TRANSECT

BIGELOW LABORATORY FOR OCEAN SCIENCES / SUMMER 2019 / VOLUME 11 / ISSUE 2

ON THE COVER

Iron-oxidizing bacteria thrive in environments as diverse as the seafloor and roadside ditches. Senior Research Scientist David Emerson studies these organisms and their potential applications, such as nanomaterials and climate change mitigation. This summer, he returned to the Arctic to continue this research with Senior Research Scientist Nick Record, Postdoctoral Researcher Alex Michaud, Research Experience for Undergraduates student Remi Masse, and artist Philippe Villard.

Photo: David Emerson

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Since the last issue of *Transect* came out, I've had the honor to be twice asked to testify before Congress. In February, I joined four other women to describe the effects of climate change on the ocean before the House Subcommittee on Water, Oceans, and Wildlife. In May, I testified before the Senate Subcommittee on Science, Oceans, Fisheries, and Weather.

The message I brought to Congress is that by pumping huge amounts of greenhouse gases into our atmosphere, humanity is conducting a massive experiment on the only planet we have. In particular, the release of carbon dioxide has resulted in a warmer, more acidic ocean. I have observed the impacts of these shifts firsthand. While I lived near the Virginia coast, I saw the reality of sea level rise and coastal flooding. Working in the coastal Arctic showed me communities whose livelihoods are threatened by melting sea ice.

Though these challenges can feel overwhelming at times, in science there is always hope. Bigelow Laboratory is working to understand many of the changes we are seeing in the global ocean — which are felt nowhere more strongly than in our own ocean backyard. In this issue of *Transect*, you can read about the crucial links our researchers discovered between deep warming in the Gulf of Maine, the health of tiny crustaceans, and changes to right whale behavior that are complicating efforts to protect them.

When it comes to developing forward-looking, science-based policies, it is essential for scientists to have a seat at the table. In order to improve right whale conservation efforts, Senior Research Scientist Nick Record is helping integrate his recent findings into the work of NOAA's Atlantic Large Whale Take Reduction Team. This is just one example of the ways we are working to understand and protect marine resources.

Bigelow Laboratory has a strong tradition of thinking creatively to develop innovative applications and tools that solve challenges — both in and out of the ocean. In this issue, you can read about how Senior Research Scientist Peter Countway is creating tools to help tackle the proliferation of toxic cyanobacteria in freshwater lakes across New England. Another exciting initiative is our effort to develop molecular tools that use environmental DNA in water samples to monitor the locations and movements of aquatic organisms. And in one of our popular Café Sci talks this summer, Senior Research Scientist José Fernández Robledo will discuss his work to understand how oysters and other bivalves can offer biomedical solutions that benefit human health.

On page 7, you can see a calendar of the weekly Café Sci talks. On July 16 at 5 p.m., I will host, "Research to the Rescue: How Science is Our Best Hope in a Changing Climate." This series is fun, free, and very popular, so please register online at bigelow.org/cafesci. Also on our website, you can find the latest information about our annual open house, which will be held on July 19 from 10 a.m. to 2 p.m.

Please join us at the lab this summer for some of the great events we have planned! I hope to see you there!

Deborah A. Bronk

DEBORAH BRONK, PhD

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COLBY COLLEGE STUDENT Henry Harris dives to assess reef health in Bermuda during a special course on coral reef ecology taught by Bigelow Laboratory researchers. Senior Research Scientists Nichole Price and Doug Rasher led the students in 10 days of fieldwork and experimentation before returning to the Laboratory for sample analysis and evaluation of their findings.

Photo: Ben Neal

Whales and Warming in the Gulf of Maine

A new study finds alarming warming in the Gulf of Maine's depths and solves the mystery of what has put one of the world's most endangered animals at increased risk.

LEFT Senior Research Scientist Barney Balch attaches a tail to the autonomous glider "Grampus" before sending it on a three-week journey in the Gulf of Maine.

BELOW Balch and Senior Research Associate Bruce Bowler wheel Grampus down to the dock to prepare for deployment.

As burning fossil fuels pump carbon into the atmosphere and warm Earth's climate, more than 90 percent of that excess heat is absorbed by the ocean's surface. Nowhere is this connection clearer than in the Gulf of Maine, where surface waters are warming faster than 99 percent of the global ocean.

New research, however, shows that the Gulf of Maine's depths are warming even more dramatically — as much as 9 degrees Fahrenheit in parts of the Northeast Channel. This is twice as much as the fastest warming waters at the surface, and it is already reshaping life in the Gulf.

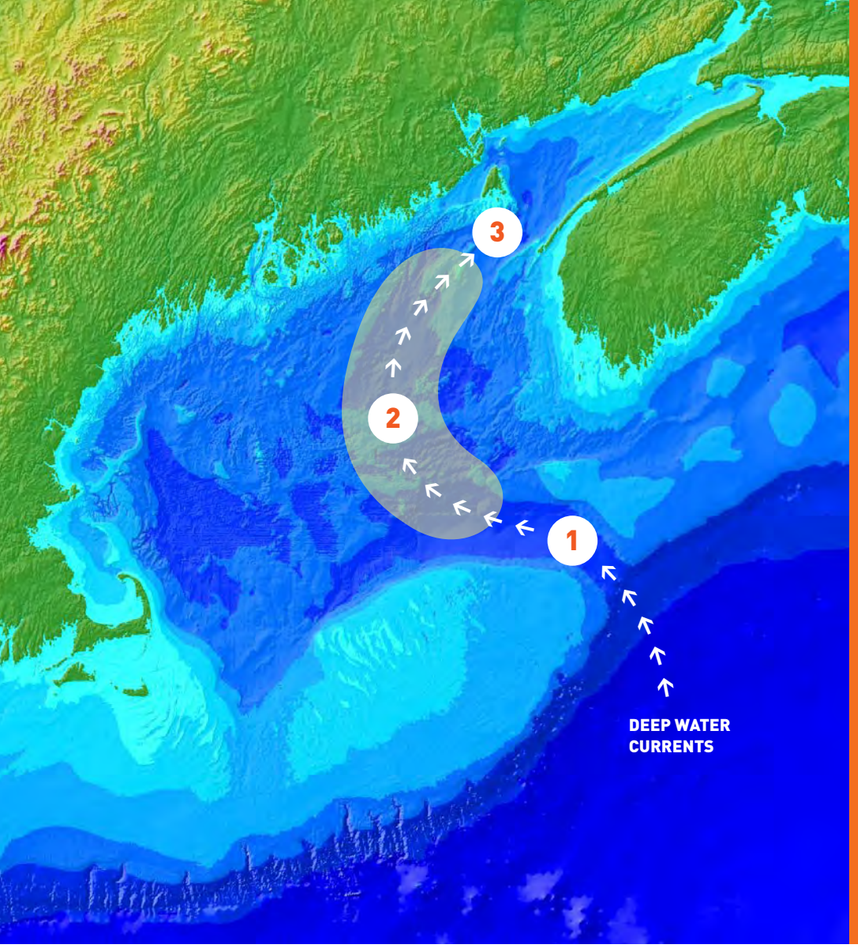
"The magnitude of this warming is extraordinary, and it is clear that there are major processes driving this change," said Barney Balch, a senior research scientist at Bigelow Laboratory for Ocean Sciences. "When you look at the data, you don't have to be a rocket scientist to see this trend in deep water temperatures."

Balch founded the Gulf of Maine North Atlantic Time Series (GNATS), which has systematically sampled the Gulf since 1998. The study uses ships from fishing boats to ferries, and it also includes two autonomous gliders that periodically cross the Gulf while gathering data from the surface to the seafloor, as much as 800 feet down. By sampling the same locations repeatedly, Balch has observed how the Gulf of Maine has warmed and changed over the last two decades.

The dramatic warming that GNATS has captured in the Gulf reflects the interconnectedness of the global ocean. The Northeast Channel funnels water into the Gulf of Maine's depths from two different sources: the Labrador Current, which bears the cold and fresh signature of melting ice in the Arctic, and the North Atlantic slope, whose water is warm and salty. Climate change has altered circulation patterns in the North Atlantic Ocean, and Balch believes a larger proportion of warm slope water may be entering the Gulf.

"Over the last 20 years, we have detected warm water penetrating increasingly farther west," Balch said. "As this warm water continues to move into the Gulf of Maine, it will directly affect species across the food web

Photo, opposite: Anderson Cabot Center for Ocean Life, New England Aquarium



RIPPLES OF CHANGE FROM THE DEEP

1 **WARMER DEEP WATERS** enter the Gulf of Maine through the Northeast Channel

2 **POPULATIONS OF THE TINY CRUSTACEAN *CALANUS FINMARCHICUS*** steeply decline in deep waters during the late summer through winter

3 **RIGHT WHALES REDUCE USE** of their traditional autumn feeding grounds, venturing outside of conservation areas in search of food

and the fisheries that rely on this ecosystem."

Deep warming is already impacting animals in the Gulf, from its smallest to its largest inhabitants. In recent years, North Atlantic right whales have turned up in unexpected places in the Gulf of Maine and beyond, making them more vulnerable to lethal dangers like ship strikes and entanglement in fishing gear.

New research led by Senior Research Scientist Nick Record connects deep water warming trends to a shrinking late-summer supply of right whale's primary prey, the rice-sized copepod *Calanus finmarchicus*. As the right whales follow this crucial food source, they are foraging well outside of the areas established to protect them. This pattern is especially concerning given that North Atlantic right whales are the second-most endangered marine mammal in the world.

"This deep water warming comes from a different source than the warming taking place at the surface, and these processes will have different — sometimes compounding — consequences," Record said. "Oceanographic models of the year 2100 predict that this warming will continue. What we do between now and then will shape the Gulf of Maine's future."

PERFECT TIMING

Springtime in the Gulf of Maine brings new life to the base of the food web. Marine algae grow rapidly and a new generation of *Calanus finmarchicus* copepods hatches and begins to feed on the phytoplankton, sending waves of new energy into the ecosystem.

"Copepods are a critical food source for everything from lobster and fish larvae to right whales in the Gulf of Maine," Senior Research Scientist David Fields said. "They are fatty little snacks that power the entire system and link the surface and deep waters."

After hatching, copepods spend the spring and early summer chowing down on the phytoplankton that live in the upper ocean. By midsummer, their bodies have reached a staggering 70 percent fat — enough to sustain them through a winter without food and produce eggs in the early spring. They migrate more than 500 feet down in the water column to pass the winter hibernating together in dense swarms.

Meanwhile, North Atlantic right whales begin their spring on the move. Traveling back from the calving grounds off the coast of Georgia and Florida, the mothers and new calves reunite with the adult males to feed on

Map: Rich Signell, USGS

'DEEP WATER WARMING THREATENS TO UNCOUPLE MANY IMPORTANT RELATIONSHIPS IN THE GULF OF MAINE, AND WE ARE ALREADY SEEING CHANGES IN THE FOOD WEB.'

copepods in the western Gulf of Maine. In the late summer, the whales move to their feeding grounds at the mouth of the Bay of Fundy, where they feast on the swarms of *Calanus* hibernating deep in the water column — the perfect high-fat meal before the scarcity of winter.

"The timing of the *Calanus finmarchicus* life cycle and the way they clump together into groups make them an ideal food source for fish larvae in the spring and whales in the late summer and fall," Fields said. "The Gulf of Maine is beautifully intertwined and synchronous. It is what has made the ecosystem so productive, but also what makes it vulnerable to compounding changes."

In recent years, right whales haven't found the usual copepod aggregations in their traditional feeding grounds. The deep warming Balch has measured is threatening *Calanus'* ability to sustain their dormant phase — the time in their life cycle that is essential for right whales. Warmer waters force the copepods to consume their fat stores faster and wake up earlier, before the bounty of the spring phytoplankton bloom is available to feed the next generation.

"Deep warming is one several problems affecting *Calanus* and therefore all the animals that rely on them for food," Fields said. "It threatens to uncouple many important relationships in the Gulf of Maine, and we are already seeing changes in the food web."

CHANGE IN THE FORECAST

As right whales fail to find *Calanus* in their traditional late-summer foraging grounds, they have started searching farther afield, including venturing into unexpected territories around Cape Cod and the Gulf of St. Lawrence. During the summer and fall of 2017, 17 right whales died in these areas — an enormous loss given that the species currently numbers about 400 individuals.

With the species in danger of extinction, people across industries are working together to adapt conservation strategies to protect right whales. In April, representatives from the fishing industry, nonprofit sector, and research community gathered for the semi-annual Atlantic Large Whale Take Reduction Team Meeting, which advises NOAA on actions to minimize right whale mortality. During the meeting, the team was tasked with evaluating strategies to cut the risk of right whale mortalities between 60 and 80 percent. The options for doing so are varied — such as redesigning fishing gear, adjusting the timing of fisheries, and using data to generate new monitoring tools — but each involves trade-offs.

"In some ways, this issue is a microcosm of all the environmental challenges we face, which are often complicated by compelling and competing interests," said Record, who is a member of the Take Reduction Team and participated in the meeting. "The Take Reduction Team sets an example for how groups can work together to tackle these challenges and make effective compromises to reach a common goal."

Much of the April meeting focused on refining a risk assessment model recently designed by NOAA to help inform decisions on the management of fisheries in the Gulf of Maine. As a mathematician and modeler himself, Record believes that models will be an essential part of protecting right whales in the Gulf of Maine — and potentially even helping their population rebound.

The strong connections between deep water warming, *Calanus*, and right whales offer a promising opportunity to improve conservation. By creating computer models that forecast right whale movement, they could provide a powerful tool for anticipating change and updating management decisions in real-time.

In 2012, Record and collaborators used data about *Calanus* and oceanographic conditions to develop an algorithm that identified potential right whale habitats.

***CALANUS FINMARCHICUS* COPEPODS** are tiny, fat-dense animals that help fuel the entire Gulf of Maine food web. A crucial stage in their life cycle is disrupted by deep water warming, leading to population decreases in areas that are key to foraging right whales.

Photo: David Fields

They determined that the region south of Nantucket might be a one such previously unknown area. Recent surveys have revealed the region is indeed a hot spot for the species, and the researchers now hope to develop similar tools to help people predict and prepare for future movement of right whales.

"We're entering a period of uncertainty. The way that right whales are currently moving and exploring new habitats suggests that they are looking for new feeding grounds," Record said. "Forecasting could help us anticipate these movements and respond to environmental changes more proactively."

Good data are critical to accurate predictions, however, and routine measurements to monitor *Calanus* abundance in the Gulf of Maine have been drastically reduced due to a lack of funding. The research community is working hard to recover this capability, and Record hopes that he may be able to develop models that use alternative data sources to forecast right whale locations, such as monitoring seawater for signs of whale DNA and collecting observations by citizen scientists.

Right whales may keep looking for *Calanus* in habitats farther and farther afield — but they will soon move into the territory of other copepod species, whose different life cycles make them less appealing prey. The specific life strategies of *Calanus finmarchicus* and needs of North Atlantic right whales may mean that their fates are intertwined too tightly to separate. Record hopes to partner with Canadian scientists to develop a dynamic conservation strategy — and perhaps one day help the population recover and fill its historical niche in the Gulf of Maine and beyond.

"We will continue to see rapid changes like this among species around the globe," Record said. "We need to study these changes carefully and proactively develop tools that help us protect our environment, and our economy, in a rapidly changing world."

TO LEARN MORE, join Dr. Nick Record for Café Sci at Bigelow Laboratory on August 13. See the opposite page for our 2019 Café Sci schedule and register at **bigelow.org/cafesci**.

Photo: Christin Khan, NOAA, NEFSC

CAFÉ SCI Summer 2019

Learn more and register at **bigelow.org/cafesci**

Café Sci is a fun, free way for you to engage with ocean researchers on critical issues and ground-breaking science. Pick a chair, grab a drink, and let's talk about the mysteries, challenges, and opportunities of the sea.

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JULY 9
Art and Science
New Insights Through Creative Collaborations
A Special Event Showcasing Innovative Teams of Artists and Ocean Scientists

JULY 16
Research to the Rescue
How Science is Our Best Hope in a Changing Climate
Led by Dr. Deborah Bronk

JULY 23
An Ocean of Life
One Drop of Seawater, One Million Organisms
Led by Dr. Ramunas Stepanauskas

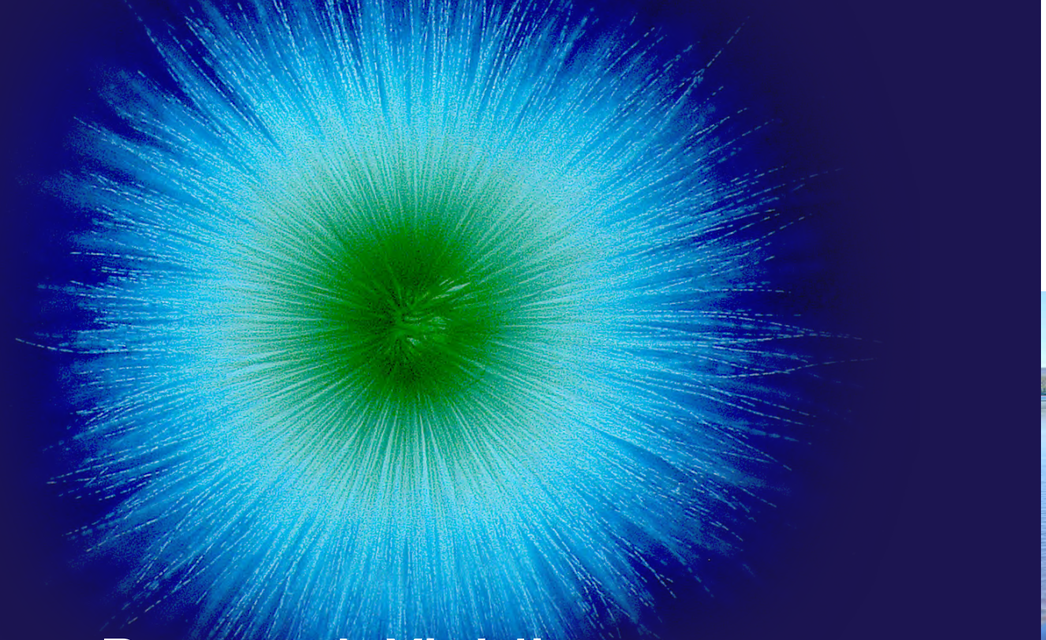
JULY 30
Ends of the Earth
A Year of Research in the Arctic and Antarctic
Led by Dr. Paty Matrai

AUGUST 6
Raw Bar to Lab Bench
Insights into Human Health from Oysters
Led by Dr. José Fernández Robledo

AUGUST 13
Whales and Warming
How Climate Change is Shaping the Future of Right Whales
Led by Dr. Nick Record

ANNUAL OPEN HOUSE
JULY 19, 10 A.M. TO 2 P.M.

Join us for free science activities and talks for all ages. ***Learn more at bigelow.org/openhouse.***



Ocean Research Yielding New Tools for Protecting Lakes

Last summer, Senior Research Scientist Peter Countway and his family took a vacation to New Hampshire. He stopped by a friend's house on Lake Winnipesaukee, walked onto the dock — and immediately recognized that potentially toxic cyanobacteria were blooming in the lake.

A dedicated scientist even while on vacation, Countway donned snorkeling gear and jumped in to collect a sample and shoot a video of the copious *Gloeotrichia* colonies discoloring the water.

Later that day, he uploaded the video to YouTube. Within 48 hours, the state had issued a precautionary warning about the bloom in Lake Winnipesaukee. Over the next six months, the local town began discussions about how to mitigate future blooms.

"Capturing a video provided the compelling evidence that was needed to get a conversation started about ways blooms could be prevented or mitigated," Countway said. "The peak bloom of *Gloeotrichia* only lasts a few days, so it's easy to miss and hard to address."

Gloeotrichia form dense colonies — they can contain as many as five thousand cells — that look like miniature dandelions gone to seed. Traditionally, a scientist trying to assess the magnitude of a bloom must undertake the arduous task of counting individual colonies in a water sample. However, the number of cells in these colonies can vary widely, and the result is not exact.

Inspired by the need for a more quantitative approach, Countway collaborated with Colby College professors Denise Bruesewitz and Whitney King and several of their students. The group developed a molecular method to estimate the number of *Gloeotrichia* cells in a water sample. Bruesewitz and King run a long-term monitoring program in the Belgrade Lakes in central Maine, working with students to comprehensively sample these lakes and test for harmful species. The researchers have used their new approach to confirm the presence of *Gloeotrichia* in several lakes, and they believe that this technique could improve efforts to monitor harmful algae and bacteria in many freshwater ecosystems.

"This technique is so sensitive that it allows us to detect even small numbers of cells, which would let resource managers see a bloom coming and take necessary precautions," Countway said. "People living near lakes take water quality seriously, and we think this method could help reduce the impact of cyanobacterial blooms on their lives."

Photo: Peter Countway

'WE THINK THIS METHOD COULD HELP REDUCE THE IMPACT OF CYANOBACTERIAL BLOOMS ON PEOPLE'S LIVES.'

LEFT Senior Research Scientist Peter Countway shows a group of students how to test a water sample for toxic cyanobacteria.

BELOW *Gloeotrichia* colonies drift underwater in Lake Winnipesaukee. This visual evidence prompted the state of New Hampshire to issue a water quality warning.

Certain cyanobacteria including *Gloeotrichia* produce potent neurotoxins, some of which also promote tumor formation. Even in Lake Winnipesaukee, Countway detected low levels of several toxins. More research is needed to confirm the source of these toxins as well as the levels at which they may become harmful. This information will help lakefront residents and resource managers make decisions about how to maintain good water quality.

This summer, Countway plans to begin screening additional lake samples for cyanobacterial toxins and the organisms that produce them. He will take advantage of Bigelow Laboratory's high-precision toxin testing capabilities, and he also hopes to use immunology-based methods that can provide a quick check for the presence of toxins. In addition to measuring these compounds, Countway plans to use molecular methods including the new test for *Gloeotrichia* to identify the particular species of cyanobacteria that are contributing to toxin production in a number of lakes.

"Bigelow has a reputation for studying phytoplankton and cyanobacteria in the ocean, and the experience and technology we've developed is equally applicable to lakes and rivers," Countway said. "This is an opportunity to build on the Laboratory's expertise in marine algal toxins to solve another pressing water quality issue that could be impacting the health and activities of many people."

In the future, Countway wants to expand this testing capacity even further by equipping citizen scientists to monitor water quality using genetic techniques. He hopes to train volunteer members of lake monitoring networks to collect and analyze samples using a portable, smartphone-enabled device that can detect the DNA from harmful cyanobacteria.

He is currently testing a device manufactured by Biomeme Inc. for this purpose. A citizen scientist using this device could go from collecting a water sample to looking at results in about an hour, which could revolutionize the way blooms are detected.

Countway envisions a distributed network of citizen scientists passing data to researchers and water resource managers, providing the nearly real-time snapshots of cyanobacterial populations that are needed to stay abreast of quickly-changing conditions. He also hopes to use the Biomeme device to ground-truth drone-based aerial surveys of regional lakes in collaboration with researchers at multiple New England colleges. This will allow the scientists to compare high-resolution imagery of blooms with the dominant types of cyanobacteria in lake water — potentially enabling managers to monitor blooms over much greater spatial scales than is currently possible.

"This technology can empower people to help protect the health of their lakes and communities," Countway said. "People want to know what's going on in their backyards, and this approach could help them find out."

SCIENCE SNAP

KELLER BLOOM students Sydnie Della Croce, Katherine Bowen, Jordan Snell, and Camille Michaud focus their microscopes on phytoplankton they collected during a local research cruise. In May, these high school students participated in the 30th annual Keller BLOOM program, completing a week of hands-on science learning while living at the laboratory. During the last three decades, this program has engaged nearly 500 students from around Maine with education based on immersive, authentic ocean research.

Photo: Robert Mitchell

PROFILE Andrew Davis

President of Davis Selected Advisers and portfolio manager for the Davis Real Estate Fund

The reflection of a full moon stretches to the horizon, gently rolling on the ocean's surface. Beneath the waves, moonlight falls on a coral reef and illuminates the innumerable specks of life swarming around as a diver drifts by.

"It's an extraordinary sight to see," Andrew Davis said. "You're watching this tiny life all around you, and you realize you are looking at the foundation of the food web that makes all life on Earth possible."

Davis has been scuba diving for more than three decades. On his almost 600 dives around the world, he has experienced firsthand the incredible beauty and diversity of the ocean. He's also been a witness to many of the growing difficulties that are reshaping the sea.

Davis has revisited many of the same places throughout his extensive diving experiences. Coral bleaching, invasive species, decreased shark activity — he says the changes have been quite noticeable, and he has captured many of them in detailed dive logs and photographs over the years.

"They aren't just pretty pictures that tell sad stories about specific locations," Davis said. "They tell a fundamentally bad story for the entire world as we know it."

Davis speaks of these dire changes with a surprising amount of optimism. He believes that the damage he has seen is reversible and that some of the people working toward solutions will be successful.

His regular dives in Caribbean locations, such as Saint Barthélemy and the Cayman Islands, have revealed not only the degradation of reefs but the success of efforts to aid their recovery. From new fishing regulations to coral transplants, he's seen local success in the face of global problems like ocean warming and acidification.

"There's no doubt that there is every reason to be concerned about our ocean," Davis said. "But there are key players doing good work and making real progress. If we're going to change course, those are the organizations that need to be supported, and I believe that Bigelow Laboratory is one of them."

Maine is profoundly important to Davis. He is a third-generation summer resident and has spent a great deal of time in the state throughout his life. During the last few years, he and his wife, Kate, have become philanthropic partners to the Laboratory. Their support stems from the belief that Bigelow Laboratory scientists make a difference by addressing challenges and opportunities that are fundamental to global issues.

"If you really want to save the whales, you've got to start with the smallest plants and animals," Davis said. "The ocean simply doesn't work without them."

Davis's affinity for the ocean and underwater exploration started at a young age, when he spent countless hours in the water along the Maine coast. While attending Colby College, he learned how to scuba dive. He continues to dive 10 to 20 times a year, now with Kate and sometimes their five children.

'I TRY TO LOOK FOR WHERE THE MONEY ISN'T. THAT'S WHERE YOU FIND THE DIAMONDS IN THE ROUGH.'

Davis has spent his professional life as an investor and is currently president of Davis Selected Advisers and portfolio manager for the Davis Real Estate Fund. It is through this lens that he views problems and evaluates ways that he might use philanthropy to further solutions.

"I try to look for where the money isn't," Davis said. "That's where you find the diamonds in the rough — organizations like Bigelow Laboratory that are doing something extremely well that few others have tackled."

Davis's work has taught him to focus on maximizing the return on his investments. He brings this ethos to the many ways in which he supports the arts, education, health, and the environment through his own philanthropy and as a trustee of the Shelby Cullom Davis Charitable Fund.

As a philanthropist who focuses on some of the world's biggest issues, Davis's approach is to seek out and develop agents of change — initiatives that might lead to transformative shifts and rally the world to action.

"Humanity has proven it has a tremendous ability to destroy, but it has also proven it has a tremendous ability to create and recover," Davis said. "I believe that science will catalyze this type of change for the oceans."

FIELDWORK Notes from the Field

From the Gulf of Maine BY SHANE FARRELL

It was the heart of winter in Maine. The snow was falling, and I had two things to do before I went to sleep — shovel out my sidewalk and get my scuba diving gear ready for the next day. Fieldwork at Bigelow Laboratory happens year-round, even when the water temperatures are a balmy 38 degrees Fahrenheit.

The next day at 7 a.m., I met Senior Research Scientist Doug Rasher and Postdoctoral Researcher Thew Suskiewicz at the pier. For the winter field season, we had one main objective — deploy 60 sea urchin larvae collectors from Downeast to southern Maine in order to study the spring spawn.

Once at the dock, we immediately started loading copious amounts of gear onto the boat for the day's outing. First came the scuba cylinders, all six of them brightly painted in yellows, reds, and silvers. Next was our diving gear: regulators, buoyancy devices, and weight belts with 35 pounds of solid lead to help us sink to the bottom. Finally, we loaded the scientific equipment, including the sea urchin larvae collectors — cinderblocks that are outfitted with artificial turf and PVC pipe traps, which capture any larvae that settle within.

We are working to understand why there are currently so few urchins in the Gulf of Maine. The urchin fishery went through boom and bust cycles and peaked during the 1990s. Despite the collapse of the fishery and the continued absence of large predators like cod, sea urchin populations haven't rebounded as expected. This experiment will allow us to quantify where and how much adult urchins are still reproducing. In the summer, we will collect the blocks and look for sea urchin larvae when we analyze the trap contents under microscopes back at the laboratory.

With the boat loaded to capacity, we ventured down the mouth of the Damariscotta River and out into the vast ocean. It was a calm day with little wind and small waves, a rarity during wintertime in the Gulf. It was 25 nautical miles to our destination near Hurricane Island, and we chatted during the 75-minute ride about the islands and shore features we passed on our way east. Inevitably, the conversation turned to wondering how the islands were named and asking questions like, "why are there never any seals on Seal Island?"

After a cold boat ride, we arrived at our study site and prepared to begin our work. These winter dives are races against the cold, as we lose fine motor skills after 40 minutes in the water.

Once we anchored, it was time for us to get in the water — a process that can take longer than our actual dives. We traded our winter jackets for insulated undergarments and then donned our drysuits. These suits are waterproof, with silicon seals at the wrists and neck protecting the rest of our bodies from the ice-cold water. After strapping on our weight belts and tanks, it was a struggle to move around carrying more than 60 pounds of gear. Finally, we put on hoods and thick neoprene gloves filled with hot water to help stave off the cold for a few extra minutes.

Then it was time — we were suited up and ready to go. I looked at Thew, my dive buddy, sitting on the edge of the boat besides me. Without saying a word, we nodded to each other, rolled back into the water, and began the race against the cold.

We descended down and saw our larvae settlement collectors glistening in the sun amidst a blanket of green and red seaweeds. New juvenile horsetail kelp and sugar kelp had already colonized the rocky bottom, replacing the older plants destroyed during winter storms. While still young, these plants were already a few feet in length, draping the rocky reef. We arrived at the bottom, set up the experiment, and headed back to the surface ready to do it all again at the next site.

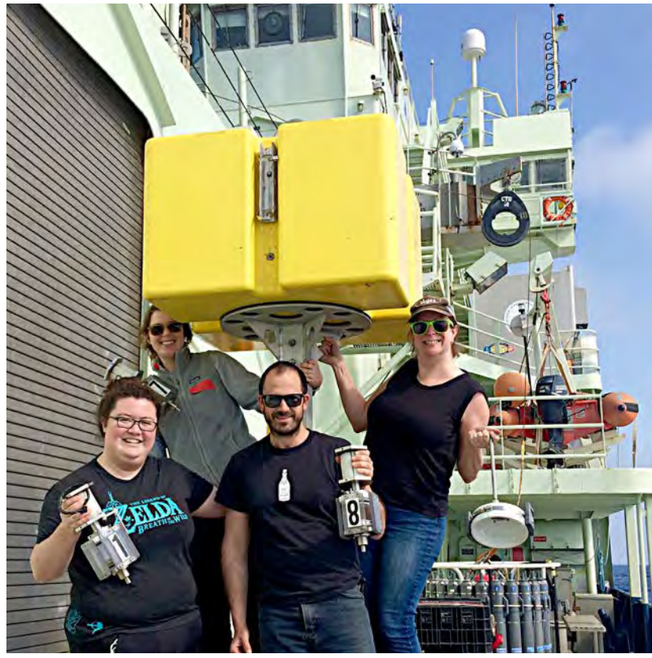
From the Juan de Fuca Ridge

BY DR. BETH ORCUTT

As soon as we arrived on station aboard the research vessel *Atlantis*, Dwight Eisenhower's phrase, "Planning is everything, the plan is nothing" crossed my mind. After years of planning, months of meetings and trainings, and weeks of packing and shipping, we had finally reached our field site above the Juan de Fuca Ridge flank off the coast of Washington.

Our target lay beneath nearly two miles of ocean and a quarter of a mile of the seafloor. Our mission for this cruise was to study the strange microscopic life that survives and thrives in the inhospitable (to humans) hot and oxygen-poor conditions below the seafloor. This "deep biosphere" of subsurface life manages to live on incredibly minute amounts of energy, and our team is trying to figure out how this is possible. We call our mission "Slow Life in the Fast Lane."

You may have heard that NASA is interested in studying icy moons in our solar system — Jupiter's moon Europa and Saturn's moon Enceladus — for signs of extraterrestrial life. Conditions at the bottom of Earth's ocean are good analogs for these moons, so if we can understand how life exists in extreme environments here, we might know what to look for there.



SENIOR RESEARCH SCIENTIST BETH ORCUTT (far right), Research Associate Tim D'Angelo, and Postdoctoral Researchers Melody Lindsay (front) and Anne Booker (back) celebrate having successfully collected fluid from the ocean crust aboard the research vessel *Atlantis*.

THIS 'DEEP BIOSPHERE' OF SUBSURFACE LIFE MANAGES TO LIVE ON INCREDIBLY MINUTE AMOUNTS OF ENERGY.

To accomplish this mission, we planned to use the remotely operated vehicle *Jason* to be our eyes and arms on the seafloor, allowing us to collect samples and conduct experiments. During *Jason*'s dives, our scientific team worked in shifts around the clock to guide the robot's activities.

How could we possibly use a robot to access samples below the seafloor? Several years ago, I was part of an international team of scientists that installed subseafloor observatories at this site. These observatories allow us to tap into the fluids that move through deep ocean crust. They are very similar to wells on land used to access aquifers, except that they sit at the bottom of the ocean.

It's important to have contingency plans when conducting research on the high seas. There are no hardware stores when things break, you are at the mercy of the weather, and discovering unexpected things requires nimbleness and creativity. Even after spending more than 500 days of my life at sea for research, I am still in awe of how plans can unravel, and I have learned to go with the flow when things quickly deviate into unplanned territory.

On this cruise, for example, we lost half our field time due to bad weather, when we had only planned on losing a few days. In order to accomplish our research mission, we got creative and turned the dials up to 11, as they say. We had a Patrick Swayze movie marathon in the TV lounge when it was too rough to do any work, and I pondered why so many Swayze characters are focused on teaching others to overcome fear.

Part of the privilege of getting to be a deep-sea explorer and lead expeditions is teaching the next generation of scientists. Of the 21 scientists aboard the *Atlantis*, more than half had never been to sea before. The three postdoctoral researchers I brought with me from Bigelow Laboratory were all new to ocean fieldwork. My goal during the cruise was to show them how to overcome the challenges of conducting research at sea, and working together made me even more excited about the new perspectives that they bring to ocean science.

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WORLD OCEANS DAY INSPIRES $291,000 IN NATIONWIDE SUPPORT

The generosity of one anonymous donor this spring inspired individuals from across the country to give in support of the ocean's future.

The donor committed to match all new or increased gifts to Bigelow Laboratory between Earth Day and World Oceans Day.

People rose to the challenge and gave more than $145,000 in eligible gifts, generating $291,000 of new funding for Bigelow Laboratory's global ocean science mission. This collaborative effort was a perfect illustration of World Oceans Day's 2019 theme — "Together We Can."

Also in celebration of World Oceans Day this year, Bigelow Laboratory teamed up with the Boothbay Region Land Trust to host a beach-side discussion about the ocean at a land preserve.

"The urgency and the opportunities facing the ocean have never been more clear," said Deborah Bronk, president and CEO of Bigelow Laboratory. "This inspiring community has come together and empowered our scientists to learn more about the ocean and its vital role."

All those who participated in this matching opportunity will be recognized in a future donor listing.

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