanding needed to protect deep-sea life from irreparable harm. Although it seems like an impossibility, Orcutt is not out of hope.

The two-year rule enacted in 2021 is under some scrutiny. Not all legal experts agree that it means mining will certainly begin in 2023, or that the regulations developed by then will be set in stone. Some member states, and even some companies, have pushed back on rushing the rule development, arguing for a moratorium on seafloor mining until the consequences are better understood. Others have urged for seafloor mining to be evaluated as part of a broader search for the best ways to solve the growing energy resource needs.

"The drive for mining metals is based on current technologies, but scientists are aggressively pursuing technologies that are not so reliant on them," Orcutt said. "If we concentrate our efforts on green chemistry and recapturing metals from used products, we can likely just avoid the complications and potential consequences of mining in the deep sea."

Photos: Ocean Exploration Trust

PROFILE Peter Handy Trustee, Bigelow Laboratory

Peter Handy is committed to changing the world and letting science guide the process. President and CEO of Bristol Seafood and a member of the Bigelow Laboratory Board of Trustees, Peter is passionate about ocean health and knows the best way to maximize his impact is by surrounding himself with others committed to doing the same.

"When you have a collection of people who love their work and really want to be there, harnessing the excitement that comes from bringing them together is unmatched," he said. "The seafood industry is like that, and I think Bigelow Laboratory is like that. People are fully engaged and proud to be there, which makes for an incredible culture."

Peter is quick to tell you that today's most pressing issues revolve around climate change and protecting our oceans. He is on a mission to combat greenhouse gas emissions and support working waterfronts by using his business to get people to eat more responsibly harvested seafood.

"One tweak to our product or packaging can have a huge impact, which is both really exciting and daunting," he said. "It means that we have a responsibility to get our decisions as right as we can. And what I learn with Bigelow Laboratory helps me to do that better than I otherwise would."

Peter thinks that an ideal relationship between business and science can be built on a foundation of accountability and innovation. He believes scientists must first help hold businesses accountable for operating in a way that is sustainable and healthy for the planet, and then work with them to innovate groundbreaking solutions for the challenges they face in doing so.

The scientific process teaches people to keep an open mind and make fact-based decisions, and Peter wants his business to use that approach to make a positive impact. He believes that data is essential to making the best choices and sees the clear benefits to industry of Bigelow Laboratory's research.

"Whether it's managing a business or figuring out what to do in the lab, we have to be open to new information and use data to help shift our approach," he said. "At Bristol Seafood and Bigelow Laboratory, there is that common culture of finding out what is true and being ready to adapt as we learn."

Peter is excited about working with Bigelow Laboratory researchers who help him understand the complex science behind our changing planet. A new member of the board of trustees this year, he tries to listen carefully and

'Whether it's managing a business or figuring out what to do in the lab, we have to be open to new information and use data to help shift our approach.'

ask questions that help channel the knowledge and enthusiasm at the Laboratory toward pressing issues he sees.

He values the way the scientists use a diverse array of tactics to fulfill a common mission, revealing how understanding foundational ocean processes can combat the impacts of climate change and improve life on the planet. He said that coordinated, interdisciplinary effort is a key strength of the Laboratory and one of the reasons it makes such a difference.

"Bigelow Laboratory is designed to maximize the impact that science can have," he said. "The entire place is built around that, and it's working. It's not just an idea. There's a track record, and it's really exciting to be a part of that."

While Peter is driven by maximizing immediate impact on urgent global issues, he also thinks it's critical to keep an eye on the horizon. He believes the fundamental questions Bigelow Laboratory scientists ask about the world around them can lead to bigger outcomes than anyone could anticipate.

"It's good to focus on specific solutions," Handy said. "However, the biggest and most consequential results don't always come from directly trying to address an issue, but from exploring ideas where the direct value is less clear. You just have to trust the process."

SCIENCE SNAP

ASSOCIATE CURATOR Kristin Heidenreich teaches an aspiring scientist how to use a microscope to reveal the hidden life in water samples taken at Bigelow Laboratory's open house in July. More than 350 people visited the East Boothbay campus to explore the facilities, participate in hands-on activities, and learn firsthand from scientists about their work to understand the life that forms the foundation of global ocean health.

Photo: Fritz Freudenberger

CURRENTS

Expansion Doubles Resource for Seaweed Research

Scientists and companies around the world gained access to more than 1,200 new strains of seaweeds through Bigelow Laboratory's National Center for Marine Algae and Microbiota this summer. This NCMA expansion more than doubled the kelp available through the collection — already the world's most diverse source of micro- and macroalgae for use in research and applications.

Researchers at Woods Hole Oceanographic Institution and the University of Connecticut provided the kelp collection to NCMA, which they developed to explore beneficial seaweed applications. Seaweed aquaculture is one of the fastest-growing industries in New England, and there is increasing global interest in exploring sustainable uses of macroalgae in food, fertilizer, medicine, and more. The new kelp strains aid the NCMA's efforts to provide access to diverse algae strains and work alongside scientists and companies to develop real solutions that harness algae's almost limitless potential.

Photo: Jeannette Yen, Georgia Tech

SCIENTISTS TO SHED LIGHT ON ANIMAL SIZE

Senior Research Scientist David Fields is leading a project to figure out why marine animals at the poles are larger than their temperate counterparts. To do so, he recently traveled off the coast of Washington to study one species of a widespread and vital crustacean.

Copepods are a critical part of aquatic ecosystems around the world, and the carnivorous copepod genus *Euchaeta* comes in a range of sizes. Fields and Research Associate Maura Niemisto started the project with a trip to the San Juan Islands to look at a variant that grows to around half a centimeter, studying the impacts of temperature and water viscosity in lab experiments. Moving forward, they plan to compare this species with others: a smaller one in Hawaii, a similar-sized one in Maine, and one in Antarctica that grows to almost twice as large. This will shed light on how animals adapt to their environments.

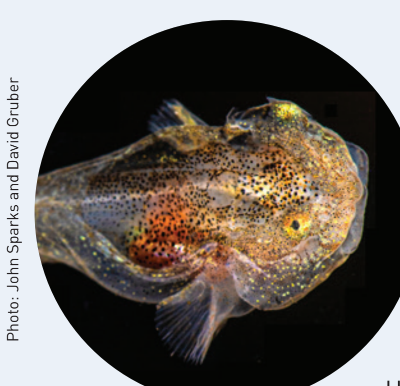


Photo: John Sparks and David Gruber

Polar Fish Illuminates Use of Antifreeze for Survival

Fish have had to develop unusual adaptations to survive the subfreezing conditions at the poles. Senior Research Scientist John Burns recently helped reveal that the only known biofluorescent polar fish protects itself by instructing its cells to make high levels of an antifreeze protein. As the Arctic rapidly loses ice, species that have adapted to it may be forced to further change. This discovery highlights the importance of this unique survival mechanism and could illuminate how polar animals might fare in a rapidly changing world. However, the study was based on a single snailfish found in a saltwater pond on top of a glacier. Burns said it is important to look at additional examples to better understand the species. He wants to conduct further research to understand exactly how much antifreeze these fish produce and how that could change in response to different temperatures.

Photo: David Drapeau

New Vessel Expands Capacity for Education and Research

Bigelow Laboratory expanded its science education and field research capabilities this fall through the acquisition of a 48-foot research vessel. Donated by Middlebury College, it will be customized over the winter and go into service in 2023. At twice the length of the Laboratory's other boat used for local work, the vessel will provide substantial new capabilities.

For hands-on education, its size will support much larger groups of students, and its lab space is outfitted with technology to collaborate and discuss field data. For research and training in and around the Gulf of Maine, the vessel's ability to cruise at 20 knots will greatly expand the Laboratory's range for sample collection and diving expeditions. The boat was previously used for research and education on Lake Champlain, but changes in faculty led to its declined use. Middlebury College's decision to donate the boat to Bigelow Laboratory will maximize its continued use for understanding aquatic ecosystems and training the next generation of scientists to study them.

Photo: Kevin Posman

EXPEDITION BEGINS TO REVEAL ARCTIC'S FUTURE

The largest-ever Arctic research expedition set off three years ago to create an unprecedented record of data from a year in the Arctic Ocean. The efforts of hundreds of international scientists, including two from Bigelow Laboratory, are now bearing fruit. Project scientists recently published the first results from the MOSAiC expedition, which present a picture of intertwined climate processes.

Senior Research Scientist Steve Archer and Senior Research Associate Kevin Posman each spent months on the expedition. Their research uncovered how important gasses like carbon dioxide, methane, and ozone interact with ecological systems and move between water, ice, and the atmosphere. They also gained insight into how connected the region is to global weather systems. This research is the beginning of what promises to be one of the largest coordinated series of scientific publications to date, setting the groundwork for years of research by dozens of science teams to understand the impacts of climate change in the Arctic.

Photo: Lin Zhao

Research Confirms Effectiveness of Oil Dispersants

Marine oil spills are one of the most direct, and harmful, examples of the toll that the extraction of fossil fuels can take on the environment. A recent study led by Senior Research Scientist Christoph Aeppli validated the efficacy of one of the few tools to mitigate that damage.

Chemical dispersants can be used to break oil into small droplets that get mixed into the water and rapidly diluted. However, adding these chemicals to the environment has been controversial, and previous laboratory research cast doubt on their effectiveness. Aeppli, alongside industry partners, set out to measure dispersants' impact. Their results suggested that dispersants were effective if applied under normal conditions within four days — a typical time frame for oil spill response.

Photo: Erick Bravo, IODP JRSO

Exploring the Deep Sea for Life

Studying the rich collection of microbial life on and below the seafloor provides unique insights into how life survives in extreme environments — and potentially even other planets. This summer, Senior Research Associate Tim D'Angelo participated in an expedition in the South Atlantic Ocean to look for microbial habitats in the deep sea.

The research cruise was part of the International Ocean Discovery Program, a collaborative effort to explore Earth's history and dynamics recorded in the rocks and sediment below the seafloor. D'Angelo and his colleagues measured oxygen concentrations in sediment, from the seafloor down to about 300 feet below it, in one of the first projects to investigate these important conditions to support life. D'Angelo will continue the research with Senior Research Scientist Beth Orcutt by applying a new method developed this year. Studying life in these extreme environments is particularly difficult because the organisms are sparsely distributed over enormous areas. The new method overcomes the challenges posed by low-concentration samples from these regions and enables scientists to study the genetic information of the microbial communities there.

PROTECTING THE ALASKAN SNOW CRAB

Alaskan snow crabs, one of the largest commercial fisheries in America, are facing a population crisis. Senior Research Scientist Maya Groner went to the Bering Sea this summer as part of a new project to find out why.

In 2019, fisheries managers calculated a large increase in the upcoming population of adult crabs. By 2021, the population declined by more than 90 percent. The cause of the crash is unclear, but an emerging ailment called "black eye syndrome" has also been on the rise during this time. Groner and Postdoctoral Researcher Reyn Yoshioka participated in the research cruise with NOAA and plan to continue their research to uncover the syndrome's prevalence and how it is impacting survival. Determining what is causing this illness and how it spreads will help the scientists inform efforts to protect the fishery and the livelihoods that depend on it.

Photo: Maya Groner

COCCOLITHOPHORE SCULPTURE SHOWCASES ARTIST COLLABORATION

A new, large sculpture of one of the world's most important — and beautiful — phytoplankton greeted guests outside Bigelow Laboratory this summer. The culmination of more than two years of work, artist Julie Crane completed the five-foot-diameter artwork through a collaboration with Senior Research Scientist Barney Balch. Coccolithophores are one of the most ubiquitous types of phytoplankton on the planet and have a major impact on food webs and global carbon and chemical cycles. They cover themselves with minuscule limestone plates called coccoliths that result in mosaics in an extensive range of stunning shapes.

The sculpture depicts the most common coccolithophore species, *Emiliania huxleyi*. Each coccolith, which is typically a fraction of the width of a hair, has been formed from an epoxy clay and scaled up to almost two feet across. It was unveiled at the summer's first Café Sci event, which showcased a number of artistic partnerships that Bigelow Laboratory scientists are engaging in to help inspire the public.

FIELD NOTES

SVALBARD, Norway

ALEX MICHAUD, Research Scientist

Most people have a distinct idea of how a glacier should look. Adjectives like pristine, white, and snowy may come to mind. However, these words would not be accurate for many Arctic glaciers. In fact, at the end of my fieldwork this summer, I had to scrub the mud off of my boots after spending a week at our glacial field site.

I traveled to Svalbard, an Arctic archipelago an hour-and-a-half flight north of Norway's mainland, for a project with colleagues from Aberystwyth University in the United Kingdom. I went there to study microbial life on top of glaciers and understand the diverse ways that life can persist in challenging environmental conditions.

During our plane's final approach through typical Svalbard fog, I couldn't see any glaciers and had to wait until we hiked into our fieldsite the next day. Our research team got ready the following morning using a packing routine similar to most polar field work — extra food, warm layers, rain gear, science supplies — along with one additional piece of kit. A rifle and flare gun are required for protection from polar bears when anyone ventures outside the confines of Svalbard's main town of Longyearbyen. Even though our work took place far from a polar bear's typical shoreline habitat, one can show up anywhere at any time.

Despite this potential, our trip had relatively simple logistics compared to most polar research. We didn't need a helicopter, snowmobile, or other form of long-distance transportation. We loaded the car with gear and drove down the only road in town, an eight-mile stretch of gravel, before hiking 45 minutes to the glacier. The first section of the hike was squishy tundra with rocks and small patches of iconic cotton grass, with its white cotton ball-like tufts. We crested a small ridge and got our first view into the small valley and our study site, Foxfonna Glacier.

This and many glaciers around the world actually look much different than the images that usually come to mind. Foxfonna glacier is covered with rocks that have tumbled down the steep valley walls, as well as dirt and debris blown in from the local valley and beyond. These dark particles absorb sunlight and heat up. This melts the surrounding ice and creates meltwater that provides a habitat for microorganisms.

Long strands of photosynthetic microbes bind dirt particles and bacteria together into spherical balls. These clumps of mud melt into the ice and become their own little ecosystems. Rain and meltwater can wash these balls of dirt into streams and deposit them in large piles on the glacier, which are the areas we're focusing on for this project.

Microbes in the Arctic play an important role in global cycles because they consume carbon and emit carbon dioxide and methane. However, we don't yet know if these glacier microbes are also part of the process.

During the dark, cold months, temperatures can drop down to around 40 degrees below zero, limiting microbial activity. However, the microbes are buried by a thick layer of snow in the winter, which can insulate them from the cold air. In addition, organic carbon produced during the summer season is buried with them. This may provide enough nutrients to keep the bacteria fed through the winter. So, while the microbes may freeze, they might not become inactive.

We want to understand if the microorganisms in these dirt piles stay active and produce or consume greenhouse gasses throughout the year. The discovery will help understand the limits of life on Earth.

As we packed up our gear to hike back to the car, I felt fortunate that I was part of the summer sampling team. Some of my colleagues will be back in the darkness of winter to dig out the snow in search of detectable signals of microbial life during the coldest months.

So, while many may have a vision of pristine glacier surfaces, the reality is that they are also a complex habitat for diverse microbial life that contributes both to the melting of the glaciers and to global greenhouse gas cycles — another example of how effective microorganisms are at influencing things much larger than themselves.

Photo: Alex Michaud

GIVING An Ocean of Hope

The issues facing our planet are undeniably dire, but our bold approach to science reveals new reasons in the ocean to have hope every day.

Our scientists are discovering how the ocean works and how we can better care for it. They are creating much needed solutions that enable our society and planet to thrive. They are equipping current leaders and inspiring the next generation of scientists to do the same.

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Photos: John Burns, top; Colby College, bottom

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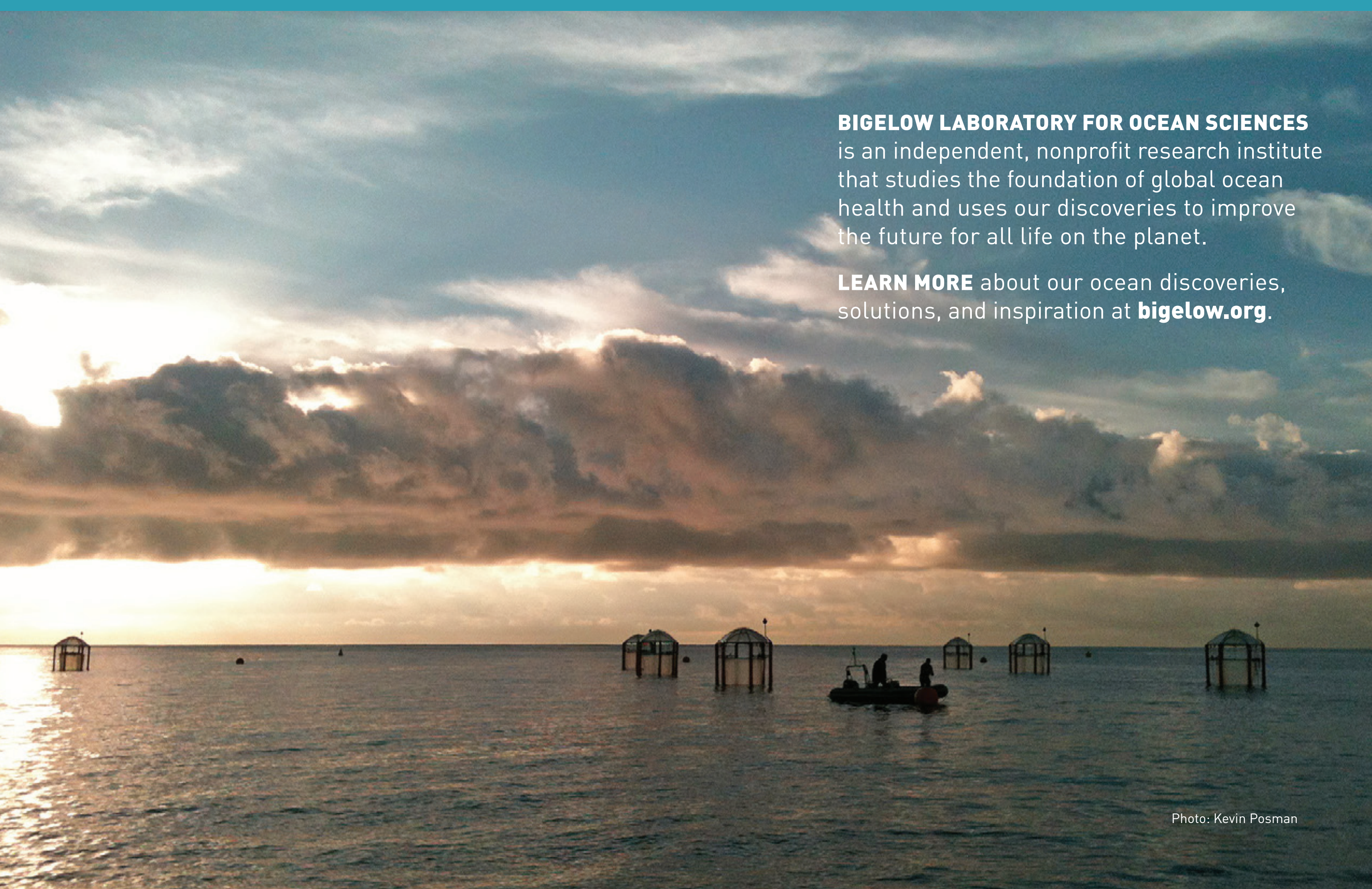

Photo: Kevin Posman