OCEAN INSTITUTES ANNUAL REPORT

2013

Woods Hole Oceanographic Institution

From the President and Director

Since their founding in 2000, the Ocean Institutes have become centers for innovation at WHOI, bringing together oceanography's brightest minds in the pursuit of some of the most pressing scientific questions of our time; 2013 was no different. Beyond the bold new research programs the Institutes made possible this year, we launched two new projects that promise to shape their work for years to come.

The Institutes launched the Ocean Acidification Initiative, an ambitious five-year, cross-institute program aimed at answering complicated, and increasingly urgent, questions about what happens when the chemistry of the ocean changes. Proposals are being funded that include field research, laboratory studies and technological development to better investigate ocean acidification along the U.S. Atlantic Coast, from the Gulf of Maine to Cape Hatteras. This initiative highlights what the Ocean Institutes do best: foster collaborative, high-risk, high-reward science that has important implications not just for the ocean, but also for humanity. You will read about some of this work in the pages to follow.

Photo by Tom Kleindinst

In late 2013, the Institutes completed a comprehensive review of activities and aspirations. The results are a renewal and refinement of the Institutes' goals as well as the creation of an Institutional Strategy Council (ISC). The ISC will identify and prioritize Institutional research initiatives that help support scientists at WHOI, and create clear, unified, messages that can be used across the Institution to enhance fundraising from private sources. These are exciting changes that promise to deepen the value and work the Institutes nurture here at WHOI.

Of course, none of the research sponsored by the Institutes would have been possible without your support. The Ocean Institutes are truly invaluable—they are the bridge between proof-of-concept projects and the innovative, interdisciplinary research that helps guide human stewardship of our planet Earth. On behalf of all of us at the Institution, I thank you for your generous support of the Ocean Institutes. We are all indeed grateful.

Sincerely,

Coastal Oceans Institute

Director's Message

The majority of the world's population lives within 50 miles of the ocean; in fact, two-thirds of the world's largest cities are situated along coastlines. It's no wonder why—the world's coastlines harbor rich resources, from food to fuel, and provide us with unparalleled beauty. But humans' impact on coastal ecosystems is not without repercussions; as the population grows, the climate warms and the sea rises, new scientific questions emerge that demand answers.

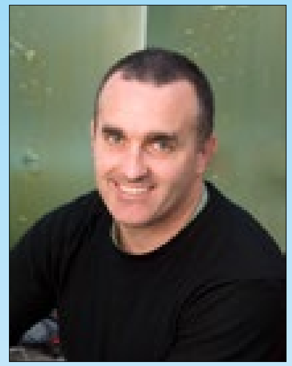


Photo by Tom Kleindinst

COI's scientists are tackling these questions and the work is by nature collaborative, as the projects described in this report highlight. For instance, the Global Rivers Observatory, a network started by WHOI geochemist Bernhard Peucker-Ehrenbrink that samples sites along the world's most important rivers, expanded last year to include the Mississippi River and Tulane University. This WHOI-Tulane partnership would not have been possible without the enthusiastic support of Corporation Member Rodney Yanker and his wife, Mary.

WHOI chemical oceanographer Zhaohui 'Aleck' Wang teamed up with researchers from several institutions to study the effects of ocean acidification in the Gulf of Maine. Wang discovered that this body of water may be more susceptible to changes in acidity, impacting commercially valuable species like clams and oysters. His work has generated questions not just for the scientific community, but for fishermen, policy makers and fisheries managers, as well.

These are just two of the projects funded through the Coastal Oceans Institute in 2013; I hope you enjoy reading about the cutting-edge research being done with the help of your support.

Thank you again for your continued support of COI. Please feel free to contact me with any questions or comments.

–*Chris Reddy*

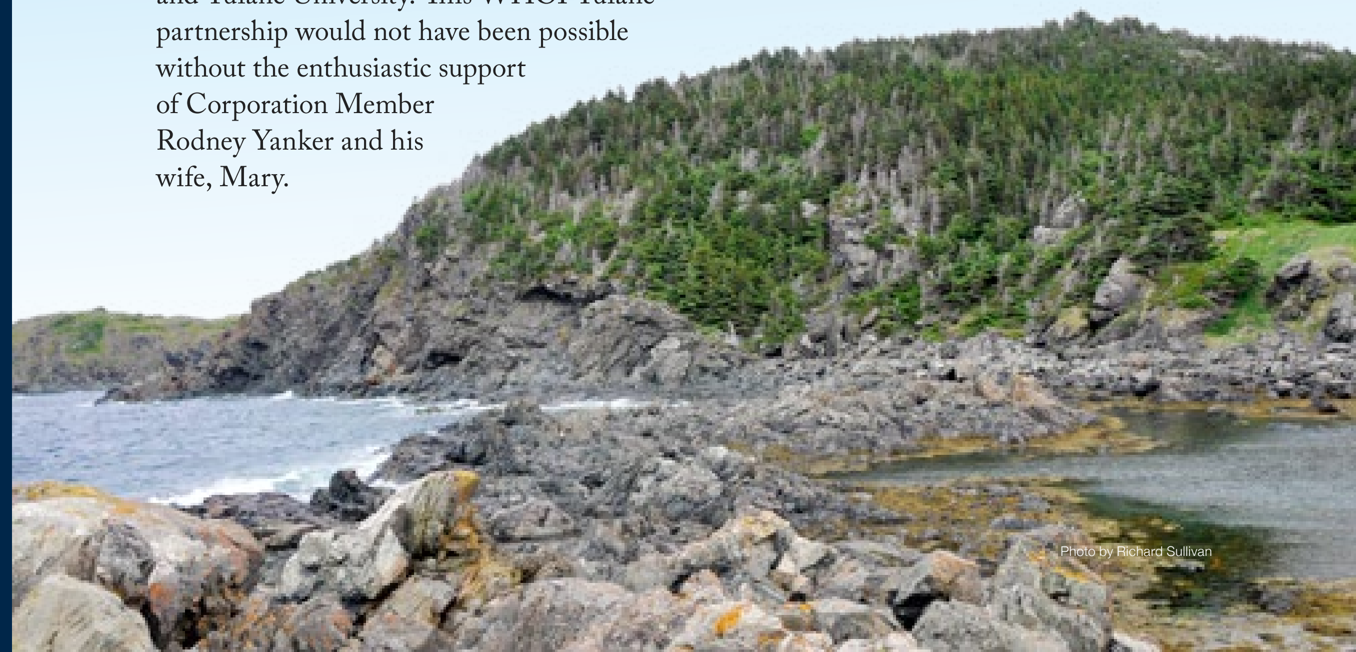


Photo by Richard Sullivan

What Is the Sound of 130 Wind Turbines Turning?

Researchers record undersea sound at offshore wind farm site

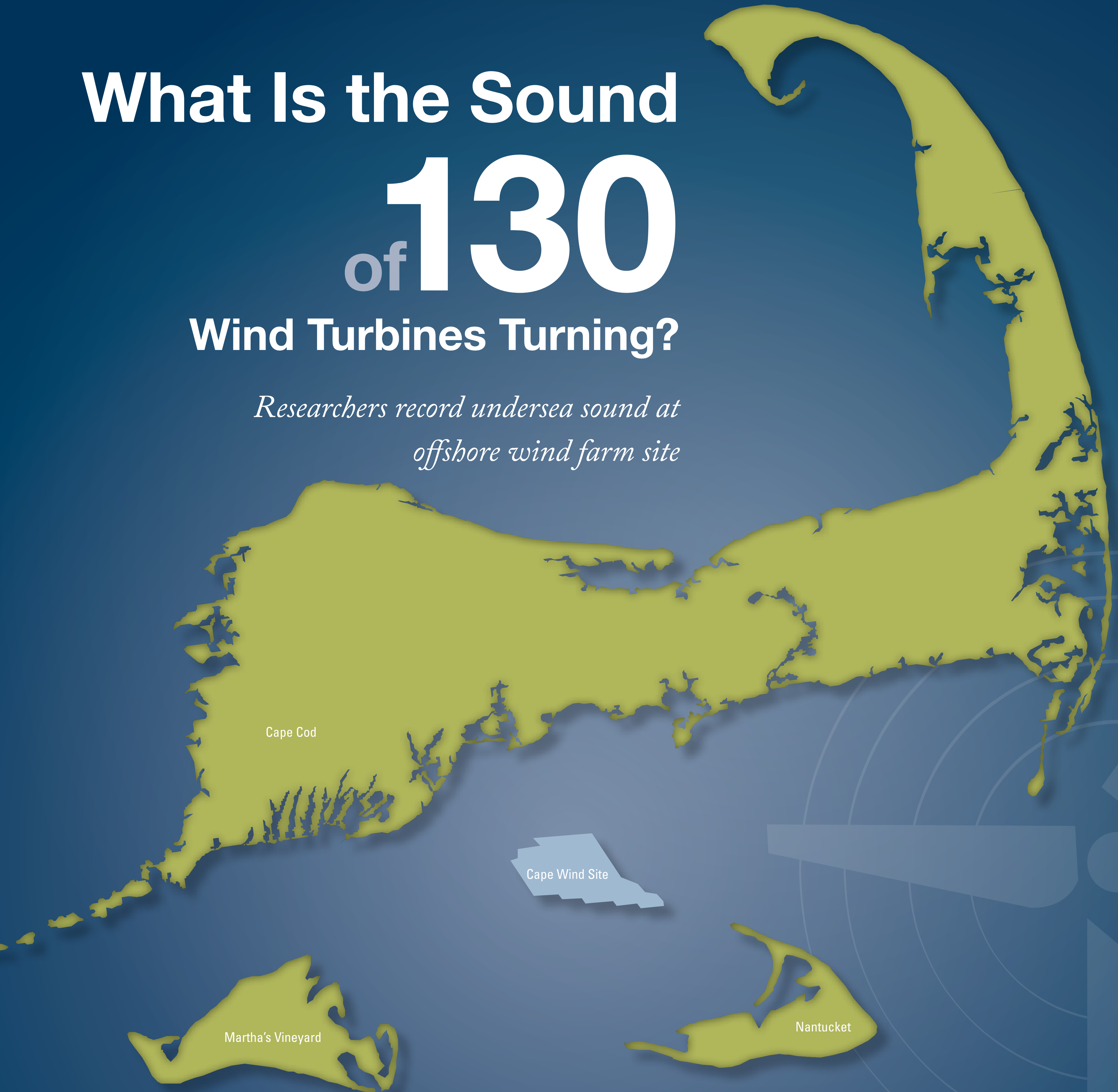


Illustration by E. Paul Oberlander

The country's first-ever offshore wind farm is expected to be installed in Nantucket Sound, the Institution's backyard. Federal officials have checked off a list of potential impacts, from air quality to shipping lanes and whales' migratory patterns. But they haven't studied how sound generated from the 130 440-foot-high turbines might impact life *under* the water.

With funding from the Woods Hole Sea Grant and the Coastal Ocean Institute, biologists Aran Mooney and Laela Sayigh in 2012 began listening to the underwater "soundscape" in the 25-square-mile area where the turbines will stand. Early results of their study revealed both familiar and unfamiliar sounds, and they anticipate learning more about what animals live there, how abundant they are, and what they are doing.

Marine animals use a range of frequencies to perceive their environment. "In a nice, healthy habitat, you have a spectrum of sounds: low-frequency sounds of fish, then invertebrates a little bit higher, and then the seals and the dolphins," Mooney said. Turbine construction may cause environmental stress, and perhaps change the soundscape.

Mooney and Sayigh are hoping to "listen" during and after construction. Mooney said this first-of-its-kind experiment could serve as a template for assessing the impacts of future U.S. offshore wind turbine projects.

WHOI biologists Aran Mooney and Laela Sayigh were awarded $10,000 from COI for their work studying the soundscape at the Cape Wind site.

A Growing Network

Photo courtesy of Bernhard Peucker-Ehrenbrink

WHOI geochemist Bernhard Peucker-Ehrenbrink sampling water in the Fraser River in British Columbia in 2011.

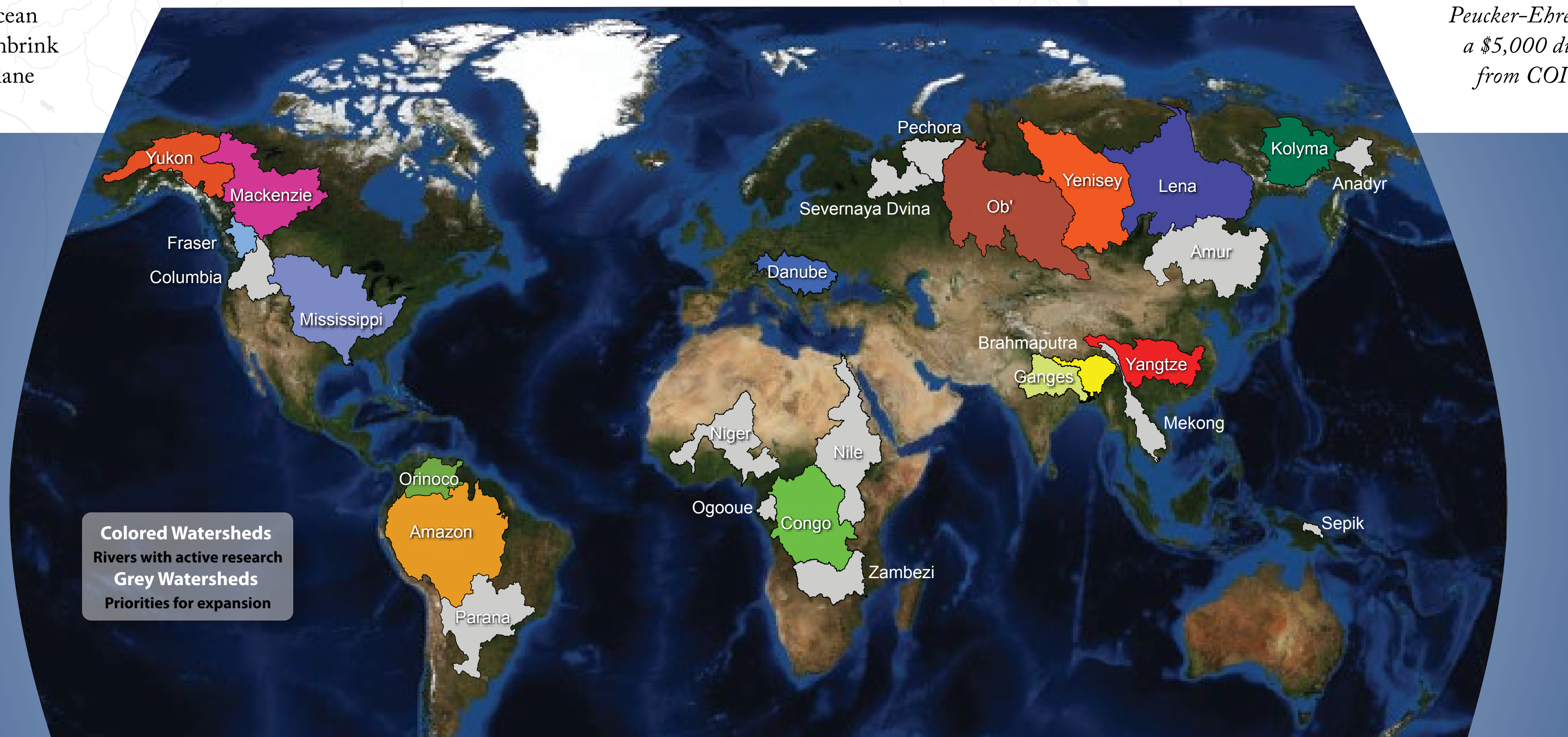
Five years after WHOI geochemist Bernhard Peucker-Ehrenbrink began sampling rivers as part of the Global Rivers Observatory, the international collaboration has grown to encompass 15 watersheds worldwide. The project measures the chemical composition of rivers to advance our understanding of how human-made disturbances like deforestation and climate change impact land-ocean links.

With the help of private funding from the Coastal Ocean Institute, Peucker-Ehrenbrink began working with Tulane University in 2013 to sample monthly in the Mississippi River. His team also will install a sensor system on a dock in downtown New Orleans to collect temperature, salinity, turbidity and other data about the Mississippi River every half hour—a first for the Observatory. Peucker-Ehrenbrink hopes to eventually install a sensor system at every river they study, coming one step closer to his vision of a public database of the world's major river systems.

"We can combine the [real-time] data with the physical samples we have," he said. "Then anyone who visits our website would essentially get a global overview of the status of these rivers."

Without private funding, work along the Mississippi would not have been possible, Peucker-Ehrenbrink said. "It's really a few individuals who make the difference," he said. "People like WHOI Corporation Member Rodney Yanker and his wife, Mary, who see the possibilities of connecting institutions—then all of a sudden you put another river on the map."

Corporation Member Rodney Yanker and his wife, Mary, awarded $10,000 to Bernhard Peucker-Ehrenbrink for his work with Tulane University. Peucker-Ehrenbrink also received a $5,000 discretionary award from COI.



Small Changes Big Impacts

Understanding ocean acidification on the East Coast

Photo by Nancy Copley

Coastal ocean acidification can occur when excess carbon dioxide is absorbed by, flushed into, or generated in coastal waters, setting off a chain of chemical reactions that lowers the water's pH, making it more acidic. One large source is carbon dioxide in the atmosphere, which has steadily increased in concentration over the last 150 years. Increased biological activity encouraged by human-made nutrient runoff like fertilizers can decrease oxygen levels and increase CO_2 and acidity as well. Species like oysters, snails, pteropods, and coral are disproportionately affected, since those organisms have problems forming and maintaining shells in a more acidic environment.

Research into the impacts of ocean acidification is raising some big questions not just for scientists, but for fishermen, too. In a study published in the journal *Limnology and Oceanography* in January, 2013, chemical oceanographer Zhaohui 'Aleck' Wang wrote that the U.S. Northeast coastal waters, including the Gulf of Maine and the Middle Atlantic Bight, may be more susceptible to ocean acidification than previously thought, an issue that may impact the future of healthy fish and shellfish stocks.

The multi-institution study surveyed distinct bodies of water, such as the Gulf of Mexico and the Gulf of Maine, to find out how they resist changes in acidity by measuring varying levels of pH, carbon dioxide (CO_2) and other forms of inorganic carbon in the ocean.

"Before now, we haven't had a very clear picture of acidification status on the East Coast of the U.S.," Wang said. "It's important that we start to understand it, because an increase in ocean acidity could deeply affect marine life along the coast and has important implications for people who rely on aquaculture and fisheries."

The study found that different regions of the coastal ocean will respond to an influx of CO_2 in different ways. "If you put the same amount of CO_2 into both the Gulf of Maine and the Gulf of Mexico right now, the ecosystem in the Gulf of Maine would probably feel the effects more dramatically," Wang said. "Acidity is already relatively high in that region, and the saturation of calcium carbonate—the mineral that many organisms need to make shells—is particularly low. It's not a great situation."

Wang and his colleagues found that a large portion of the Gulf of Mexico showed a high ratio of alkalinity to dissolved inorganic carbon (DIC), meaning it would be more resistant to acidification. But as the team traveled farther north, they saw the ratio steadily decrease. The waters in the Gulf of Maine had the lowest alkalinity to DIC ratio of any region along the eastern seaboard on average, meaning that they would be especially vulnerable to acidification should CO_2 levels rise in those waters, Wang said.

Photo by Nancy Copley

Zhaohui 'Aleck' Wang

While it's unclear exactly why this ratio is lower in northern waters, Wang thinks part of the issue may be linked to alkalinity sources in the region. For example, an along-shore current that originates from the Labrador Sea brings relatively fresh, low alkalinity water down to the Gulf of Maine and the Middle Atlantic Bight. Local river water that discharges into the coast also has very low alkalinity.

If the along-shore current is the major source of alkalinity to the region, it may mean that the Gulf of Maine's fate could be linked to changes in global climate that, through melting sea ice and glaciers, increase the flow of fresh water to the Gulf of Maine, he said. However, whether this freshening is accompanied by a decrease in seawater alkalinity and "buffer" capacity remains unknown.

Photo by Peter Wiebe

"How are oysters going to be affected? What about other shellfish?" Wang asked. "If the food chain changes, how are fish going to be impacted?" Fisheries regulators will be better able to manage fish stocks if scientists can get a better understanding of this changing ocean chemistry, he said.

COI awarded Zhaohui 'Aleck' Wang $49,500 in 2012 for the study, "The marine inorganic carbon system along the Gulf of Mexico and Atlantic coasts of the United States: Insights from a transregional coastal carbon study." He also got a $9,600 supplement in 2013 from all four Ocean Institutes as part of the Ocean Acidification Initiative.

Photo by Erin Koenig

Other Coastal Ocean Institute projects funded in 2013

The Response of Mercury Species and Related Genes to Long-term Fertilization in a New England Salt Marsh

- Carl Lamborg, Marine Chemistry and Geochemistry
- Tracy Mincer, Marine Chemistry and Geochemistry

Coastal Sea Level from the Mid-Atlantic United States to Canada—What Causes the International Variability in this "Hotspot" of Sea Level Rise?

- Magdalena Andres, Physical Oceanography

Can Old Plants Learn New Tricks? Testing Adaptation Potential of Crustose Coralline Algae Along a Natural Gradient in Ocean Acidification*

- Anne Cohen, Geology and Geophysics

Funding Highlights

COI's total spending for 2013 was $420,812. Although the Institute focused the majority of its funding on research grants ($139,858), significant support also went to fellows, graduate education and outreach activities. COI supported one fellow in 2013, Dan McCorkle ($108,152), and postdoctoral scholars Christopher Hein and Roxanne Beinart ($97,939). Discretionary and communications funding was also used for conferences and publications ($46,076).

**Also funded by the Institutes' Ocean Acidification Initiative*

"Without your support, this forward-thinking work would be much more difficult, if not impossible, to complete."

Ocean & Climate Change Institute

Director's Message

As it has for the past 13 years, the Ocean and Climate Change Institute continues to support the critical research that will help us understand how Earth's climate system works, how climate is changing with time, and what that means for the ocean and people.

Our researchers fanned out across the globe in 2013, funded with seed money to kick-start basic research, grants to continue studies with implications for government policy and society, and support to nurture high-risk projects that meet the goals of OCCI.

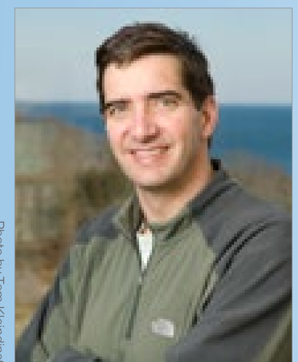


Photo by Tom Kleindinst

In the following pages you'll read about some of the work OCCI has funded over the past year. WHOI researchers got a glimpse under the ice in the Arctic, discovering a plankton bloom with four times more plankton than in neighboring ice-free waters. Until this discovery, sea ice was thought to block sunlight and limit the growth of microscopic plants living under the thinning ice in the Arctic. Our scientists also looked back in time, probing historical data to understand how wind and sea surface temperature changes in the Indian Ocean can affect farmers in southwest Australia. Other researchers and engineers even deployed to the fjords of Greenland to study the melting of the massive Greenland Ice Sheet. In these and other projects supported by OCCI, scientists tested new technology developed right here at WHOI to help them answer these questions.

I am pleased to introduce you to OCCI's newest fellow, Kristopher Karnauskas (G&G). With funding from the James E. and Barbara V. Moltz Institute Research Fellowship, Kris will also peer into the past to improve our understanding of climate variability over the timespan of centuries. His research focuses on understanding the dynamics of the tropical ocean and atmosphere as a coupled system, its interaction with ecosystems and with higher latitude regions. He'll do this by incorporating global climate model simulations with on-site observations, along with paleoclimate proxies and high-resolution ocean models.

Without your support, this forward-thinking work would be much more difficult, if not impossible, to complete. We are grateful for your continued support of OCCI scientists, engineers and postdoctoral and graduate students.

–*Scott Doney*

Photo by Benjamin Linhoff


Photo by Clark Richards

Innovation on the Ice


Photo courtesy of Fiamma Straneo

WHOI researchers use novel tools to study the melting Greenland Ice Sheet

The Greenland Ice Sheet is one of the world's largest deposits of freshwater ice and it's melting at a record pace. These changes could have huge impacts on global sea level, marine life, ocean circulation patterns and Earth's climate, yet studying this remote, unforgiving region is dangerous, expensive and difficult. For glaciologists like WHOI's Sarah Das, getting the right people and equipment to the ice is half the challenge of executing a successful field mission in Greenland.

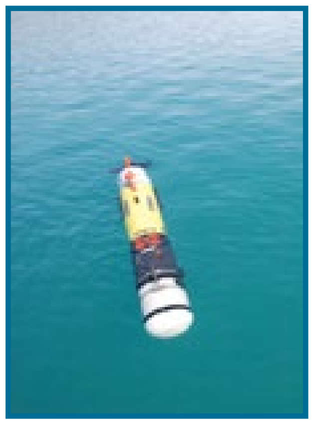


Photo by Robin Littlefield

"Polar ice sheets are really under-sampled in terms of understanding how they work and how they are changing," Das said. "[Answering] a lot of the big questions means we're turning to numerical models, but the models are only as good as what they're built on, so it comes back to needing to get a lot more observations."

With funding from the Arctic Research Initiative and the Ocean and Climate Change Institute, Das and a team of WHOI scientists and engineers carried out two field missions in July 2012 and 2013. Their goal was to use novel techniques and equipment to learn more about how glacial meltwater travels from the top of a glacier out to sea, as well as the fate and characteristics of that meltwater in the ocean.

For instance, roving helicopters deployed ocean moorings along the ice front—which Das said is a first—and took aerial photos. The team also tested a prototype vehicle called a "Jetyak," a modified kayak developed by WHOI engineer Hanu Singh that is capable of autonomously navigating to the edge of a glacier to take samples, measurements and video.

Testing the tools didn't come without surprises. When they deployed a REMUS (Remote Environmental Monitoring UnitS) autonomous underwater vehicle (AUV), engineers were at first perplexed as to why the robot was having trouble communicating with the acoustic pingers positioned on moorings in the fjord. The team soon realized that the noise from calving icebergs and melting glacial ice chunks was interfering with the AUV's navigation.

"Imagine a glass of ginger ale [with all the] popping, fizzing and ice clinking around. It was a unique environment for REMUS," Das said. "These are the kinds of things that seem obvious once you've been there, but you just don't know what the challenges are going to be."

REMUS proved to be valuable for the team though, as it was able to navigate close to the ice face and measure physical and optical properties of the water as far down as 100 meters.

The team also detected a plume of glacial meltwater entering the fjord from under the glacier. The plume was below the surface in 2012 and reached the surface at the edge of the glacier in 2013. The upwelling plume drove fish to the surface, attracting hundreds of hungry birds. The meltwater plume had also picked up various chemicals, minerals and sediment in its travels through the glacier. Scientists think the water acquires this "signature" when it comes in contact with bedrock, though they aren't sure of all the details, Das said.

"We have no reason to think that it doesn't—but it's very hard to study the process underneath [the ice]," she said.

The trip also showed the team just how difficult, and expensive, it can be to gear up for even two weeks in an extreme climate and remote location like Greenland. "We had originally planned to also go in the winter and compare conditions during times of low and high meltwater discharge, but we soon realized that undertaking would take more resources than we had available," Das said.

Nonetheless, the team's two summer trips were a success; they applied to the National Science Foundation for funds to analyze their data. Das, who is also former Ocean and Climate Change Institute fellow, said this work wouldn't be possible without support from the Ocean Institutes and WHOI programs like the Arctic Research Initiative.

"WHOI's really an exciting place to work because everybody here is looking for new ways to interact and to tackle new, big science questions," she said. "The fellowship was fantastic for giving me breathing room to explore new ideas, develop new relationships and take some risks scientifically."

WHOI glaciologist Sarah Das, engineers Hanu Singh and Lee Freitag, and physical oceanographers Al Plueddemann and Fiamma Straneo were awarded $457,654 in 2011 by the Arctic Research Initiative for the pilot study, "Seasonal Fluxes Across Submarine Ice Sheet Margins."

Cause & Effect

Exploring how changes in the Indian Ocean affect farmers in Australia

Australia experienced more than half a dozen major droughts in the 20th century, often with disastrous consequences for humans and ecosystems. Scientists have linked these droughts to the Indian Ocean Dipole, an ocean-atmosphere event similar to El Niño that either keeps rain-bearing clouds away from Australia or brings them onshore. As the Indian Ocean generally grows warmer though, dipole events could change in intensity and frequency, making Australia's wet and dry spells more extreme.

WHOI physical oceanographer Caroline Ummenhofer has been at the forefront of studying this phenomenon; her sea surface temperature indices have helped Australian farmers better predict seasonal rainfall. Now, with funding from the Ocean and Climate Change Institute, she is pairing temperature data from corals with ocean models to illustrate how the Indian Ocean Dipole has acted over decades.

"We understand quite well how the Indian Ocean has behaved over the last 20 years," she said. "But it's hard to assess how it's changing if we don't have a good understanding of what the long-term variability has been."

The picture is complex. Not only is the Indian Ocean getting warmer, it is also influenced by events like El Niño. And, when compared to the Atlantic and Pacific Oceans, the Indian Ocean is still vastly under-studied.

"There's so little data," she said. "But that's also why I think it's exciting—there are a lot of unknowns."

OCCI awarded WHOI physical oceanographer Caroline Ummenhofer $74,942 in 2012 for her work studying Indo-Pacific connectivity.

Caroline Ummenhofer

Photo courtesy of Caroline Ummenhofer

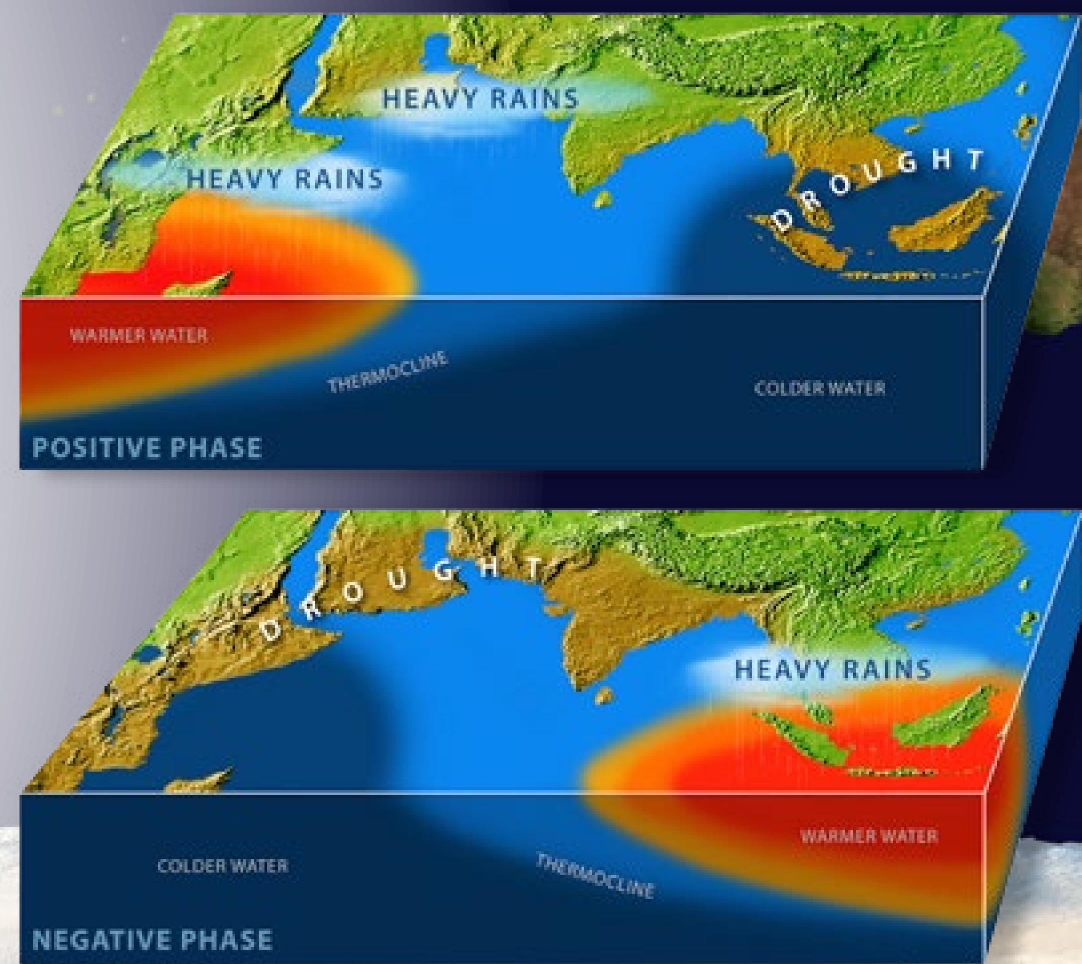


Illustration courtesy of Caroline Ummenhofer

NASA Goddard Space Flight Center Image by Reto Stöckli (land surface, shallow water, clouds). Enhancements by Robert Simmon (ocean color, compositing, 3D globes, animation). Data and technical support: MODIS Land Group; MODIS Science Data Support Team; MODIS Atmosphere Group; MODIS Ocean Group Additional data: USGS EROS Data Center (topography); USGS Terrestrial Remote Sensing Flagstaff Field Center (Antarctica); Defense Meteorological Satellite Program (city lights).

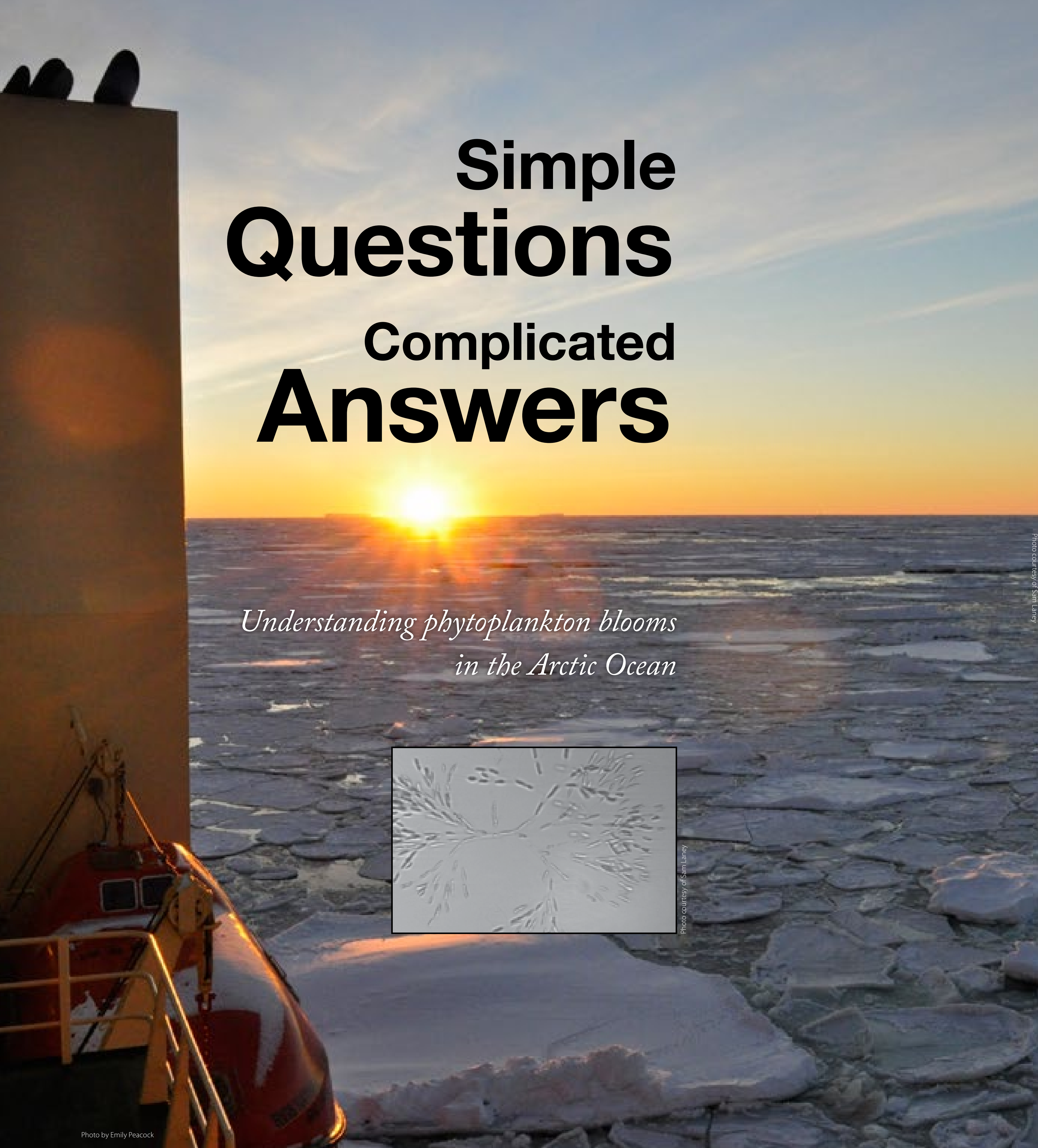


Photo by Emily Peacock

Simple Questions Complicated Answers

Understanding phytoplankton blooms in the Arctic Ocean

Photo courtesy of Sam Laney

Compared to other ocean regions, scientists know relatively little about phytoplankton in the Arctic Ocean—what species live there and how they survive. As significant amounts of sea ice melt over the next decades, understanding the state of organisms at the base of the Arctic food chain *now* will be critical in predicting future changes. With funding from the Ocean and Climate Change Institute, WHOI biologist Sam Laney has begun studying arctic phytoplankton with the goal of understanding what happens from their peak in summer to the dark of winter.

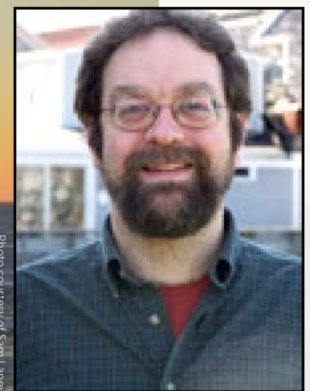


Photo courtesy of Sam Laney

Sam Laney

"These are very basic ecology questions," he said. "If no long-term measurements of phytoplankton have been done under the ice, the first thing you have to do is find out who's there and when. Then you can ask the more interesting questions, like 'How are they doing?'"

Laney modified instruments such as the Imaging FlowCytobot, an automated underwater microscope developed at WHOI, to make it strong enough to work in high-vibration environments such as research icebreakers. He also developed sensors for the Ice Tethered Profiler, an autonomous time-series instrument also developed at WHOI, to measure how deep phytoplankton extend in the water column.

"Climate change in the Arctic is going to have a big effect on phytoplankton; we just can't predict what it's going to be," he said. "The more solid our understanding is now, the more effective we can be in studying ecosystem changes in the Arctic Ocean."

WHOI biologist Sam Laney was awarded $148,091 from OCCI for his study, "Arctic Phytoplankton: Surviving the Winter and Preparing for Spring."

Other Ocean and Climate Change Institute projects funded in 2013

Autonomous CTD Profiling at the Edge of Calving Glaciers

- Fiamma Straneo, Physical Oceanography
- Hanu Singh, Applied Ocean Physics & Engineering
- Sarah Das, Geology & Geophysics

Indian Monsoon Variability, Himalayan Climate, and Terrestrial Ecology from Bhutanese Lake Sediments

- Jessica Tierney, Geology & Geophysics

Reconstructing Marine Nutrients, Their Utilization, and Role in Past CO_2 Sequestration Using Cadmium Isotopes

- Tristan Horner, Marine Chemistry & Geochemistry
- Phoebe Lam, Marine Chemistry & Geochemistry

An Automated Biogeochemical Observatory on a Ship of Opportunity: Biweekly Assessment of the Carbon Cycle in the Northwest Atlantic

- David Nicholson, Marine Chemistry & Geochemistry
- Sam Laney, Biology

North Atlantic Deep Water Formation During the Deglacial Rise of Atmospheric CO_2

- David Thornalley, Geology & Geophysics
- Lloyd Keigwin, Geology & Geophysics

Abrupt Sea Level Change in the Geologic Record: Reconciling Contradictory Evidence

- William Thompson, Geology & Geophysics

Coastal Ocean Acidification and Carbon Cycling Due to Geochemical and Biological Processes: Development of a Novel High-Resolution O_2/H^+ Eddy Correlation Technique*

- Matt Long**, Marine Chemistry & Geochemistry
- Matt Charette, Marine Chemistry & Geochemistry
- Bill Martin, Marine Chemistry & Geochemistry
- Dan McCorkle, Geology & Geophysics

WHOI Coupled Model Intercomparison Project Phase 5 Community Storage Server

- Young-Oh Kwon, Physical Oceanography

Funding Highlights

The total budget for OCCI in 2013 was $597,355. While the Institute spent the majority of its budget on research grants ($336,920), OCCI supported other initiatives including education, student support and communications outreach. The Institute supported fellow Kristopher Karnauskas and postdoctoral scholars Peter Kimball and Ben Harden ($143,054). OCCI also funded outreach activities with discretionary and communications funding ($45,138).

*Also funded by the Institutes' Ocean Acidification Initiative **2013 Ocean Acidification Initiative Postdoctoral Scholar*

Ocean Life Institute

Director's Message

In 2013, OLI funded a wide range of projects through a combination of research grants and fellowships to scientists, postdoctoral investigators and graduate students. As you'll read in the pages to follow, the projects supported by OLI are often cross-disciplinary collaborations that foster technological advances. These, in turn, facilitate cutting-edge science.

Photo by Tom Kleindinst

OLI continues to support initiatives that will enhance ocean conservation science. Since 2011, OLI researchers have been collaborating with the New England Aquarium and Conservation International to deliver a scientific template that will help island nations in the Pacific Ocean develop comprehensive conservation and management strategies in a designated area called the Pacific Oceanscape.

Over the last two years, work has focused on the Phoenix Islands Protected Area (PIPA), part of the island nation of the Republic of Kiribati in the central tropical Pacific Ocean. PIPA remains largely untouched by humans and is therefore a "Rosetta Stone" for understanding how coral reef systems are responding to the changes that have begun to take place rapidly in the 21st century. Our work in PIPA is an excellent example of the potential cross-disciplinary work has for making a profound impact across science, policy and economic disciplines.

Your support of this work has been and continues to be invaluable, and for that, we are grateful.

–*Simon Thorrold*

Photo by Amy Apprill

New Beginnings

Using larvae to understand how the sea repopulates itself after a destructive event

When a hydrothermal vent erupts, it can wipe out whole communities of thriving animal life. But just as in a forest scorched by wildfire, new species soon colonize these barren regions, continuing the cycle of renewal after destruction. After a 2006 hydrothermal vent eruption along a section of the Eastern Pacific Rise known as "9 North," scientists discovered larvae that came from nearly 300 miles away. The transport of larvae from their birthplace to a new community is known as "connectivity," and WHOI biologist Lauren Mullineaux says understanding how the ocean populates itself will help scientists better predict what disturbances like deep sea mining may have on life along the seafloor.

"Part of the reason I like working at vents so much is because it's a disturbance-dominated environment," she said. "Not only can you study the dynamics at one spot and look at colonization and succession, but what's happening at one spot will influence other communities in the region through larval connectivity."

Midway through a three-year Ocean Life Institute fellowship, Mullineaux is studying larval connectivity from a variety of angles. She is developing methods for imaging their movement, analyzing their trajectories and modeling their swimming patterns using shellfish larvae from New England waters. It is easier to use local shellfish because they don't have to be kept in pressurized chambers like larvae from the deep sea, she said.

"Growing oyster larvae for 30 days is a piece of cake compared to deep sea larvae," she said. "Larvae at deep hydrothermal vents don't survive if you bring them to surface pressure."

Regardless of where she studies larval connectivity, understanding the process is complicated, she said. She has to consider a host of variables that can affect how far larvae can travel. For instance, when a clam releases its larvae, they can be carried away in a current, tossed higher into the water column in a storm, or be forced back to the seafloor near their birthplace. Larvae aren't completely helpless either; they can respond to chemical cues that tell them when to leave the water column and descend to the seafloor, she said.

There is also the issue of identifying a larva's home community. Mullineaux is working on a pilot project that would use a laser and mass spectrometer to identify the chemical composition of a larva's shell to pinpoint exactly where a larva originated. Each larval shell has its own "signature," a unique makeup of the chemicals that were present in the water where the larva was born. Once they determine the chemical makeup of the larval shell, scientists can compare it to larvae spawned in other known locations until they find a match, a process that could be useful for studying larvae at hydrothermal vents, she said.

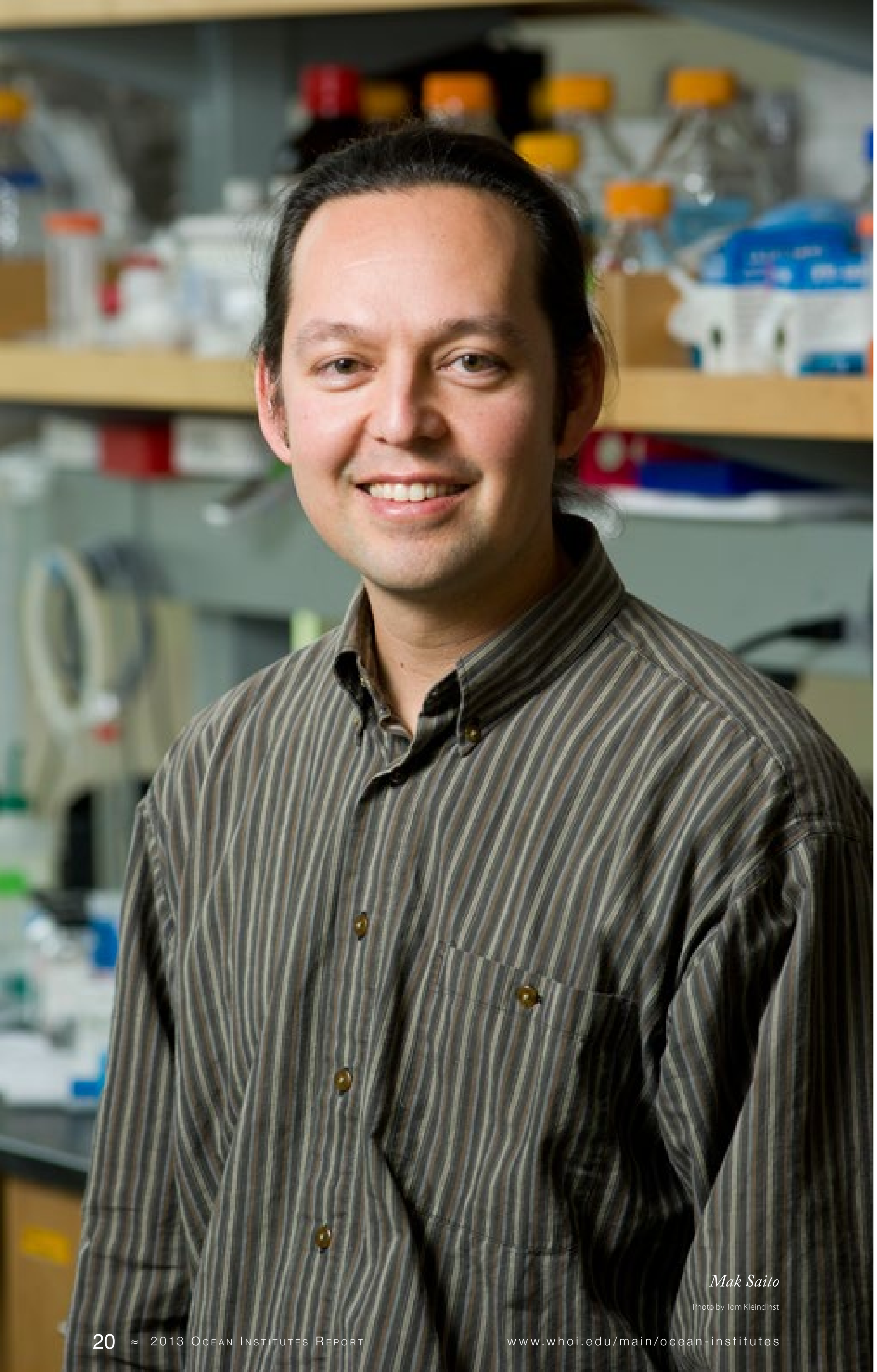
Mullineaux's work illuminates how life in the ocean is interconnected, and she is part of several international committees working to raise awareness about the importance of understanding larval connectivity in the context of deep sea mining.

"When people are mining…they don't think about how they're influencing other communities in the area. How many vent sites can you eradicate before you change the dynamic of a whole region?" she asked. "Ten years ago I would have said this was basic research. Now this has a timely application."

WHOI biologist Lauren Mullineaux was awarded an OLI fellowship in 2011 for her work studying larval connectivity in New England waters and on hydrothermal vents. The fellowship provides nine months of salary and a small discretionary award over three years.

Photo courtesy of WHOI Archives

Photo by Stace Beaulieu



Mak Saito

Photo by Tom Kleindinst

High-Risk yet High-Reward

Mak Saito receives the Gordon and Betty Moore Foundation Marine Microbiology Initiative Investigator Award

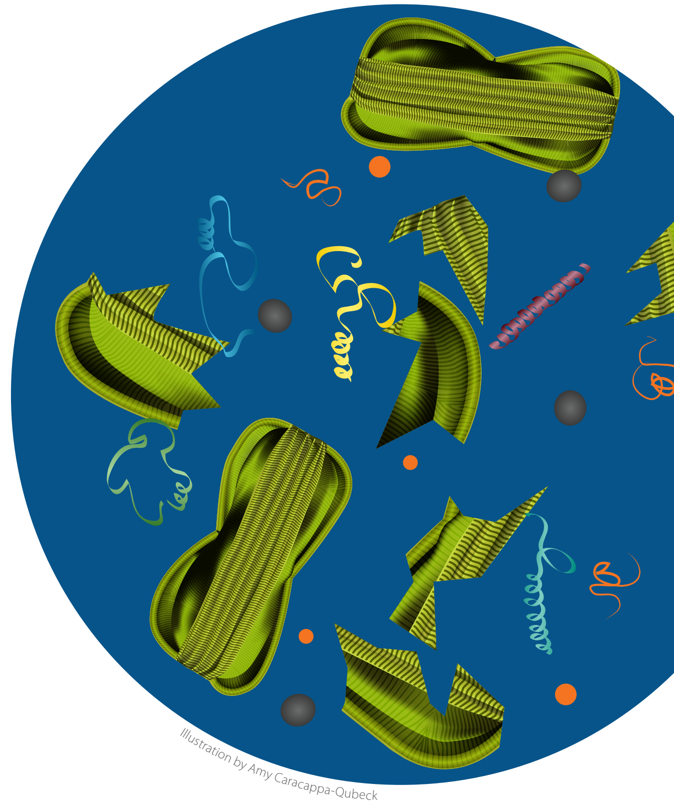


Illustration by Amy Caracappa-Qubeck

WHOI biogeochemist Mak Saito has been selected for a Marine Microbiology Initiative (MMI) investigator award by the Gordon and Betty Moore Foundation. Saito is one of 16 scientists from 14 different institutions who will receive funds totaling up to $35 million over five years to pursue high-risk, pioneering research in the field of marine microbial ecology.

Saito's research focuses on the nutritional requirements of metals in marine microbes. Metals are essential components in biogeochemical reactions, and their scarcity in seawater can have a profound effect on cycles such as the carbon and nitrogen cycles and has resulted in unique adaptations. Saito, an Ocean Life Institute Fellow from 2008 through 2011, has developed sophisticated methods called proteomics for understanding these interactions, as well as sampling and analytical methods for low-level trace metal measurements in different parts of the ocean.

"We're providing some of the Louis Pasteurs of this field with additional, flexible funding to give them more freedom to pursue bold, new discoveries," said Steve McCormick, then-president of the Gordon and Betty Moore Foundation when the awards were announced.

The Gordon and Betty Moore Foundation's Marine Microbiology Initiative was launched in 2004. The current cohort was chosen through an extensive review process that considered over 180 applications.

WHOI biogeochemist Mak Saito was awarded $1,125,081 for his study, "Metalloenzymes as Indicators of Ocean Biogeochemical Processes" from the Gordon and Betty Moore Foundation.

All in the Family

Could self-fertilizing coral be better equipped to handle ocean acidification?

Coral reefs are among the most biologically diverse habitats in the world. Yet, within these diverse ecosystems are coral species that self-fertilize, producing offspring from their own sperm and eggs. WHOI biologist Ann Tarrant is studying the species *Porites astreoides* to understand why some corals self-fertilize and how their larvae respond to environmental stressors such as ocean acidification.

"We tend to think of [self-fertilization] as inbreeding, and it's bad for humans," she said. "But for other animals there can be advantages—if you're well adapted to your environment, you'll produce children who are well adapted."

With funding from the Ocean Life Institute, Tarrant exposed the larvae of 10 colonies of coral to an acidic ocean environment. The coral were particularly interesting to Tarrant because they self-fertilize in some instances and cross-fertilize (use two parents) in others. She expected to find that bigger larvae would be more resilient to a lower pH because they had more energy to grow. But Tarrant found that the larger larvae were *less* resilient, a discovery she found puzzling. Tarrant thinks the answer may be in the larvae's genetics and is working with researchers at Penn State University to analyze the coral.

"OLI funding was really helpful because this genetic angle is new for us," she said. "It's given us the chance to get a new dataset we wouldn't get otherwise."

A year into this project, Tarrant has found more questions than answers. "Maybe [self-fertilization is] natural and it's what they normally do," she said. "Or is it something the corals do just because there's no other option?"

She plans to apply for federal funding to continue her analyses.

OLI awarded $37,443 to WHOI biologist Ann Tarrant in 2012 for her work studying coral larvae and ocean acidification.

Ann Tarrant

Photo by Tom Kleindinst

Photo by Neal Cantin

Photo by Tom Kleindinst

Photo by Hanny Rivera

Other Ocean Life Institute projects funded in 2013

Integrating Measures of Animal Movements to Estimate the Winter Distribution of Two Penguin Species

- Michael Polito, Biology
- Leah Houghton, Biology
- Simon Thorrold, Biology

Is Cannibalism Really an Evolved Survival Strategy of Bluefin Tuna Larvae?

- Joel Llopiz, Biology

Simulating Coral Calcification in the Lab: Impact of Ocean Acidification and Rising Temperature*

- Weifu Guo, Geology & Geophysics
- Zhaohui 'Aleck' Wang, Marine Chemistry & Geochemistry

Funding Highlights

Although OLI focused the majority of its funding on research grants, significant support also went to fellows, graduate education and outreach activities in 2013. OLI's budget was $524,399, and the Institute spent $168,769 on research awards. The Institute also funded salary support for fellow Lauren Mullineaux ($109,355), and postdoctoral scholars Ian Carroll and Matt Long ($125,263). OLI also supported graduate students Kathleen May Munson and Alejandra Ortiz ($57,168) and used discretionary and communications funds ($46,599) for outreach and education.

**Also funded by the Institutes' Ocean Acidification Initiative*

> "OLI funding was really helpful because it's given us the chance to get a dataset we wouldn't get otherwise."

Deep Ocean Exploration Institute

Director's Message

The ocean is truly the world's last frontier. It covers nearly 70 percent of Earth's surface, yet there are vast regions of the ocean, such as the mid-water environment and deep ocean seafloor, that are not well understood. Scientists and engineers supported in part by Deep Ocean Exploration Institute funding are at the forefront of expanding our knowledge of these frontiers, seeking to answer complex questions about the biology, chemistry and geology of the deep ocean seafloor.

I'm pleased to report that the Ocean Ridge Initiative, a four-year effort focused on the mid-ocean ridge (MOR), Earth's most continuous volcanic and tectonic feature, successfully concluded in 2013. The projects funded during this initiative covered a broad research agenda ranging from microbial and geological/geochemical processes at deep-sea vents to the nature of deep-sea fauna at oceanic spreading centers. It also included research related to understanding deep-sea eruptions and the impacts they have on bio-geochemical processes in these extreme environments of the MOR.

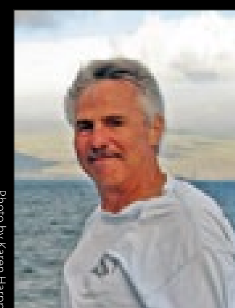


Photo by Karen Harpp

As with all thematic areas supported by DOEI, technology has been an integral part of the research efforts, and ORI work also included engineering advances for autonomous and remotely operated vehicle sensors and systems. Much of the work DOEI supports is inter-disciplinary, and this synergistic collaboration is highlighted by the innovative tools, techniques and equipment co-developed by WHOI engineers and scientists involved in both DOEI-and ORI-funded research.

Part of the work that DOEI and ORI have fostered looks to the future. Certainly WHOI's involvement in the Ocean Observatories Initiative, a major 21st century program funded by NSF to provide real-time observational capability in the oceans and on the seafloor, fits well with DOEI and ORI objectives. DOEI and ORI, along with the generous support of the Burke family, have provided funding to facilitate WHOI scientists and colleagues to monitor changes in the ocean in real-time through the high-definition, web-based imaging and audiovisual infrastructure installed in the newly-named Coleman and Susan Burke Ocean Observing Operations Room in the LOSOS Building. Support for facilities and capabilities such as this one enables the scientific collaboration and innovation that has made WHOI a world-leader in ocean science and technology.

With your support, we will continue to foster the high-risk, cross-disciplinary work that leads to breakthroughs in our understanding of processes in ocean and deep seafloor environments.

–Dan Fornari

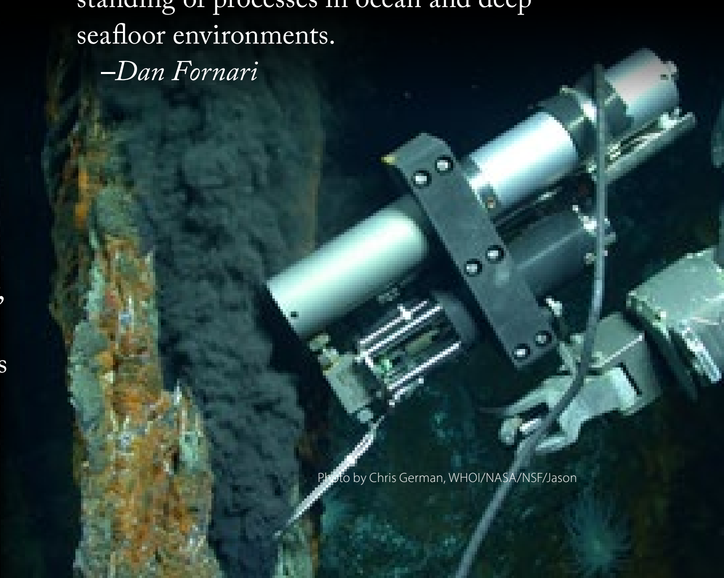


Photo by Chris German, WHOI/NASA/NSF/Jason

A
Closer Look at Underwater Volcanoes

Photo by Tom Kleindinst

Adam Soule

In geological terms, the Kermadec Arc is among the most significant features on the ocean floor. Its 50-plus submarine volcanoes extend along the 1,500-mile collision zone between the Pacific and Australian tectonic plates, just north of New Zealand. The shallow depth and sediment-free summits of many arc volcanoes make them important oases for animal communities and fisheries, and their robust hydrothermal circulation produces large mineral deposits that are rich in precious metals. Understanding the relationship between seafloor processes and formation of mineral deposits is necessary to inform any future activities in the region, including commercial mining.

In the first near-bottom sidescan sonar survey of an arc volcano, Associate Scientist Adam Soule of the Geology and Geophysics Department is evaluating the size, type, and relative age of volcanic deposits, sedimentary deposits, and faulting on volcano summits and flanks. The level of detail and coverage provided by these data are unique for arc volcanoes and fill a crucial gap in knowledge.

"The closer we look, the more confident we are that we're asking the right questions," Soule said. "This work raises as many new questions as it answers."

The high-resolution acoustic images of submarine volcanoes Soule and his colleagues collected in the Kermadec Arc offered a number of surprises. They found that Rumble III, a known volcano in the chain, was growing a new dome, a 400-meter spire that hadn't shown up in previous bathymetric data. A closer look at the Healy volcano revealed that it is capped by hard deposits—the opposite of what scientists believed. These high-resolution images offer insight into the relationship between rock structure and the flow of fluids from the volcano.

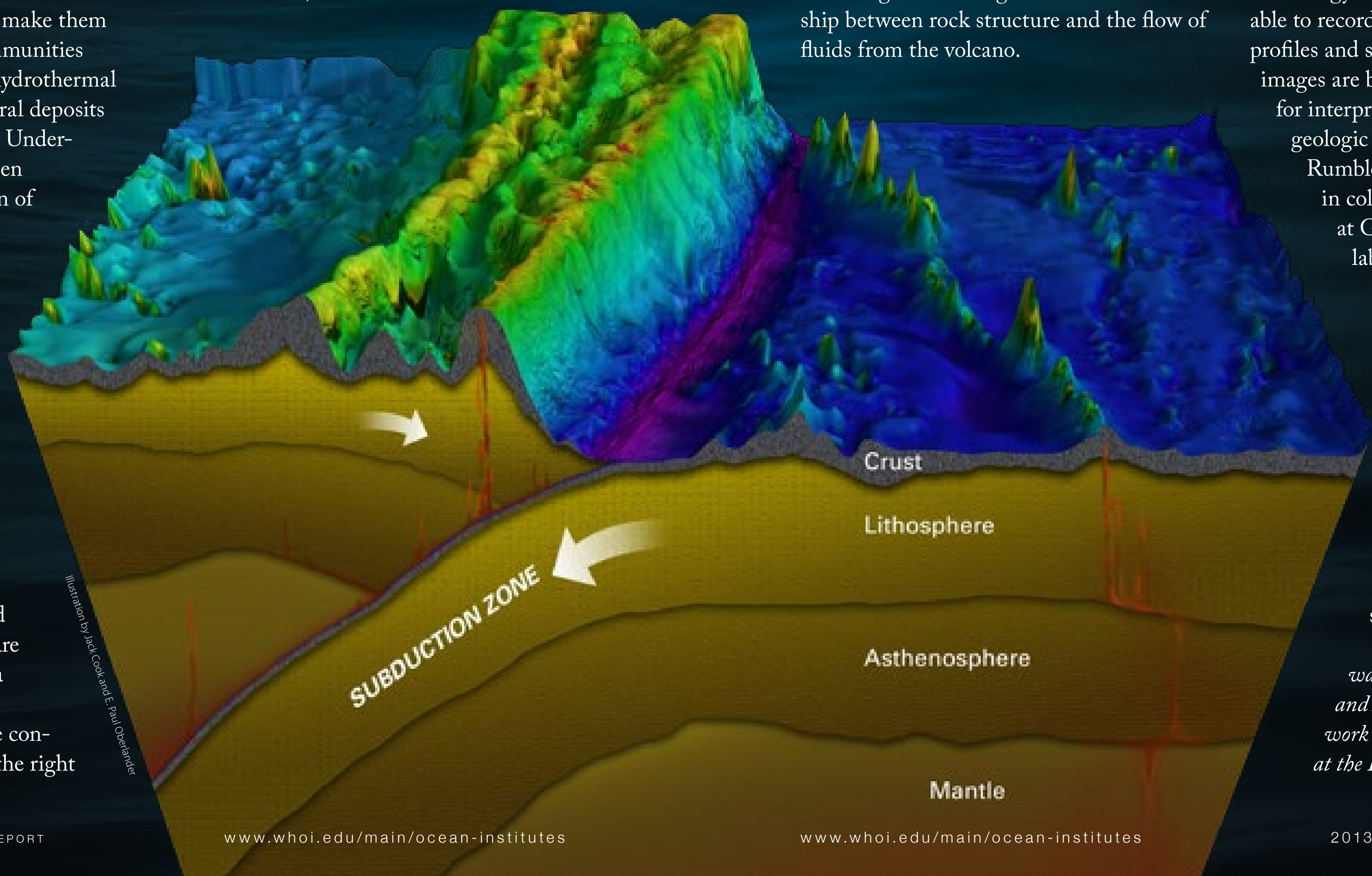
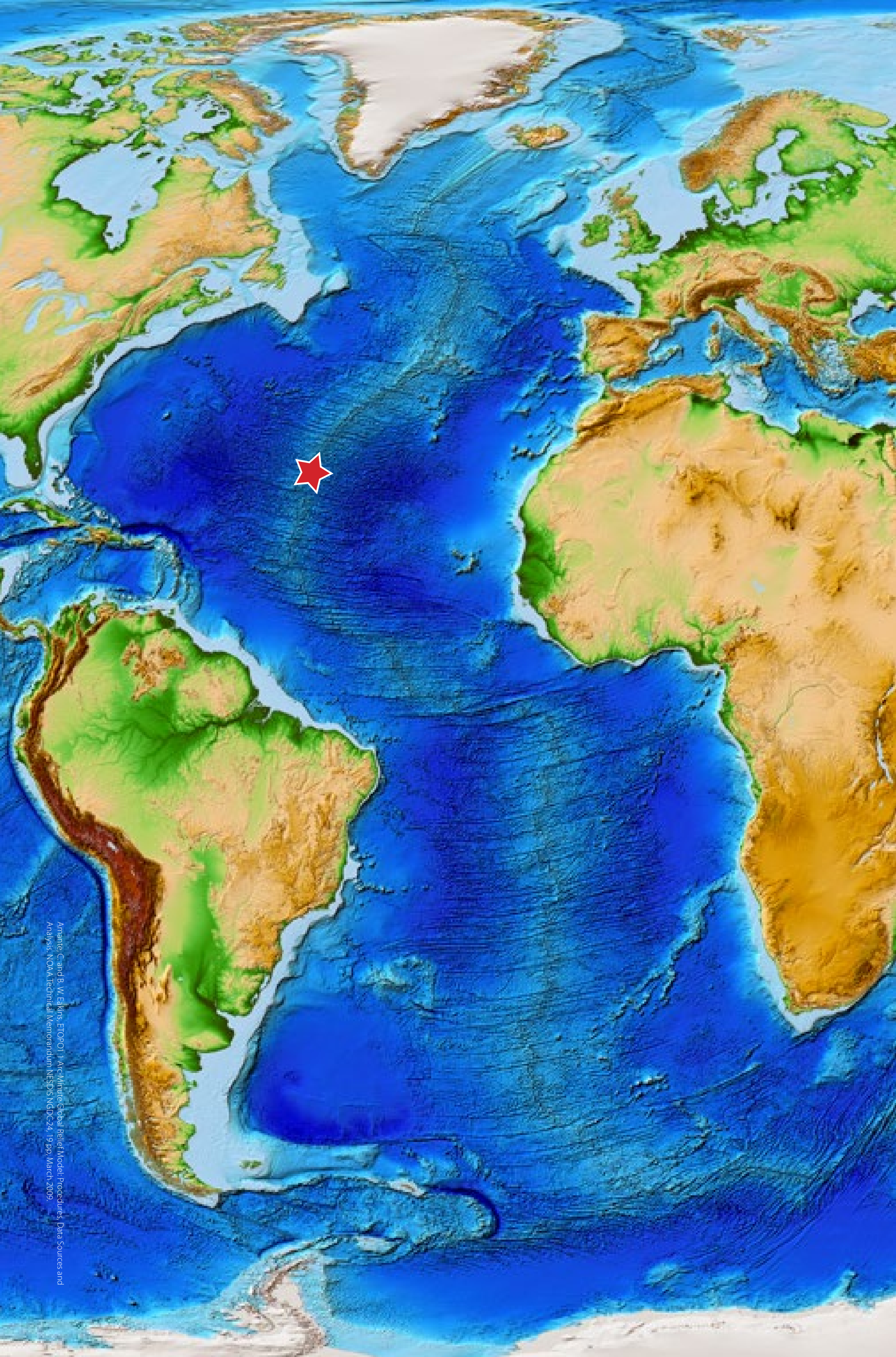


Illustration by Jack Cook and E. Paul Oberlander

Another important part of Soule's Kermadec work is to demonstrate new capabilities for the autonomous underwater vehicle *Sentry*, which was developed at Woods Hole and is capable of diving to 6,000 meters equipped with imaging and sensor technology. In this expedition, *Sentry* was able to record sidescan sonar, subbottom profiles and seafloor photographs. These images are being compiled in a database for interpretation and construction of geologic maps at three volcanoes: Rumble III, Healy and Brothers, in collaboration with colleagues at GNS-Science, a government laboratory in New Zealand.

"Construction of detailed geologic maps will allow me to test hypotheses regarding volcano growth, caldera development, and hydrothermal discharge," Soule explained. "These data have significant implications for our understanding of mass and heat transfer and chemical exchange at the seafloor and along ocean ridges."

Associate Scientist Adam Soule was awarded $61,763 from DOEI and Access to the Sea in 2011 for his work collecting high-resolution images at the Kermadec Arc.



Amante, C. and B. W. Eakins, ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24, 19 pp, March 2009.

Living Rock

A JP graduate links sub-seafloor hydrology & earthquakes

The Trans-Atlantic Geotraverse (TAG) hydrothermal field on the Mid-Atlantic Ridge is the largest known hydrothermal deposit on the mid-ocean ridge. At this site, there are intersecting faults that serve as fluid pathways, supplying black and white smokers laden with minerals and chemicals that form the TAG deposits.

The result of all this movement is a mound of mineral deposits as big as the Roman Coliseum. Recent MIT/WHOI Joint Program graduate Claire Pontbriand believed that the relationship between seismic activity and hydrothermal flow on the TAG mound could tell us how sulfide deposits are built. With unrestricted support from the Deep Ocean Exploration Institute, then-student Pontbriand was the first to investigate a catalog of more than 32,000 microearthquakes around the TAG mound, finding links between the quakes and hydrothermal activity.

Photo by Stace Beaulieu

"The whole thing is a living, breathing community," Pontbriand said. "Naturally occurring cracking creates pathways for heated fluids to break through the seafloor."

Pontbriand successfully defended her dissertation in 2012 and graduated in February 2013. She now works at Air Worldwide, a Boston-based risk modeling software and consulting service, using her skills in statistical modeling and seismology.

DOEI awarded $42,185 to former MIT/WHOI Joint Program student Claire Pontbriand for her work investigating microearthquakes near the TAG mound.

Named Spaces

Help Advance Innovation

Real-time monitoring is a critical part of the Ocean Observatories Initiative (OOI), a multimillion-dollar effort funded by the National Science Foundation to build and operate an underwater network of buoys, sensors and autonomous underwater vehicles to provide real-time data to researchers from a variety of oceanographic and plate tectonic settings 24/7. The Coleman and Susan Burke Ocean Observing Operations Room is the command center of OOI, and the Burkes' gift of state-of-the-art technology allows researchers real-time access to the health and status of monitoring systems in the field, and results from sensor arrays and vehicles.

The operations room features monitors displaying oceanographic and meteorological conditions at field sites and streaming data from instruments and observing stations deployed at sea. It is part of the Laboratory for Ocean Sensors and Observing Systems (LOSOS) at WHOI, a 27,000-squre foot LEED (Leadership in Energy and Environmental Design) facility that where OOI researchers conduct their work.

"The Burkes recognize the value and promise of LOSOS as well as the science and exploration it will enable," said Larry Madin, Director of Research. "These spaces have already begun to define the future of how we observe and learn about the ocean."

Trustee Coleman Burke and his wife, Susan, made a gift of $150,000 as part of their pledge to endow the Coleman and Susan Burke Ocean Observing Operations Room. DOEI also awarded WHOI Senior Scientist Chris German $22,050 in 2013 to add telepresence and cruise connectivity capability to the room.

Photo by Tom Kleindinst

Photo by Chris German

Illustration by Jack Cook and E. Paul Oberlander

Other Deep Ocean Exploration Institute projects funded in 2013

Experimental Investigation: The Influence of Small Amounts of Water on Peridotite Melting in the Oceanic Upper Mantle

- Glenn Gaetani, Geology & Geophysics

Establishing a Center for Telepresence & Dive Review

- Chris German, Geology & Geophysics

Generation of Subduction—Zone Magmas from Melange Diapirs

- Horst Marschall, Geology & Geophysics
- Glenn Gaetani, Geology & Geophysics

Innovative Tracers for Hydrous Melting in the Earth's Mantle

- Veronique Le Roux, Geology & Geophysics
- Nobumichi Shimizu, Geology & Geophysics

Development of a Modular Deep Sea In situ Dissolved Gas Extractor System*

- Anna Michel, Applied Ocean Physics & Engineering
- Scott Wankel, Marine Chemistry & Geochemistry

Funding Highlights

In 2013, DOEI allocated the majority of its $665,863 budget to research and grants ($387,215). Significant support ($119,879) also went to graduate students Jennifer Martinez Panlilio and Santiago Herrera and postdoctoral scholar David Barclay. Salary support was allocated for Institute fellow John "Chip" Breier ($70,874). The Institute sponsored the Geodynamics Program ($43,548), and also supported conferences and publications using discretionary and communications funds ($24,621).

**Also funded by the Institutes' Ocean Acidification Initiative*

> "WHOI is an exciting place to work because everybody here is looking for new ways to tackle big science questions."

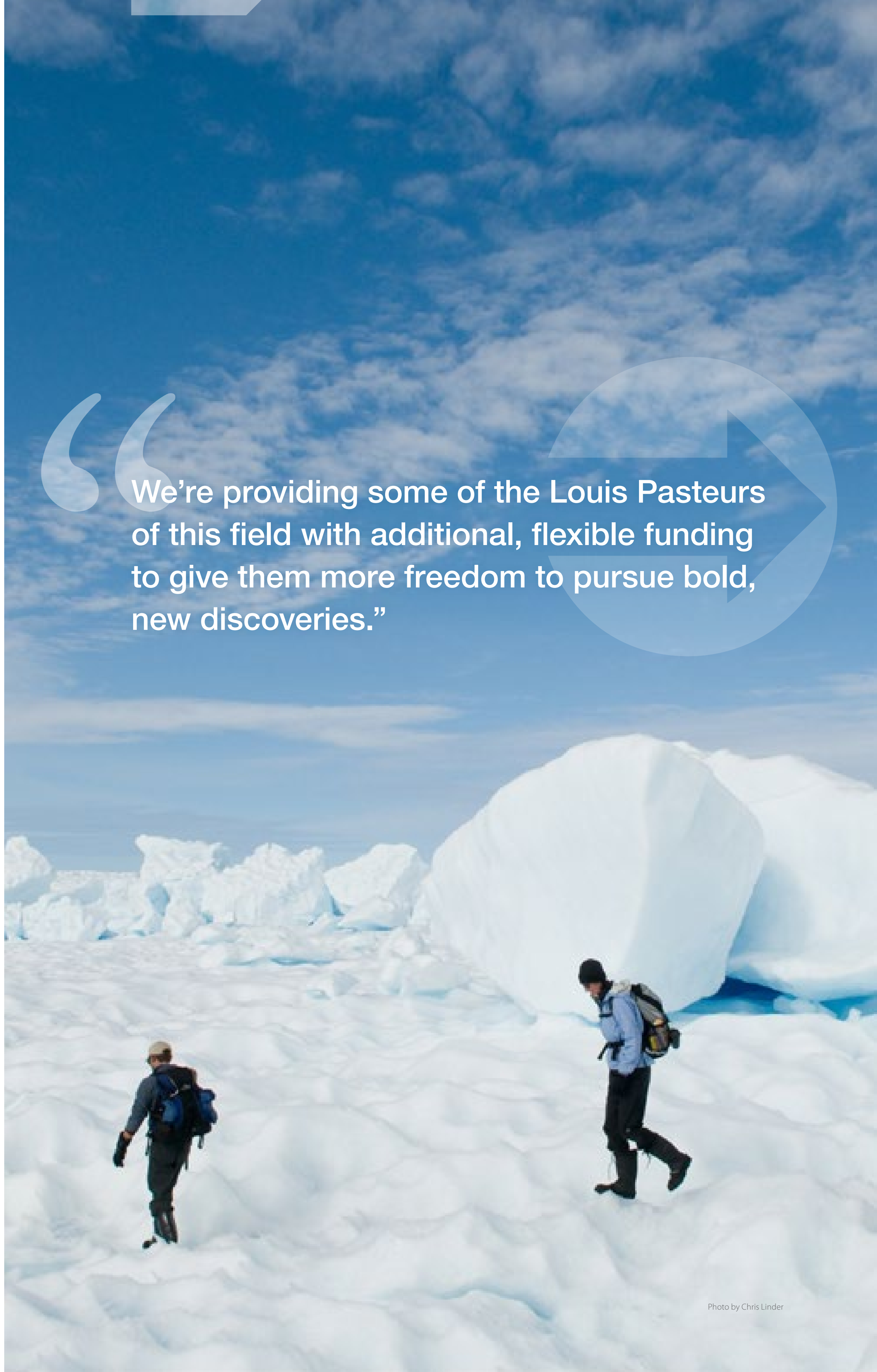


Photo by Chris Linder

About the Ocean Institutes

Four institutes, one approach to interdisciplinary oceanography

The Ocean Institutes bring together the best minds in oceanography, engineering and related fields to foster innovative thinking and launch interdisciplinary initiatives in ocean science. These initiatives tackle many of society's greatest issues, including climate change, sustaining and conserving ocean ecosystems, and responding to disasters. The Institutes provide seed funding for these high-risk, high-reward projects. They also nurture rich graduate and post-doctoral education experiences for future leaders in oceanography, and serve as a public resource for science information.

The Ocean Institutes

Woods Hole Oceanographic Institution

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Cover: Members of Associate Scientist Anne Cohen's lab diving in the Caribbean.
Photo by G.P. Lomann