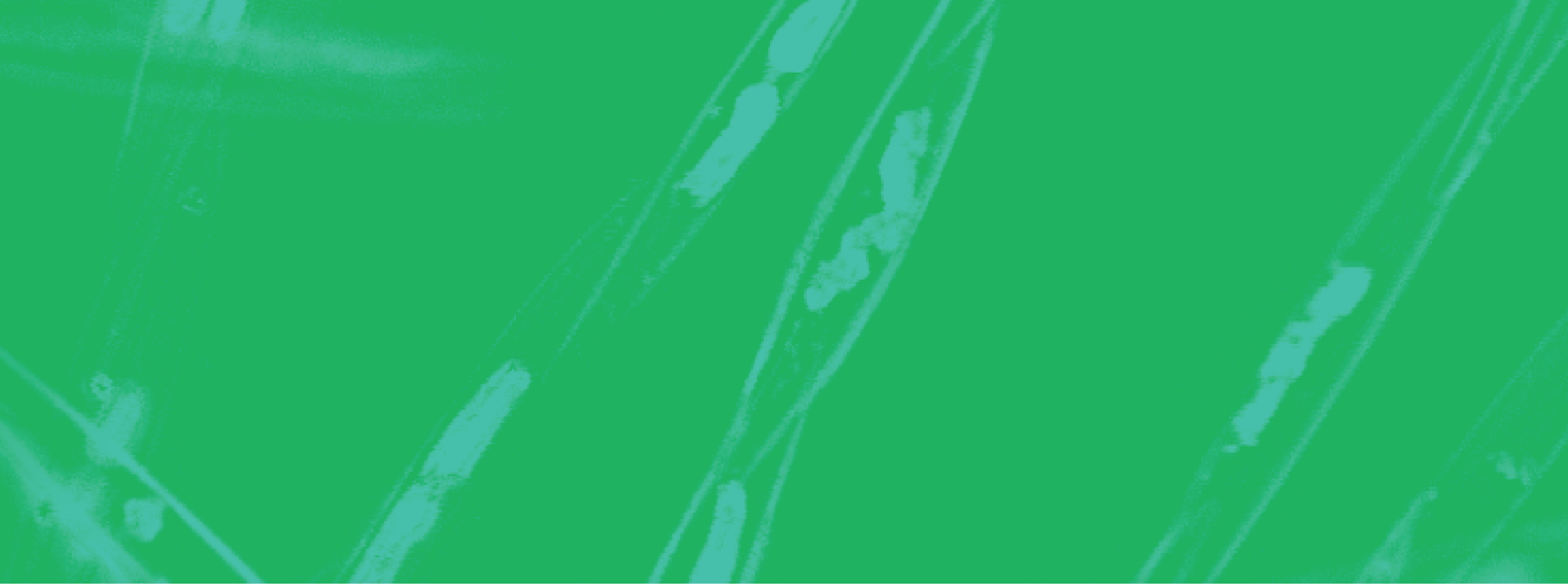

OUR RESEARCH ILLUMINATES PREPARES EQUIPS EDUCATES INSPIRES COLLABORATES

Bigelow | Laboratory for Ocean Sciences

2016 ANNUAL REPORT

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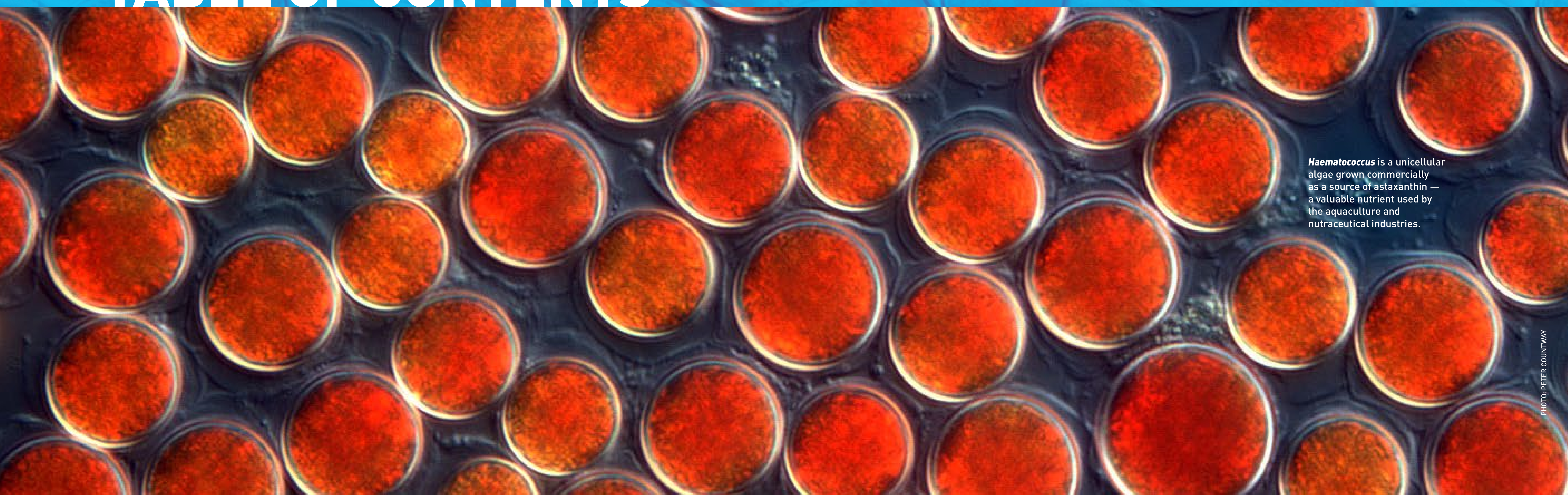
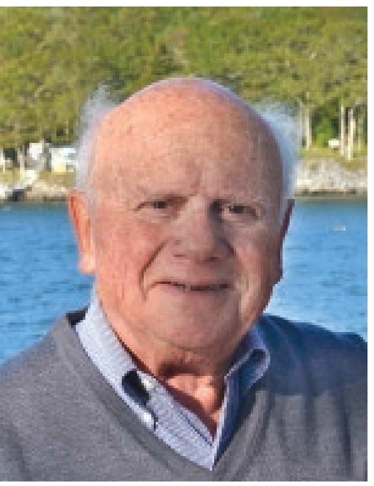


Haematococcus is a unicellular algae grown commercially as a source of astaxanthin — a valuable nutrient used by the aquaculture and nutraceutical industries.

PHOTO: PETER COUNTWAY

OUR DEDICATED SCIENTISTS, STAFF, AND BOARD OF TRUSTEES HAVE DRIVEN INCREDIBLE PROGRESS THIS YEAR ALONG THE PATH LAID OUT IN OUR STRATEGIC PLAN.



The campus buzzed throughout the year with construction of new research and education facilities. We strengthened Laboratory leadership by adding three new board members and re-envisioning the administrative structure. We created two new Centers for Venture Research to match stakeholder needs with philanthropic funding. And as always, our scientists delivered critical insights into our oceans and how they are changing.

This remarkable year came to a very sad end with the passing of our executive director, Graham Shimmield. His vision, leadership, and devotion were transformative for Bigelow Laboratory — and for those of us who had the privilege of working with him.

As we undertake the search for Graham's successor, we continue to be guided and inspired by his extraordinary legacy. I am grateful for the direction and momentum he provided to the Laboratory, which I am confident will carry us well into the future.

Sincerely,

Herbert Paris
Chairman, Board of Trustees

GRAHAM B. SHIMMIELD
DECEMBER 1, 1958 – DECEMBER 24, 2016

Our executive director, Graham Shimmield, passed away this year after a hard-fought battle with cancer. Graham was an accomplished scientist, a visionary leader, and a kind and compassionate human being who changed our organization and our lives.

A globally recognized leader in oceanography, Graham served in his role at Bigelow Laboratory since 2008. He transformed the organization during his time with us, building upon our longstanding scientific reputation to develop a state-of-the-art research and education campus in East Boothbay, Maine. Under his leadership, the Laboratory doubled in size, developed significant education programs, and increased the reach and impact of our science through expanded outreach and our new Centers for Venture Research.

His leadership and friendship will be sorely missed, but his vision, commitment, and perseverance will continue to inspire us and guide our evolution.

YEAR AT A GLANCE

PEOPLE

84
EMPLOYEES

18
SENIOR RESEARCH SCIENTISTS

18
POSTDOCTORAL SCIENTISTS

401
GENEROUS DONORS

CAMPUS GROWTH

Constructed a 32-bed residence
THAT WILL BEGIN HOUSING VISITING STUDENTS AND SCIENTISTS IN 2017

Built a 3,000-square-foot research and innovation greenhouse
TO HELP US DEVELOP AND TEST ALGAL PRODUCTS ALONGSIDE INDUSTRIAL PARTNERS

Added a 264-panel solar array
THAT PRODUCES MORE THAN ENOUGH ELECTRICITY TO POWER OUR NEW RESIDENCE FACILITY

RESEARCH

20%
GROWTH IN SCIENCE FUNDING FROM FEDERAL AND FOUNDATION SOURCES

72
PAPERS PUBLISHED IN PEER-REVIEWED JOURNALS — ONE EVERY 5 DAYS!

2
NEW CENTERS FOR VENTURE RESEARCH THAT HELP OUR SCIENCE GENERATE SOLUTIONS

ENTERPRISE

4
PROJECTS WITH COMMERCIAL POTENTIAL LAUNCHED THROUGH THE SASH A. AND MARY M. SPENCER ENTREPRENEURIAL FUND

11%
GROWTH IN REVENUE GENERATED BY THE SERVICES AND PRODUCTS OF OUR CORE FACILITIES

~100
ORGANIZATIONS IN 28 DIFFERENT COUNTRIES ORDERED ALGAE STRAINS FROM THE LABORATORY

EDUCATION

27
SUMMER UNDERGRADUATE INTERNS

7
CHANGING OCEANS SEMESTER-IN-RESIDENCE STUDENTS FROM COLBY COLLEGE

4
PROFESSIONAL TRAINING COURSES OFFERED BY OUR SCIENTISTS

THIS WAS A YEAR OF SUBSTANTIAL GROWTH AND CHANGE AT BIGELOW LABORATORY. WE SIGNIFICANTLY DEVELOPED OUR INFRASTRUCTURE AND RECRUITED WORLD-CLASS TALENT.

We expanded our engagement with commercial partners and the general public. We grew the scope and scale of our research to address the mysteries of our rapidly changing oceans.

Of particular significance was the passing of our executive director, Graham Shimmield, in December 2016. During the last nine years, Graham led us through strategic planning that resulted in substantial growth in our staff and the construction of our ocean research and education campus in East Boothbay, Maine. A remarkable leader, mentor, and friend, Graham was a bold visionary who led us to new levels of impact and influence.

In 2016, we achieved 20 percent growth in science funding from federal and foundation sources, which is particularly noteworthy considering that federal funding levels remained flat. Our education programs continued to grow as well, including record-breaking cohorts of summer interns and Changing Oceans semester-in-residence students.

We also expanded our campus with the construction of a student residence hall, funded in part by the Harold Alfond Foundation, as well as a new algae research greenhouse, funded through an impact investment by the Maine Community Foundation. Just as importantly, we continued to invest in our staff resources. This included creating and filling two vice president positions, as well as hiring two new senior research scientists, a new director of finance, and a new director of communications.

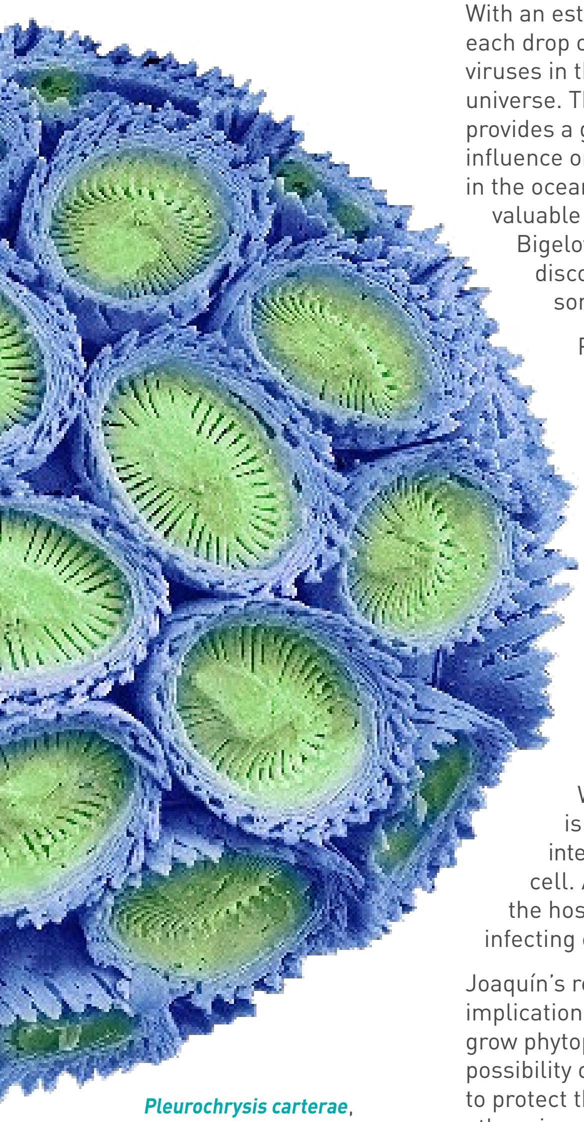
In the following pages, we highlight the impact of our research — how it illuminates, prepares, equips, educates, inspires, and collaborates. Our science has never been more important or more urgent, and we are grateful to the partners, donors, and funding agencies that make it possible.

We hope you enjoy this look back at our last year. We're already excited to show you what we're working on in 2017.

Benjamin Twining, PhD
Interim Executive Director
Senior Research Scientist
Henry L. and Grace Doherty Chair for Research and Education

OUR RESEARCH
ILLUMINATES

THE STAGGERING BEAUTY, COMPLEXITY, AND POTENTIAL OF THE OCEAN



Infections that Break the Rules

Marine viruses are unbelievably numerous. With an estimated 10 million viruses in each drop of seawater, there are far more viruses in the ocean than stars in the known universe. This unfathomable abundance provides a glimpse at their profound influence on our planet. Viruses' primary role in the ocean is to balance life and return valuable nutrients to the water, but Bigelow Laboratory scientists recently discovered that they sometimes do something quite different.

Persistent viral infection, when a virus lives inside the host without killing it, has long been known to occur in bacteria and multicellular organisms. Senior Research Scientist Joaquín Martínez Martínez identified the first example in phytoplankton this year. In fact, his discovery revealed that three different viruses persistently infect *Pleurochrysis carterae*, a coccolithophore that has been in culture for more than 50 years.

With this example identified, he is now working to determine what interactions are happening inside the cell. Are all three viruses co-infecting the host, or are some of them actually infecting each other?

Joaquín's research has important implications and may help industries that grow phytoplankton, as it raises the possibility of using harmless viral infections to protect their crops from being killed by other viruses.

Pleurochrysis carterae, a coccolithophore in culture at Bigelow Laboratory, is persistently infected by three different viruses that do not kill it.

Hidden Branches in the Tree of Life

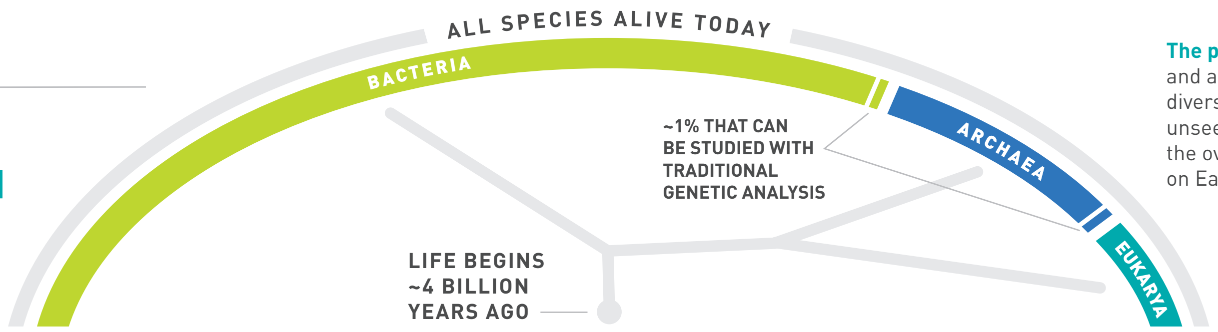
The path of genetic evolution of life on Earth is often represented as a tree. As time passed, the tree grew. Its trunk divided into three domains, each of which then grew many branches and twigs. All plant and animal life evolved in the part of the tree with the fewest branches, Eukarya. However, most of the biological diversity on our planet exists in the two domains that split from ours long ago — Archaea and Bacteria.

Senior Research Scientist Ramunas Stepanauskas and Postdoctoral Scientist Eric Becraft are leveraging state-of-the-art technologies to explore and map the genomic blueprints of these little-understood groups.

Traditional methods of genetic analysis require species to be kept alive in culture. As more than 99 percent of archaea and bacteria live in environments that are essentially impossible to replicate in the lab, scientists have largely been in the dark regarding the dominant forms of life on the planet. Single cell genomics technology, which was developed at Bigelow Laboratory, has removed the necessity of maintaining species in culture and provided new access to their genetic information.

The scientists and their international collaborators have so far isolated more than 2,000 individual genomes from 12 subsurface environments. From those samples, they have already identified and sequenced the genomes of more than 40 uncultured phylum-level branches of archaea and bacteria, including at least six that were previously undiscovered. Their findings are helping redraw the tree of life and reshape our understanding of how life evolved on Earth.

THE TREE OF LIFE MAPS THE HISTORY OF EVOLUTION ON EARTH



The phyla of Eukarya, which include all plant and animal life, compose the least genetically diverse evolutionary branch. In contrast, the unseen world of Bacteria and Archaea represent the overwhelming majority of biological diversity on Earth, and most have yet to be discovered.

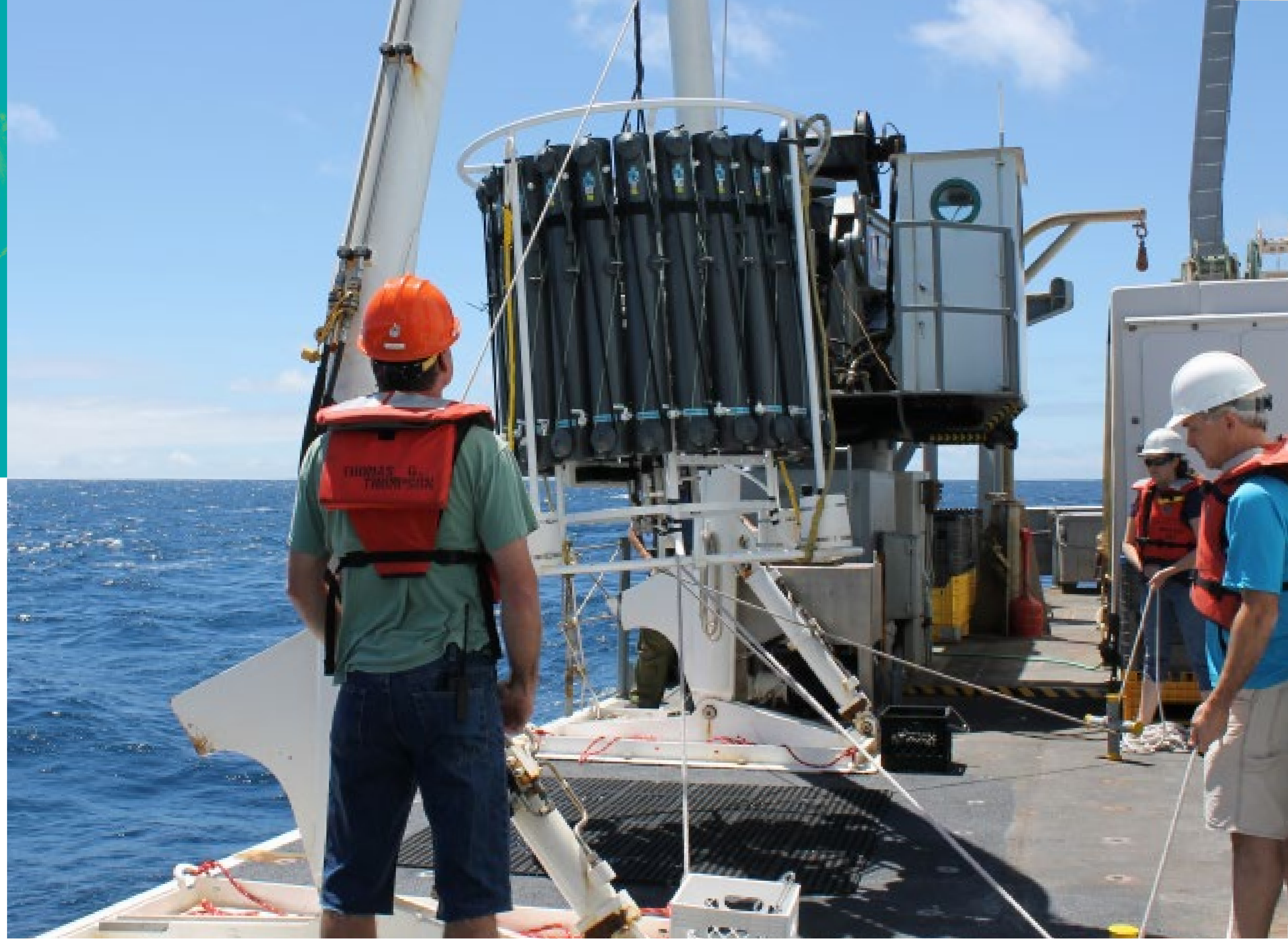


PHOTO: KATLIN BOWMAN

Scientists prepare to lower a CTD into oxygen-deficient waters off the coast of Peru. The instrument was used to gather samples of microbes that live on the brink of these low-oxygen zones.

Life on the Edge of "Dead Zones"

Oxygen-deficient zones in the ocean are sometimes called dead zones, as most sea life cannot survive there. However, as with most other harsh environments on Earth, what is an obstacle for most organisms is an opportunity for others.

Senior Research Scientist Ben Twining and Postdoctoral Scientist Dan Ohnemus have been studying the microbes that thrive along the top fringe of these regions. These bacteria live in the transition area between the oxygenated surface water and the low-oxygen water that lies below. Little is known about the micronutrient requirements of species that reside in these regions of the ocean, as the environmental conditions are difficult to replicate in the lab.

Ben and Dan were the first to measure the elemental composition of these microbes, during a GEOTRACES cruise to an oxygen-deficient zone off South America. They brought particle samples back to Maine and analyzed their content of metals, such as iron, nickel, and vanadium. This year, the scientists discovered that the organisms contained much higher quantities of trace metals — vital and scarce nutrients — than microorganisms that lived above or below them in the water column.

Climate change is driving growth of oxygen-deficient zones around the world and expanding the habitat for these bacteria. By studying the nutrients they remove from the water, the team hopes to understand how the microbes will influence future ocean conditions.

PHOTO: MIKE ALLEN, TRACEY BEACHAM, AND STEVE GSCHMEISSNER

OUR RESEARCH PREPARES

FOR THE FUTURE THROUGH INSIGHTS INTO HOW OUR OCEANS ARE CHANGING

PHYTOPLANKTON PRODUCTIVITY IN THE GULF OF MAINE

DROPPED 80%

FOLLOWING THE ONSET OF SEVERAL ANOMALOUSLY RAINY YEARS

Wavelengths of Change in the Gulf

The Gulf of Maine has long nurtured the rich community of microscopic plants and animals that underpin one of the most productive marine ecosystems on Earth. But the Gulf is changing, and rising temperatures and shifting climate patterns are two of the primary drivers.

Bigelow Laboratory scientists have discovered that increasing river runoff is yellowing the Gulf of Maine. This shift appears to be reducing the light available to phytoplankton for photosynthesis and growth, causing a marked decline in productivity at the foundation of the food web. Led by Senior Research Scientist Barney Balch, the team published its findings this year, including a comparison of its water color measurements with those collected by Henry Bryant Bigelow more than a century ago.

River water is rich in dissolved organic carbon that is leeched from dead leaves and soil on its way through the watershed. Much like steeping a tea bag, these humic substances impart a brown color to the waters that eventually flow into the Gulf.

Scientists predict that precipitation and runoff into the Gulf of Maine will continue to increase throughout the 21st century. Moreover, like tea, the steeping of humic materials intensifies as temperatures increase. This research reveals the complexity of the impacts that could be affecting some of the keystone species that support this remarkable ecosystem.

Arctic Models versus Measurements

Computer models can provide vital insights to future environmental conditions. This information is especially valuable to communities and governments on the forefront of climate change. However, models are only helpful if they are accurate, so it is essential for scientists to evaluate and continuously improve them.

Researchers at Bigelow Laboratory recently completed a thorough comparison of actual measurements taken in the Arctic Ocean to simulations generated by general circulation and Earth systems models. By leveraging 50 years of compiled field data, the scientists were able to examine how well models could reproduce the activity at the bottom of the marine food chain, as well as the three primary non-biological factors that influence its production — food, light, and water mixing.

The study was published in December 2016 by Senior Research Scientist Paty Matrai and Postdoctoral Scientist Younjoo Lee. It was a follow-up to a similar paper they wrote together in September 2015 that evaluated ocean color model simulations. For both projects, the researchers partnered with numerous international modelers who ran simulations based on the data the team provided.

The papers have generated great interest in the scientific community. By studying the models that yielded the best results, scientists should be able to hone their approaches and provide better projections about our rapidly changing planet.

PHOTO: JESICA WALLER

Looking into the Future of Lobsters

Maine fishermen harvested more than a half billion dollars worth of lobsters last year, but there is growing concern over this iconic fishery. As the ocean warms and becomes more acidic, scientists are working to understand how these changing conditions will impact the species and the fishery.

Senior Research Scientist David Fields and Research Technician Jesica Waller recently conducted a series of experiments to examine how the expected environmental changes are likely to affect lobsters during their vulnerable larval stages. This cooperative research project with the University of Maine brought scientists from both institutions together to provide insights into these emerging challenges.

The team, including four summer interns, raised more than 3,000 lobster larvae at the Laboratory — some in water matching today's conditions and some in water matching the temperature and acidity predicted for the Gulf of Maine at the end of the century.

While increased acidification had little direct impact, the young lobsters struggled to survive in water that was just 3 degrees Celsius warmer than current conditions. As Gulf of Maine temperatures are expected to rise 5 degrees by 2100, this finding suggests the lobster population will shift further north during that time and create economic challenges for many of Maine's coastal communities.

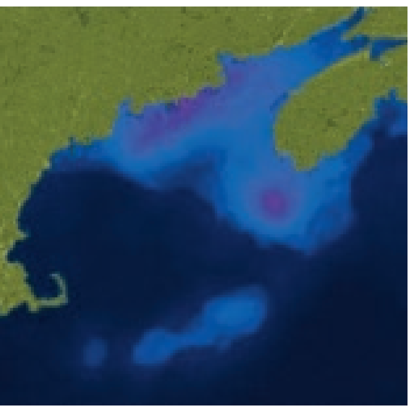
The team plans to continue this research into how lobsters, and Maine's lobster industry, might fare over the next century.

American lobsters are particularly vulnerable to the effects of warming water temperatures and ocean acidification during their first few weeks after hatching. A team of scientists raised more than 3,000 lobster larvae this year to test the young lobsters' ability to cope with the expected future ocean conditions.

OUR RESEARCH

EQUIPS

COMMUNITIES AND INDUSTRIES WITH VITAL INFORMATION AND TOOLS



Mathematical modeling and citizen science data can be combined to create environmental forecasts. In this example, the map shows where beachgoers and mariners are likely to encounter jellyfish on the forecasted day.

Cloudy with a Chance of Jellyfish

Imagine a world without weather forecasts. Would you leave the windows open? Pack shorts or pants? Go on that camping trip or stay home?

Forecasting has changed the way people and businesses interact with the weather, and it is far from the only environmental condition that scientists may be able to predict. Senior Research Scientist Nick Record identifies candidates for forecasting and then develops the models and datasets needed to make them a reality.

This year, Nick officially launched his forecast for Maine jellyfish. Throughout the summer of 2016, he used a predictive model he developed to produce forecast maps that showed where people were most likely to encounter jellyfish. He is currently evaluating and refining the model, and he hopes to release a daily forecast for beachgoers and mariners throughout the summer of 2017.

Further south on the Eastern Seaboard, Nick also launched a forecast as part of a contract with the South Carolina Aquarium. The forecast uses data on the trash that Aquarium volunteers find on beaches to predict the distribution of marine debris along the South Carolina coastline.

With many other useful environmental forecasts in the works, Nick is expanding the toolset available for people to use when planning and preparing to interact with the environment.

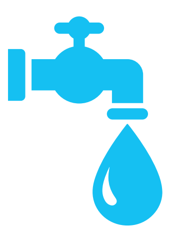
Cost-Saving Insights for Industry

Microscopic organisms can sometimes be major nuisances. This year, Bigelow Laboratory helped provide valuable insights on some microbes that were making a mess of a water company's filtration system.

Carol White is a Maine hydrologist who works with the water industry on well monitoring and water quality. One of her clients draws water from pristine, spring-fed aquifers but would frequently need to replace the filters it uses to produce its drinking water. There was evidence that microbes, including ones that oxidize iron, might be to blame, and she reached out to Senior Research Scientist Dave Emerson for assistance.

Dave, with the help of Postdoctoral Scientist Jarrod Scott, set out to study the microbial communities in the two problem wells and identify the culprits behind the clogging. Using DNA-based community analysis, they determined that the two wells were actually dealing with different nuisance organisms — iron oxidizers and methane oxidizers. Both types of microbes were taking advantage of the natural resources coming from the surrounding rock in the aquifer and converting them to energy for growth.

While neither microbe appears to have yet been described in scientific literature, they are similar to other organisms Dave studies. He is now working to develop strategies to mitigate the impact of the problem microbes by relocating them away from the company's filters.



MICROORGANISMS CAUSE

BILLIONS OF DOLLARS

OF DAMAGE EVERY YEAR TO THE NATION'S INFRASTRUCTURE

New Approach to Problem Solving

The ocean is changing in ways that are difficult to see and even more difficult to understand. Industries, communities, and policymakers on the front lines of these changes can no longer use past experience to guide them, and they are looking for ways to predict and adapt.

To better address these issues, we developed a new approach to solving problems through science this year — Centers for Venture Research. Targeting two critical issues, our CVRs match urgent stakeholder needs with the scientific information required to make sound decisions in the face of extraordinary change.

The Opening Arctic Ocean

Nowhere is the power of climate change as evident as the Arctic. The significance and extent of the ongoing transformation are difficult to overstate. As the polar ice melts, new challenges and opportunities are emerging. The world is facing questions it has never had to answer before.

That is why we formed the Center for Venture Research on the Opening Arctic Ocean, and it is also why representatives of concerned nations and indigenous communities formed the Arctic Council. This intergovernmental group met in Portland, Maine, in October 2016, providing us an opportunity to engage Arctic leaders with our unique perspective on the changes and challenges in the Arctic.

Bigelow Laboratory scientists engaged in public presentations and personal conversations throughout the weeklong meeting. Senior Research Scientist Christoph Aeppli, director of the CVR, participated in panel discussions on industry and research synergies in the Arctic, as well as on marine pollution issues in the Bering Strait.

Some of the most important developments were the relationships that were built or strengthened with community leaders, Arctic researchers, and industry representatives. These invaluable conversations provided us with the opportunity to share our knowledge and identify where our science can make the biggest difference in the coming years.

Seafood Solutions

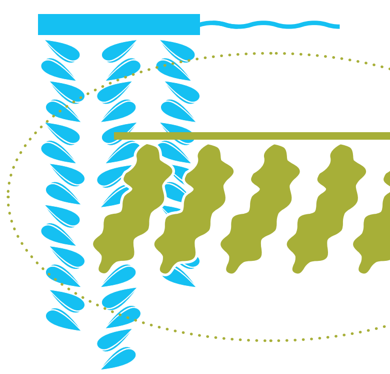
Our Center for Venture Research for Seafood Solutions is operationalizing our wild harvest and aquaculture research. Through the CVR, we collaborate with industry partners to identify critical needs, secure new funding sources, and rapidly deliver actionable data. Senior Research Scientist Nichole Price directs the CVR, which has made major strides in its first year.

Ocean acidification is one of the primary environmental threats facing the $1 billion U.S. shellfish industry. As the ocean absorbs an increasing amount of carbon dioxide, its waters are becoming more acidic. This can be devastating to the health and reproduction of shellfish, and solutions are needed to mitigate the impact.

During her ongoing studies at Ocean Approved's kelp farm in Casco Bay, Nichole's research revealed that kelp has a "halo effect" on its surrounding waters, enhancing its quality by removing excess carbon dioxide. This can increase growth rates for shellfish in the area and may even be enough to protect against acidification of coastal waters.

Through the CVR, her collaboration with industry partners and other nonprofits will continue in 2017 as she works to study the scope of the halo created by kelp, develops tools to measure and maximize the benefits, and equips shellfish and kelp farmers with the resulting knowledge and technology.

OUR CVRS HAVE REDEFINED OUR ABILITY TO HELP SOLVE URGENT PROBLEMS.



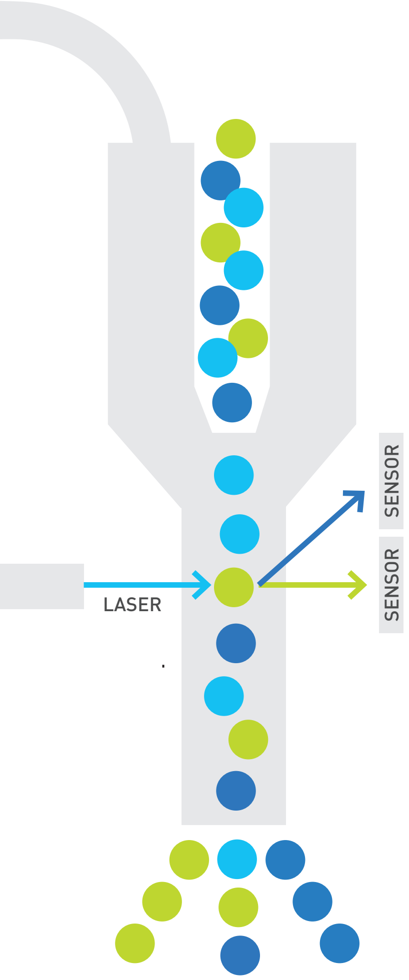
Kelp enhance the quality of their surrounding water by removing extra carbon dioxide from it as they grow. This "halo effect" can increase growth rates for nearby shellfish, such as mussels.

OUR RESEARCH

EDUCATES

STUDENTS OF ALL AGES THROUGH HANDS-ON SCIENCE PROGRAMS

Flow cytometers create a single-file stream of cells contained in a fluid. Each cell then passes by a laser, and sensors gather the data needed to rapidly analyze and sort them.



Shedding Light on Aquatic Microbes

A flow cytometer enables scientists to rapidly detect, count, and sort cells within a liquid. While there are many training courses available on its use for biomedical purposes, Bigelow Laboratory conducts a unique course dedicated to the use of flow cytometry for aquatic environments. Our scientists pioneered this application of flow cytometry in the 1980s, and they remain some of the foremost experts in this specialized technique.

Research Scientist Nicole Poulton is director of Bigelow Laboratory's Facility for Aquatic Cytometry. This year, she revamped and led our five-day Introduction to Aquatic Cytometry course, attracting a group of specialists from across the country.

Mornings consisted of discussion on the principles and applications of flow cytometry led by Nicole and several Bigelow Laboratory scientists who use the technique in their research. Afternoons were reserved for hands-on training in the Laboratory's J.J. MacIsaac Facility for Aquatic Cytometry. The students learned about using the machines for both freshwater and saltwater applications, including best practices for running samples, cleaning the machines, and preserving samples in the field.

Nicole plans to offer the introduction course again in future years and will likely expand the Laboratory's offerings to include an advanced course.

The Art of Spotting Harmful Algae

Scientists have developed powerful molecular and genetic tools to identify harmful algal bloom species during the last 20 years. However, scientists need to know what species they are looking for in order to use those new techniques. With climate change disrupting expectations of when and where species are likely to appear, there is renewed interest in training people to recognize harmful algae by their appearance.

In August 2016, we hosted a 10-day, NOAA-funded course designed to teach classic methods of microscopic identification to 17 people responsible for monitoring harmful algal blooms across the country. Senior Research Scientists Cindy Heil and Mike Lomas led the course and enlisted the help of some of the country's top experts in phytoplankton taxonomy.

The course was a mix of lectures, demonstrations, and hands-on time using microscopes to examine samples of harmful diatoms, flagellates, and dinoflagellates. The visual differences between toxic and non-toxic strains of these algae are often extremely subtle, but they can be seen by a carefully trained eye.

Advanced molecular techniques may one day make this morphological expertise obsolete. For now, climate change is breathing new life into this dying art.

HARMFUL ALGAE IDENTIFICATION COURSE PARTICIPANTS CAME FROM:

7 STATE AGENCIES

3 FEDERAL AGENCIES

3 NATIVE AMERICAN TRIBES

3 UNIVERSITIES

1 OCEANOGRAPHIC INSTITUTE

While participants came from diverse institutions, they were all professionals responsible for monitoring harmful algal blooms and safeguarding human health.

Colby College students collect water samples on the Damariscotta River during the Changing Oceans semester-in-residence program at Bigelow Laboratory.

Engaging with a Real-World Issue

An unprecedented harmful algal bloom this year provided a unique opportunity for semester-in-residence students studying at Bigelow Laboratory.

Each fall, the Laboratory hosts a group of undergraduate students for an immersive, hands-on semester in marine research. When a bloom of toxic *Pseudo-nitzschia* algae closed shellfisheries throughout New England in September 2016, Senior Research Scientist Peter Countway saw a unique opportunity to engage the students with a cutting-edge genetic technique.

Pseudo-nitzschia is difficult to count by looking at a seawater sample through a microscope. As a diatom, the phytoplankton forms long, tangle-prone chains that make manual counting even more time-consuming. Peter uses an advanced molecular technique that quickly detects and counts the copies of a gene that is specific to *Pseudo-nitzschia*.

The students collected samples from set locations along the length of the Damariscotta River. Once back in the lab, they worked with Peter to analyze the samples and determine the abundance of *Pseudo-nitzschia*. Using the molecular technique, they could analyze all the samples from a river cruise in about 90 minutes.

Their findings contributed valuable data to the team of Bigelow Laboratory scientists working to understand the unusual algae bloom and uncover ways to predict similar events in the future.

OUR RESEARCH

INSPIRES

PEOPLE TO SEE THE OCEAN — AND SCIENCE — IN NEW WAYS

PHOTO: LAURA LUBELCZYK

Ostracods are miniature crustaceans that serve as an important food source for many marine species. This image is one of 18 photographs that compose the Tiny Giants exhibit.

Making the Invisible Visible

Marine microbes matter. These microscopic plants and animals provide a foundation for life on Earth — both in the ocean and on land. They produce half the oxygen we breathe, serve as a source of food for marine life from fish to whales, and help mitigate the effects of climate change. And yet, their enormous influence is dramatically contrasted by their diminutive size.

We wanted to engage people with this idea and introduce them to some of the most influential yet least-known organisms on the planet. So, we created Tiny Giants to reveal marine microbes on a grand scale. The photographic exhibit features 18 large-scale images, up to four feet wide, that provide people with a new way to admire the beauty and surprising intricacy of these organisms.

Bigelow Laboratory scientists captured the images during the course of their research using a variety of high power microscopes. Most of the photographs depict organisms less than the width of a human hair, but each plays a vital role in sustaining our planet.

Tiny Giants toured the Northeast throughout the year, with stops in Maine, New Hampshire, Massachusetts, Rhode Island, and New York City. This provided us with many unique opportunities to share the fascinating stories of these amazing organisms and our research to better understand them.

OCEAN EMISSIONS OF CLOUD-FORMING DMS GAS COULD

DECREASE 20 PERCENT BY 2100

The Science Behind the Art

Bigelow Laboratory's first artist-in-residence, Carter Shappy, found his inspiration in the work of Senior Research Scientist Steve Archer. Steve studies the exchange of gases between the ocean and the atmosphere.

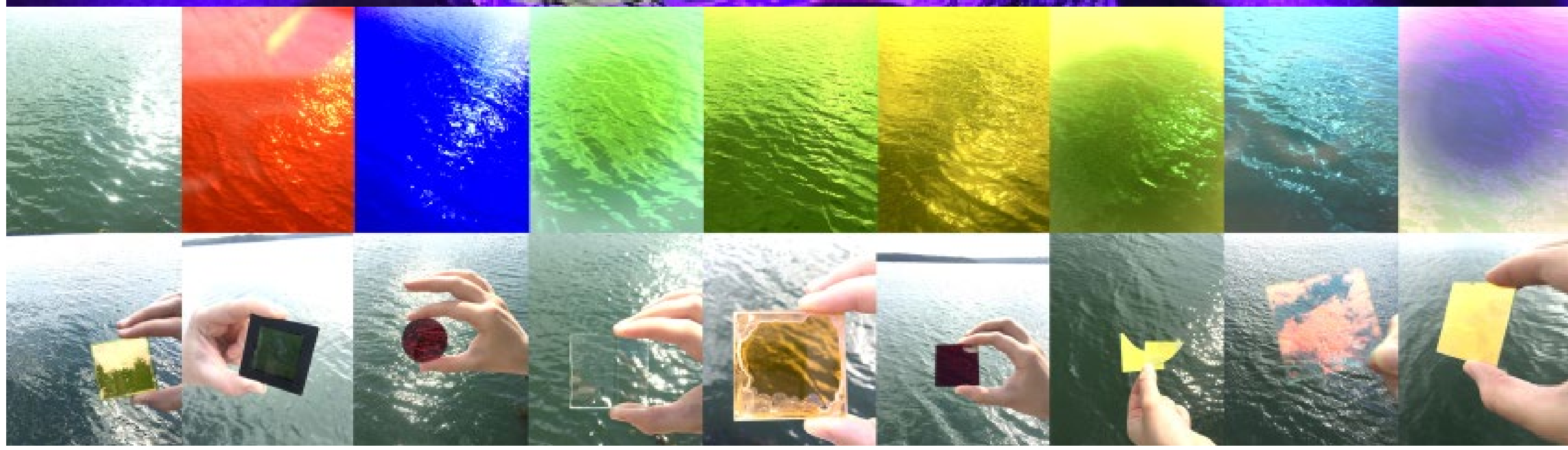
He is particularly interested in a compound called dimethylsulfoniopropionate (DMSP). DMSP provides critical nutrients to marine bacteria and leads to the release of dimethyl sulfide (DMS), a gas that enhances cloud formation and may play a key role in regulating Earth's climate.

To study this process, Steve uses pelagic mesocosms — 60-foot-tall containers that isolate a column of seawater for experimentation. Once deployed into the ocean, scientists can manipulate the water inside the mesocosm to test how a community of microbes responds to changes in the environment. The shape of these submerged cylinders was one of the inspirations for *Colorcosm*, the artwork that Carter created during his time at the Laboratory.

Past mesocosm experiments revealed that DMS emissions decrease as the acidity of the ocean increases. During the last year, Steve has been working with Senior Research Scientists Peter Countway and Paty Matrai to understand why. Understanding the complex processes behind the change in emissions is essential to translating the short-term mesocosm experiments into predictions for the next century.

The scientists have been using samples from two recent mesocosm experiments to examine whether changes in DMS emissions result from rapid responses in gene expression or from longer-term shifts in the makeup of the microbial community.

They are now beginning to compare their results with those from seven previous mesocosm experiments around the world. This may reveal an important positive feedback loop between ocean acidification and rising global temperatures.



Sharing Through a New Lens

Our science is vital and fascinating. It is full of surprising discoveries, staggering beauty, and perplexing mysteries. However, these attributes can sometimes be obscured by the technical and nuanced nature of science, and we are always looking for new ways to connect people with the excitement and intrigue of scientific research.

In 2016, we launched a program to explore how science and art can work together to tell our stories and reveal the hidden world of marine microbes.

Carter Shappy became the first artist-in-residence at Bigelow Laboratory in the spring of 2016. A recent Maine College of Art graduate, Carter worked closely with Senior Research Scientist Steve Archer and his team. Their many conversations and hours in the lab together engaged Carter with the team's research and fueled his creative process. The end result was *Colorcosm*, a two-story artwork that incorporates aspects of what Carter learned about light transmission, ocean acidification, and marine research tools.

Josie Iselin, a fine art photographer and author, joined us as our second artist. She has worked for years to share the world of macroalgae, or seaweed, through her art. This summer, she dove into the world of microalgae and ocean color with the help of Senior Research Scientists Barney Balch, Paty Matrai, and Nick Record. Josie used Barney's collection of antique glass filters to create, *Through A Lens*, inspired by each scientist's individual lens into the ocean.

Carter Shappy created the two-story *Colorcosm* (top) this summer as the first artist-in-residence at Bigelow Laboratory. Josie Iselin followed closely behind him, creating *Through A Lens* (above) from a collection of antique scientific filters.

COLLABORATES

WITH PARTNERS AROUND THE WORLD TO MULTIPLY OUR IMPACT

OUR SCIENTISTS ARE WORKING WITH OYSTER FARMERS ALONG MAINE'S COAST TO STUDY MICROSCOPIC PARASITES.

OUR NEW ALGAE GREENHOUSE PROVIDES

20X

MORE GROWING CAPACITY FOR INDUSTRY COLLABORATIONS

Growing Algae Industry Partners

Marine algae have long attracted the interest of industry. From new medicines to new fuel sources, they are packed with potential to solve many of the world's most pressing problems.

Bigelow Laboratory is home to the National Center for Marine Algae and Microbiota, which has a rich history of studying phytoplankton's environmental role and resource potential. Led by Senior Research Scientist Mike Lomas, the Center surged forward this year with the creation of the Maine Algal Research and Innovation Accelerator (MARIA) — a comprehensive effort to provide the knowledge, infrastructure, and collaboration needed to grow the algae economy in Maine and beyond.

MARIA unifies many of our existing activities and provides a clear indication of areas poised for growth. The hub of this effort, a 3,000-square-foot research and innovation algae greenhouse, took shape during the fall of 2016 thanks to a seed grant by Maine Technology Institute, an impact investment by The Maine Community Foundation, and an anonymous donation.

Through MARIA and this state-of-the-art facility, we are now positioned to take on new and larger industrial partners, better pursue aquaculture solutions and natural products, provide outreach and training, and further enhance the science and art of growing algae in support of innovation.

Parasite Science on the Half Shell

Oyster farmers increasingly rely on the latest scientific research to maximize their harvests and protect their investments.

In May 2016, a team led by Senior Research Scientist José Antonio Fernández-Robledo started working with six oyster farmers to launch a two-year survey for microscopic parasites affecting oysters grown along Maine's coast. The team — which includes Senior Research Scientists Nick Record and Peter Countway, as well as Research Technician Nicholas Marquis — is working to generate the dataset necessary to forecast when and where the parasites are most likely to appear in great number.

Each volunteer farmer collects water and oyster samples throughout the summer. José's team then performs genetic tests on the oyster samples to determine the presence and abundance of five common parasites. They also document the oysters' health and use DNA-based community analysis to look for any correlation between the parasites in the oysters and the microbial community present in the surrounding water. These data may reveal the seasonal timing, geographic hot spots, and conditions preferred by the parasites.

The scientists and farmers hope this information can be used to model the parasites' behavior and develop forecasts that will help farmers safeguard their oysters and prevent the spread of pathogens.

A Search for New Life in the Dark

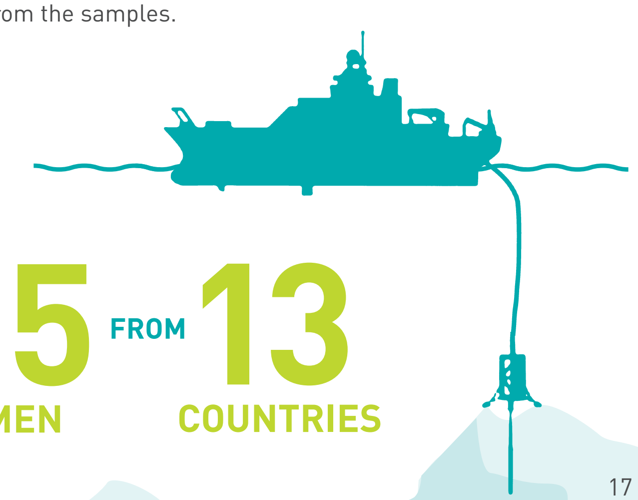
International collaboration is one of the hallmarks of scientific research, but it is often not without its challenges — such as balancing the needs and priorities of 31 scientists from 13 countries.

Senior Research Scientist Beth Orcutt co-led a 47-day International Ocean Discovery Program expedition in October 2015. The team's mission was to collect rock cores from the Atlantis Massif, a 4,000-meter underwater mountain along the Mid-Atlantic Ridge. The ripping apart of tectonic plates underneath the mountain has made it possible to access highly reactive rocks that have been pushed up from Earth's mantle.

When exposed to seawater, mantle rocks undergo serpentinization, a reaction that may be able to sustain microbial life without the need for sunlight. As the rocks are similar to those scientists expect to find on other planets, studying them is an important step in the search for extraterrestrial life.

Beth helped to carefully assemble the multidisciplinary science team needed to study the complex reaction. Once the rock cores were retrieved, they were sent to Germany, where the group gathered for two weeks of intense scientific study and experimentation. The project is ongoing, but the international team has already revealed signs of life, unique carbon cycling, and ocean crust movement from the samples.

SUBSURFACE MICROBES CAN TEACH US ABOUT THE POTENTIAL FOR LIFE ON OTHER PLANETS.



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16 WOMEN AND **15** MEN FROM **13** COUNTRIES

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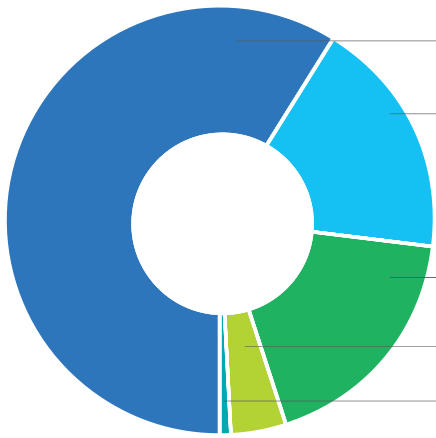
View our audited financial report at bigelow.org/financials

OPERATING REVENUE $10,308,295 TOTAL

An additional $6.2 million of philanthropic support was raised for construction of a residence hall on our campus, along with a **$1 million** endowment to cover its maintenance and upkeep.



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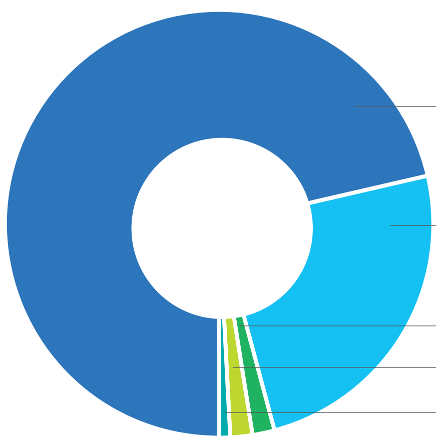
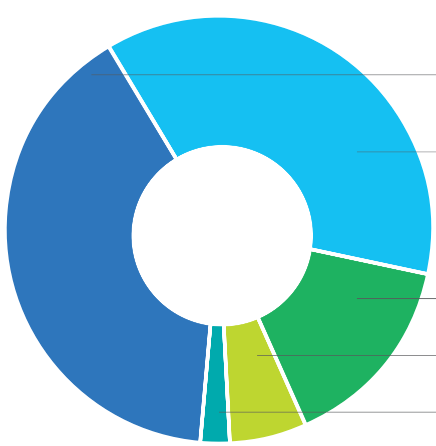
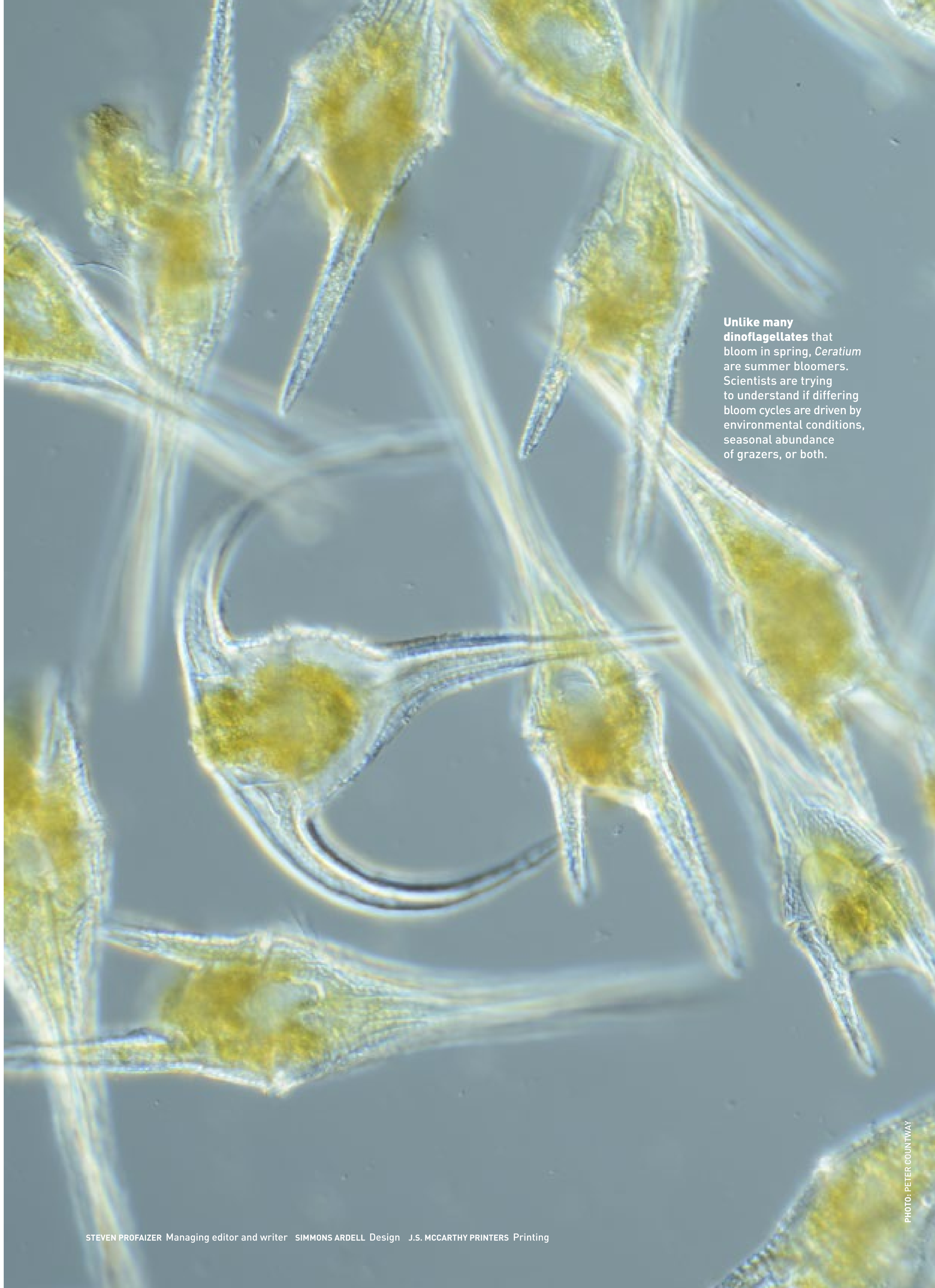


OPERATING EXPENSES $10,083,345 TOTAL





Unlike many dinoflagellates that bloom in spring, *Ceratium* are summer bloomers. Scientists are trying to understand if differing bloom cycles are driven by environmental conditions, seasonal abundance of grazers, or both.

PHOTO: PETER COUNTWAY

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Pseudo-nitzschia (cover) is a neurotoxin-producing marine algae that can cause amnesic shellfish poisoning when ingested. Bigelow Laboratory scientists helped monitor and study an unusually toxic and widespread bloom of this diatom in the fall of 2016.

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