TRANSECT

BIGELOW LABORATORY FOR OCEAN SCIENCES / SUMMER 2018 / VOLUME 10 / ISSUE 1

ON THE COVER
Sea urchins in Alaska's Aleutian Islands consume kelp forests and erode reefs in the absence of the ecosystem's top predator, the sea otter. Senior Research Scientist Doug Rasher studies this dynamic relationship, and others around the globe, to identify the interactions among species and human activities that foster healthy ecosystems.

Photo by Joe Tomoleoni

It turns out that winter is a great time to move to Maine! I started my tenure as president and CEO of this amazing institution in February, and it has been a thrilling ride ever since. In Bigelow Laboratory, I have found a community of individuals committed to the advancement of knowledge, the translation of science to solve real world problems, and the stewardship of our oceans and environment.

From its beginnings as the brain child of two rebel oceanographers, Bigelow Laboratory has distinguished itself through innovation.

Founder Charlie Yentsch harnessed the power of satellites to study ocean processes on a planetary scale. This work continues to drive groundbreaking technologies and applications that allow scientists to better understand the global role of our oceans.

Founder Clarice Yentsch imported the use of flow cytometry into ocean science from the biomedical field, providing a new way to quickly count and identify cells in seawater. It is now a commonly used oceanographic tool that has enabled the discovery of the most abundant photosynthetic cells on our planet — *Synechococcus* and *Prochlorococcus*.

Their spirit of innovation continues at Bigelow Laboratory, keeping our science at the forefront of new technologies and ocean discoveries. One clear example of this is featured prominently in this issue of *Transect*. Our Single Cell Genomics Center, along with many individual researchers at Bigelow Laboratory, is using cutting-edge molecular techniques to study the ocean through genetic information. Commonly referred to as "omics" techniques, these rapidly evolving tools are revolutionizing our understanding of the ocean and uncovering new applications.

I am excited to help carry on the unique approach to science that has made Bigelow Laboratory one of the most respected oceanographic institutions in the world. This summer, we will start creating a new strategic plan to define a path forward for the coming years.

We have a critical mission, limitless opportunities, and an astounding legacy upon which to build. However, dwindling federal resources and declining ocean health represent significant challenges.

Our continued success will require us to strengthen the four revenue streams that keep Bigelow science at the leading edge — federal grants, commercialization activities, analytical services, and the philanthropic support that is so critical for us to push the envelope and put our science to work.

I hope you will join me this summer for the many activities we have planned. On page 10, you will see a calendar of our popular Café Sci talks. On July 10 at 5 p.m., I will lead the first of these six weekly events, "Nitrogen to the Rescue: How Arctic Ice Reduction is Fertilizing the Sea." My talk will provide an introduction to myself and my research, in particular my work in the Arctic and what it can tell us about changes in the Gulf of Maine. This fun, free series is 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 20 from 10 a.m. to 2 p.m.

I hope to see you at the lab this summer. I would love to meet you and talk about the amazing science that drew me here.

Deborah A. Bronk

DEBORAH BRONK, PhD

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Photo, opposite: Christoph Aeppli

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OIL FROM THE DEEPWATER HORIZON SPILL can still be collected from Gulf of Mexico beaches. Senior Research Scientist Christoph Aeppli gathers samples as part of his continuing research about how the chemistry of spilled oil changes over time.

‘Omics’ Technologies Decoding the Genetic Seascape

Senior Research Scientist José A. Fernández Robledo has studied the oyster parasite *Perkinsus* for decades. He has grown generations of *Perkinsus* in his laboratory, delved into the parasite’s historical impact on Damariscotta River oyster populations, and is currently evaluating the potential of engineering it for a malaria vaccine. And yet, *Perkinsus* can still surprise him.

One day, when he and Senior Research Scientist Joaquín Martínez Martínez were browsing old *Perkinsus* images taken with an electron microscope, they saw a few cells dotted with something unexpected: viruses.

The scientists set out to study the relationship between virus and host, but they quickly ran into limits of traditional techniques and could not isolate the virus from *Perkinsus*’ cells.

“Using the classical microbiological tools was tough and only partially successful,” Martínez Martínez said. “Viruses don’t look like much more than dots when viewed through an electron microscope, so we needed really clear samples to identify them.”

These challenges led Martínez Martínez and Fernández Robledo to try a new approach: a state-of-the-art suite of technologies frequently referred to as “omics.” This rapidly evolving methodology includes molecular techniques such as genomics, transcriptomics, and proteomics.

Omics allow scientists to characterize and quantify pools of genetic data — from all the genes of a single organism to an entire community of organisms.

OMICS ALLOW SCIENTISTS TO CHARACTERIZE AND QUANTIFY POOLS OF GENETIC DATA.

Studying specific genes reveals fundamental information about any organism. An oyster's genes can show what shape its shell will be or how it regulates its body temperature. Studying all of the genetic information of that same oyster can help scientists answer much more complex questions — what the oyster eats, how it interacts with its environment, and what other species it is related to.

The power of omics lies in the capacity to analyze these large sets of genetic information, and to do so quickly. This enables researchers to pinpoint issues that would have been impossible two decades ago and explore two of the most complex questions in microbiology: what microbes exist in the environment, and how do they function?

“Omics are some of the most powerful tools we have to understand life in its many forms,” Martínez Martínez said. “In this project, they let us read the parasite’s genetic activity and pinpoint the presence and impact of the virus.”

Traditionally, microbiology has relied on growing samples in the laboratory, but this process has limitations. Microbes grown in the laboratory may act differently than they would in nature. Certain environments, like the deep sea, are so extreme that they cannot be replicated.

Omics tools give scientists the option to bypass cultivation and go straight to the source — microbes grown in their natural environment. This analysis can take place on many scales: from a single cell to an entire microbial community. Certain omics techniques pinpoint only the active genes in a microbe, and others reveal all the genetic information an organism possesses.

Bigelow Laboratory researchers are utilizing these technologies to answer many complex questions. Several senior research scientists use omics to explore questions at scales that range in magnitude from microscopic to global — from identifying how specific bacteria are related, to cataloging every microbial species in the ocean.

“Omics tools replaced techniques that had been the core of microbiology for over a century, becoming our main toolset,” said Senior Research Scientist Ramunas Stepanauskas, who directs the Single Cell Genomics Center, a hub of omics work at Bigelow Laboratory. “They tell us about environments from the ocean, to soils, to human guts — anywhere you find microbes.”

Across these varied microbial environments, omics techniques allow Bigelow Laboratory researchers to analyze how a given ecosystem functions and unravel the relationships between the microbes that live there. These lines of questioning have the potential to resolve fundamental mysteries and generate revolutionary applications.

“Omics technologies are allowing us to study these specific, nuanced questions that are essential for our understanding of how the planet works,” said Senior Research Scientist Peter Countway.

He is using omics techniques to interrogate an ecosystem that is still full of microbial mysteries: the Southern Ocean surrounding Antarctica. Certain phytoplankton produce a compound called dimethylsulfoniopropionate (DMSP) that provides essential nutrients to marine bacteria. The consumption of DMSP can lead to the release of dimethyl sulfide (DMS), a gas that helps form clouds, thereby influencing global climate.

In the spring of 2018, Countway, Senior Research Scientist Paty Matrai, and Senior Research Associate Carlton Rauschenberg returned to Antarctica to continue their study of how marine microbes respond to different concentrations of DMSP. Omics techniques allow them to examine this system at multiple scales: from the specific ways that individual microbes are processing DMSP, to the way the entire community functions and changes.

“This process takes place on a molecular level, but it has a huge potential impact on atmospheric chemistry

RESEARCH SCIENTIST NICOLE POULTON unloads a microplate of individually sorted cells in the Single Cell Genomics Center. The genetic information of each cell is then amplified and analyzed to create a microplate "heat map," like the one shown on page 5.

and global climate," Countway said. "It's a process we'd struggle to understand without the power of omics."

These rapidly evolving technologies also have the potential to change how we look at life itself. The ability to examine entire microbial communities has revealed a level of diversity that biologists have long suspected but been unable to prove with traditional techniques.

"Omics technologies have opened our eyes to the true diversity of the world," said Senior Research Scientist Dave Emerson. "That's their real power."

MARINE VIRUS INVESTIGATION

The oyster parasite *Perkinsus* spreads disease that causes significant losses to the United States shellfish aquaculture industry — all while sustaining a viral infection. This apparent paradox led Senior Research Scientists José Fernández Robledo and Joaquín Martínez Martínez to ask an interesting question in their virus-parasite study: what if this virus wasn't actually bad, but somehow beneficial to the parasite?

Investigating that question requires unprecedented research. Martínez Martínez and Fernández Robledo are undertaking the first coordinated effort to isolate and characterize a marine virus, as well as the first research into the virus of a marine parasite. Access to modern omics technologies means that Martínez Martínez and Fernández Robledo will be able to take further strides than researchers studying viruses ever have.

"Virus research used to be mostly descriptive," Fernández Robledo said. "Now we have tools that allow us to interrogate the virus and answer questions, so our research will be proactive."

In tandem with omics approaches, Fernández Robledo plans to use the powerful gene-editing tool CRISPR-Cas9 to label the virus so that it will fluoresce under the microscope, making it easier for Martínez Martínez to perform experiments on the virus itself.

This research has the potential to clarify the complex interactions between virus, parasite, and oyster, and it could shed light on other parasitic relationships as well. *Perkinsus* can serve as a model of how a pathogen is infected by a virus — which is by definition a parasite itself.

"We're investigating the parasite of a parasite," Martínez Martínez said. "This project is difficult, but omics tools are putting us on the right path."

'OMICS TECHNOLOGIES HAVE OPENED OUR EYES TO THE TRUE DIVERSITY OF THE WORLD. THAT'S THEIR REAL POWER.'

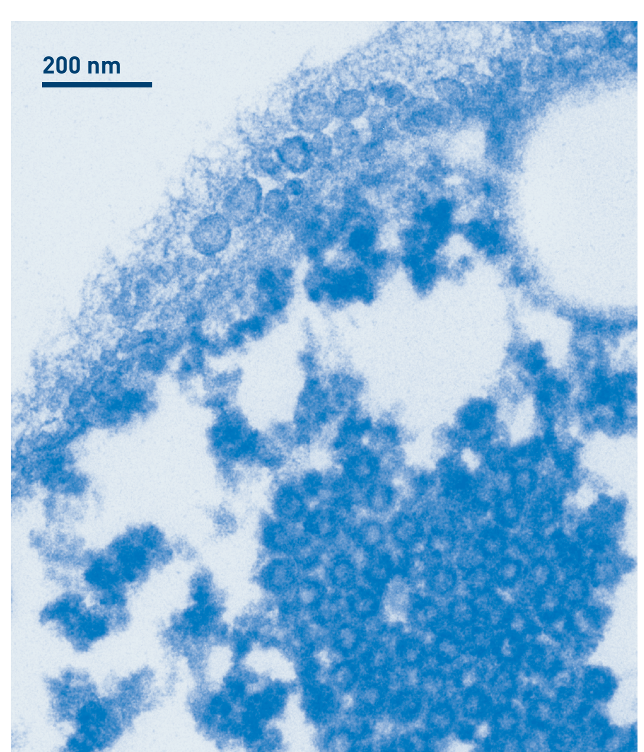
Understanding this relationship could have impacts far beyond biology, as well. Developing a robust, sustainable aquaculture industry is key to growing Maine's coastal economy — but the disease caused by *Perkinsus*, which has increased in oysters by 65 percent over the last decade, is a severe threat. Preventing and treating oyster disease would benefit Maine and other states whose economies rely on shellfish aquaculture.

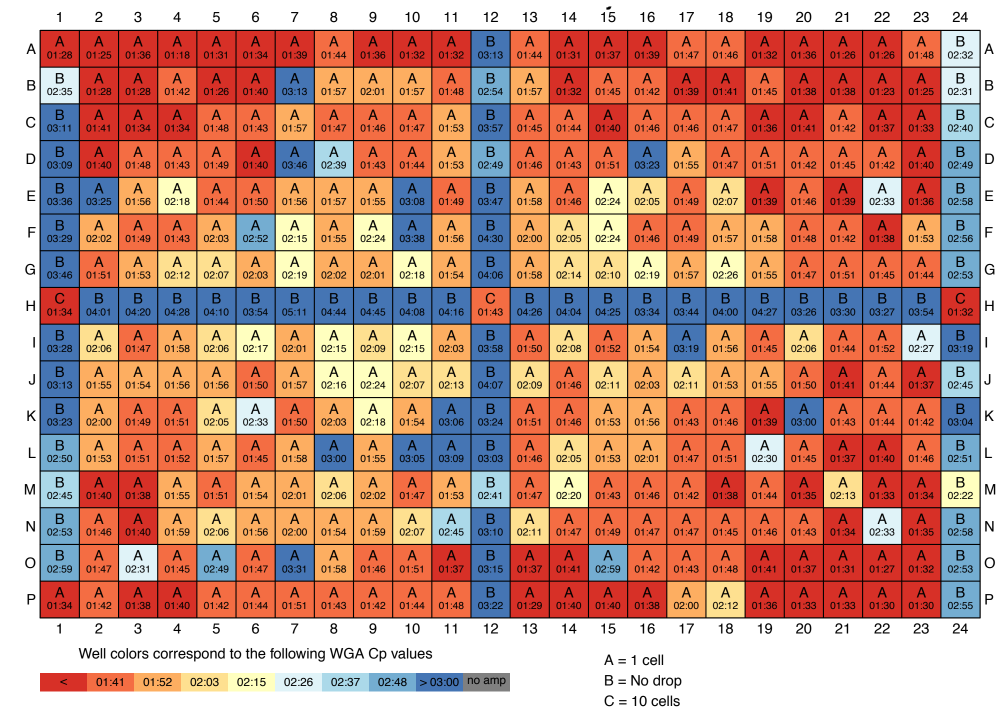
"There's a lot of research into preventing this parasite from spreading on oyster farms," Martínez Martínez said. "Adding an understanding of viruses to the mix makes it possible to get the biological and ecological information that will let us cure this parasite once and for all."

In Maine's aquaculture industry and beyond, Martínez Martínez and Fernández Robledo believe this project could cause a paradigm shift. Using omics tools to pinpoint how the virus shapes *Perkinsus*' impact on its host has the potential to change the archetype of how biologists think about parasitic infections — with repercussions for human, as well as shellfish, health.

"Everyone in the world has been infected by a virus," Fernández Robledo said. "Sometimes the clue to help solve such a major problem is in a marine organism, and omics approaches make this important research possible."

VIRUSES can be seen as dark spots inside infected *Perkinsus* cells when they are viewed through an electron microscope.





AFTER INDIVIDUAL CELLS are sorted into the 384 wells of a microplate, an amplification method developed by the Single Cell Genomics Center replicates the genetic material and creates a "heat map" of the microplate useful for future analysis.

CREATING A GENOMIC DATABASE

In 2000, the Human Genome Project forever changed the field of biology when it published the first genetic blueprint of a human being. This genome provided a crucial reference point for future studies and enabled the development of omics technologies.

"Marine microbiologists took these new omics techniques and started using them on microbes in the ocean, but without the genomic blueprints needed to understand the results," Senior Research Scientist Ramunas Stepanauskas said. "Now the field is upside-down. Scientists are producing tons of data, but we can only interpret a small fraction of it without reference genomes."

Stepanauskas has an ambitious goal: to create a marine parallel to the Human Genome Project — with one big difference. Instead of mapping the genetic code of one organism, he aims to create a comprehensive global database that contains the genomes of all marine bacteria and phytoplankton on the planet.

This database will provide the reference necessary for the marine microbiology research community to take full advantage of the opportunities omics offer.

The hub of this work is the Single Cell Genomics Center, the research and service center Stepanauskas directs at Bigelow Laboratory. It is the first facility of its kind, and uses techniques pioneered at Bigelow Laboratory to read the genomic blueprints of individual cells. In the decade since the facility opened, Stepanauskas' team has analyzed tens of thousands of cells from environments as diverse as soils, seawater, the International Space Station, and gut contents of bees and mice.

Their ocean microbe database project was launched through funding by the Simons Foundation, and Stepanauskas' team is currently working to sequence the surface layer of the tropical and subtropical ocean.

Though the aim of this effort is large, the samples needed to complete it are surprisingly small. Omics methods allow Stepanauskas to extract genomic information for thousands of organisms from a single drop of seawater.

The first sample came from Bermuda. About 15,000 genomes were produced from that one drop, equal to the number of microbial genomes sequenced by the entire world in 2014.

"That's an indication of how fast technology is moving forward in this field," Stepanauskas said. "We can do things now that were completely impossible just a few years ago."

The ocean microbe database is already more extensive than that of the human genome. Stepanauskas' team has the capacity to complete it in two years, creating a global reference database from tens of thousands of genomes. This speed is especially staggering when compared with the traditional laboratory cultivation techniques that were the bread and butter of marine microbiology before omics existed.

"The sun will turn into a red giant before we can do this with cultivation techniques," Stepanauskas said. "Omics is what makes this challenge possible."

Stepanauskas also hopes that this project will clarify fundamental questions about how microbes evolve. In addition to sharing genes "vertically," the way human parents transfer genes to their children, microbes also transfer genes "horizontally" between one another in the environment.

This process creates complex family trees and drives microbial evolution. Understanding horizontal gene transfer will shed light on microbial diversity, help redraw the lines between species, and could even redefine what a species is.

"In a given drop of water, does horizontal gene transfer happen once in a million years, or every minute?" Stepanauskas asked. "We can't answer these relatively simple questions yet, but single cell genomics gives us the tools to do so."

UNLOCKING THE IRON MICROBIOME

Senior Research Scientist Dave Emerson can learn a lot from a dab of mud or a teaspoon of water — with potentially enormous impacts for oceanography, industry, and human health.

Complex ecosystems exist at scales large and small, and that scale determines the tools at a scientist's disposal. A forester can visit a stand of trees and count each pine, ash, and beech. Microbial ecosystems, where Emerson's research takes place, do not afford the luxury of being able to see your study subject.

Emerson studies the iron microbiome, the world of microbes that process iron for energy. Just as a forest is a community of species, the iron microbiome is a complex community of iron-processing microbes that interact with one another and their environment. These microbes are crucial to chemical processes in places as diverse as underground aquifers and deep-sea hydrothermal vents.

Emerson uses omics techniques to study how these microbes are related to one another and understand the roles they play in their environment. From a small water sample, he can extract and analyze the genetic information of all the microbial species in a community.

"The beauty is that it's easy to go out and take a sample of water," Emerson said. "These techniques give you an inexpensive, broad snapshot of the community."

This work is at the core of omics: studying the link between a microbe's physiology and potential function in its ecosystem. Emerson essentially asks two questions of every sample: who lives in the environment, and what do they do there?

One of the prime tools at his disposal is a gene referred to as "16S." All microbes — and humans — have this gene, but the exact code is unique to each species.

Identifying the 16S genes in a sample is like taking attendance in a classroom. Finding all versions of 16S present tells Emerson which microbes live in the sampled environment. To determine their roles, Emerson uses multiple omics techniques, including sequencing individual cells in Bigelow's Single Cell Genomics Center.

OMICS ARE REVEALING NEW MICROBIAL PROCESSES THAT EXIST ON EARTH — AND POSSIBLY MARS.

Together, these approaches are revealing new microbial processes that exist on Earth — and possibly Mars, which is known as the "red planet" for its high iron content.

"Omics are incredibly powerful for answering a whole range of questions, on topics from ecology to physiology to biochemistry to evolution," Emerson said.

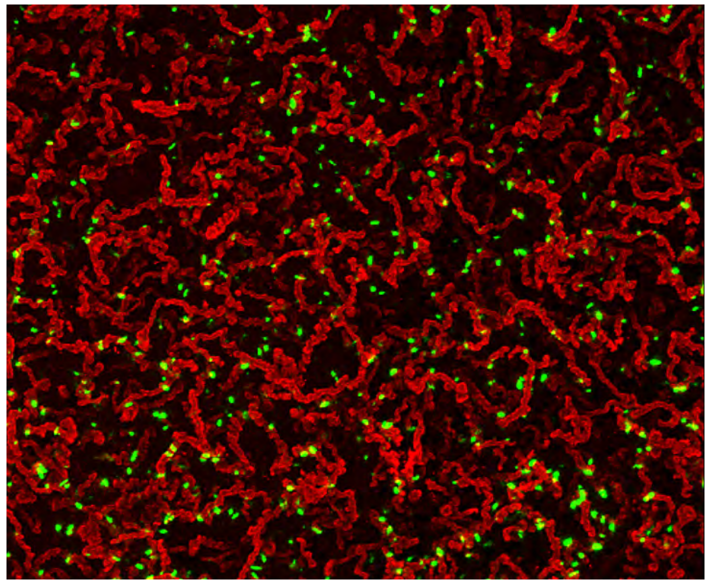
Answering such questions about the iron microbiome will have far-reaching implications, including clarifying large-scale ocean and global climate processes. The amount of iron available in the ocean controls the growth of phytoplankton, microscopic plants that fuel marine food webs and influence gas exchange with the atmosphere.

"The iron cycle is incredibly important globally, and we know very little about it," Emerson said. "Omics tools are letting us delve into the functional relationships that regulate it."

Microbes are also essential to life outside of the ocean, and communities of microbes exist almost everywhere on Earth — including inside animals. All complex animals have microbiomes, where microbes living in the gut interact with one another and with the animal's cells.

Learning how the relatively simple iron microbiome works can teach scientists about much more complex systems. Environmental omics studies have already helped to identify the human microbiome, one of the biggest advances in biomedicine in the last decade.

"Not only are omics revolutionizing our understanding of how our planet works," Emerson said, "they are changing our whole view of what it is to be human."



IRON-OXIDIZING BACTERIA grow on a piece of steel. In this image taken by a microscope, the bacteria fluoresce green and the iron oxide stalks they produce are stained red.

PROFILE Deborah Bronk

President and CEO,
Bigelow Laboratory for Ocean Sciences

Like many oceanographers, Deborah Bronk started her academic career thinking she wanted to study whales and dolphins. The field owes a huge debt to these marine mascots, who have provided generations of aspiring scientists with an alluring path that leads to other more impactful but less charismatic sea life. In Bronk's case, her oceanographic journey led her to study how nitrogen controls the growth of the microscopic organisms at the base of ocean food webs.

"You can't have a whale if you don't have phytoplankton, and you can't have phytoplankton if you don't have nitrogen," Bronk said. "Whales and dolphins are amazing, but I now know they're not nearly as fascinating as phytoplankton, which essentially control everything that's going on in the ocean. At this point in my career, if you can see it, it's probably not something I'd be interested to study."

Her fascination with the microscopic organisms and chemicals of the ocean has guided her career. She now has more than two decades of experience as an oceanographer, professor, and administrator. During that time, she has conducted more than 50 research cruises and field studies in freshwater and marine environments from pole to pole. This February, she became president and CEO of Bigelow Laboratory.

Born in Wisconsin and raised in Nashville, Bronk had a landlocked childhood that failed to dampen her interest in the sea. Her early inspiration came from watching *The Undersea World of Jacques Cousteau*, a documentary series that easily rivals whales and dolphins as a recruiting influence for oceanography during the last 50 years. Lacking access to beaches, she combed neighborhood yard sales for shells and curated a respectable collection — for a kid in Nashville. At age six, she knew we wanted to study the ocean. She still describes the first time she saw it at 13 years old as "amazing" with a big smile.

Before joining Bigelow Laboratory, Bronk was the Moses D. Nunnally Distinguished Professor of Marine Sciences and chair of the Department of Physical Sciences at the College of William & Mary's Virginia Institute of Marine Sciences. She previously served as division director for the National Science Foundation's Division of Ocean Science and as president of the Association for the Sciences of Limnology and Oceanography. These diverse experiences have shaped her perspective on the challenges facing our oceans, and ocean science.

At the National Science Foundation, she oversaw a $356 million dollar budget. While that is a lot of money by almost any standard, she came to realize it isn't nearly enough for all the ocean science that needs to be done.

"If you look at all the areas where our country needs to invest in ocean research, even that much money is inadequate, and it is not increasing," Bronk said. "I got very interested in how we could become more efficient and do more science with the available resources. How could we accelerate the pace of discovery and translation into things that help people and strengthen the country?"

This question stuck with her. It was clear the country needed to overhaul its approach to ocean science, but what would the right model look like? It would need to be nimble. It would need to be interdisciplinary. It would need to lack the traditional boundaries between labs in academic institutions, and its scientists would need to be given much greater intellectual freedom.

'I IMMEDIATELY RECOGNIZED THAT THIS INSTITUTION SHARED MY VISION.'

"When I visited Bigelow Laboratory for the first time in 2016, I immediately recognized that this institution shared my vision," Bronk said. "Its collaborative and entrepreneurial approach is unique, and it is absolutely the way science needs to be done in this country."

Running an independent and unconventional science laboratory is not without its challenges, however. Bigelow Laboratory currently gets about 70 percent of its funding from federal project grants. Bronk said the institution has a remarkable proposal success rate that speaks to the quality of its science, but long-term security, growth, and innovation will require diversification of funding strategies. She envisions an expansion of commercialization activities and analytical services, as well as increased philanthropic support for solution-focused science.

"As a country, we used to be bold and invest in a lot of crazy ideas, some of which worked and changed the world," Bronk said. "I want to partner with philanthropic organizations and supporters that can help us push the limits of our creativity to try and develop science-based solutions to global problems."

Crowd-sourced Data Fuels Ecoforecasts

GET INVOLVED!

Submit jellyfish sightings at jellyfish.bigelow.org

Submit tick sightings at tick.bigelow.org

What do right whales, deer ticks, and jellyfish have in common? They are all animals for which Senior Research Scientist Nick Record can "forecast" encounters with humans — with a little help from Mainers.

Record believes that it is possible to forecast ecosystems just like meteorologists forecast the weather. A mathematician, he writes algorithms that combine weather data with animal sightings and calculates the likelihood of more sightings.

"Ecosystem forecasting is a transformative way to understand ecosystems and engage people in science," Record said. "And the forecasts it creates are enormously valuable."

The bulk of his data comes from citizen science, an approach in which members of the general public collect data about the natural world in collaboration with professional scientists. Citizen science has been an effective tool in efforts as varied as bird censuses with the Audubon Society to a NASA project identifying interstellar dust particles.

"There is incredible value in having people distributed throughout the ecosystem making all these observations," Record said. "We could actually never capture this detail with a typical survey."

The first time Record fused citizen science and ecosystem forecasting was in the summer of 2015. He heard news reports of beachgoers noticing dense aggregations of jellyfish along the coast of Maine, but realized that no formal surveys were being conducted.

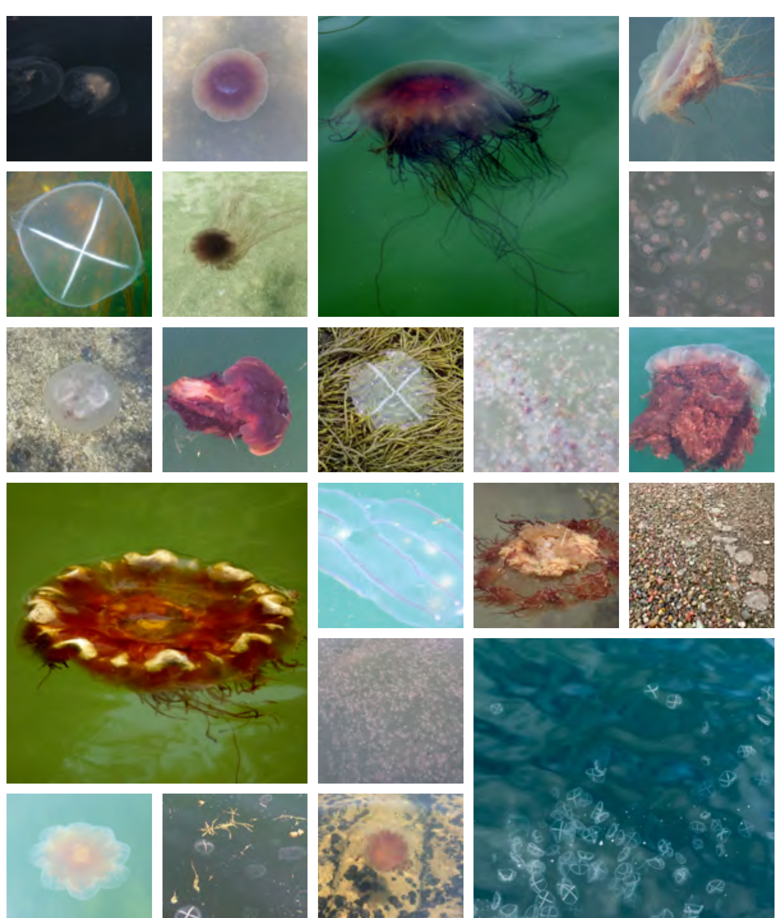
Record saw an opportunity to engage with the public's curiosity about jellyfish. He set up an email account for people to send him their sightings — and quickly received hundreds of emails. Record compiled all reported jellyfish sightings, and he used the data to develop an algorithm predicting where in the Gulf of Maine people are most likely to encounter lion's mane, white cross, and moon jellyfish on a given day.

"I really like connecting with people who are out observing the environment," Record said. "They have new insights, interesting hypotheses and questions, and funny stories."

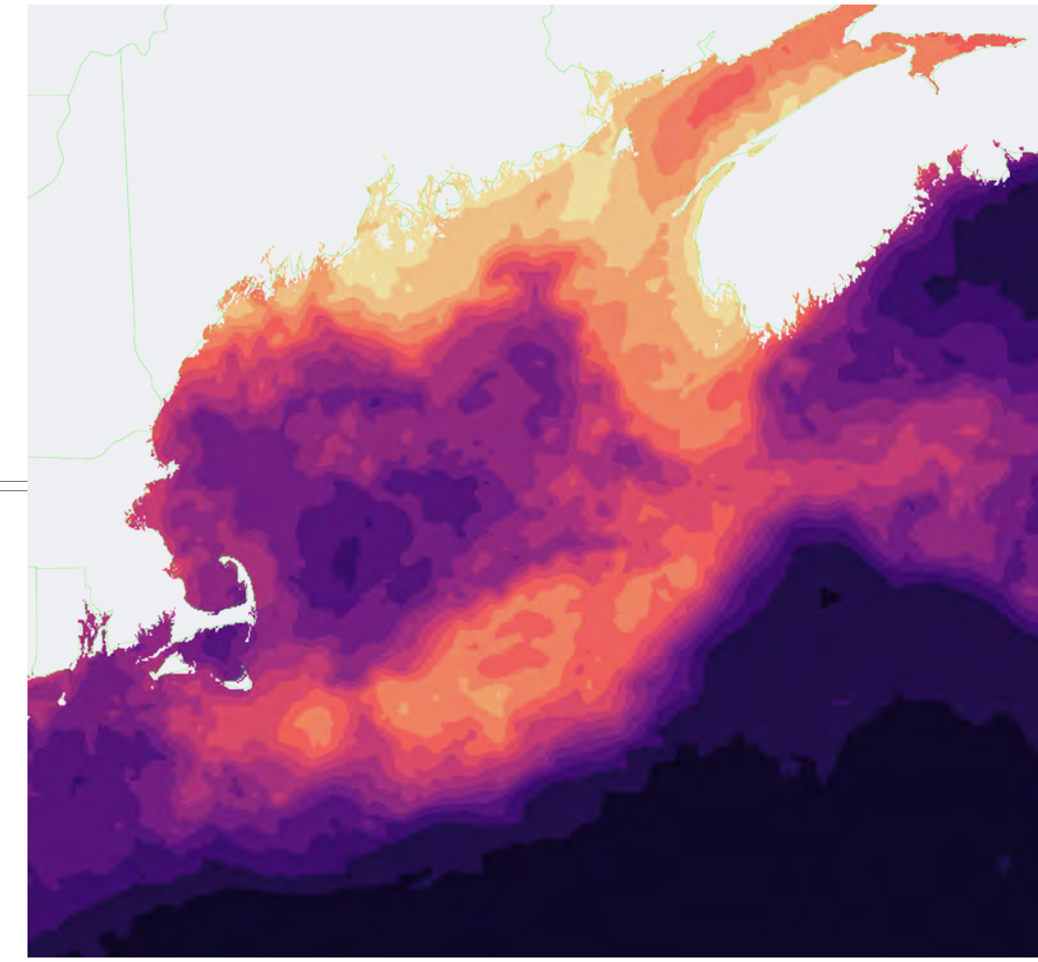
Much of the power of citizen science lies in the capacity for the general public to help conduct science — but this process also impacts the participants. Record wants to explore how his forecasting tools affect the way people make reports and interact with their environment. He will use this additional layer of data to adjust his models as needed, and he believes this process can also help shape the field of ecosystem forecasting.

"Citizen reports create a full loop in terms of the generation of science, its communication, and the movement of knowledge and information," Record said. "I think the human element is something major that has been missing from ecosystem forecasting."

Record sees an opportunity to tap into the broader knowledge that citizen reporters have and capitalize on the expertise that arises from group efforts. Studies show that when groups work collectively on a problem, they often perform better than experts.



CITIZEN SCIENTISTS' SUBMITTED PHOTOS and reports enable Record to build complex ecosystem forecasts.



JELLYFISH FORECASTS (left) and deer tick forecasts warn of the likelihood of an encounter throughout the region on a given day.

CITIZEN SCIENCE COULD EVEN PLAY A MAJOR ROLE IN UNDERSTANDING GLOBAL CLIMATE CHANGE.

"There's something deeper that we could get out of this information," he said. "I'd like to figure out a way that working with citizen reporters could allow us to tap into unusual things that are happening in real time, like rapid changes to an ecosystem."

Record has continued to search for opportunities to engage with citizen scientists. After creating the jellyfish forecast, his attention was drawn to a much peskier invertebrate — deer ticks.

"I was inspired to start that project because my wife and I were constantly finding them on our kids," he said.

Just as with his jellyfish project, Record solicits tick sightings from the public and creates a forecast for the East Coast region, from New York to Atlantic Canada. These forecasts also take the form of a "heat map," and spawned another type of communication as well — an audio podcast.

Record cohosts "Ecocast" with the persona he created for the computer that generates his forecasts. "Kraken" delivers a holistic ecosystem report, telling listeners what they can expect for weather, jellyfish patterns, and deer tick encounters in the coming week. Kraken always ends the forecasts with a polite, "Back to you, Dr. Record."

Currently, Record is working to forecast deer-car interactions. He envisions that, one day, drivers could input deer sightings into a smartphone application. Just as the application Waze generates navigation suggestions based on traffic data submitted by drivers, aggregating deer sightings along a route would create real-time recommendations.

Armed with the hammer of citizen science, everything looks like a nail. Record sees the potential for forecasts fueled by citizen reports to inform people about garden pests, bumblebees, mosquitoes, and much more.

Citizen science could even play a major role in understanding global climate change. The impacts of these changes are often clearest in phenology, the seasonal changes in plants and animals. Phenology covers everything from bird migration patterns to the timing of iris blooms — phenomena often observed at broad scales by birders, gardeners, and other people engaging with nature around them. As changes to global climate progress, reports by citizen scientists would comprise a powerful tool to help scientists understand and anticipate these shifts.

"Ecosystems are incredibly complex," Record said. "A researcher or research team naturally has a somewhat narrow view, which could be enriched by aggregating all of these other perspectives on the ecosystem."

CAFÉ SCI Summer 2018

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.

TUESDAYS, 5 TO 6:30 P.M.
JULY 10 – AUGUST 14
60 Bigelow Drive
East Boothbay, Maine

JULY 10
Nitrogen to the Rescue
How Arctic Ice Reduction is Fertilizing the Sea
Led by Dr. Deborah Bronk

JULY 17
Deep Sea Mining
How Your Smartphone is Driving the Hunt for Seafloor Minerals
Led by Dr. Beth Orcutt

JULY 24
Incredible, Edible Kelp
Harvesting the Potential of Seaweed Aquaculture
Led by Dr. Nichole Price

JULY 31
Precious Metals
A Global Hunt to Understand Scarce Ocean Nutrients
Led by Dr. Ben Twining

AUGUST 7
Are We Alone?
What Microbes Can Tell Us About Possible Life on Other Planets
Led by Dr. Jackie Goordial

AUGUST 14
Guardians of the Reef
Identifying the Species that Promote Coral Reef Recovery
Led by Dr. Doug Rasher

JULY 20 Annual Open House 10 a.m. to 2 p.m.
Join us for free science activities and talks for all ages. ***Learn more at bigelow.org/openhouse.***

PROFILE Arthur Martinez

Trustee, Bigelow Laboratory for Ocean Sciences

Whether sitting in a Fortune 500 board room or standing on his Maine dock, Arthur Martinez is a problem solver. Well-known in the business world for his ability to refocus and rescue struggling retail corporations, you know his work if not his name. Sears, Saks Fifth Avenue, and Abercrombie & Fitch have all benefited from his leadership and guidance.

Five years ago, he turned his skill set toward another huge challenge — the health of the oceans — becoming a donor and then an advisory board member of Bigelow Laboratory. Two years ago, he joined the board of trustees.

"The health of the oceans is vital to the health of the planet and its population," Martinez said. "There is so much half-baked science out there, so many half-truths and bogus theories. It's important to have a scientific North Star to show us the way, and that is what Bigelow delivers."

Long before he was a nationally known executive or a trustee at the Laboratory, Martinez developed an understanding of the importance of the oceans. He grew up in New York City, where his father ran a wholesale seafood business. This experience taught him early lessons about the importance of the ocean as a food source and economic engine. It also taught him that both of those valuable contributions relied on the health of the ocean's waters.

At 16, he became the first in his family to go to college. He earned a bachelor's degree from New York University Tandon School of Engineering before spending two years in the army. By then he had grown an interest in applying the math skills and rigorous approach he had developed as an engineer toward analyzing and solving business problems. In 1965, he received his master's in business administration from Harvard University.

Rising up through finance positions, he became the Chief Financial Officer of Saks Fifth Avenue and over time transitioned into general retail management. He had countless achievements throughout his illustrious career, but he is perhaps best known for saving Sears. He stepped in to lead the challenged company in 1992 and implemented a bold new vision that delivered new customers and large profits.

Martinez's extensive experience at large, publicly held companies has added valuable perspective to the Bigelow Laboratory Board of Trustees. And the opportunity to serve on a small, independent nonprofit board has also been fulfilling for the seasoned executive.

"There are so many layers and filters at larger organizations that often obscure whatever is really going on from the board," Martinez said. "At Bigelow Laboratory, we get to be so much closer to the work that it has been a very different and rewarding experience. You can really engage with the mission. The people aren't just numbers on spreadsheets; they're names and faces. That sort of intimacy with the people and the work is really terrific."

Regardless of the context and size of an organization's challenges, Martinez's approach to problem solving has always centered on the search for truth and the restoration of focus. In retail, he learned early on that the truth is usually resident with the people who are closest to the customer, and companies tend to look increasingly inward and lose their perspective.

He brings this same approach to his work with Bigelow Laboratory, focusing on the problems the Laboratory's science can help solve and the people it can help. Basic scientific research has always played a key role in stimulating the progress of societies, and he sees the dual importance of Bigelow Laboratory's work as a source of fundamental truth and of practical applications.

"A critical contribution of the scientific endeavor is to, over time, produce solutions that benefit mankind," Martinez said. "I really admire the way that Bigelow scientists pursue their research while keeping their eyes on the horizon for ways their discoveries can really make a difference."

'IT'S IMPORTANT TO HAVE A SCIENTIFIC NORTH STAR TO SHOW US THE WAY, AND THAT IS WHAT BIGELOW DELIVERS.'

Summering along the ocean, the sea is never far from his mind — nor are the changes he has witnessed at the Mount Desert Island residence that he has called home for almost 45 years. The fireplace now sits unused during the summer. The garden can be started earlier and grows longer. These changes have done wonders for his tomato plants, but they have contributed to his deep concern for the environmental changes occurring around the globe.

"I really treasure the opportunity to contribute to Bigelow Laboratory's role in keeping our oceans, and our planet, healthy," Martinez said.

FIELDWORK Notes from the Field

From Palmyra Atoll BY BRITTNEY HONISCH

After a few hours of flying over the vast Pacific Ocean, the brilliant azure reefs and lush islands of Palmyra Atoll came into view below. The plane rumbled to a short stop on the rough, mile-long airstrip. Our research team joined the frenetic offloading of scientific equipment, personal effects, and much-anticipated fresh produce. After, we gathered to watch the plane take off. The last tangible contact with the outside world for the next month disappeared on the horizon, and our field season began.

Palmyra Atoll, once used as a military outpost during World War II, is now a National Wildlife Refuge managed by the U.S. Fish and Wildlife Service and The Nature Conservancy. Palmyra's remote research station presents a unique opportunity to study healthy reefs largely unaffected by the pollution and overfishing that plagues other locations.

We went to Palmyra to investigate a marine fungus that targets crustose corralline algae. These algae cement reefs together, provide the preferred settlement surface for juvenile coral, and serve as complex habitat for numerous tropical species. Despite the destruction marine fungi can cause to coral reef structure and function, they are studied infrequently. Our research, in conjunction with The Nature Conservancy, U.S. Fish and Wildlife Service, and U.S. Geological Survey National Wildlife Health Center, is designed to determine the impact of the fungus on Palmyra's reefs.

We traveled to this remote place to pursue this question in a number of ways. We conducted scuba diving surveys to assess prevalence of this disease over time, and across locations around the reefs. Even isolated places like Palmyra are not immune to global change, so we also devised on-shore experiments to test how the disease responds to ocean warming and acidification.

Our days quickly fell into a rhythm. We rose early to check on the experiments, making sure the heaters and bubbling CO_2 were simulating future ocean conditions in our tanks. After a quick breakfast, we loaded the research boat with dive gear and headed out to the reef. Our dives focused on describing the fungus, the reef composition, and the parrotfish and surgeonfish grazing, which we believe helps control the spread of the disease.

As we descended underwater, the sheer diversity of the reef threatened to overwhelm us. Corals and algae in iridescent hues carpeted the bottom, and schools of fish pulsated above in shimmering clouds. When I measured the fungus, my face was near the reef, and it was easy to notice the interactions and cryptic organisms that I missed from above — the frilly nudibranchs the size of my pinky nail, spotted crabs hiding in coral, a sleeping octopus nestled into a hole. I also had to remember to look up occasionally, or risk missing the sharks, giant wrasse, and manta rays gliding overhead.

Above water, Palmyra is also a land of extremes. Our team adjusted to working in high heat, humidity, and torrential downpours that left us soaked for hours. It can be challenging to plan for everything that may happen during a field season, so some problem solving requires a good dose of humor, creativity, and MacGyvering. Even when diving was done for the day, monitoring the experiments, data entry, and gear maintenance kept us working at night. The camaraderie, laughter, and snacks from the galley kept our spirits high.

Every day, no matter how tiring, left me feeling fortunate to ask questions and make observations about such an extraordinary ecosystem. The thrill of discovery and gratitude for immersing myself in that place — even temporarily — brought a smile to my face long after I returned home.

From Gran Canaria BY KEVIN POSMAN

When you tell people that you're going to the Canary Islands for two months on a work trip, they're not usually sympathetic. The very words "Canary Islands" invoke images of clear blue water, beaches, and volcanic mountains, and visiting is a rare opportunity.

However, reality is a little different. Most of the islands are developed and not exactly pristine, with a collective population of two million people. My fieldwork entails more beakers and lab benches than beaches.

The research team I am part of visits the Canary Islands to study rapid changes in ocean and atmospheric chemistry that are having profound and dire impacts on humanity and ocean life. On our most recent trip, we wanted to see if this process could be slowed on a small scale.

This was our second trip to the Canary Islands. We joined collaborators from Kiel, Germany, at GEOMAR Helmholtz Centre for Ocean Research, and were hosted by the scientists at the Oceanic Platform of the Canary Islands on Gran Canaria. Gran Canaria is located approximately 150 miles west of North Africa off the coast of Morocco and offers unique opportunities to study the subtropical waters of the Atlantic.

I was participating in an artificial upwelling experiment, along with Steve Archer, a senior research scientist at Bigelow Laboratory. Upwelling refers to the process by which deep, nutrient-rich water is transported to the surface, replacing the nutrient-depleted water. Upwelling is an important ocean dynamic and responsible for creating some of the most productive fisheries on the planet.

Replicating this process may help remediate the effects of ocean acidification where artificial upwelling occurs. As human activities continue to elevate the levels of carbon dioxide in the atmosphere, the ocean is also affected — absorbing more carbon dioxide and thereby increasing its acidity. This makes life harder for many shell-forming sea creatures and impacts other organisms fundamental to the ocean food web.

As phytoplankton and other organisms grow, they use carbon. If we can stimulate biological activity like natural upwelling does, it could be enough to reduce elevated carbon levels, simultaneously strengthening food webs and supporting sustainable finfish aquaculture at those sites of artificial upwelling.

Science can be a lonely enterprise at times, but projects like this epitomize collaboration. Immediately after I arrived, I felt like the band was back together. The experiment was underway and the research machine was firing on all cylinders. After a few days of overlap, Steve passed the baton to me, boarded his flight home, and the work continued.

The machine continued to hum along. Each morning, the sampling team loaded the van with bottles and carboys, which we had organized the previous evening. We would unload the gear and boat out to the experiment, which consisted of large plastic columns suspended in the harbor, each carefully controlled to have specific water chemistry.

Our larger team worked in pairs. Some scientists took measurements, while others collected water and divvied it up for that day's analyses. After we collected the samples, the process ran in reverse: we got in the truck, drove up the hill, and walked through the door into the labs. The scientific analysis carried on into the evening, finishing when the bottles were rinsed and staged for the next day, barely given the opportunity to dry.

SCIENCE CAN BE A LONELY ENTERPRISE AT TIMES, BUT PROJECTS LIKE THIS EPITOMIZE COLLABORATION.

This process continued seven days a week, for weeks on end. When the experiment ended, we packed up entire labs worth of gear, virtually overnight, and shipped it back to where they came from. It's an impressive logistical ballet.

Despite the constant churn, the work was very gratifying. We laid groundwork for techniques and technology that could combat the serious threats posed by ocean acidification. And it wasn't all work. We celebrated birthdays and experiment milestones. Each day was punctuated by a pleasant stroll along the boardwalk between the lab and the apartment, and maybe even a swim or meal by the water. It's a demanding but ultimately humbling experience to be a part of such a hardworking and talented group determined to tackle challenging problems.

It's not for everyone, but I guess this work doesn't warrant much sympathy. Instead, just wish us luck this fall when we plan to return to the Canary Islands and continue researching this remediation opportunity.

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