TRANSECT

BIGELOW LABORATORY FOR OCEAN SCIENCES / WINTER 2019 / VOLUME 11 / ISSUE 1

A photo can tell you a lot about a particular moment in time, but it provides little information about what happened before and after it was taken. Without this context, it can be easy to draw incorrect conclusions about what you're looking at.

The same principle applies to environmental studies, which typically capture a snapshot of an ecosystem. This is why time series studies are vitally important. By taking the same measurements year after year, scientists gain perspective on how an environment is evolving over time.

In this issue you can read about the contributions Bigelow Laboratory scientists have made to ocean time series. As a taxpayer and a naturally frugal person, my personal favorite is GNATS — the Gulf of Maine North Atlantic Time Series. In an era where research vessels can cost tens of thousands of dollars a day, Senior Research Scientist Barney Balch and his team have used a passenger ferry to build a 20-year time series of Gulf of Maine data. It is a perfect example of the scrappy ingenuity for which Bigelow Laboratory is well-known.

One of the changes our scientists are observing in the Gulf of Maine is an increased appearance of harmful algal species. Florida has been hit hard by a record-setting red tide this year, highlighting the importance of better monitoring and stronger preventative measures. I spent a decade studying harmful algal species in Florida and saw firsthand the devastation that blooms and the resulting fish kills can cause to the environment, the economy, and the psyche of a region.

Much of the coast of Maine is in sharp contrast to the highly developed coast of Florida. We have an opportunity to mitigate the threat of increased harmful algal blooms before it grows to be the size of the problem facing Florida. We must work to quantify and reduce the sources of nutrients to our coastal waters, continue building robust and cost-effective programs for monitoring harmful algal species, and educate the next generation to make informed decisions that continue to protect our coast.

This is a big challenge, and harmful algal bloom research remains grossly underfunded — along with much of ocean science. Thankfully, efforts to further reduce federal research funding did not succeed this year. In fact, the National Science Foundation, our primary source of science funding, saw a slight increase.

However, as a former National Science Foundation division director, I also know that this is not enough to keep up with the ever-increasing costs of its critical infrastructure, such as the research fleet and ocean drilling program. This continues the downward trend of funding available for the research grants that have kept our country at the forefront of ocean science.

Ocean science needs better funding at the federal level. It also needs bold, nimble institutions like Bigelow Laboratory to continue leading the way in reimagining how we make science more efficient and more effective.

I am truly inspired by the innovation and devotion to discovery shown by the scientists and staff here. For someone who loves the ocean, science, and this country, I can't imagine a better place to be.

DEBORAH BRONK, PhD

ON THE COVER

Kelp grows at the Ocean Approved farm in Casco Bay. Senior Research Scientist Nichole Price is studying the benefits of growing mussels and kelp together, which can improve water quality and shellfish health. Read more about this project on page 14.

Photo by Brittney Honisch

DESIGN Springtide Studio
PRINTING J.S. McCarthy Printers

PRINTED WITH CERTIFIED WIND POWER

Photo: Reggie Huang, opposite

TABLE OF CONTENTS

RESEARCH TECHNICIAN Debra Lomas sorts zooplankton samples collected by the Bermuda Atlantic Time-series Study (BATS). Learn about the unique power of BATS and other long-term environmental studies to reveal how our oceans work and how they are changing on page 2.

The Power of Time

In critical environments around the globe, long-term environmental studies are illuminating our oceans and their future.

The Industrial Revolution brought with it new manufacturing processes, the rise of factories, and a dramatic increase in the carbon humans pump into the atmosphere. About a quarter of this carbon ends up in the ocean, affecting everything from chemical processes to sea life.

At the same time, natural climate and seasonal cycles continue to cause variability in the ocean. Untangling all these effects is a major challenge.

"You have to measure long enough to capture natural cycles and detect underlying change associated with the last 200 years of putting carbon into the atmosphere," Senior Research Scientist Mike Lomas said. "The challenge is that if you don't measure frequently or long enough, you can't answer questions about climate change."

Coincidentally, Bigelow Laboratory for Ocean Sciences began next door to the site of one of the longest sea surface temperature records on the Atlantic coast, at the Maine Department of Marine Resources in West Boothbay Harbor. The richness of a century of temperature data inspired Bigelow Laboratory scientists to start collecting complementary data from their dock. Michael Sieracki, a former senior research scientist at Bigelow Laboratory, launched a comprehensive study from the dock in the mid-1990s. Research Scientist Nicole Poulton recognized that continuing these measurements had the potential to capture significant changes in the harbor and inform long-term research. She formalized the study into a time series in 2000.

Time series studies provide the consistency and longevity to understand and untangle ocean changes. Through consistent measurements, Poulton's team has gradually built a comprehensive picture of both stasis and change in Boothbay Harbor. They have

TIME SERIES STUDIES PROVIDE THE CONSISTENCY AND LONGEVITY NEEDED TO UNDERSTAND OCEAN CHANGES.

tracked its temperature and salinity, the composition of its plankton communities, and nutrient cycling at the base of its food chain.

"This is a labor of love. This project was started so long ago, and I feel it's really important to maintain," Poulton said. "By sampling frequently and over decades, we can capture the fluctuations that take place over the course of a year, as well as shifts we believe are related to climate change."

This is one of many similar efforts around the planet that are overseen or contributed to by Bigelow Laboratory scientists. These long-term studies are providing unique insights into our oceans.

Poulton's team is learning how phytoplankton communities in Boothbay Harbor are responding to a changing climate. She has observed that some phytoplankton bloom at different times during the year than when the time series began. She believes these shifts may be related to rising surface temperatures in the Gulf of Maine, which is steadily warming by about a hundredth of a degree every year.

As they build this time series, Poulton is careful to preserve her data so it can be useful long into the future — a challenge with ever-evolving technology and storage systems. She uses cell-imaging technology to take photographs of the phytoplankton within her samples. Scientists in the future will be able to use her data to examine trends that they are researching.

"Working with other researchers that are generating similar data makes a time series even more powerful," Poulton said. "It's incredibly important to observe the ocean in order to identify trends, and time series studies provide crucial data for understanding ecosystems around the globe."

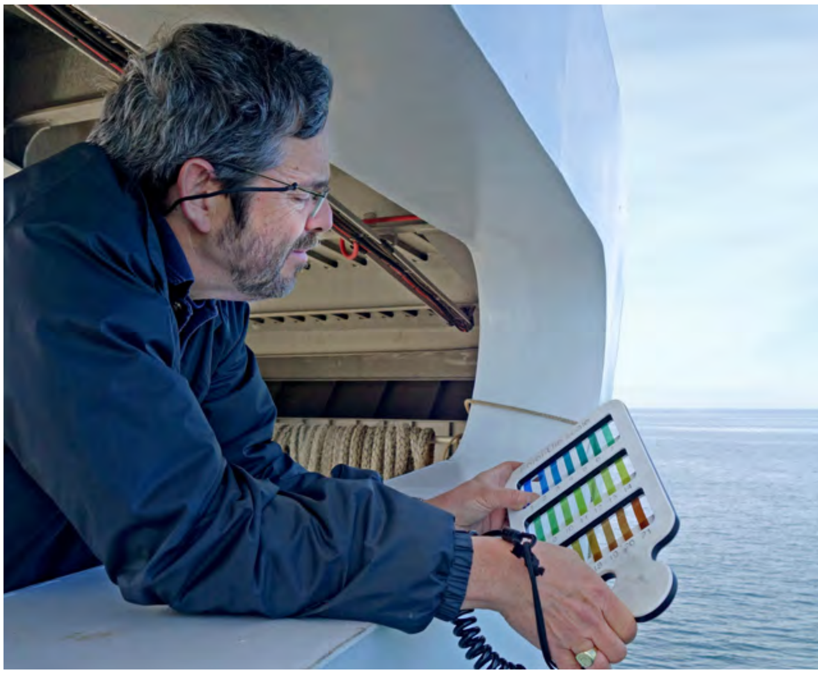
GULF OF MAINE

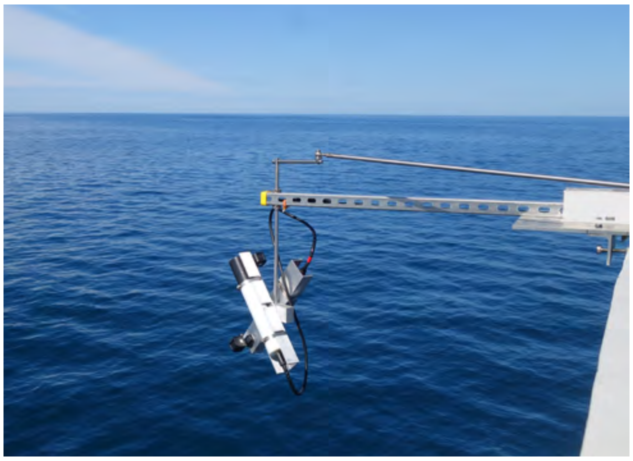
The Gulf of Maine is changing quickly, and Maine with it. About thirty years ago, warming waters bolstered the Gulf's lobster population, fueling a booming industry at the heart of Maine's economy and culture. More recently, acidifying waters have concerned fishery managers and residents alike.

Over the last century, the Gulf of Maine has warmed, become more acidic, and even turned more yellow. These developments come from shifts in an ecosystem so complex it requires decades of observation to understand. In 1998, Senior Research Scientist Barney Balch set out to do just that when he began the Gulf of Maine North Atlantic Time Series (GNATS), a coastal time series inspired in part by the open-ocean Bermuda Atlantic Time-series Study (BATS), which Lomas leads.

"I came up with that tongue-in-cheek acronym to rhyme with BATS," Balch said. "The idea with GNATS is that by sampling the same line over and over again, we can understand critical connections between the land and sea."

This September, GNATS completed its 20th year and 200th trip. About 10 times per year, Balch drives a truck that holds a mobile laboratory onto a passenger ferry,

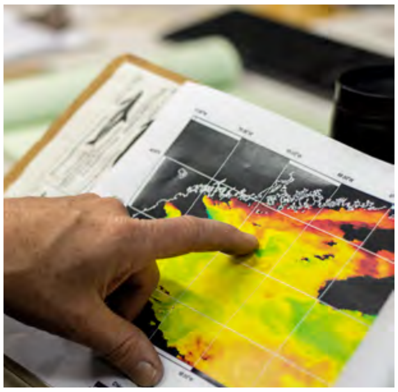




SENIOR RESEARCH SCIENTIST BARNEY BALCH observes ocean color using both the classical Forel-Ule scale that he can compare to historical data (top) and a radiometer to help calibrate NASA satellites (bottom).

TOP LEFT, RIGHT GNATS team members work inside their mobile laboratory as they cross the Gulf of Maine aboard a passenger ferry.

BOTTOM The RV *Atlantic Explorer* cruises through the Sargasso Sea while collecting samples for a BATS expedition.



Photos: Bermuda Institute of Ocean Sciences, bottom; Andrew Collins, opposite temporarily turning it into a research vessel. While crossing the Gulf between Maine and Nova Scotia, his team takes the same measurements at the same geographic points. Over the last two decades, GNATS has built a vast dataset that captures both the influences of seasonality and climate change on the Gulf.

"The power of any time series is the ability to connect global phenomena with the ecosystem you're observing," Balch said. "Having a time series of this length allows us to see the complex effects of temperatures warming and weather becoming more extreme."

Balch has observed how these climatological trends are shaping the Gulf of Maine, from its water quality to the food chain it supports. As more precipitation falls over the land, more water percolates through the soil — like steeping a tea bag — before flowing down rivers and into the Gulf.

"As temperatures and the amount of rain go up, the water steeps better and more material is flushed into the Gulf of Maine," Balch said. "We've seen it fifty miles out to sea. It is striking."

This colored water soaks up light, competing for the sun's energy with phytoplankton — a foundational food source for the entire Gulf of Maine. Small phytoplankton are becoming more common and large phytoplankton species rarer, reorganizing the food web in a way that impacts animals from tiny zooplankton to whales.

Integrating historical measurements taken by Charlie Yentsch, a founder of Bigelow Laboratory, and Henry Bigelow, the father of modern oceanography, enables Balch to look back more than a century in the Gulf of Maine. This allowed him to identify the yellowing waters and use weather station data to measure an air temperature increase of 1.4 degrees Celsius during the last century. Most recently, Balch discovered rapid warming in deep Gulf of Maine waters, which he believes is connected to shifting circulation patterns in the North Atlantic Ocean.

"The value of a time series increases exponentially with how long it runs," Balch said. "While 20 years may seem like a long time, we're just getting to the point where we have enough data to address the big questions. Being able to use historical datasets to look back at a full century puts us in a fascinating position where we can really examine how the Earth responds to climate change."

'THE POWER OF ANY TIME SERIES IS IN THE ABILITY TO CONNECT GLOBAL PHENOMENA WITH AN ECOSYSTEM.'

SARGASSO SEA

Earth's only sea unbounded by land, the Sargasso Sea lives large in literature and cultural imagination. Over the last three decades, the Sargasso has warmed, movements of nutrients between seawater and phytoplankton have shifted, and the water itself has become saltier.

These changes are representative of what is happening in other regions of the global ocean, and their impact is huge. Sixty percent of Earth's surface area has the same key characteristics as the surface of the Sargasso Sea, and areas of the ocean deeper than 1,000 meters have similar processes of mixing and circulation. Studying this region serves as a barometer for the change occurring across much of the planet.

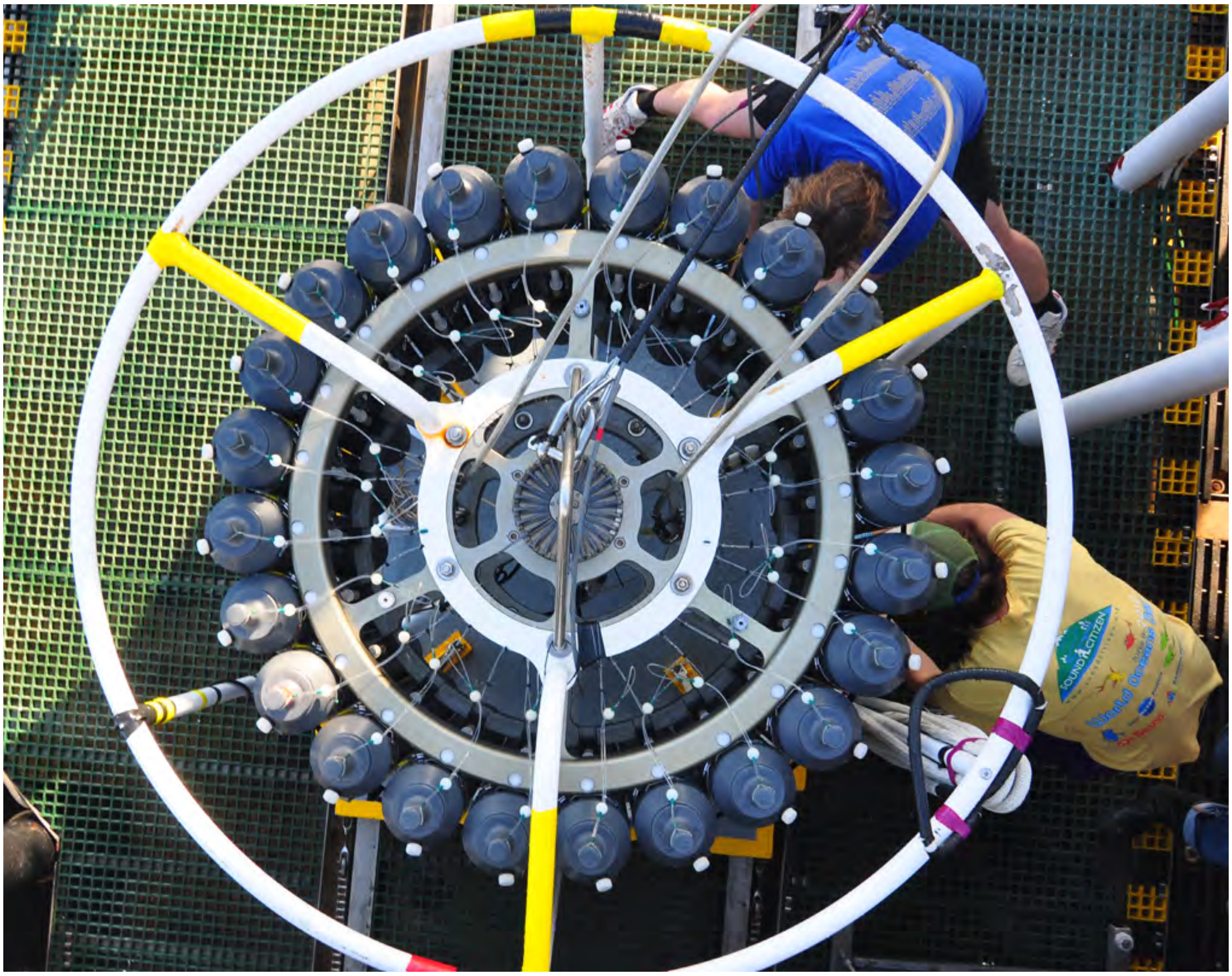
Despite the challenges of accessing such a remote place, it is one of the best studied parts of the ocean. This is due in large part to BATS, which has run monthly since 1988.

BATS TEAM MEMBERS aboard the RV *Atlantic Explorer* prepare to collect oceanographic samples off the coast of Bermuda.

"Our objective is to assess change over a very long time, like monitoring the heartbeat of the ocean," said Lomas, who has been a lead investigator on BATS since 2001. "Programs like this are critically important, because the scales of variability in the ocean are numerous."

BATS measures ocean characteristics and processes

'TIME SERIES ALLOW US TO OBSERVE THE WORLD AND CONFIDENTLY CONCLUDE WHETHER THINGS ARE CHANGING.'



BATS SCIENTISTS retrieve water samples that were captured at different depths in the Sargasso Sea, which can reveal processes taking place throughout the water column.

that shape the Sargasso Sea. Every month, scientists board a research vessel at the Bermuda Institute of Ocean Sciences and sail to the same geographic point in the ocean they have studied for three decades.

The consistency and duration of the time series has allowed Lomas and other investigators to assess what is happening in the Sargasso Sea — as well as the rest of the ocean.

"Even small shifts in the ocean scale up to big change," Lomas said. "BATS and other time series allow us to build an understanding of how key measurements of ocean health and function change over time."

One of the most important trends Lomas has measured is rapid warming. Since BATS began, the surface of the Sargasso Sea has warmed almost a full degree — a huge increase in a relatively short amount of time. In addition, the water has become saltier and more oxygen-rich, and the biological community has transformed. As in the Gulf of Maine, populations of large phytoplankton are decreasing while smaller species increase.

As the BATS dataset becomes longer and more powerful, Lomas and the other investigators can ask more questions of it.

One persistent mystery is how the Sargasso Sea pulls so much carbon from the atmosphere. Lomas believes it is related to other processes taking place in the Sargasso Sea and around the globe. It could be caused by an increase in the atmospheric dust that blows seaward from deserts and fertilizes the ocean, or it could be related to an uptick in the efficiency with which phytoplankton use nutrients.

"As the amount of carbon in the atmosphere increases, it is essential to understand the processes that transfer carbon into the ocean," Lomas said. "Time series allow us to observe the world and confidently conclude whether things are changing."

Photo: Andrew Collins

REFLECTIONS ON 20 YEARS OF GNATS

BY BARNEY BALCH, SENIOR RESEARCH SCIENTIST

Charlie Yentsch, a founder of Bigelow Laboratory, often referred to "our ocean garden." To be good stewards of the Gulf of Maine, we must regularly observe it and learn what makes our ocean garden grow during this new era of climate change.

The germ of the Gulf of Maine North Atlantic Time Series (GNATS) was planted in the 1970s, when I worked for Bigelow Laboratory while in high school. I watched Charlie ride a ferry across the Gulf of Maine, inexpensively collecting validation data for the first ocean color satellite.

This September, GNATS celebrated its 20th anniversary and surpassed 200 trips across the Gulf, providing a great moment to look back at where we've come from and where GNATS is headed.

In 1997, I wrote a proposal to build a portable laboratory we could carry aboard a flatbed truck onto a ferry. The port captain loved that we'd turn his ship into a sophisticated research platform to validate satellites and study the Gulf. With the company's help and NASA's support, GNATS was born.

Since then, we've crossed the Gulf about 10 times per year. As we cross from Portland, we set up equipment and get power and water flowing to our laboratory. In Yarmouth, we wake up at 4:30 a.m. to prepare for the intense trip back. Ferries today travel faster than when GNATS began, and the team must operate like clockwork as we race back toward Portland.

It takes dedication and hard work to complete over 200 such trips back and forth across the Gulf of Maine. I've been fortunate to work alongside a dedicated crew throughout. Bruce Bowler and Dave Drapeau have worked with me since the project began, and countless technicians, postdocs, and students provided invaluable assistance over the years. Together, we've created a long-term dataset that provides an unparalleled look at the Gulf of Maine and how it is changing.

Around 2006, we began seeing subtle changes among the phytoplankton that form the foundation of the food web. The Northeast experienced some extraordinarily dry years in the late 1990s and early 2000s, followed by some record flood years. These events resonated through the fragile coastal ecosystem, and they showed in starkest terms how complex and intertwined the Gulf of Maine is with its surrounding watershed.

Recently, we started giving talks during the trip to Yarmouth. Though most passengers have never thought about the bottom of the marine food web, they are interested in stewardship of the Gulf of Maine and have an insatiable appetite for information. Nothing is as powerful as looking out the ferry window, noticing the water color, and contemplating that microorganisms stretch from horizon to horizon — so many that they can be seen from space.

OVER THE LAST 20 YEARS, GNATS HAS MADE IT CRYSTAL CLEAR THAT CLIMATE CHANGE IS HAPPENING FASTER THAN EVER PREDICTED.

As we move into the future, GNATS gives us the power to detect climate change with extraordinary accuracy and precision. I often posit that the power of a time series increases exponentially with the time it is maintained.

Over the last 20 years, GNATS has made it crystal clear that climate change is happening faster than ever predicted. Creating a time series that allows us to understand, predict, and prepare for these interconnected changes has been one of the most fulfilling things I've ever done — in essence, caring for the ocean garden within the Gulf of Maine.

SCIENCE SNAP

THE ICEBREAKER *ODEN* cruises toward the North Pole at the beginning of a two-month expedition in August. The Arctic climate is changing faster than anywhere else in the world, and these polar changes may impact global temperatures by altering cloud formation. Forty researchers from around the world, including two from Bigelow Laboratory, took part in the expedition to study this important relationship. Learn more in the Fieldwork section on page 13.

Photo by Lars Lehnert

Leaving a Legacy at Bigelow Laboratory

As a nonprofit research institute, we are only as strong as the community that believes in the power of our science to transform understanding, seize opportunities, and inspire the next generation.

We have been fortunate throughout the last 45 years to have earned the support of a truly amazing community, and we thank you for being part of it. You are passionate about the ocean. You are generous with your time, your knowledge, and your finances. We wouldn't be here without you.

One of the most meaningful and powerful ways to support our work is through a planned gift. Whether you choose to name us in your will, or designate the Laboratory as a beneficiary of your IRA or life insurance policy, it is easy to create a lasting legacy that reflects your values and helps you realize significant financial and tax benefits. You become an invaluable, long-term partner in ocean research and science education far beyond your lifetime. Proceeds from planned gifts like these are invested in the Laboratory's permanent endowment fund and support your commitment to the ocean for generations to come.

REMEMBERING NEIL ROLDE

Neil Rolde was a young child when he caught the "ocean bug." His summer days were filled with snorkeling, fishing, and sailing the coast of Maine. His passion for the water, combined with an unyielding curiosity for how things work — and a penchant for fixing them when they didn't — were driving forces behind his long affiliation with Bigelow Laboratory for Ocean Sciences.

Rolde joined the board of trustees in 1991. He secured the Laboratory's first executive director and helped usher in an era of positive change and growth for the institute. In 2000, Rolde became chairman of the board of trustees. He led the board to adopt his vision for new and expanded research facilities, which ultimately resulted in the Laboratory's award-winning campus in East Boothbay. With the institution of term limits, Rolde moved from the board of trustees to the advisory board in 2011, where he maintained his unwavering commitment to the Laboratory until passing away in 2017.

Neil's friendship and counsel are sorely missed, but we are grateful for his support and its continued influence on our work.

SHARE YOUR COMMITMENT

TO DISCUSS A NEW PLANNED GIFT or let us know about your existing plans, please contact Jennifer Cutshall, vice president of advancement, at jcutshall@bigelow.org or 207 315-2567 x106.

Photo: Kevin Fahrman, left; Amy Root-Donle, right

Ocean Insights to Life on Mars

According to popular culture, extraterrestrial life might look like the iridescent green egg that launched terror in the 1979 movie "Alien," or fly in sophisticated spaceships to deliver linguistically complex messages as in 2016's "Arrival." But if you ask a scientist, the most likely extraterrestrial life looks like the microbes that live in Earth's deep ocean and subsurface.

"The evolution of life on Earth has been a huge, ongoing biological experiment," Senior Research Scientist Ramunas Stepanauskas said. "Finding life on Mars would provide a second case of life in the universe and allow us to have a meaningful discussion about what it takes for life to emerge."

Looking for this life is complicated. It is difficult to know what visual and chemical clues to expect, where to find them, and how to avoid contaminating the research site and samples with microbes from Earth. Several researchers at Bigelow Laboratory are looking for answers to these problems by applying what they've learned through ocean research to the search for life on Mars.

Postdoctoral Researcher Rose Jones and other team members working with Senior Research Scientist Beth Orcutt are wielding chemistry and physics to narrow down what types of microbes could live on Mars. Jones studies microbes that live in "analog environments"—places on Earth that resemble Martian environments and can yield valuable insights about what life could look like there.

"Some really weird microbes live on Earth," Jones said. "We have microbes that thrive in pools of acid and in hydrothermal vent fluids. Some environments on Mars are probably no more extreme."

The microbes Jones is interested in thrive in places like the ocean subseafloor, inside the continental crust, buried beneath ice in subglacial lakes, and under polar desert soils. These environments are isolated from the sun, limited in oxygen, and barely influenced by the surface world. By studying the chemistry of these environments and the characteristics of microbes that make a living there, Jones can narrow down what astrobiologists should look for in comparable places on Mars.

Jones and colleagues recently published a study on low-energy analog environments in the journal *Frontiers in Microbiology*. As future Mars missions bring back more detailed data, Jones will be able to refine her calculations about the possible chemical pathways microbes could use to live on Mars. This research drew on grants from the Center for Dark Energy Biosphere Investigations Science and Technology Center, the NASA Astrobiology Institute Life Underground program, and the Deep Carbon Observatory.

"What we're doing now would have been considered science fiction even 20 years ago," Jones said. "It boggles the mind that similar organisms could live on Mars and Earth."

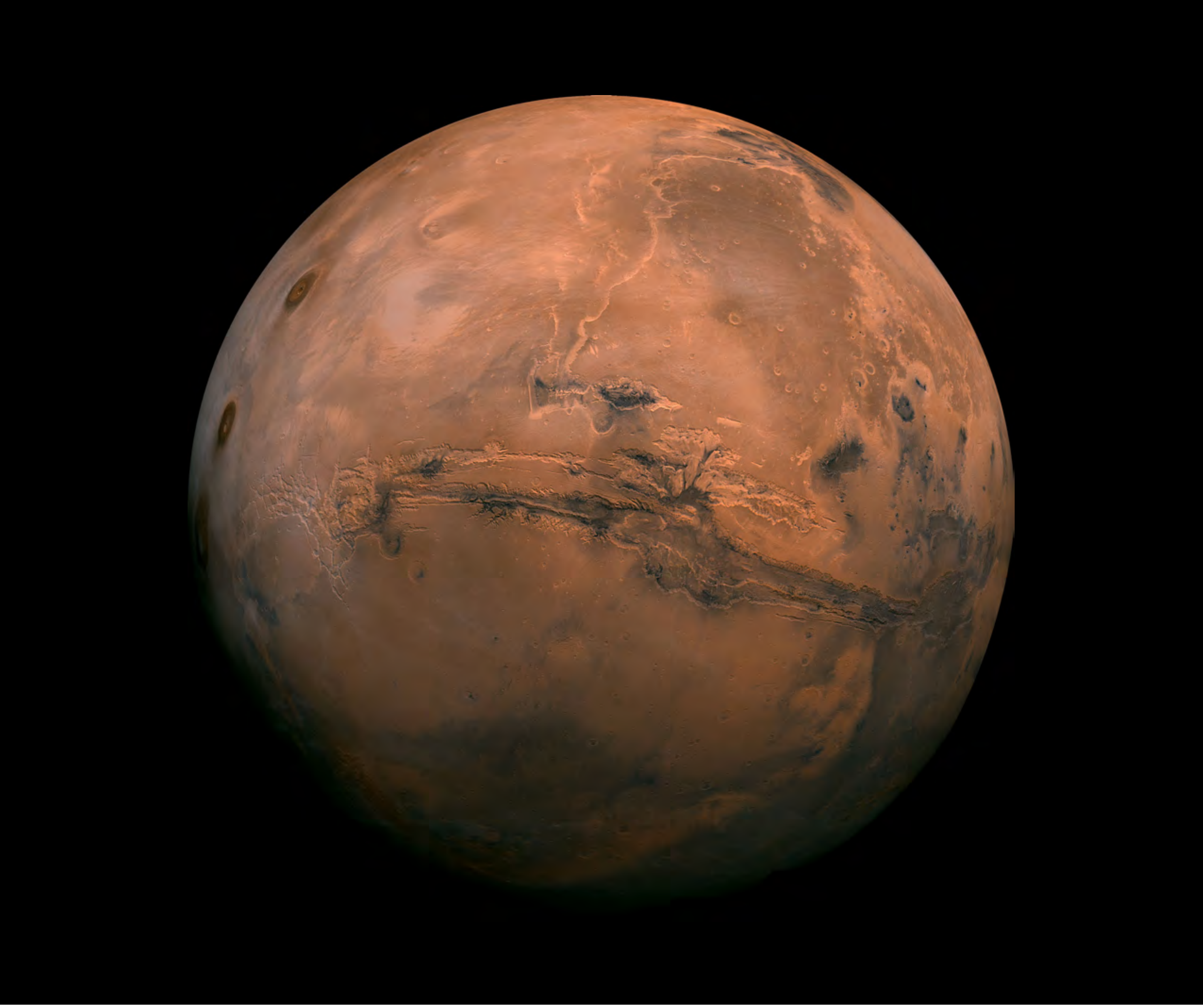
Senior Research Scientist Dave Emerson is also developing new ways to search for life on Mars. He is an expert on iron-oxidizing bacteria, microorganisms that process iron for energy.

'WHAT WE'RE DOING NOW WOULD HAVE BEEN CONSIDERED SCIENCE FICTION EVEN 20 YEARS AGO.'

"Iron-oxidizing bacteria are ancient microbes, and they thrive in environments as common as roadside ditches and as extreme as deep-sea hydrothermal vents," Emerson said. "I think they could live on Mars as well. After all, it's called the 'red planet' because its rocks are so rich in rust."

Iron-oxidizing bacteria generate energy by transferring electrons between iron and oxygen. This process produces rust minerals as byproducts, which the microbes often convert to ribbon-like structures as they grow. These twisted stalks are visually distinctive and can become fossilized, making them an effective biosignature that provides evidence of past or present life.

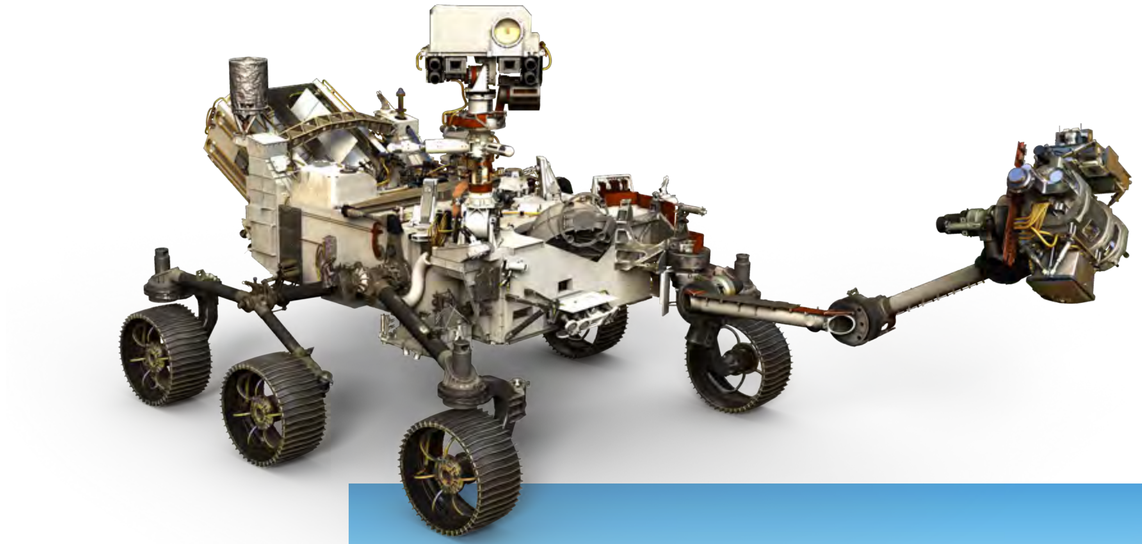
Leveraging funding from the NASA Exobiology



TOP Mars is known as the "red planet" because its surface is rich in rust.

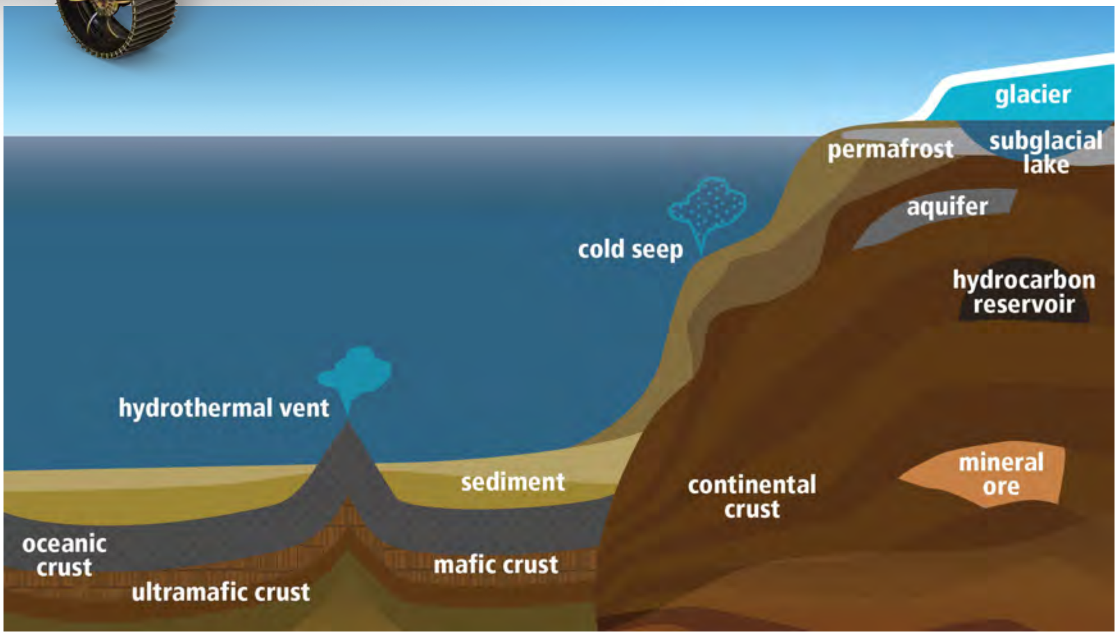
BOTTOM Iron-oxidizing bacteria build complex structures in dark, high-pressure ocean environments. These microbes are inspiring new ways to search for life on Mars.

Photos: NASA/JPL-Caltech, top; Ocean Exploration Trust and NASA SUBSEA expedition, bottom



TOP Bigelow Laboratory is helping NASA prepare the Mars 2020 rover for one of its primary missions — collecting rock samples that scientists will analyze for microbial life.

BOTTOM Low-energy environments in Earth's subsurface can act as analogs to comparable places on Mars, yielding insights about what life could look like there.



By Josh Wood
© Jones, Goordial, and Orcutt 2018, *Frontiers in Microbiology*

program, Emerson and colleagues at NASA's Goddard Space Flight Center recently discovered an organic molecule that seems unique to iron-oxidizing bacteria and can be preserved in rocks under the right conditions. This biosignature could provide another way to identify iron-powered life on Mars. Emerson and his NASA colleagues recently published a paper announcing this discovery in the journal *Astrobiology*.

"These are molecules we wouldn't expect to be formed any way other than by life," Emerson said. "Using this biosignature could be transformational for our understanding of both Mars and ancient Earth."

If microbes are found on Mars, it will be essential to know whether they indeed originated there or traveled to the planet aboard NASA's spacecraft. Success of the mission will depend on rover cleanliness and a thorough understanding of the microbes that might make the journey. Stepanauskas is collaborating with NASA's Jet Propulsion Laboratory to help minimize the risk of microbial contamination for the Mars mission that launches in 2020, which has a key goal of searching for microbial life. Stepanauskas directs the Single Cell Genomics Center at Bigelow Laboratory, where he uses novel techniques to detect and genetically sequence individual cells.

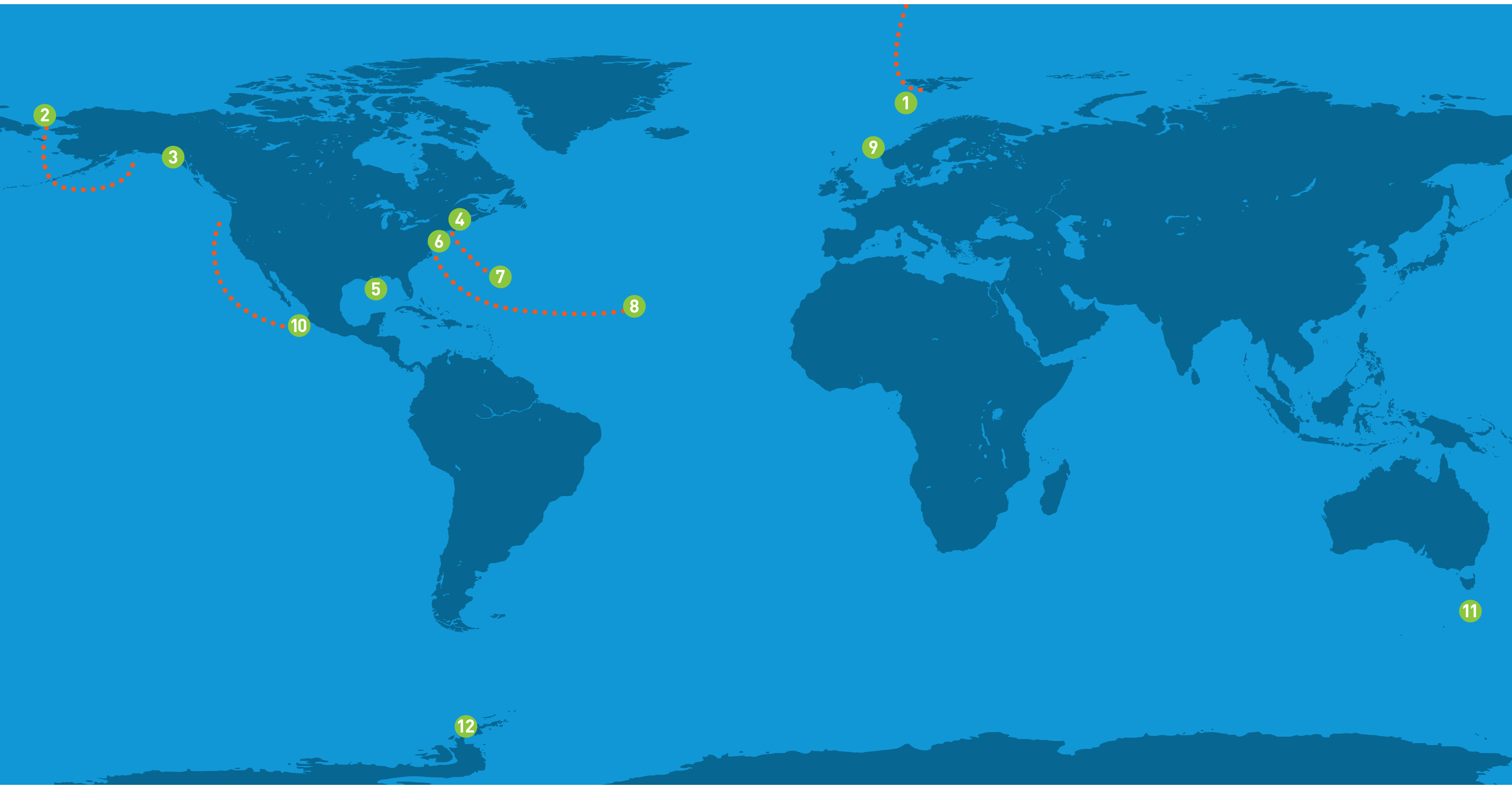
"If microbes are really rare in Martian samples, it won't be simple to identify life that is actually from Mars, rather than contamination from Earth," Stepanauskas said. "Any doubt about the origin of the microbes would be detrimental to the science and very costly, so we must maximize the chances of clean results."

Protecting the planet will also be essential during the mission. Remote sensing suggests that Mars has slopes covered by flowing liquid in the summertime, which may be hospitable to life. NASA currently avoids the places it believes are most suitable for microbial life, for fear that spacecraft could contaminate them with microbes from Earth. The work done in the Single Cell Genomics Center will feed into the decision-making process on selecting sites for the Mars rover to explore.

"This is a good example of how technology we developed from marine microbiology finds use in diverse applications as exotic as the search for life on other planets," Stepanauskas said. "Microbes have thrived in the ocean for nearly a third of the age of the universe. Finding them on Mars as well would put in perspective what is so special about ocean microbes."

Photo: NASA

FIELDWORK 2018 Overview



ALASKA/ARCTIC

1 In August, **Dr. Paty Matrai** and Senior Research Associate **Carlton Rauschenberg** set sail on a two-month expedition to the North Pole aboard the icebreaker *Oden* to study how polar changes may alter cloud formation, impacting global temperatures. Moored to a moving ice floe, they performed experiments examining how sea spray particles in the air influence clouds in the high Arctic. This research is important to understanding polar ecosystems and equipping us to predict the future of this fast-changing region.

2 **Dr. Steven Baer**, a postdoctoral scientist with Dr. Mike Lomas, went on a cruise in June aboard the RV *Sikuliaq* to study the Bering and Chukchi Seas as part of the North Pacific Research Board's Arctic Program. The primary goal of this study is to improve our understanding of the biogeochemical processes that structure the Arctic ecosystem, which includes documenting many ecologically and commercially important species. The scientists are helping conduct the baseline research needed to understand the vulnerabilities of key processes in the rapidly changing Arctic.

3 In August, **Dr. Douglas Rasher** completed a week of research in Glacier Bay, Alaska, a region at the nexus of global climate change and local recovery of marine megafauna. Rasher assessed the abundance of sea otters, surveyed the subtidal community, and observed sea otter foraging behavior to understand how these apex predators are shaping both rocky reef and soft sediment communities. This research is yielding valuable insights into how animal populations and human activities should be managed in coastal realms during this era of rapid environmental change.

OUR SCIENTISTS CONDUCT RESEARCH IN EVERY OCEAN AND BRING WHAT THEY LEARN BACK TO OUR LAB IN MAINE.

GULF OF MAINE

4 **Dr. Nichole Price** is continuing her research into the benefits of growing kelp and shellfish together. Last summer, her team installed juveniles from Bangs Island Mussels in cages both inside and outside the Ocean Approved kelp farm. A few months later, they tested how much pressure the shells could withstand before breaking. This project is revealing the "halo" of improved water quality that kelp can create and its physical benefit to nearby mussels. Price aims to provide Maine aquaculturists information about how to capitalize on the ocean remediation opportunity offered by growing seaweed.

4 This year, **Dr. José Fernández Robledo** and his team completed the largest-ever survey of oyster parasites in coastal Maine. Information from the survey allows him to map pathogen "hotspots" across the state, providing guidelines to inform local management agencies and help aquaculturists keep their shellfish stocks healthy. Fernández Robledo uses molecular biology techniques to study the oyster genome, and he plans to identify genetic markers that would help guide selective breeding for oyster strains resistant to parasites.

4 **Dr. Barney Balch** is continuing to expand his Gulf of Maine time series, which completed its 20th year and 200th trip in September. The data his team generates allows NASA to calibrate and validate ocean color satellites.

It also creates an invaluable data set for studying long-term change in coastal phytoplankton productivity as well as a multitude of other physical, chemical, biological, and optical ocean properties. This research is revealing how the Gulf of Maine is responding to global climate change. Read more about the last 20 years of insights on page 7.

4 Last summer, **Dr. Douglas Rasher** and his team initiated a two-year ecosystem assessment of kelp forests in the Gulf of Maine. They seek to understand the degree to which kelp forests are returning to the state of Maine, identify areas of high resilience and productivity, and identify threats to the future of kelp forests in the region. This project will illuminate what changes to kelp forests mean for Maine aquaculture and how management practices may better support these ecosystems in light of an uncertain future.

GULF OF MEXICO

5 **Dr. Christoph Aeppli** and his team went on two expeditions to Gulf of Mexico beaches in Alabama last winter, where they collected samples of oil remaining from the 2010 Deepwater Horizon spill. This is a continuation of a study that began in 2011 to measure how the various components of oil change over time and to determine their potential toxicity. Read reflections on this fieldwork by Research Associate **Erin Beirne** on page 16.

ATLANTIC OCEAN

6 In October, **Dr. Deborah Bronk** went on a 10-day cruise aboard the RV *Hugh R. Sharp* from the Delaware Estuary to the continental shelf, conducting a series of experiments on nitrogen sources for marine microbes. She is studying the rates at which microbes use creatine and other compounds, to determine if creatine is an important but unrecognized source of nitrogen. This project represents a proof of concept for the idea that genomic analyses can inform the search for important processes in the environment.

7 In July, **Dr. Barney Balch** and his team set sail on a two-week cruise aboard the RV *Endeavor*. As they steamed from Rhode Island towards Bermuda and back, they searched for single-celled phytoplankton called coccolithophores in the dark portion of the ocean. The project aims to determine how much organic carbon coccolithophores consume without photosynthesis, which has important implications for ocean food webs, carbon cycles, and the biological pump.

8 **Tim D'Angelo**, a research associate with Dr. Beth Orcutt, spent a month aboard the RV *Atlantis* at Lost City, a hydrothermal field in the Atlantic Ocean and one of the most extreme ecosystems on the planet. Lost City teems with

microscopic life living in extremely high pH water. Orcutt's team is studying how these microbes make a living under extreme pressure and temperatures. D'Angelo and the rest of the international fieldwork team used a remotely operated vehicle, *Jason*, to collect fluid and rock samples from the deep sea, which will help inform the search for life on other planets as well as its origin on Earth.

9 Throughout the year, **Dr. David Fields** made several visits to Austevoll Research Station off the coast of Norway, where he is studying the behavior and physiology of zooplankton. By exposing a type of tiny crustacean to elevated temperatures and seawater acidity, Fields hopes to reveal how climate change will affect genetic adaptation. This is one of the first experiments that uses a marine water flea as a model organism.

PACIFIC OCEAN

10 Last summer, **Dr. Jim McManus** and Senior Research Associate **Sara Rauschenberg** participated in a three-week cruise aboard the RV *Oceanus* from Oregon to Mexico. This region provides a natural laboratory for examining how the amount of oxygen in ocean water influences the metal composition of marine sediment, which can be used to reconstruct causes and consequences of past environmental change. This project will help evaluate the chemical processes governing how metals accumulate in typical marine sediments, which will improve interpretation of the geological record.

SENIOR RESEARCH SCIENTIST Dave Emerson looks at rust-coated worm burrows in a mudflat near Castine, Maine. Emerson specializes in iron-oxidizing bacteria, which create rust minerals that are an important source of iron in sediment.

SOUTHERN OCEAN

11 In March, **Dr. Ben Twining** and Postdoctoral Scientist **Dr. Dan Ohnemus** went on a cruise to the Southern Ocean Time Series site. The Southern Ocean is the largest iron-limited region of the global ocean, and it soaks up about 40 percent of the human-generated carbon absorbed by the ocean. By measuring the nutrient contents of microbes and particles, they will determine how cells are degraded as they sink from the surface to the deep ocean. This work is important to understanding how ocean plankton control the flow of iron, which is the limiting nutrient for 30 percent of the ocean.

12 At the end of March, **Drs. Pete Countway** and **Paty Matrai** and Senior Research Associate **Carlton Rauschenberg** traveled to Palmer Station, Antarctica, to spend two months investigating the interactions between marine phytoplankton and bacteria. Their project focused on uncovering the role of a sulfur-containing organic molecule called DMSP in shaping the diversity and function of microbial communities in the Southern Ocean.

5 From the Gulf Coast BY ERIN BEIRNE

Picture white lab coats, purple latex gloves, goggles, and clear liquids being poured from one glass beaker to another, and you will be pretty close to a typical day in our lab. It was a wonderful change of pace to find myself walking on a sandy beach in Alabama overlooking the Gulf of Mexico — especially in February, when the charm of snowstorm after snowstorm in coastal Maine was beginning to wear off.

There were four of us on this particular field mission: Dr. Christoph Aeppli, two undergraduate students named Nina and Haining, and me. We must have made for some pretty strange-looking beachgoers — bent over at the waist, wearing gloves, and searching for dark disks of sand. But we didn't have to search all that hard and found hundreds of samples in just half a day of walking the beach.

On April 20, 2010, the Deepwater Horizon oil spill began. For 87 days, crude oil escaped from a well head on the ocean floor, releasing approximately 200 million gallons. Much of the oil rose to the surface, where it was cleaned up or found its way to beaches and salt marshes. However, large amounts of oil remain on the seafloor, where it is gradually stirred up and washed ashore.

Because this is not an uncommon phenomenon, we had no trouble gathering hundreds of oil-soaked sand samples, called "sand patties," in a quick trip. This marked the eighth consecutive year we have sampled this particular beach, creating a "time series" of oil that shows how it evolves over time.

A few bold beachgoers asked what we were doing, which allowed us to share our research. We explained that we gather samples not to clean up the beach, as many supposed, but to understand the changes the oil has undergone since the initial spill.

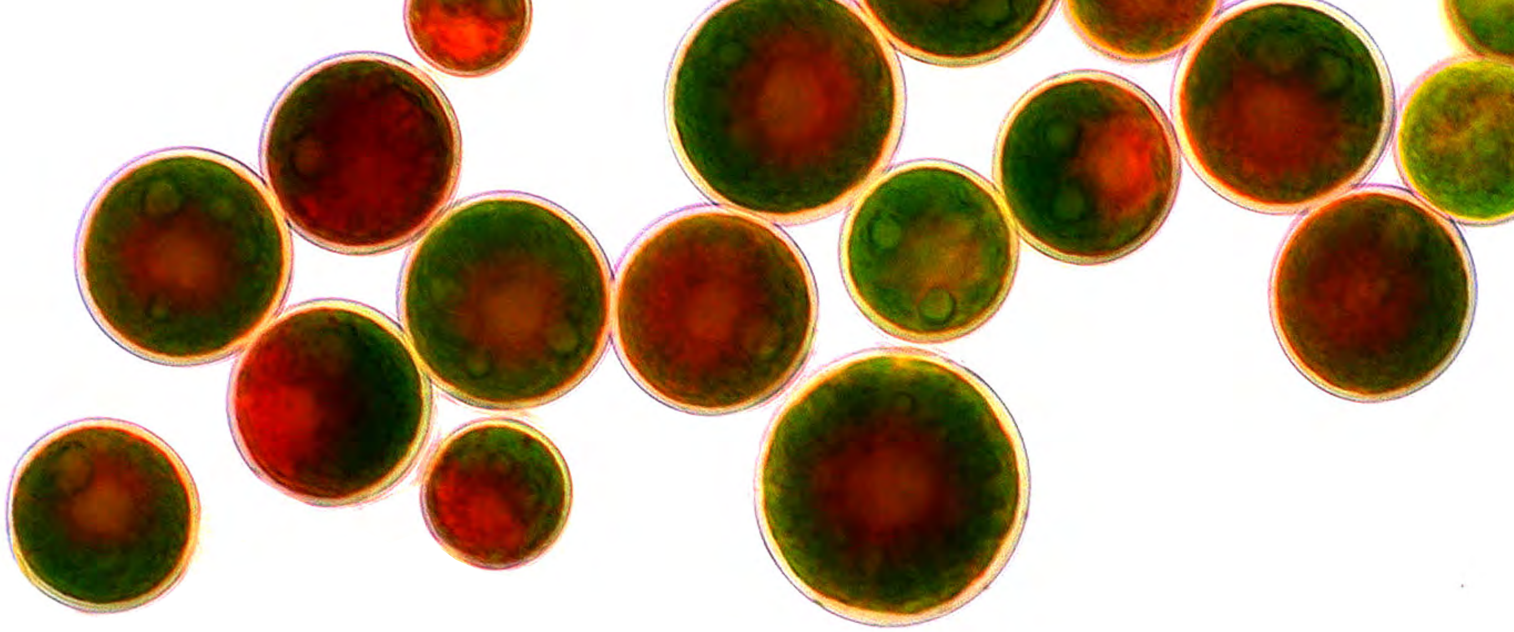
OUR JOB IS TO LEARN AS MUCH AS WE CAN FROM THESE EVENTS SO WE CAN BE BETTER PREPARED NEXT TIME.

RESEARCH ASSOCIATE Erin Beirne (right) and summer intern Nina Forziati collect "sand patty" oil samples on a Gulf of Mexico beach, eight years after the Deepwater Horizon spill.

We are primarily interested in understanding how the oil has changed chemically and how those changes influence the toxic effects of the oil. The more accurately we characterize these changes and their environmental effects, the more useful this information will be to the people and agencies who respond to spills. The reality is that as long as we use oil, we will have oil spills. Our job is to learn as much as we can from these events so we can be better prepared next time.

Nina and Haining had become involved in this research through the Research Experience for Undergraduates internship program and the semester-in-residence program at Bigelow Laboratory. It was wonderful to bring them into the field, where they could see firsthand the context for all their hard work.

So much of our work takes place in the lab that it can be easy to become disconnected from the "big picture" questions we are pursuing. Finding so many sand patties on a beautiful beach, surrounded by homes that likely witnessed flames from the spill in 2010, made it easy to remember why we put on our lab coats and sterile gloves, triple wash our glassware, and start another analysis.



GIVING All Life Depends on the Ocean

Support Bigelow Laboratory and become our partner in unlocking the opportunity of the ocean.

It is full of microscopic life that generates half our oxygen, seeds clouds that cool our planet, cleans our atmosphere, feeds our oceans, and holds astounding potential for new medicines and products.

Our scientists conduct global research that helps us to understand our oceans and harness their hidden potential. We deliver unbiased information and expertise that helps educate decision-makers, mentor the next generation of ocean leaders, and develop technology that benefits society.

This important work is only possible with the help of visionary donors who provide the vital philanthropic support that powers much of our most progressive work.

Empower our ocean discoveries with your tax-deductible donation today.

"THERE IS AN ENTREPRENEURIAL SPIRIT AT BIGELOW LABORATORY THAT I HAVE NOT SEEN ELSEWHERE. THIS IS IN NO SMALL PART DUE TO THE VISIONARY DONORS WHO SUPPORT OUR WORK." *— Dr. Deborah Bronk, president and CEO of Bigelow Laboratory*

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.

We also welcome gifts of securities, IRA distributions, boat donations, planned gifts, and more. Please call 207 315-2567 x106 for details.

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

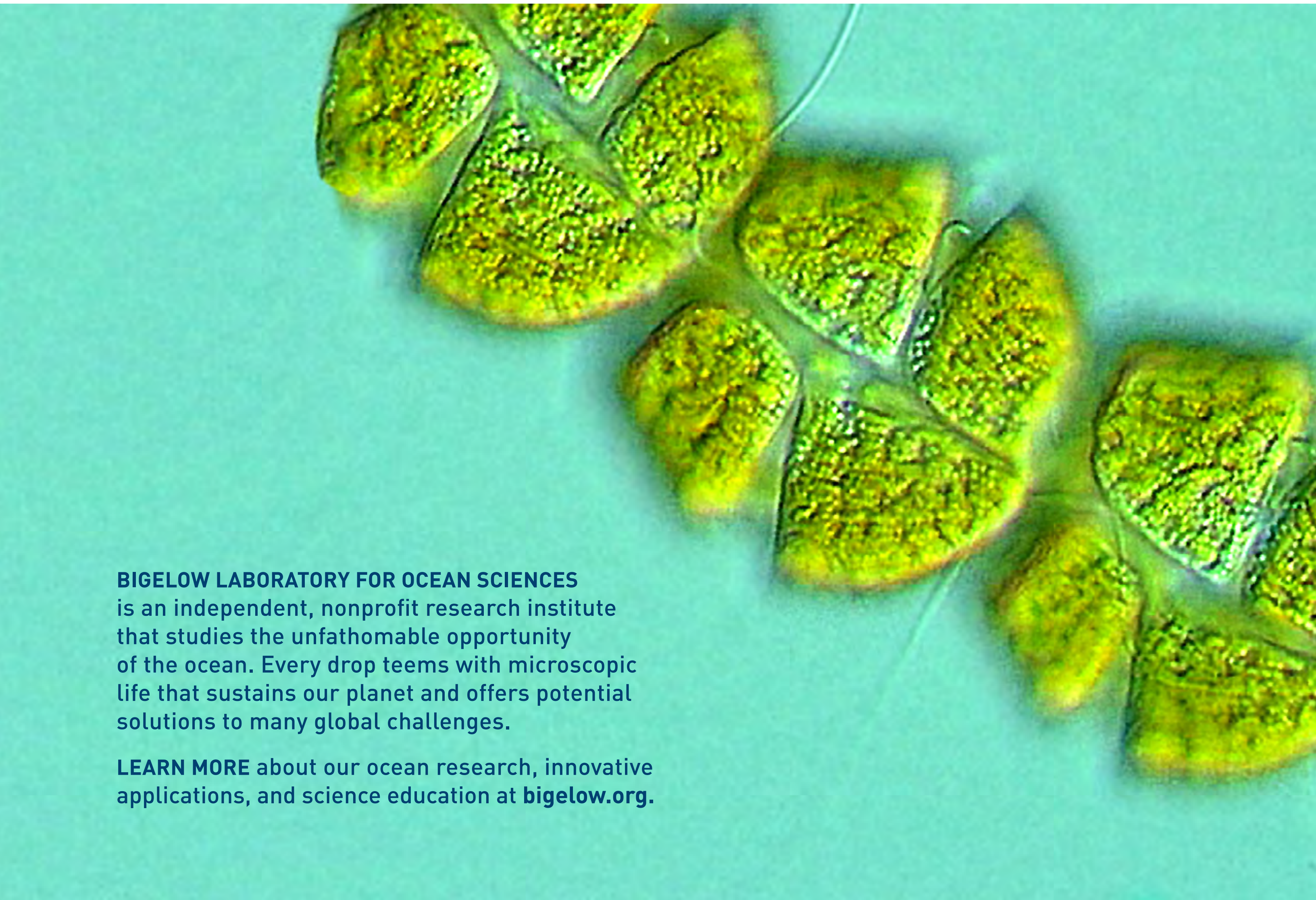
BY MAIL

Send checks to:

Bigelow Laboratory
for Ocean Sciences
60 Bigelow Drive
East Boothbay, ME 04544

Bigelow | Laboratory for Ocean Sciences

60 Bigelow Drive | East Boothbay, ME 04544 USA



BIGELOW LABORATORY FOR OCEAN SCIENCES
is an independent, nonprofit research institute that studies the unfathomable opportunity of the ocean. Every drop teems with microscopic life that sustains our planet and offers potential solutions to many global challenges.

LEARN MORE about our ocean research, innovative applications, and science education at **bigelow.org.**