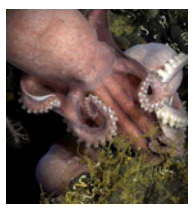
TRANSECT

BIGELOW LABORATORY FOR OCEAN SCIENCES / WINTER 2024



ON THE COVER

This summer, Vice President for Research Beth Orcutt co-led a scientific expedition to investigate the biodiversity of unprotected and underexplored seamounts off the west coast of Costa Rica. There, the international team of scientists discovered two new deep-sea octopus nurseries on hydrothermal springs. Learn more about Orcutt's work to protect the deep-sea environment on page 13.

Photo: Schmidt Ocean Institute

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Ocean microbes form the foundation of global ocean health, and Bigelow Laboratory plays an important role in understanding them and influencing the other institutes that study them around the world. From the development of genomic tools for looking at individual cells to satellite methods for looking at the entire ocean, this is just an incredibly impactful institution.

Our work has never been more important. Understanding the ocean and climate change starts with understanding the microbes. They will determine how the ocean responds to a changing climate, and they are our greatest tool to address the damage that's been done and heal the planet. The ocean supports our society in so many ways and offers so much untapped potential. It is vital to our future, and we must start taking better care of it.

That future is what our new ocean education and innovation center is all about. Hundreds of government officials and supporters joined us to break ground on this transformative expansion on Oct. 12 (see page 6), and I couldn't be more excited about what it means for our institute, Maine, and the nation.

At this pivotal moment, the world needs Bigelow Laboratory. Our approach is bold and creative, fusing the insights of scientists from many different backgrounds to generate critical insights and inspire the next generation of scientists (see page 2). Our approach is collaborative and inclusive, drawing in community and industry leaders to inform, guide, and benefit from our research (see page 8).

When the challenges feel overwhelming, Bigelow Laboratory's work is a place to find and invest in hope. As we close out this year and head toward our 50th anniversary next summer, I ask all of you to consider joining us in support of this work. Your contributions matter to each scientist and student here — and to the bright future our work shows is possible.

Deborah A. Bronk

DEBORAH A. BRONK, Ph.D.

CONTENTS

FRESHWATER CYANOBACTERIAL CELLS from the genus *Dolichospermum*, which look like chains, and ciliates from the genus *Vorticella*, the two halo-shaped cells, often form close associations. Genetic testing has confirmed that this "curly" type of *Dolichospermum* lacks the gene to produce the potent toxin microcystin.

Photo: Pete Countway

FROM ASH TO ALGAE

An interdisciplinary team of researchers is working at all scales to illuminate the relationship between the nutrients in aged volcanic ash and the phytoplankton that need them to grow.

Mount Shishaldin, a conical volcano covered in snow and ice in the Aleutian Islands of Alaska, erupted this July, spewing a large ash cloud miles into the air.

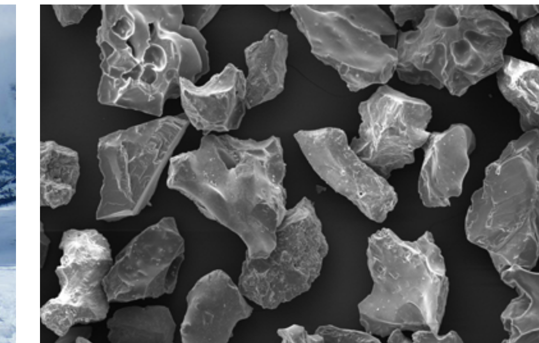
By chance, just a few weeks later, an international team of scientists set off to that remote corner of the North Pacific to collect data for a long-running oceanographic time series study. On board were a Bigelow Laboratory researcher and student with an interest in mountains like Shishaldin. They were there as part of an interdisciplinary project seeking to better understand the connection between the region's volcanoes, which are some of the most active in the world, and its rich marine resources.

Phytoplankton form the base of the food web in this part of the ocean, supporting traditional subsistence livelihoods and a multi-billion-dollar fishing industry. Scientists have previously observed blooms of these microscopic algae after eruptions, suggesting that the minerals in volcanic ash provide critical nutrients, especially iron, that phytoplankton need to grow.

"It's like a multivitamin for phytoplankton," said Laura Sofen, a postdoctoral scientist at Bigelow Laboratory who was involved in the fieldwork this summer.

PAVLOF VOLCANO is one of the most active in the U.S., erupting most recently in 2022. It is one of several Alaska volcanoes researchers are studying in connection to algal blooms.

Photo: Chris Waythomas (Alaska Volcano Observatory/USGS)



LEFT AND ABOVE Researchers from Colby College and partner institutions use ground-penetrating radar and collect sediment samples for geochemical analysis from the Kahiltna Glacier in Alaska for work related to the Volcanic Blooms project. **TOP RIGHT** A scanning electron microscope image shows a close-up of ash erupted from Pavlof Volcano in 2016.

But much of the ash that erupts out of a volcano doesn't land directly in the ocean. It lands on the volcano's slopes, where it slowly erodes or is buried under mountains of snow, dirt, and peat. That "aged" ash can be remobilized later, picked up by the wind and blown out to sea years after it was originally deposited, potentially fertilizing a phytoplankton bloom. Yet, few studies have considered this significant source of nutrients.

The Volcanic Blooms project, a collaboration between Bigelow Laboratory and Colby College, is trying to better understand that process. Working at every scale — from satellites hundreds of miles up to individual cultures of phytoplankton — the team is trying to understand the impact of aged ash on marine productivity and how it compares to fresh ash and other sources of iron in this part of the world.

"We don't have a good understanding broadly about the impacts of ash on phytoplankton communities, but there may also be a difference between the newly erupted ash versus this aged ash," said Karen Stamieszkin, a Bigelow Laboratory research scientist who helped develop the project. "So, it's the quality and quantity of ash that we're asking about."

FROM SPACE...

Stamieszkin and Senior Research Scientist Catherine Mitchell are focused on the macro scale, using satellite data to quantify the impact of dust plumes full of ash. Given how unusual — and difficult to predict — these wind-driven ash plumes are, this remote sensing approach is critical for detecting whether a plume produces a phytoplankton bloom and how long it lasts.

The assumption was that using satellite data might also be relatively easy. It's not.

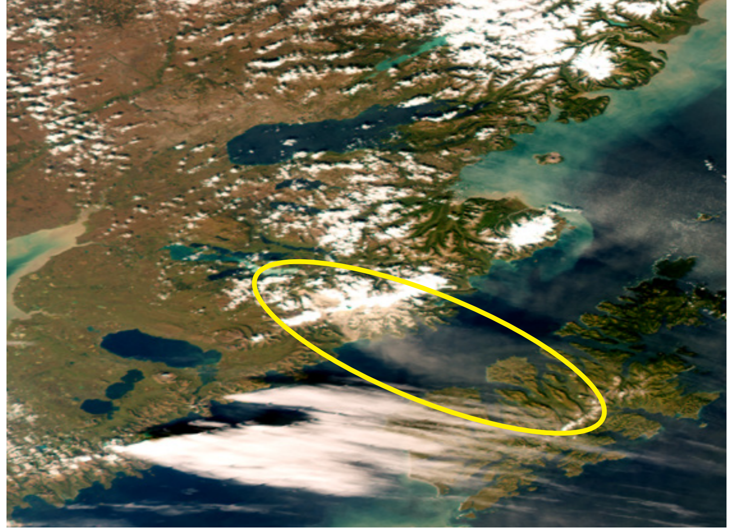
Researchers have developed algorithms that enable them to use satellite images of ocean color to measure the amount of chlorophyll in the water. Chlorophyll is the green pigment found in algae and plants that helps them absorb energy from light, and it can be used as a proxy for phytoplankton abundance. The problem is, when ash is floating around in the water, those calculations appear to be wrong.

"The standard methods we use for interpreting ocean color assume that phytoplankton is the only thing in the water," Mitchell said. "So, because the ash may be mistaken for phytoplankton, those methods overestimate the amount of chlorophyll."

Satellites also appear to be confused by ash in the air. Ocean color satellites sit at the top of the atmosphere, picking up everything between there and the sea surface. In fact, 90% of the signal they produce is coming from particles in the air, not in the ocean. The standard calculations for removing that atmospheric noise struggle when there's a dust or ash plume, making it appear, again, like there's more phytoplankton than there actually is.

Mitchell has been using lab experiments, adding ash into water and seeing how it affects the color, to create a

Photos, clockwise from left: Bess Koffman, Pavel Izbekov (Alaska Volcano Observatory/UAF-GI), Bess Koffman



A SATELLITE IMAGE shows a plume of ash and dust, amid regular clouds, coming off of volcanoes in southwest Alaska and blowing toward Kodiak Island. These plumes of remobilized ash deposit much-needed iron and other nutrients into the ocean, which can stimulate phytoplankton blooms.

more nuanced algorithm for translating ocean color into phytoplankton abundance. Stamieszkin, meanwhile, is trying to automate a process for identifying these plumes of ash-laden dust from satellite data. Together, they'll be able to provide a more accurate method for detecting these ash clouds and accounting for their effects in satellite models, providing an important tool to help researchers understand the impact of atmospheric events on the ocean.

"Satellite data is incredibly useful, but we can't use it off the shelf," Mitchell said. "We need to understand what the limitations are, and learn to work around them as much as we can."

...TO A SHIP

At the other end of the spectrum, several researchers, including Senior Research Scientist Ben Twining and Bess Koffman, an assistant professor of geology at Colby College, are exploring the relationship between ash and algae at the microscopic scale. With lab and field experiments, they're aiming to understand the geochemistry of different kinds of ash and the biology of the phytoplankton communities that feed on it. Their results are also essential for validating the satellite models Mitchell and Stamieszkin are developing.

Last fall, Twining mentored a Colby College student, TJ Guercio, who participated in Bigelow Laboratory's Sea Change Semester program. Guercio spent several weeks growing cultures of phytoplankton and observing how they responded to different iron-rich materials, including several sources of ash that Koffman obtained from the U.S. Geological Survey in Alaska.

This summer, the team took that work to the next level by running similar experiments in the field using samples of water and phytoplankton collected directly from the Northeast Pacific. Rather than growing algae in a lab, they incubated fresh water samples drawn from the ocean — full of phytoplankton and other microbes — and added ash to observe what grew in response. Laura Sofen, the Bigelow Laboratory postdoctoral scientist, and Guercio participated in the cruise, sailing for 14 days aboard a Canadian Coast Guard Vessel.

At 500 and 900 nautical miles out — far enough that the phytoplankton should be iron limited — Sofen and Guercio collected several samples of water. They then divided all that water into individual one-gallon sterile containers, adding unique amounts of ash of different ages from several Alaskan volcanoes to each before sealing them off and leaving them in a pool of seawater on the deck. After four or five days, they measured the amounts of chlorophyll and organic carbon particles inside each container, both proxies for phytoplankton growth, and took photos of the specific species that grew.

Going from the lab to the field was more complicated, though, than just handling larger samples. For example, Guercio and Sofen had to filter out larger organisms or risk a single hungry zooplankton eating all of the phytoplankton before the experiment could begin. Even timing how long they would let the samples incubate was a complex question.

"We were hoping four to five days was the sweet spot where you have enough time to actually see a response but don't get 'bottle effects' because things are trapped in this artificial environment," Sofen said. "That's when the phytoplankton consume all the other nutrients in the seawater and become starved of those, rather than the nutrients you've added from the ash."

The primary concern with research that involves trace amounts of metal such as iron, though, is that there's a high risk for contamination. Not only did Sofen and Guercio have to work in a specialized shipping-container-turned-clean-room, they also had to modify the normal

COLBY COLLEGE STUDENT TJ Guercio (right) secures a water sample from the North Pacific for an experiment, adding iron-laden ash to stimulate phytoplankton growth. To avoid metal contamination, they had to use plastic equipment and modified sampling procedures.

Photos, top to bottom: NASA MODIS, Lynn Wharram

'There are very different aspects to this project, so having us all in the room has been useful to help piece together the full story.'

oceanographic sampling procedures. For example, they had to collect water further out from the deck to avoid rust coming off the ship, and they had to avoid any metal in their equipment.

Despite the challenges, Twining stressed that the ship-based work is an important expansion of the lab experiments and provides a more accurate reflection of the complex interactions in the ocean.

"There are a lot of things going on in the upper ocean that impact iron cycling, and it's really hard to replicate those accurately in the lab," Twining said. "So, taking a natural community in its natural water under natural ambient sunlight and adding our ash materials directly has a lot of benefits."

A UNIQUE SCIENCE MODEL

This interdisciplinary research project illuminates the advantages of Bigelow Laboratory's approach to science.

An essential piece of that model is the involvement of students, who have been integrated into almost every step of the project. Stamieszkin hosted a student two summers ago from the University of Michigan who started the work using satellites to study these remobilized ash plumes. Mitchell worked with a student this summer from University of Virginia who undertook experiments looking at the impact of ash on the optical properties of water. And a student who both Twining and Stamieszkin taught in an introductory class at Colby College is now working with Twining and Koffman on X-ray analysis of volcanic ash to better understand its geological properties.

Guercio's ongoing involvement in the project would also not have been possible without the institute's long-term relationship with Colby College. He first met Twining his freshman year in a class on geoengineering during Colby's "Jan Plan" term, and he began lab experiments during the Sea Change Semester program. This upcoming February, he also plans to attend the 2024 Ocean Sciences Meeting to present on this work.

"It's a really nice example of a student who does a program and comes back for another opportunity," Twining said. "That's the model we like to follow in our education programs."

Guercio is somewhat different from the other students who have been involved, though, because he is also majoring in anthropology. In fact, he got involved with the Volcanic Blooms project as a sophomore working with Koffman to examine the ethnohistory of the Indigenous Unangax̂ people and their relationship to the environment of the Aleutians.

In fact, one of the broader goals of the project is to tie the scientific findings to Indigenous knowledge of volcanoes and their impacts on the ocean. That effort highlights the interdisciplinary nature of the project and the advantages of having several research scientists, all with unique expertise, working together.

"I'm really excited about the science coming out of this project because it's so multi-dimensional," Stamieszkin said. "We can get at this question with a much greater depth of understanding."

Twining described it as a Venn diagram, where each researcher has enough overlap to understand each other but also brings a unique niche to contribute to the project.

"There are very different aspects to this project, so having us all in the room has been really useful to help piece together the full story," Mitchell said. "It's a perfect example for me of why I like Bigelow Laboratory."

TOP Kasatochi is one of the volcanos from which the team has collected ash. A 2008 eruption deposited multiple inches of ash onto neighboring Adak Island, which may be remobilized in the future. **BELOW** Postdoctoral Scientist Laura Sofen measures phytoplankton growth from water samples in a specialized lab designed to minimize metal contamination.

Photos, top to bottom: Burke Mees (Alaska Volcano Observatory/USGS), Ian Tomkins

AN EXTERIOR RENDERING of the center for ocean education and innovation shows how the 25,000-square-foot expansion will transform Bigelow Laboratory's campus.

'A Promise of Great Things to Come'

Government Leaders and Supporters Gather to Break Ground on New Education and Innovation Center

Over 200 supporters, Maine's governor, and several members of the state's congressional delegation gathered at Bigelow Laboratory's East Boothbay campus on Oct. 12 to break ground on a new center for ocean education and innovation. The 25,000-square-foot, $30 million laboratory addition will revolutionize the institute's education and solutions-focused work with expanded facilities, and endowed funds to support promising, early-stage ideas.

"This new center for ocean education and innovation will help expand and enhance Bigelow's research, as well as inspire the next generation of ocean scientists," said U.S. Senator Susan Collins during the event. "With the 50th anniversary of the lab coming up next year, this is a wonderful way to launch that birthday celebration."

The groundbreaking ceremony and reception brought together Bigelow Laboratory supporters and staff at the future site of the new center, which will include dedicated teaching spaces, new laboratories, and a multi-purpose, 300-seat forum.

Before gathering for the ceremonial groundbreaking and a reception, several of the leaders who made this significant investment possible provided public remarks to celebrate the important contributions of Bigelow Laboratory and the exciting advancements that the new center will enable.

Speakers included U.S. Senator Angus King, speaking in a pre-recorded video; Bill Burgess, Bigelow Laboratory Trustee; Bigelow Laboratory President and CEO Deborah Bronk; Sarah Lawrence, district representative speaking on behalf of Congresswoman Chellie Pingree; Mark Lee, the principal and CEO of design firm Harriman Associates; and Dave Thomas, project executive for Consigli Construction Co., Inc.

Dr. Wendy Wolf, chair of the Bigelow Laboratory Board of Trustees, described it as an "exciting inflection point for the lab" during her remarks, while president and CEO of the Harold Alfond Foundation, Greg Powell, called the day's events "a promise of great things to come."

Fundraising for the construction and future maintenance of the new facilities continues, even as the project gains speed. It is being supported by private donations, as well as a $12 million federal grant and an $8 million gift from the Harold Alfond Foundation. The federal support was made possible by Maine's congressional representatives, who recognized the importance of Bigelow Laboratory's education and research initiatives for Maine's residents, ecosystems, and economy.

"The expertise you share here and the discoveries your researchers have made are more important now than ever," said Governor Janet Mills. "Your research will help humanity chart a new course for the health of our planet."

BIGELOW LABORATORY BOARD Chair Wendy Wolf (right) and other event speakers (below), including Governor Janet Mills, took part in the groundbreaking.

ABOVE The groundbreaking ceremony was followed by a reception that included recorded remarks from U.S. Sen. Angus King. **RIGHT** U.S. Sen. Susan Collins (center) and Greg Powell, president and CEO of the Harold Alfond Foundation (second from left), both spoke at the event.

RENDERINGS OF THE CENTER for ocean education and innovation (above) show how the interior of the new facilities will look with dedicated teaching spaces and a 300-seat, multi-purpose forum for scientific collaboration and community outreach.

Supporting Local Science

Community groups, tribal organizations, and local resource managers bring valuable, in-depth knowledge that's too often ignored in the scientific process. Bigelow Laboratory is creating lasting relationships with those on-the-ground partners to help protect ecosystems and human health across the country.

NEW BRUNSWICK POWER recently began dismantling Milltown Dam on the Skutik River. Despite a fish ladder, visible under the yellow walkway, Milltown has been a barrier to fish passage for over a century.

Photo: International Joint Commission

Partnerships with community groups, tribal organizations, and local government partners bring in-depth knowledge, data, and long-term engagement that Bigelow Laboratory can both enhance and benefit from. Those groups are also able to start conversations around solutions and policy that extend the impact of the institute's expertise.

This July, authorities began dismantling the Milltown Dam, situated on the Skutik River (also known as the St. Croix) between St. Stephen, New Brunswick, and Calais, Maine. The dam is one of the oldest hydroelectric facilities in the world, located on an ancient village site known as Salmon Falls. For over a century, it has blocked fish like alewives and shad coming up from the ocean, species that the Passamaquoddy people have subsisted on for thousands of years.

Bigelow Laboratory is working with the Sipayik Environmental Department of the Passamaquoddy Tribe at Pleasant Point to monitor fish populations and water quality as the dam removal progresses, supporting their ongoing efforts to protect the health of the river.

"There's been an ongoing effort on both sides of the border to remove the dam and restore fish passage," said Senior Research Scientist Rachel Sipler, director of the institute's Water Health and Humans Initiative. "We saw this as a great opportunity to contribute to that science."

Since coming to Bigelow Laboratory in 2021, Sipler has been connecting with potential community partners across the state to find opportunities where the institute could bring its scientific expertise and specialized research tools to bear. One of those groups was the Skutik River Restoration Trust, an international collaboration between Canadian and U.S. tribal and government entities, including the Passamaquoddy.

One of the trust's primary goals has been to understand the state of sea-run fish and what impact the dam removal might have on their movement up river.

In May and July of this year, several Bigelow Laboratory researchers went north to participate in water quality sampling alongside Sipayik Environmental Department scientists. The team collected numerous samples before and after dam removal began to test for excess nutrients, metals, PFAS chemicals, and environmental DNA — the floating fragments of DNA organisms leave behind that can be used to track their movements. Together, these data can will illuminate if fish are making it up the river and what contaminants they're being exposed to.

In September, three Sipayik Environmental Department scientists visited East Boothbay to work with Bigelow Laboratory scientists to process those samples and think through ways that tools like environmental DNA, or eDNA, can support their broader scientific goals.

"Where this could really help us is to see how fish are interacting with other barriers to passage and start thinking about how to prioritize those features," said Chris Johnson, the organization's ecology manager. "It could also help us more easily figure out how far up the system these fish are going."

Johnson said they're exploring ways to correlate the eDNA results with their existing methods for tracking fish, which includes traps, seine nets, and video counts. The goal is to understand how the system responds to the decommissioning of Milltown and better monitor fish passage over the other dams that are still on the river. And with eDNA, they'll be able to use the same samples to analyze for countless other species of interest as their work expands and evolves. That includes identifying endangered species in the watershed like Atlantic salmon.

During the visit to Bigelow Laboratory in September, the group continued the collaboration by making plans for future work. They also brainstormed opportunities to broaden the partnership, including possible student exchanges and trainings.

"We went up and did it this summer basically with no money knowing that it needed to be done, and it was time dependent," Sipler said. "Now is the time to find funds to process the samples that were collected and continue this meaningful work."

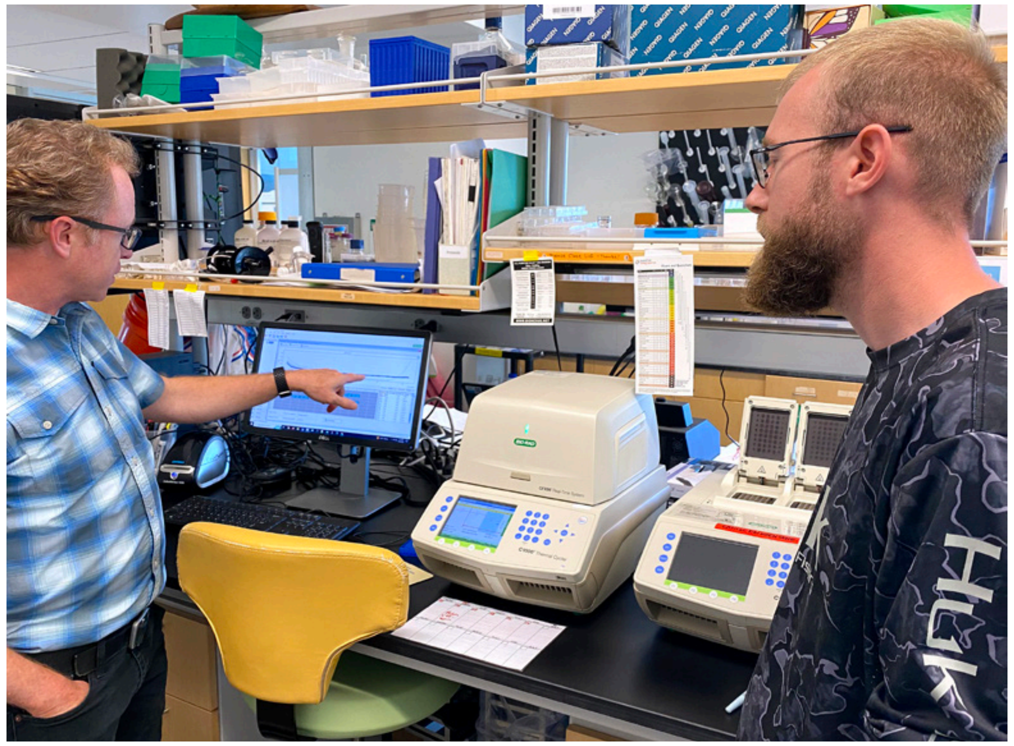
Sipler stressed that while Bigelow Laboratory is helping train the scientists on how to take and process samples, especially around new techniques like eDNA, the Sipayik Environmental Department is leading this project — guided by their questions and deep knowledge of the watershed.

"At Bigelow Laboratory, we have the equipment and specialized knowledge to help with the things they know they need to do," Sipler said. "We're supporting their research team, which is established, knowledgeable, and self-determined."

'At Bigelow Laboratory, we have the equipment and specialized knowledge to help with the things they know they need to do.'

BIGELOW LABORATORY RESEARCHERS and scientists from the Sipayik Environmental Department collect environmental DNA and other data from the Skutik River to understand how the dam removal is affecting water quality and fish passage.

Photos: Rachel Sipler



‘We have to acknowledge each other’s skill sets and learn from each other, which makes us stronger as researchers.’

SIPAYIK ENVIRONMENTAL DEPARTMENT SCIENTISTS work with Bigelow Laboratory researchers to learn new laboratory techniques, process water quality samples, and brainstorm how to expand the collaboration in the future.

LESSONS LEARNED ACROSS BIGELOW

The ongoing collaboration with the Sipayik Environmental Department is just one of several partnerships that Bigelow Laboratory scientists are pursuing, each bringing the institute’s technical expertise and analytical capacity to bear on the needs and existing efforts of community groups, resource managers, and local scientists.

For example, Senior Research Scientist Pete Countway, who has helped train the Passamaquoddy scientists on eDNA techniques, is sharing that knowledge with other community groups in the region to monitor a range of water quality threats. As the required technology has become more portable and user-friendly, it’s created opportunities to empower people to take control of their own monitoring efforts and meet the unique needs of different communities.

“I got one of these devices, and suddenly I could take my science to where there was real-world need,” Countway said. “That really opened up a lot of possibilities for the type of collaborations we could do that were meaningful.”

Countway is now working closely with the Midcoast Conservancy in Maine to help monitor the Damariscotta Lake watershed for bacteria and harmful algal species. He’s also working with Wolfeboro Waters in New Hampshire, a community group established to protect water resources that approached Countway with concerns about excessive plant growth in their local lakes. In addition to training those groups on how to use the equipment and interpret data, Countway has brought their teams to Bigelow Laboratory to learn more about the possibilities and limitations of current analysis techniques.

“We don’t want to be gatekeepers of technology,” Countway said. “We want to turn the technology loose, and help people see what they can do with it.”

The results are often surprising and can multiply the effectiveness and impact of science.

Senior Research Scientist Maya Groner and Postdoctoral Scientist Reyn Yoshioka also work with resource managers to study the impact of infectious diseases on economically important species. For the last several years, they have engaged with numerous academic and agency partners, such as the Alaska Department of Fish and Game, on research related to snow crabs, one of Alaska’s most lucrative fisheries, which catastrophically collapsed in 2022.

They are using experiments and models to understand the nature of an emerging condition called black eye syndrome, which may potentially affect hormonal regulation and impact the fishery. They’re also modeling bitter crab syndrome, a fatal blood disease caused by a parasitic species of plankton, to determine whether a recent epidemic could have contributed to the snow crab collapse. They plan to present their research directly to affected fishermen through the Bering Sea Fisheries Research Foundation, a collective of regional stakeholders working to improve fishery management through collaborative research.

“It’s been awesome to work with people who are on the ground, making the decisions, and have very different insights into the questions we’re asking,” Yoshioka said.

Yoshioka and Groner, with Senior Research Scientist Nick Record, were also recently funded by the Sea Grant American Lobster Initiative to study epizootic shell disease, a potentially fatal infection that has devastated the lobster fishery in southern New England. Working with state managers in Maine and Massachusetts, the team is exploring the impact of warming waters on the prevalence of the disease in the Gulf of Maine. They’ll also present those findings to fishermen and other stakeholders as the project progresses.

These partnerships have provided an important avenue for data sharing and collaboration. The agencies help with data collection and experiments, guiding the research based on local needs. Bigelow Laboratory scientists bring the expertise needed to design complex research projects and perform analyses that can inform fishery management.

“These collaborations with partners that are straddling research and policy are really satisfying, and there’s no way this work could happen without them,” Groner said. “There’s just a lot of relationships and logistics that they have worked out over many years that enable us to do this work.”

Co-creating science with on-the-ground partners can be harder than the “ivory tower” approach to science. It requires adapting equipment and protocols for new uses, sustaining relationships across funding cycles, and supporting a community that may have different priorities than a research scientist.

But those challenges are more than offset by the benefits of these collaborations for protecting ecosystems and human health.

“We have to acknowledge each other’s skill sets and learn from each other, which makes us stronger as researchers,” Sipler said. “It’s about finding collaborations that fit, not forcing ourselves into anything, which makes Bigelow Laboratory stronger.”

LEFT, BOTTOM LEFT Senior Research Scientist Pete Countway shares his expertise and collaborates with partners like Wolfeboro Waters and Midcoast Conservancy to expand access to cutting-edge technology and support community groups in protecting their aquatic resources. **BOTTOM RIGHT** Postdoctoral Scientist Reyn Yoshioka works with resource managers to study the impact of infectious diseases on marine species, like snow crabs, to help inform fisheries management.

Photos, clockwise from top: Pete Countway, Nicole Charriere, Pete Countway

FIELD NOTES

REYKJANES RIDGE, Iceland

MELODY LINDSAY, Research Scientist

"Core on deck!" shouts the driller over the loudspeaker — almost every hour for two months. Each time this alarm sounds, a crew of technicians and scientists scurry to the top laboratory of the research vessel *JOIDES Resolution*. There, they retrieve a 10-meter-long core of sediment or rock brought up from the deep subsurface of the Reykjanes Ridge, a piece of the Mid-Atlantic Ridge near Iceland where the North American and Eurasian tectonic plates are slowly spreading apart. Each core contains sediments deposited over millions of years and hard basalt rock laid down in V-shaped ridges and troughs, buried kilometers deep below the seafloor.

From June 12 to Aug. 13, I was part of an international team of scientists, technicians, drillers, and crew aboard Expedition 395 of the International Ocean Discovery Program. We set sail from the port of Ponta Delgada, Azores, before transiting to our first drilling site a couple hundred kilometers south of Iceland. Over the course of the expedition, which was decades in the making, we successfully collected over 5,229 kilometers of sediment and hard rock basalt from drill sites deep in the ocean.

Even though it covers 70% of the planet, the deep oceanic subsurface remains a largely understudied environment. Most investigations of this region are made possible by scientific ocean drilling ships, which have enabled key findings into the history of Earth's climate, captured within the sediment and rock of the ocean floor.

Our expedition was focused on several aspects of this work, including discovering the dynamic geologic history of the ocean gateway between the Norwegian Sea and Arctic Ocean. We also collected samples that will be key to deciphering the formation mechanisms of the V-shaped ridges and troughs visible on the ocean floor and illuminating how hydrothermal fluid alters basalt rocks and enters overlying sediment.

My particular research, and that of the Deep Biosphere Team at Bigelow Laboratory, is focused on the biology of these extreme subsurface environments. These ecosystems are characterized by a lack of sunlight and photosynthesis, which means low nutrients and low biomass — so low that it can be hard to even tell if organisms exist there! Nonetheless, life does persist in these challenging conditions. In fact, the unique water chemistry of these sediment cores, influenced by the movement of overlying seawater and by fluids cycling through the crust, fuels rich microbial communities.

Fortunately, we're well-equipped to identify the species living there. As the team pulled up the cores, we took subsamples of each — over 450 samples from sediment and 90 from hard rock — to extract whatever biomass was there. Then, we cryopreserved them on board the ship at -80 degrees Celsius, which is necessary to later identify what species are inhabiting the samples.

It's a difficult and expensive enterprise to conduct this sort of research on the *JOIDES Resolution*, a ship that has operated as a research drilling vessel since 1984. The "JR" remains a leader in deep-sea ocean drilling, providing invaluable access to this large and diverse ecosystem. Unfortunately, the JR is set to soon retire — four years earlier than expected — and there isn't another ship capable of this type, magnitude, and frequency of scientific drilling.

Deep biosphere investigations into the oceanic subsurface rely on fresh core samples that are immediately processed and preserved shipboard, so this research will be largely paused, potentially for decades.

Though this kind of research is challenging, the discoveries enabled by the JR and other scientific ocean drilling ships highlight the need to invest in this kind of bold science. As we begin to explore the precious samples collected during this expedition, it is clear they will be invaluable for years to come as we work to unravel new discoveries in the deep marine subsurface about the past, present, and future of our planet.

Photo: Justin Dodd

CURRENTS

Photo: IISD/Earth Negotiations Bulletin

Orcutt Pushes for Science-Based Policy for the Deep Sea

Beth Orcutt, Bigelow Laboratory's vice president for research, is one of the leading experts working to ensure that science — and science-informed policy — is front and center in global negotiations over deep-sea mining. This year, Orcutt contributed to several meetings of the International Seabed Authority, or ISA, the intergovernmental body charged by the United Nations with regulating mining and minimizing its impacts in international waters.

As a representative of the Deep Ocean Stewardship Initiative, associate director of the Crustal Ocean Biosphere Research Accelerator, and an expert in microbial ecology, Orcutt works to illuminate how deep-sea ecosystems function and respond to change. She also educates the public about the potential impacts of emerging industries on those ecosystems. In July, citing the significant knowledge gaps highlighted by Orcutt and her colleagues, the ISA announced that it needed more time to develop adequate regulations for mining. Scientists like Orcutt say at least a decade of research is needed to build sufficient knowledge to inform the development of those rules.

Photo: Colin Fischer

SCIENTISTS EXAMINE FLEXIBLE FEEDING

Coccolithophores, a globally ubiquitous type of phytoplankton, play an essential role in the cycling of carbon between the ocean and atmosphere. A team from Bigelow Laboratory, led by Senior Research Scientist Barney Balch, recently showed that these vital microbes can survive in low-light conditions by taking up dissolved forms of carbon.

The ability to extract carbon from the direct absorption of dissolved organic carbon is known as osmotrophy. Though scientists had previously observed osmotrophy by coccolithophores in the lab, this was the first evidence of the phenomenon in nature. By showing that these organisms take up dissolved organic carbon, the findings will push researchers to reconsider the processes that drive carbon cycling in the ocean. Several of our scientists have begun researching osmotrophy and other forms of "flexible feeding" at the base of the food web, providing new insights into how carbon flows through marine ecosystems.

Photo: Rachel Sipler

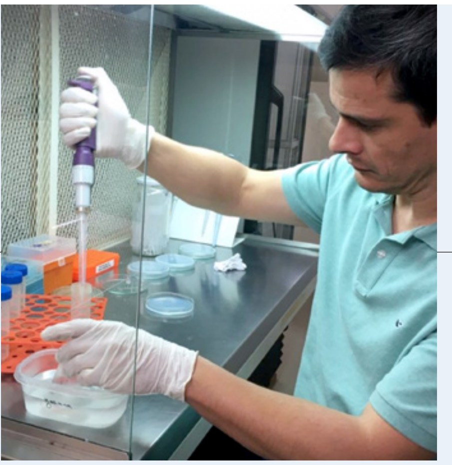
Regional Initiative Protects Drinking Water

Bigelow Laboratory is one of the core members of the Boothbay Region Clean Drinking Water Initiative. The collaboration has brought together the Boothbay Region Water District, local municipal governments, and several nonprofits to work toward maintaining the health of the region's freshwater reservoirs. Bigelow Laboratory's role in the partnership is to understand the science needs of the system and provide analytical capacity to address potential water quality threats — before they become a problem. This summer, the team's research efforts focused on monitoring potential harmful cyanobacteria in two drinking water reservoirs. The Boothbay Region Water District collected samples from both lakes twice a month, which scientists at Bigelow Laboratory analyzed. The study provided more frequent and real-time information than was previously available, helping the community begin to proactively tackle the environmental conditions that drive harmful algal blooms.

Students Get Hands-On Training

Bigelow Laboratory's new research vessel, the R/V *Bowditch*, set sail on its maiden voyage this May, providing 16 Maine high school students with hands-on research experience as part of the Keller BLOOM program. This summer, the institute's interns used the boat for their own series of expeditions to learn the ins and outs of ocean science. And this fall, Sea Change students participated in research cruises throughout their semester at Bigelow Laboratory. The *Bowditch* is already proving to be an invaluable resource to education program participants looking for real-world training.

The research vessel — donated last year by Middlebury College — is just one of several exciting new upgrades to Bigelow Laboratory education programs. The $30 million investment into our forthcoming center for ocean education and innovation (see page 6) includes dedicated teaching labs, classrooms, and funding for a marine educator position. Together, these investments represent an evolutionary leap in the institute's education programs and will greatly expand student access to these transformative experiences.



RESEARCHERS DISCOVER GIANT FUNGAL VIRUSES

A team of researchers, including Senior Research Scientist Joaquín Martínez Martínez, recently found evidence in the ocean crust of "giant" viruses — those with double-stranded DNA that can be several orders of magnitude larger than average — that may be infecting fungi.

Viruses play an essential role in the ecology and evolution of microbial life in systems around the world, and previous work has shown that they are found just about everywhere, including in the crust. But little was known about the kinds of viruses living there, and traditional methods led scientists to believe that most fungal viruses were small-RNA viruses. The team's discovery provides the first evidence of both viruses infecting eukaryotic life in the deep subsurface and giant viruses infecting fungi. That raises questions about the role of these subsurface organisms in biogeochemical cycling in this poorly understood ecosystem.

Photo: Kyle Oliveira

Statewide Project Enters its Final Year

This summer was the final field season of the Maine-eDNA project, a five-year, multi-institutional initiative to develop ecological management tools using the DNA organisms leave behind. Co-led by Bigelow Laboratory and the University of Maine, the project aims to use environmental DNA to develop technologies that equip coastal communities to adapt to changing conditions. From monitoring harmful algae in lakes to tracking species at sea, our scientists, students, and interns have been collecting eDNA samples across the state over the last five years.

Through the project, seven of our scientists have worked alongside numerous interns and eight University of Maine graduate students based at Bigelow Laboratory. This summer was a critical last opportunity to gather data and test some of the new tools that are already in development. Processing and analysis of samples will continue through the spring, as will planning for next steps to apply all that the team has learned to pressing environmental challenges in Maine.

Scientists Teach Harmful Algae Identification

Effective monitoring and management of harmful microalgal blooms relies on accurate and timely identification of the species involved, especially as warming waters and expanding coastal development increase the prevalence of blooms across the country. To that end, there's a growing need for identification training, and 18 resource managers, scientists, and technicians gathered at Bigelow Laboratory this summer for a 10-day course.

The National Center for Marine Algae and Microbiota's harmful microalgal identification course provides comprehensive training to professionals on microscopy techniques and alternative technologies for microalgae identification. The program specializes in traditional taxonomic methods that are increasingly essential as climate change alters the distribution of species and limits options for identifying organisms solely through genetic techniques. Since it began in 2016, the course has trained 114 professionals from 23 states and several countries. This year, it was posthumously renamed in honor of Karen A. Steidinger, a leading researcher on harmful algae who was central to getting the course started.

STUDY EXPOSES NUANCES OF CO2 REMOVAL STRATEGY

Removal of excess carbon dioxide in the atmosphere, in addition to major reductions in emissions, is required to stave off the most severe consequences of climate change. Large-scale ocean iron fertilization is one of several strategies that are being explored to help remove atmospheric carbon dioxide. However, a team of researchers, including Senior Research Scientist Ben Twining, recently showed that iron fertilization may negatively affect marine ecosystems in far corners of the ocean.

Using advanced models of biogeochemistry and ecology, the researchers found that iron fertilization in the Southern Ocean could exacerbate climate change-driven nutrient shortages and productivity losses in the tropics, potentially hurting the coastal fisheries on which many people rely. Their findings reflect the interconnected nature of the ocean and the need for objective research on the relative advantages and unintended consequences of marine carbon dioxide removal methods.

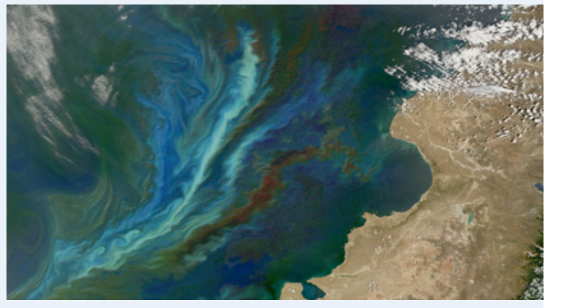


Photo: NASA Earth Observatory

ARTIST ILLUMINATES BEAUTY OF MICROBES

Daisy Braun, an interdisciplinary artist from Maine, installed a new exhibit showcasing the beauty and importance of microscopic ocean life at Bigelow Laboratory this summer. The sculptures are abstract representations of plankton made of reed, silk, and string, which hang from the ceiling of the two-story atrium. Their presence in the laboratory's public space serves to inspire people to see the ocean — and think about ocean science — in new ways.

Planktonic plants and animals drift across the world's oceans carried by currents, sustaining the ocean food web and producing over half of Earth's oxygen. Braun, whose work explores biological connection, was inspired to call attention to these drifting organisms and how they reflect the ever shifting, interconnected web of ocean life. Between our open house and Café Sci events, professional courses, and public tours, more than 1,000 visitors have already been able to appreciate the installation.

PROFILE

Council Members

David and Mary Otto

'The ocean could provide some breakthrough that we can only dream about, and if it does, Bigelow Laboratory is going to be a part of that.'

Both David and Mary Otto are from Iowa, about as far as one can get from the ocean, and neither grew up with much exposure to science. That didn't change when they first moved to the coast. The couple arrived in New York City in the 1960s — she to get her advanced degree in English and he for seminary school and, ultimately, a career in finance. And though they bought their summer home in Boothbay Harbor in the 1970s, it was almost 20 years before they really knew much about the ocean science laboratory they would occasionally glimpse from their sailboat.

One summer, though, they stumbled into a Bigelow Laboratory Café Sci talk at the Opera House in town.

"That event was the first time I ever even heard the word phytoplankton, but I became curious to know more about it and why it mattered," Mary said. "And that made me curious about Bigelow Laboratory's efforts to educate people like me who have very little contact with that scientific world."

The pair have been supporters of the institute's education and solutions-focused work ever since. And it's become a family affair. In 2020, their granddaughter, Eliza Goodell, participated in the Sea Change Semester program. Eliza, who majored in geology at Oberlin College, worked with Senior Research Scientist Emerita Paty Matrai. They sought to understand how a warming ocean changes the production of a sulfurous compound that, through a complex exchange between phytoplankton and bacteria, plays a key role in regulating the climate.

But one semester wasn't enough for Eliza, and she stuck around that spring as a research assistant with scientists Beth Orcutt and Melody Lindsay. During that time, Eliza was part of the "Single Cell Genome-to-Phenome" project, a cutting-edge effort to use genetic information to understand the biological activity of marine microbes, such as those found below the seafloor.

"It was a welcoming environment and an empowering situation for her," Mary said of Eliza's experiences that year. "Bigelow Laboratory is such a source of guidance and mentorship for her, and it's comforting to me that she has this level of expertise just next door, as it were."

Mary said those relationships continue to be meaningful now that Eliza has graduated and begun to think about next steps in her scientific career. And given what Bigelow Laboratory's education programs have meant to both Eliza and the Ottos, she's pleased to see plans for a large forum in the new center for ocean education and innovation that's currently under construction.

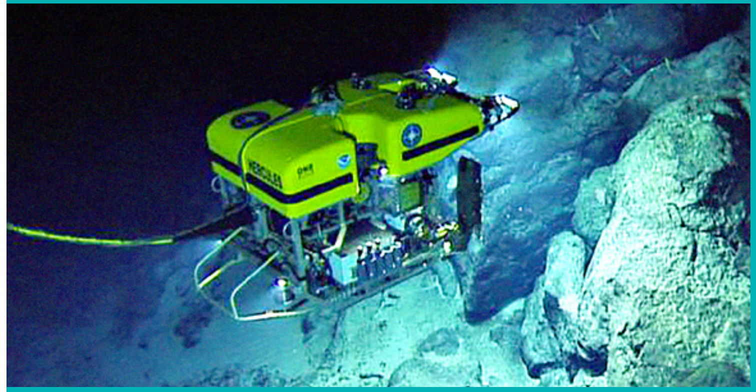
Their granddaughter provides more abstract motivation for the Ottos as well.

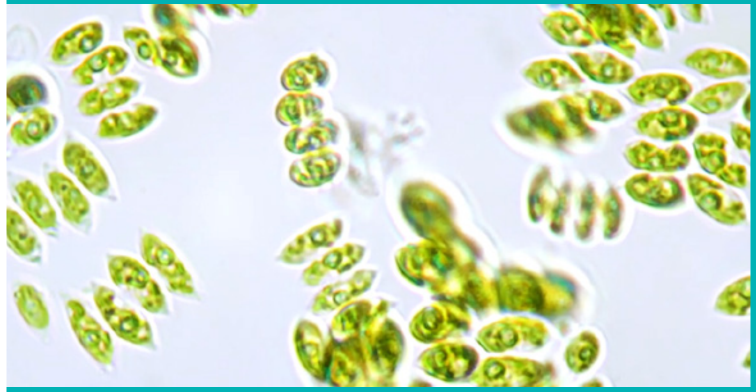
"It's her generation that could pay big time," David said of the growing danger of climate change. "We're confident that Bigelow has a good chance at making an impact on the world of our granddaughter."

The Ottos believe they have a moral obligation to help solve a global problem the U.S. helped create, and they've been inspired by Bigelow Laboratory's efforts to unlock the potential of the ocean to that end. That includes the work of several scientists to explore different strategies for marine carbon dioxide removal. As former Midwesterners, they're also particularly excited by the coast-cow-consumer project, which is looking at incorporating algae into the diets of cows to reduce the production of methane at dairy farms. But the Ottos also appreciate the importance of the institute's more fundamental research mission, knowing how the pure science of today may lead to valuable solutions in the future.

"We've got to get creative on how to solve this climate issue," David said. "The ocean could provide some breakthrough that we can only dream about, and if it does, Bigelow Laboratory is going to be a part of that."

Photo: Robert Mitchell





GIVING

Secure Your Legacy

Bigelow Laboratory scientists study the foundation of global ocean health to help secure the future for all life on our planet.

Our donors, meanwhile, provide crucial support that helps secure the future of that work.

We offer the opportunity to invest in planned gifts to ensure your support continues long beyond your lifetime. These contributions can take many forms — from bequests to real estate — and allow you to continue making a difference on the issues you care about far into the future.

Our team would be honored to help secure your legacy as a partner in our work to turn the tide on global challenges. You can learn more about the options and process of gift planning at bigelow.org/gift-planning.

A TRIBUTE TO Barbara LaVoy

Though previously unknown to Bigelow Laboratory, Barbara Anapol LaVoy's legacy shines brightly through an unexpected and generous bequest received last year. Barbara was a Westport, Connecticut, resident, lawyer, artist, and accomplished equestrian. She passed away in January 2021 and chose to leave her estate to charity, naming Bigelow Laboratory as one of four environmental nonprofit beneficiaries. This extraordinary gift was a testament to her selflessness, love for the ocean, and desire to safeguard it for future generations. Barbara's legacy will be making an impact on ocean discovery beyond her lifetime, and she has forever etched her memory in our hearts.

WAYS TO GIVE

Would you like to help make our ocean discoveries possible? We offer several easy ways to make your fully tax-deductible donation.

BY PHONE Call Bigelow Laboratory's Advancement Team to make a credit card gift over the phone at: 207 315-2567 x106

ONLINE Donate to Bigelow Laboratory via credit card using our secure online form at: bigelow.org/support

BY MAIL Send checks to: Bigelow Laboratory for Ocean Sciences, 60 Bigelow Drive, East Boothbay, ME 04544

We also welcome gifts of securities, IRA distributions, Donor Advised Fund grants, boat donations, planned gifts, and more. Please call 207 315-2567 ×106 for details.

Photos: Denise Bruesewitz (top), Ocean Exploration Trust (middle)

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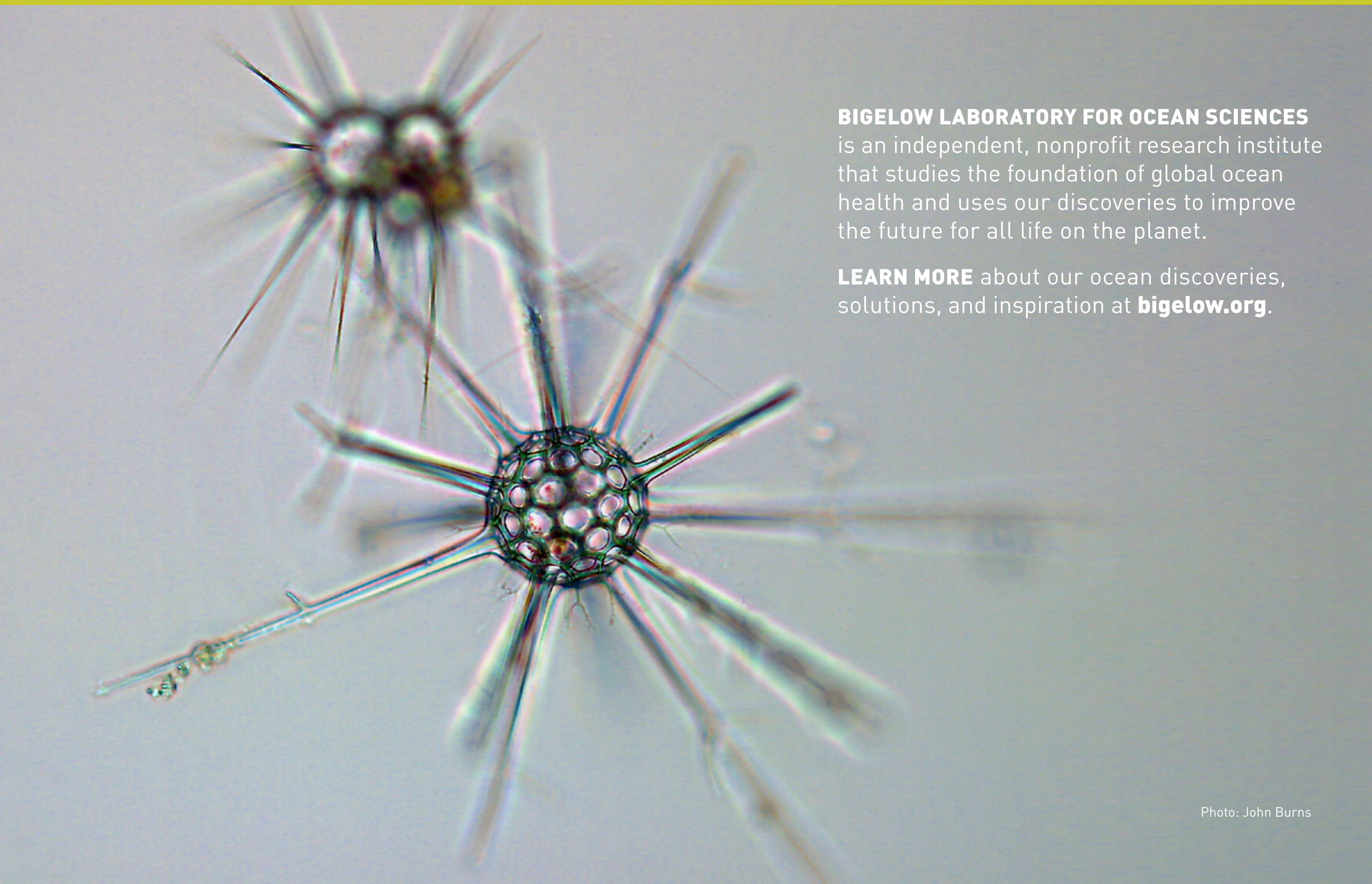

BIGELOW LABORATORY FOR OCEAN SCIENCES is an independent, nonprofit research institute that studies the foundation of global ocean health and uses our discoveries to improve the future for all life on the planet.

LEARN MORE about our ocean discoveries, solutions, and inspiration at **bigelow.org**.

Photo: John Burns