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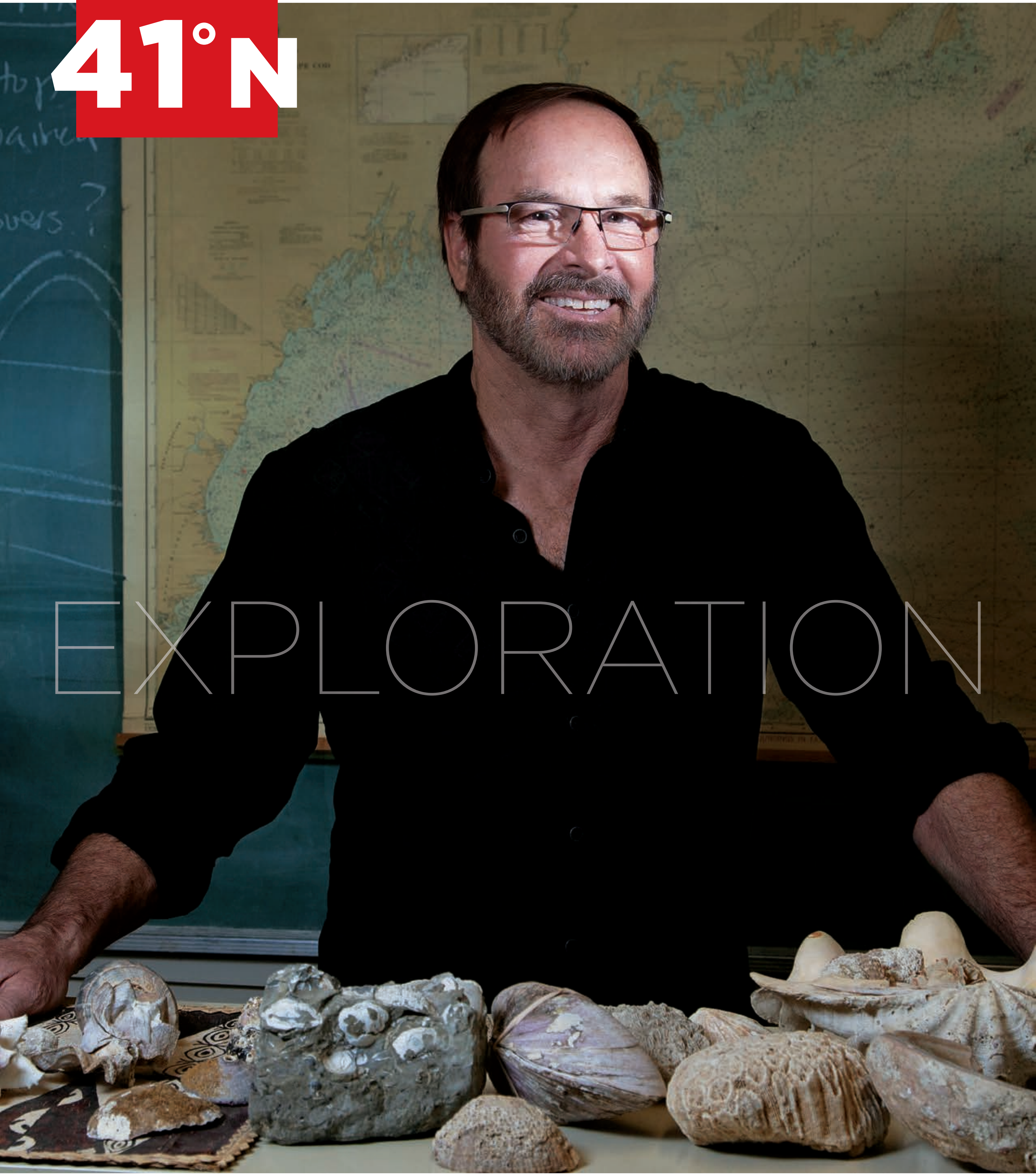
41°N



EXPLORATION

A PUBLICATION OF RHODE ISLAND SEA GRANT & THE COASTAL INSTITUTE AT THE UNIVERSITY OF RHODE ISLAND • A SEA GRANT INSTITUTION

COVER

Portrait of Jon Witman by Dana Smith

ABOUT 41° N

41° N is published twice per year by the Rhode Island Sea Grant College Program and the Coastal Institute at the University of Rhode Island (URI). The name refers to the latitude at which Rhode Island lies.

Rhode Island Sea Grant is a part of the National Oceanic and Atmospheric Administration and was established to promote the conservation and sustainable development of marine resources for the public benefit through research, outreach, and education.

The URI Coastal Institute works in partnerships to provide a neutral setting where knowledge is advanced, issues discussed, information synthesized, and solutions developed for the sustainable use and management of coastal ecosystems. The Coastal Institute works across and beyond traditional structures to encourage new approaches to problem solving.

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THE NEXT ROBERT BALLARD

EVEN AS THIS ISSUE OF 41° N WAS BEING PUT TOGETHER, THE *OKEANOS Explorer* was busy examining deep-water sites in the Gulf of Mexico and may or may not have discovered a new species of squid. Boston College deep-sea biology students got to participate virtually on the expedition, viewing the live video stream on the University of Rhode Island Inner Space Center's 288-square-foot screen and communicating via intercom with the team.

The vast oceans—responsible for generating half of the air we breathe, sequestering carbon to reduce the impacts of climate change, and providing us with food and other natural resources—yield new discoveries regularly, but much about them remains mysterious. The research needed to better understand them is challenged by a number of issues, one of which is funding contraints—something that is nowhere more recognized than at the URI Graduate School of Oceanography, home to the Inner Space Center and the soon-to-be-retired R/V *Endeavor*.

The competition to be the host of a replacement for the *Endeavor* (see *Endeavor* story on page 12) has brought together a number of institutions and universities along the East Coast, all contributing to URI's proposal to the National Science Foundation, which owns the academic research fleet. Partnerships like these are the present and future of ocean exploration (see "Discovery in the Dark" on page 2), not only because they marshal limited financial resources, but also because they speed up discoveries. For example, Northeastern University's Ocean Genome Legacy Center, a repository for marine DNA and tissue samples from all over the world, is open to contributions from anyone and distributes samples for study to researchers all over the world. "We're pretty open minded about the value of samples, because you never know where discovery is going to come from," said Dan Distel, executive director of the Ocean Genome Legacy Center, in a page about the project on Northeastern's website.

Similarly—though iconic explorers like Robert Ballard, discoverer of the *Titanic*, will always capture the imagination—more and more, it will be teams of researchers (see "Drilling Down" on page 8) from a variety of institutions, businesses, and countries who are uncovering the lost treasures, new species, and hidden terrains of the oceans' vast depths.

—MONICA ALLARD COX
Editor

THE UNIVERSITY OF RHODE ISLAND
GSO
COASTAL INSTITUTE
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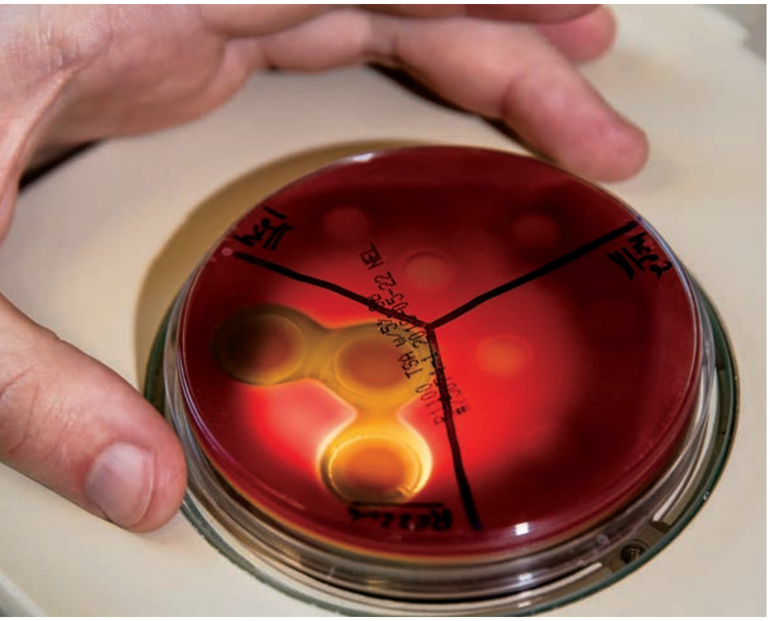
Photograph by JAMSTEC/IODP



Discovery in the Dark

EXPLORING THE DEEP OCEAN TESTS THE LIMITS OF TECHNOLOGY AND FUNDING

by **Ellen Liberman**

In 2011, the *Okeanos Explorer* examined deep-sea habitats in the Galápagos region. Photograph by Carl VerPlanck courtesy of NOAA

The remotely operated vehicle can descend to survey deep reaches of the ocean.
Photograph © Brian Skerry

BEFORE THERE WERE SATELLITES, THERE WERE submersibles, and before that, sextants, and before that, sticks.

The Marshall Islands consist of 29 atolls, scattered over 180,000 nautical miles in the Northern Pacific. The Southeast Asians who settled there in the second millennium B.C. learned to canoe around the island chains by mapping the ocean. Using the mid-ribs of coconut fronds, cowrie shells, and curved threads, ancient cartographers constructed stick charts—open frameworks depicting the islands and the ocean surface patterns as the waves swelled and refracted. They were part art and part science—stick charting was the province of a few who passed their techniques to successive generations, and each map could only be read by the map-maker.

Today, scientists fly undersea remotely operated vehicles, equipped with manipulator arms and suction systems to collect samples, sonar systems to detect objects, and video cameras that beam high-resolution images to satellites, which, in turn, transmit other-worldly panoramas and hard data to other scientists on shore, participating on their computer screens. The race is on to develop devices that can explore the deep ocean more easily, quickly, and cheaply. And consortiums of scientists across many disciplines are pulling together to mine every byte of data that can be extracted from the sea bottom.

Nonetheless, these leaps are not yet the bounds that the scientific community says must be made. The ocean covers 71 percent of the planet's surface, and half of the United States' land mass lies beneath its waters, yet we know it but slightly. Experts estimate that humanity has probed about 15 percent of the seabed. Only three people have made the nearly 7-mile drop into the Challenger Deep at the southern end of the Mariana Trench, the lowest known point of the seafloor. For comparison, four times as many have walked on the moon. The fleet is tiny. Globally, there are a handful of vessels dedicated solely to exploring nearly 140 million square miles of ocean. The tens of millions of dollars dedicated to exploration each year are a drop in an ocean of need.

"The world relies heavily on the ocean as a resource to sustain our livelihoods, as a food source, [and] 50 percent of our oxygen comes from the ocean. It governs climate and moderates our temperature," says Alan Leonardi, director of the National Oceanic and Atmospheric Administration's (NOAA) Office of Ocean Exploration and Research (OER). "Times change and resources change. No matter what, exploration is the first step in gaining understanding and knowledge of the ocean and its ecosystems."

The Paradigm for Ocean Exploration Shifts

In 2009, ocean exploration took a bold step forward. The *Okeanos Explorer*, NOAA's 224-foot ocean exploration ship, was testing its state-of-the-art mapping systems and remotely operated vehicles (ROVs) in a series of shakedown cruises around the national marine sanctuaries in the Pacific. The E/V *Nautilus*, a 215-foot research vessel owned by the Ocean Exploration Trust, was on its maiden voyage, documenting the seabed around the Gallipoli Peninsula. And the University of Rhode Island opened its $15 million Ocean Science and Exploration Center, featuring the Inner Space Center, a unique facility that would transmit the data collected at sea in real time to observers on shore.

The combination of an exploration fleet, technology that allowed scientists to gather high-resolution images and other data at greater depths, and telepresence changed what is collected, how it is collected, and who has access to it.

Most ocean scientists still do their field work aboard one of the 21 vessels that make up the University-National Oceanographic Laboratory System (UNOLS). Getting a berth aboard the academic research fleet requires a mature hypothesis, says David C. Smith, associate dean for academic affairs at URI's Graduate School of Oceanography (GSO). "You have to sell it to your peers, submit your proposal, and go through a vetting process with external experts who rank projects. That is a fundamental difference between the *Okeanos* and a UNOLS ship—two complementary approaches."

Indeed, explorer and URI oceanography professor Robert Ballard, who has been at the forefront of crafting national ocean strategies as a member of the Panel on Ocean Exploration and the U.S. Commission on Ocean Policy, founded the Ocean Exploration Trust in 2008 to build capacity for hypothesis-generating exploration. With support from NOAA, the Navy, GSO, National Geographic, and Citgo, the trust embarks on months-long expeditions each year.

"The problem with ocean exploration is, your mission is to boldly go where no one has gone before on this planet, and you can't rely on the UNOLS fleet for that," he says. "Our program is very unique, run by professional explorers, with a no-nonsense objective to make discoveries. I wanted a ship that was run by the inmates."

Telepresence exponentially increases the corps of scientists who can participate in ocean exploration. The Inner Space Center works closely with the research fleet so that scientists interested in carnivorous sponges, or the geology of the Kick'em Jenny submarine volcano, or the impact of the 2010 Deepwater Horizon Gulf of Mexico oil spill can not only follow cruises from live video feeds, but also can help direct their route and evaluate their finds in real time. The Inner Space Center's mission control features banks of computers dominated by a 20-foot projection screen, a small broadcast studio, and a hub of servers that capture and store the data.

"Telepresence increases the efficiency of the dives—dozens, if not hundreds, of scientists are helping us interpret what we find. Not everyone can take the time to spend a month at sea, and we needed to involve a much broader group to understand what we are looking at," says Dwight Coleman, a geological oceanographer and the center's director. "It has become part of the model for ocean exploration."

Academic tradition also dictated that the data was held by individual scientists for up to two years to give them time to publish. The last nine years has seen the advent of open-source data at OER—initially a difficult transition for many scientists who must publish to maintain their careers, says Catalina Martinez, a NOAA OER regional program manager and liaison to URI.

"We were turning their model upside down," she says. "But we had to make this data publicly accessible if we really wanted to broaden our reach. And because of the way technology has evolved and the world has evolved, everyone expects this immediacy—people's mindsets evolved. Even some of the most seasoned ocean-going scientists have really bought into this way of doing business."

Technology has been another game changer. Many of the devices used—sonar, submersibles, and ship-tethered ROVs developed by the Navy and academia—have been in existence for a couple of decades, but they have gotten smaller and lighter, with more sensors, better visualization, and faster computational capabilities. The next phase is fully autonomous vehicles.

Christopher Roman, a GSO associate professor of oceanography and ocean engineering who specializes in acoustic and photographic seafloor mapping, has been working on an unassuming three-foot, cylindrical "photofloat" to map the seafloor at shallow depths. He was inspired by ship time working with ROVs—"complex and crazy, over-the-top expensive devices," he says. "It made me think: what's the opposite end?"

Roman's imaging platform delivers high-quality, low-cost images, and can be launched by hand from any vessel. The float consists of a stereo camera system that can take black-and-white or color images, a strobe light, an auto-ballasting system, and a sensor that can measure the conductivity, temperature, and pressure of seawater.

Roman envisions his photofloats as part of a reconnaissance force, scouting in advance of more sophisticated, ship-based devices.

"We're looking at smart ways to use robots to get more information, to better strategize operations," he says.

While some predict a future in which ocean scientists spend little of their time at sea, robots can't do everything, says David Smith, who studies microorganisms that live in marine sediment.

"I don't deny that it's happening. We are able to do a lot of things remotely, and it's opened up new avenues in terms of endurance, but some of us still need a sample in our hands to manipulate in the lab on the ship or bring back home. We just don't have sensors for that."

Exploration on a Shoestring

Despite potential scientific rewards for ocean exploration, public support for it has remained modest. In 1828, President John Quincy Adams requested funding for a major expedition to the South Seas and Pacific Ocean. But Congressional wrangling over the appropriation delayed its implementation by eight years. In 1838, a flotilla of six U.S. naval vessels finally weighed anchor at Hampton Roads, Virginia. Four years later, the U.S. Exploration Expedition returned with a staggering scientific haul: tens of thousands of ethnographic, botanical, geological, and zoological samples; precise nautical charts; and notebooks stuffed with data about astronomy, meteorology, and oceanography.

More than 150 years later, the U.S. formally re-entered the ocean exploration business—with a small pot of funding. While the federal government had supported ocean surveys and undersea research programs as far back as 1807, fears that the U.S. had lost its leadership role prompted President Bill Clinton in 2000 to establish a multidisciplinary group to develop a strategy for exploring the oceans. One of the Panel on Ocean Exploration's principal recommendations was 10 years of funding at $75 million annually. A year later, NOAA established the OER with a budget of $4 million. In fiscal 2017, the OER budget was just under $32 million, and the 2018 OER appropriation is $36.5 million.

"It's peanuts," says Jacqueline Dixon, dean of the University of South Florida's College of Marine Science and a member of the Ocean Advisory Board. "It's not enough to do the job, and we have a lot of the discussion about how difficult it is to generate the same enthusiasm with the public and legislators for exploration of our own planet, versus exploration of space. How do we do a better job communicating to the public and policymakers about how important the ocean is to our survival as a species and for the global economy and national security? They are all tied together."

This photofloat delivers high-quality, low-cost images of the seafloor. Photograph courtesy of Christopher Roman

With ship time costing anywhere from $25,000-$120,000 a day, OER does its best to leverage public dollars by working with partners, says Alan Leonardi.

But David Lovalvo, president of the Global Foundation for Ocean Exploration (GFOE), headquartered in Mystic, Connecticut, sees these budget constraints as troubling limitations.

"Autonomous vehicles are very popular now, but they are just another tool in the toolbox. A lot of what is driving this [focus on autonomous technology] is the cost, and this is a dangerous position. When a scientific question is important enough, it should not be gauged by the cost of answering the question."

Partnering for the Cause

On March 8, 2014, Malaysian Airlines flight MH370 vanished on a flight from Kuala Lumpur to Beijing, with 239 people aboard. The search for the wreckage—considered the most expensive aviation recovery effort in history—was as needle-in-a-haystack as one could imagine. A multinational squadron of planes and ships scoured almost 3 million square miles of the waters of Southeast Asia and the Indian Ocean for four years without locating the body of the aircraft.

What the searches did stumble upon piqued the interest of the nonprofit XPRIZE, however, which, since 1996, has been holding technology competitions to solve complex problems. A survey of the seafloor conducted by the Australian government in pursuit of Flight MH370 discovered two ancient shipwrecks, deep ocean trenches, and undersea volcanos. These incidental findings, in part, led the organization to design a contest around advancing ocean mapping technologies, says Jyotika Virmani, senior director of Planet and Environment for XPRIZE.

In March, 32 entrants were winnowed to nine finalists vying for $7 million in prize money for a device that could advance "the autonomy, scale, speed, depths and resolution of ocean exploration," without a ship. Launched from air or shore, each entry must explore the competition area and produce a high-resolution bathymetric (depth measurement) map and images of a specific object and identify other features.

"We want to be on a path of a healthy, valued, and understood ocean within the next decade," Virmani says. "To make it healthy, you have to value it, and valuing it requires understanding. A map is the most basic level of understanding you can have in the world."

The GFOE and the Schmidt Ocean Institute also focus on developing new ocean exploration technologies. The former designs, builds, and operates robotic platforms and trains young ocean engineers. The Schmidt Ocean Institute, based in Palo Alto, California, operates the R/V *Falkor* as a testing platform for new devices.

"As things move to more autonomous vehicles, we spend a lot of time enabling people to advance technology," says institute spokesman Logan Mock-Bunting. "We are trying to advance the frontiers. There aren't many places that will allow you to go out and test in real-world conditions and work the kinks out."

Yet, ocean scientists have concluded that without coordinating these separate efforts, ocean exploration will proceed at an unacceptably slow pace.

"With our current technology, it is estimated that we will still need nearly 1,000 ship years to map 100 percent of the ocean floor at a resolution of 100 meters, considering that 50 percent of the world ocean is deeper than 3,200 meters and parts are permanently ice covered," says Dawn Wright, chief scientist for the Environmental Systems Research Institute (ESRI), which makes GIS mapping software. "We need to coordinate a global effort of new mapping projects initiated by many parties using many vessels and with the necessary funding."

In 2016, two organizations came together to do that. Seabed 2030 is a global initiative to coordinate the complete mapping of the ocean floor by the year 2030 that was developed by the Nippon Foundation, a Tokyo-based nonprofit, and the General Bathymetric Chart of the Oceans (GEBCO), an international organization of geoscientists and hydrographers. The first objective of Seabed 2030 is to gather all the seafloor mapping information out there—the maps privately held by industry, hard drives buried in a closet, and government-generated charts— "dark data," says Vicki Ferrini, one of Seabed's regional directors, based at Columbia University. Then, the group will identify the gaps to help the global community prioritize the areas that need mapping.

The challenges are many. The foundation seeded Seabed 2030 with $18 million over 10 years, but the group will need to raise more funds. Persuading entities with proprietary interests in their maps to share is another issue. Wrangling the massive volumes of data and meeting the deadline make this almost "an unfathomable goal," she says.

What's Down There

On July 4, 2016, a three-inch snailfish caused quite a stir. Wraith-white, with yellow eyes set in an oval head, and a tadpole's body, it was pursuing its business along a ridge 8,200 feet below the surface of the Pacific Ocean, when it wandered into the path of the ROV *Deep Diver*. The *Okeanos* was exploring the Mariana Trench as part of the multi-year project to survey U.S. marine-protected areas in the central and western Pacific. There is no record of anyone ever seeing a living member of the *Aphyonidae* family, so the news made a splash, from *CBS News* to *Ripley's Believe it or Not*. The U.K.'s *Daily Mail* heralded the discovery with "Move Over Casper!"

Faceless fish, 12-foot long spider crabs, and vampire squid; Byzantine shipwrecks preserved in the Black Sea; the body of the long-sought *Titanic*—discoveries with each voyage answer questions and generate others no one thought to ask. And oceanographers know the ripples of excitement can't die on the shores of the next academic conference. The public must be engaged in pushing the boundaries of time and money to get to the bottom of the planet.

"The scientific community has woken up to the necessity of communicating well," says ESRI's Wright.

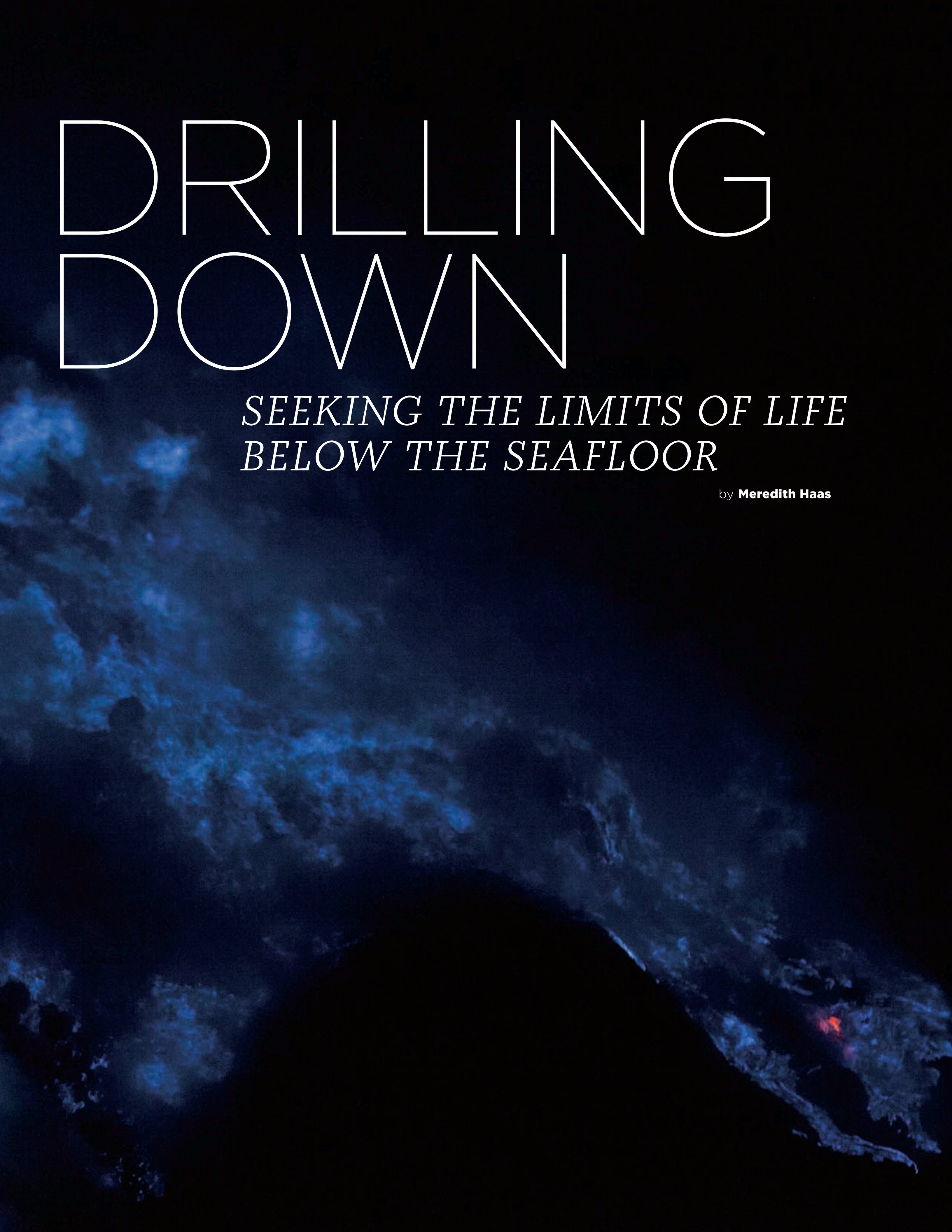
The thrill of discovery never gets old. In more than 150 expeditions—with many high-profile finds—Ballard himself still marvels at the 1977 expedition he led to probe the Galápagos Rift in the Pacific. They expected to find a desert in the deep down dark, but a trail of clam shells led their submersible to a biosphere thriving on the chemical energy pouring from the hydrothermal vents.

"It was the discovery of a life system that broke all the rules—that all life on this planet was dependent on the friendly sun driving the food chain," Ballard recalls. "In total darkness, we found a highly developed, highly complex ecosystem living independently. We unlocked Pandora's Box, and we didn't even know it was there. What else is there to bump into?"

DRILLING DOWN

SEEKING THE LIMITS OF LIFE BELOW THE SEAFLOOR

by **Meredith Haas**



IT USED TO BE ASSUMED THAT DIRECT SUNLIGHT was necessary to sustain all major forms of life on Earth. That was until 7-foot tube worms, giant white clams, eyeless shrimp, and many other creatures were discovered to be thriving in complete darkness nearly a mile below the surface of the sea. This whole other world was not only flourishing in the dark but in tremendous water pressure—over 3,000 pounds per square inch—in temperatures double the boiling point of water, and where sulfur, iron, copper, and other toxic metals and minerals spew from vents in the seafloor.

These deep-sea hydrothermal vents are a result of volcanic activity that allows seawater to seep through cracks in the seafloor, absorbing minerals and metals from the sediment and becoming super-hot from the underlying magma. The water erupts back out through the vents like underwater geysers. Scientists had suspected their existence near rift valleys where the seafloor is spreading apart, allowing magma below the Earth's crust to be pushed up. But they had not expected to find life in these extreme environments. So, when scientists traveled to the Galápagos Rift in the 1970s in search of hydrothermal vents, they were surprised to find a thriving oasis in the darkness of the deep sea.

Instead of using energy from the sun, like plants on land, bacterial communities near these vents were found to be using energy from the Earth—absorbing sulfur compounds (which are toxic to most land-based life) gushing from the seafloor. This process allows them to grow and reproduce, providing a food source for other creatures.

"We were struck by the thought, and its fundamental implications, that here, solar energy, which is so prevalent in running life on our planet, appears to be largely replaced by terrestrial energy ... bacteria taking over the role of green plants," said the late biologist and oceanographer Holger Jannasch in the *Annual Review of Microbiology* in 1997. Jannasch was one of several scientists, along with Bob Ballard, now at the University of Rhode Island's Graduate School of Oceanography (GSO), to be aboard the 1977 Galápagos expedition that first discovered these hydrothermal ecosystems. "This was a powerful new concept and, in my mind, one of the major biological discoveries of the 20th century."

Major, because the discovery of life in such harsh conditions made scientists reconsider environments that were previously viewed as too hostile for life, such as the barren landscape of Mars or the icy moon Europa that orbits Jupiter. But instead of looking up to the stars, many scientists are looking down into the depths of oceans to better fathom the possibilities of where life could exist.

"Understanding the limits of life is fundamental to our exploration for life outside of Earth," says Art Spivack, an oceanography professor at GSO who was part of an international science expedition in 2016 to examine life beneath the seafloor. "We use extreme environments on Earth to understand the potential for life throughout the rest of the solar system and universe."

The "deep biosphere," or the zone of life below the seafloor, also fits the requirements of such an extreme environment. It's dark, food sources are severely limited, the pressure is very high, and the deeper you dig, the hotter it gets.

"The deep ocean is a good analog of what could go on in other planets," says Spivack.

Spivack, along with GSO graduate students, was among a team of 31 scientists from eight nations that embarked on a 60-day scientific drilling expedition to the Nankai Trough off the coast of Japan as part of the International Ocean Discovery Program's (IODP) Expedition 370. The mission was to study the deep biosphere to find out how hot it can get before life can no longer exist and to determine what conditions ultimately limit life on Earth.

The Nankai Trough was chosen for this study because it is a known hot spot at a relatively shallow depth in the seafloor, making it easier for scientists to collect samples from extreme temperatures. This boundary marks a subduction zone right under Japan where one tectonic plate bends down under another less-dense plate. As the one plate bends down, sinking into the fluid mantle just under the Earth's crust, the underlying heat is then transferred closer to the surface. Here, scientists were able to take core samples from an environment exceeding 248˚F, the highest temperature at which life (in the form of microbes) is known to exist, at a depth just over 1 kilometer—roughly three-quarters of a mile—below the seafloor.

"We found abundant [microbes] all the way to the bottom of the hole," says Spivack, referring to the 1,200-meter hole the crew dug using special diamond-crystal-coated drill bits to cut through the seafloor for deep core samples. "We don't know yet how much of those are being actively produced or consumed, or if they're just relics, and that's a major part of the continuing effort."

The presence of these microbes at such depths leaves scientists wondering about how deep in the Earth life can subsist. "Where is the bottom of the deep biosphere? What ultimately limits life here?" asks Verena Heuer, a geochemist at the University of

Life thriving near hydrothermal vents was "one of the major biological discoveries of the 20th century."
EyeEm/Alamy Stock Photo

Bremen and co-chief scientist of the international expedition, in the expedition's video summary.

This kind of expedition wouldn't have been possible over a decade ago. Advances in drilling technologies, the development of telepresence to connect scientists at sea with colleagues on land, enhanced laboratory capabilities for measuring and storing samples on the ship itself, and especially improvements in analytic methods have allowed scientists to detect microbes in concentrations as low as 10 cells per cubic centimeter. That's like looking for 10 grains of sand in an Olympic-sized pool.

"The techniques are now 1,000 times more sen-sitive, allowing scientists to look for microbes at deeper depths where they are less abundant," says Heuer.

The first inkling of life beneath the seafloor goes back as far as the 1920s, when two petroleum scientists found bacteria in fluids produced from drilling oil wells, says Steve D'Hondt, a GSO oceanography professor, who led the first scientific expedition dedicated to studying life beneath the seafloor in 2002. It wasn't mainstream science at the time, he says, but interest grew as scientific ocean drilling began with the Deep Sea Drilling Project in 1968, followed by the Ocean Drilling Program in 1983, and the IODP in 2003.

The primary drivers, in the beginning, were focused on geologic questions. It wasn't until the 1970s that scientists became aware of the magnitude of life in the deep sea. In the 1980s and 1990s, scientists began to look more seriously at the potential for life beneath the seafloor. The vast reservoir of microbial life found there is now considered comparable to that found in the oceans themselves and plays an important role in global climate by storing carbon and influencing other chemical processes. "[Understanding] the range of what's possible biologically has been expanded tremendously by studying the subseafloor," says Spivack. Yet, the full impact of microbial activity on chemical cycling or even how microbes get energy is not fully understood, according to the IODP, but it is what scientists like Spivack are looking to find out from the 13,000 samples still being analyzed from the Nankai Trough.

In addition, Spivack admits scientists might find answers for questions they haven't even asked yet. "We don't become limited by the ideas which we came in with," he says. "We should try to see where the data leads us."

And to follow the data is an enormous undertaking. To conduct key microbial research, a stable laboratory onshore, equipped with state-of-the-art cell detection and quantification capabilities, was required as well as fresh core samples delivered directly from the ship. Over 44 helicopter trips were made from the ship to the onshore lab during the 2016 IODP expedition. Nearly 40 scientists of different disciplines from eight nations, in addition to a helicopter crew and drilling technicians, made such a feat possible. Although field operations concluded two years ago, scientists are still analyzing and collecting data from a temperature sensor left inside the drill site to better characterize temperature changes in the subseafloor.

"Studying these extreme environments to better understand how evolution happens in these systems could revolutionize and reframe what we know," says Justine Sauvage, a Ph.D. student at GSO who focused on how microbes use hydrogen for food.

"How do the organisms survive? We try to interpret the chemistry in terms of the metabolism of the deep biosphere. How much do they eat? What do they eat? How much do they produce?" says Spivack, who headed the inorganic geochemistry analysis of the expedition with Sauvage and fellow graduate student Kira Homola.

This drill bit was used by the IODP expedition in searching for life beneath the seafloor.
Photograph by JAMSTEC/IODP

OPPOSITE
The expedition ship, *Chikyu*, was home to an international team of scientists of different disciplines.
Photograph by JAMSTEC/IODP

But measuring the chemistry is only "half of the story," says Sauvage.

Takehiro Hirose, a physical properties specialist at the Japan Agency for Marine-Earth Science and Technology, is working with both geochemists and microbiologists to see if there's a link between earthquakes and microbes. Other scientists are also investigating how microbial activity in the deep biosphere influence the carbon cycle and climate.

"The special thing is, you have scientists from all over the world coming together and just trying to solve one problem," says Florence Schubotz, an organic geochemist from Marum, Germany. "You have scientists with backgrounds in geochemistry, microbiology, geology, and sedimentology. Every day, you learn something new."

Building that community was one of the primary goals of the Deep Carbon Observatory (DCO), one of several international organizations that supported the IODP 2016 expedition. The DCO is a 10-year global research initiative to better understand the backbone of all life on Earth—carbon—especially as life in the deep biosphere plays an important role in the fluxes of carbon both below and above the surface. "It's about challenging our assumptions about what life is like on Earth," says Katie Pratt, DCO's communications director, who is part of the program's outreach and engagement team based at GSO.

The other primary goal of the DCO is to expand the field of deep carbon research. "The DCO has done a good job of growing the field and community," said D'Hondt, who has been involved in its Deep Life program, which has supported postdoc and graduate students to work on relevant topics.

"It provides a great opportunity for students to get involved in international research and build experience to lead future expeditions of this magnitude," says Spivack. "Justine and Kira were instrumental in producing an unprecedented dataset that wouldn't have happened without their involvement and drive, and preparation at GSO. It sounds corny, but it's true."

Although DCO's 10-year initiative concludes in 2019, it's not the end. The program's website will remain as a "legacy" site, storing all the information collected over the various projects, including the IODP 2016 expedition. The most lasting effect, however, is the network of over 1,000 scientists in 40 countries and counting.

"Even though DCO will cease to exist as an entity, the community of scientists that we've built will continue doing this work in this new field of deep carbon science," says Pratt.

The results—and the questions—that arise from studying life beneath the seafloor will no doubt further science's continued quest to understand this world and any others that may exist.

ENDE

FANTASTIC VOYAGES NEAR END

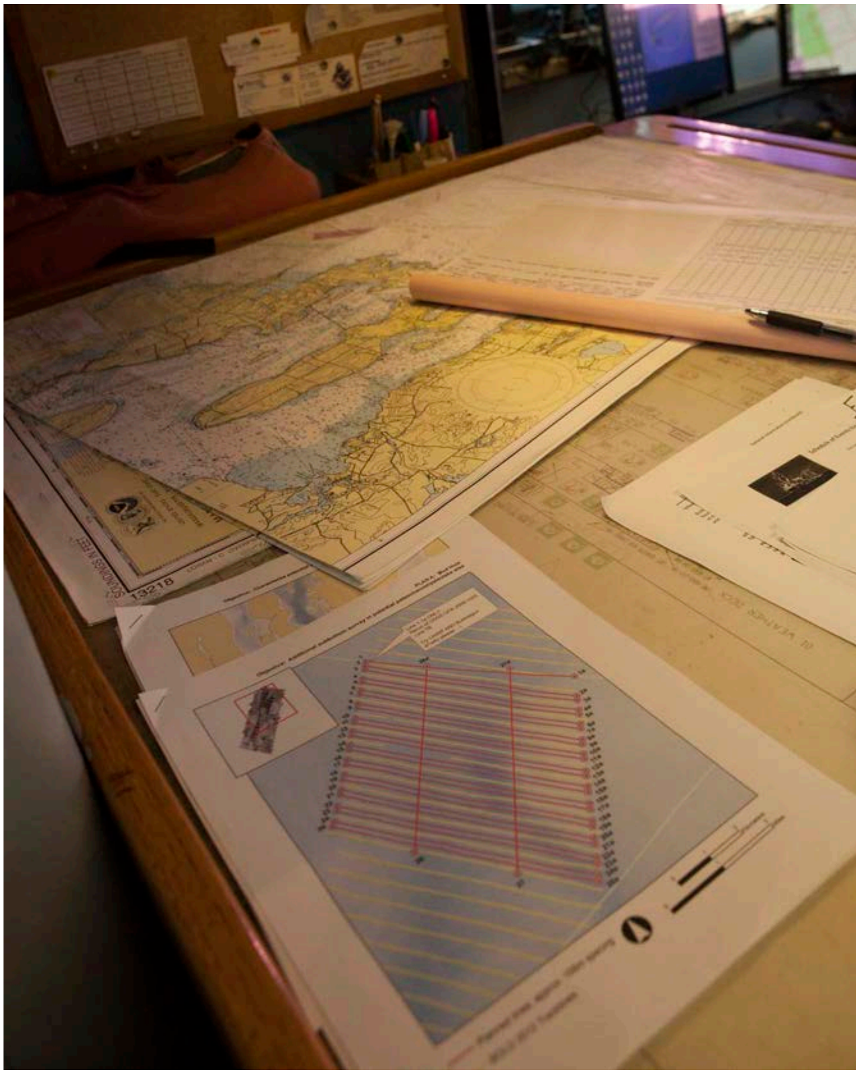
by **Todd McLeish**

AVOR

Endeavor photograph by Alex DeCiccio

STUDYING ABOARD THE *ENDEAVOR* IS A “LIFE-CHANGING EXPERIENCE” FOR SOME STUDENTS

Melissa Omand, seated, served as chief scientist for an *Endeavor* cruise while pregnant by utilizing the capabilities of the URI Inner Space Center.
Photographs on this and opposite page courtesy of GSO



IT HAS CRUISED THE WORLD'S OCEANS FOR 42 years—more than a million nautical miles from the North Atlantic to the South Pacific and from the Arctic to the Black Sea—and now is nearing retirement. But the R/V *Endeavor* is still hard at work about 200 days each year, taking oceanographers and students from the University of Rhode Island and dozens of other institutions wherever they need to go to conduct their scientific investigations.

The 185-foot steel-hulled ship, owned by the National Science Foundation but operated by URI since its commissioning in 1976, was one of the first in the nation to be designed as an oceanographic research vessel rather than converted from a military vessel. It has carried a crew of 12 and up to 17 scientists on nearly 600 expeditions.

On its first operational cruise, Endeavor responded to the M/V *Argo Merchant* oil spill near Nantucket in December 1976. Thirty-four years later, in 2010, the ship was on the scene of the Deepwater Horizon oil spill—the largest in U.S. history—in the Gulf of Mexico, where scientists assessed the spill's environmental impacts. Earlier that year, it delivered humanitarian supplies to the people of Haiti during a 14-day scientific survey of the seafloor seeking geologic evidence of the devastating earthquake that had just struck the region.

The *Endeavor*'s most notable journey may have occurred in 2006, when an international team of scientists, led by Robert Ballard, URI oceanography professor and discoverer of the *Titanic*, searched for ancient shipwrecks in the Mediterranean Sea and the Black Sea. During that trip, professors Haraldur Sigurdsson and Steven Carey sought evidence of a massive volcanic eruption that occurred circa 1600 B.C. around the Greek island of Thera.

During the expedition, the research team hosted live educational programs that were broadcast to audiences at aquariums, science centers, schools, and other venues around the world via the Inner Space Center at the URI Bay Campus. It was the first time the *Endeavor* was equipped with the satellite technology to broadcast its activities in real time. In recent years, this kind of outreach has become a routine part of the ship's agenda.

The *Endeavor*'s role in education has continued to grow year after year. Hundreds of students at the Graduate School of Oceanography (GSO) have had their first experience at sea aboard the ship, and numerous early-career oceanographers have been trained on the *Endeavor* in how to be a chief scientist.

Plenty of undergraduates have gotten a taste of oceanographic research on board, as well. The ship has been used as a floating classroom many times, including when a summer class in ocean ecology journeyed to the edge of the continental shelf, where students went scuba diving to collect specimens, trawled for fish as deep as 1,800 meters, and conducted measurements of the physical characteristics of the water column. Another group of undergrads, led by oceanography professors Susanne Menden-Deuer and Melissa Omand, spent spring break on the *Endeavor* studying plankton at Georges Bank.

"For several of the students, it was a life-altering experience that inspired them to go to graduate school to study oceanography," says Menden-Deuer. "I feel very strongly that the hands-on experience undergraduates get aboard the *Endeavor* is a truly unique opportunity that cannot be reproduced in the classroom."

Omand also taught an undergraduate honors course last year that she called CSI: Ocean, which included a six-day trip aboard the *Endeavor*. The class cruised to hot spots of marine life about 100 miles south of Rhode Island, where they used various state-of-the-art technologies to examine the relationship between the ocean's physical dynamics and a wide variety of marine creatures, from plankton to whales.

"It was a new experience for almost all of them, and they were taken aback by how challenging it was," recalls Omand. "But it also really elevated the significance of the class in their minds. The weather was reasonably harsh, and we dealt with some seasickness and equipment failure, which was not unusual. But they still had a lot of fun and bonded together."

Omand also had the unusual experience of serving as chief scientist for the first time on an *Endeavor* expedition without setting foot on the ship. She was pregnant when the long-planned cruise occurred, so she spent every day in the Inner Space Center leading the research and interacting with the captain and crew by telepresence.

"The captain was very accommodating, the crew and science party were all amenable, and we got into a rhythm after the first day or so," she says. "I don't even think of that cruise as being one that I spent on land because I was so engaged. I feel like I was 100 percent on board."

Local schoolteachers have also had the opportunity to travel aboard the *Endeavor* with URI scientists as part of the Rhode Island Teachers-at-Sea program, providing them with hands-on experience conducting oceanographic research that they can incorporate into their classroom lessons. In a typical three-day cruise, they spend a day at a shallow water site like Mud Hole, about midway between Block Island and Martha's

Photograph by Ryan Donnelly

Vineyard, where they deploy instruments to collect samples of sediment, water, and plankton to study in the on-board lab. They repeat the process the next day at a deep-water site to compare the samples and finish up on the third day at the Block Island wind farm.

"The main objective is to get teachers to understand how science happens at sea," says David Smith, associate dean of the GSO. "Working at sea is a lot more difficult than working on land, and the variability of the ocean itself somewhat limits what we can do and observe about it. Hopefully the teachers can bring what they've learned back to the classroom and work it into their curriculum."

The *Endeavor* isn't URI's first research ship. In 1962, the university acquired the R/V *Trident*, a 180-foot former Army coastal freighter built in 1945 and later converted into a research vessel. When *Trident* arrived at the URI Bay Campus, it boasted one of the largest scientific laboratories of any research vessel in the country.

But the reputation of the *Endeavor* has far surpassed that of *Trident*. In 2012, the *Endeavor* gained national recognition as the first ship in the U.S. academic fleet to convert its propulsion system to burn more environmentally friendly fuels. This was the first step in the GSO's effort to "green the fleet," which included the installation of more efficient LED lighting and the use of biodegradable hydraulic oil and lubricants for its winches, cranes, and other equipment. It has made the ship one of the more earth-friendly academic research vessels in the country.

According to Thomas Glennon, URI's director of marine operations, the environmental improvements to the ship's operations are just one element of the *Endeavor*'s stellar reputation among scientists. In post-cruise assessments by those leading each expedition, the crew and the marine technicians who assist the researchers always get high marks. As does the food.

"It's often physically difficult and can be stressful working at sea, so everyone always looks forward to a good meal," says Glennon. "It boosts morale and keeps

Melissa Omand programs the sensors on her "Wire-walker" platform—a wave-powered profiler that allows her to monitor properties of the ocean.
Photograph on this page courtesy of GSO; opposite photograph by Alex DeCiccio

everybody happy. It's rare that I don't get positive comments about the food."

Much of the credit for the high-quality meals is due to Chief Steward Michael Duffy, who orders the food, plans meals, and cooks delicacies that one wouldn't expect aboard a working research vessel. On almost every trip, he makes a complete roast turkey dinner, prime rib with Yorkshire pudding, rack of lamb, and numerous fresh fish dishes. The *Endeavor* was recognized in 2016 with the "Best Grub of the Year" award, beating out the other 18 vessels in the nation's academic fleet.

As with all ships, however, the *Endeavor* cannot continue operating in perpetuity. The typical life span of a large commercial vessel is about 30 years, and the *Endeavor* has lasted 42. But as normal maintenance costs increase with age—along with shipyard and drydocking costs—the National Science Foundation determined that the ship will be retired in 2020. When that happens, the ship's title will be turned over to the university, and the ship will either be sent to a federal or state institution or sold on the private market, most likely to an overseas research organization.

Bruce Corliss, dean of GSO, formed a consortium to operate the *Endeavor* for its last two years and to prepare a proposal to acquire a new vessel, which would be based at the Bay Campus. The new vessel, one of three being constructed to replace retiring ships in the academic fleet, will feature improved science labs, more comfortable berthing, better workspace, and state-of-the-art technologies, including a dynamic positioning system, which enables ships to remain in one precise spot for extended periods.

"The vessels are being designed now, with input from the oceanographic community. It was a competitive process so we're honored to have been selected to get one of them," Corliss said. "We're collaborating with the Woods Hole Oceanographic Institution and the University of New Hampshire, as well as 13 other members of what we call the East Coast Oceanographic Consortium, to pool our resources and I think that presented an undeniably strong case."

The selection of the URI-led consortium to operate a new ship, Corliss said "is a testament to GSO's 50 years of leadership in ocean science. This is also outstanding news for the state's blue economy because the cutting-edge technology and exciting new opportunities for research, education and outreach that the new vessel provides will strengthen the Ocean State's reputation as a hub for innovation."

DIVING DEEP FOR NEW DRUG THERAPIES

by **Todd McLeish**

Photographs by **Jesse Burke**

HUMANS HAVE RELIED ON A WIDE VARIETY OF natural compounds from plants, fungi, and other organisms for their medicinal properties for many thousands of years.

The search for new medicines to treat diseases has long relied on these natural products, so much so that approximately 75 percent of the medicines in use are believed to have originated from molecules extracted from wild species. The most widely used breast cancer drug, for instance, was developed with elements from the bark of the Pacific yew tree, and the anti-inflammatory agent in aspirin is derived from the bark of the willow tree. Penicillin, codeine, quinine, and many other well-known medicines originated in this way as well. Only about 10 percent of the world's biodiversity has been evaluated for its potential for medicinal use, however, and the challenge has become how to access likely candidate species, especially those in the oceans.

David Rowley has accepted that challenge, which some have described as a global scavenger hunt. The professor of biomedical and pharmaceutical science at the University of Rhode Island College of Pharmacy is leading the search for potential medicinal agents from microorganisms in the ocean. He has collected and tested samples from water bodies around the world—


got symbioses?

David Nelson, Kathleen Castro, Marta Gómez-Chiarri, and David Rowley search for microorganisms that will prevent disease in farm-raised oysters.

from Narragansett Bay to the South Pacific—and he collaborates with scientists who travel to even more extreme realms.

"The marine environment is the biggest source of biodiversity on the planet, and the tiny microorganisms there produce some truly novel chemistry," he says. "I've always been fascinated by those molecules [they produce] and the fact that they've been produced for a purpose, though that purpose is often unknown."

Rowley knows that the drug development process takes many years from the initial research to an approved drug, and his research is the very first step in that process. But he enjoys imagining what might be possible with newly discovered molecules, such as curing antibiotic-resistant infections, which Rowley says are one of the world's biggest health threats. Much of his research has focused on finding microorganisms from the ocean with antibiotic properties.

"With our current challenge of trying to overcome drug resistance ... the marine environment is one area we need to explore more fully if we're going to come up with the next generation of antibacterial agents to combat disease," he says.

What he's looking for are interesting chemical interactions between microorganisms.

"If we just went out into the environment and isolated lots of bacteria—in an average milliliter of water there's probably a million molecules of bacte ria—we'd fail far more often than we succeed. So we want to focus our attention where we feel chemistry is involved in the competition between organisms."

URI has a long and rich history of research into the biomedical applications of marine organisms. Heber Youngken, the founding dean of the URI College of Pharmacy, studied the medicinal properties of plants, and he believed that the next frontier of drug discovery would come from the world's oceans. He hosted the country's first conference on marine natural product chemistry in 1967, and two years later he hired the university's first faculty member to study the subject, Yuzuru Shimizu.

A pioneer in the search for potential anti-cancer agents in the oceans, Shimizu spent more than 30 years studying marine microalgae, especially the toxins produced by red tides. Believing that those toxins might make good drugs, he partnered with the Bristol-Meyers Squibb Pharmaceutical Research Institute and discovered numerous molecules with medicinal properties. "Drugs and poisons can sometimes be synonymous," he said in a 2001 interview. At the time, his lab contained room after room of test tubes, jars, and jugs growing various species of microalgae from around the world.

As Shimizu prepared to retire in the early 2000s, he sought to ensure that the international reputation he helped establish at the College of Pharmacy would continue, so he initiated a search for his replacement. That's when Rowley was hired. "I came here because URI was one of the most important homes for marine drug discovery and marine exploration," Rowley says. "It was Shimizu's success that drew me to URI."

As a child, Rowley dreamed of becoming an oceanographer, but he wasn't sure how to do so. When he enrolled in college, he discovered that he enjoyed organic chemistry. Later, while working for a biotechnology company synthesizing molecules, he took a class in natural products chemistry and was inspired by it. "That's when I first found people studying marine natural products, and it brought me full circle to combine my interests in organic chemistry and oceanography," he says.

Matthew Bertin had a similar epiphany, but his occurred among coral reefs while working as a photographer for the state of Florida. Every time he went scuba diving, he became increasingly curious about the chemical ecology of the reef systems and how many corals were being stressed by diseases carried by marine microbes. Now an assistant professor of biomedical and pharmaceutical sciences at URI, he studies the compounds produced by blooms of marine cyanobacteria—the mats of blue-green algae that are among the most ancient organisms on Earth.

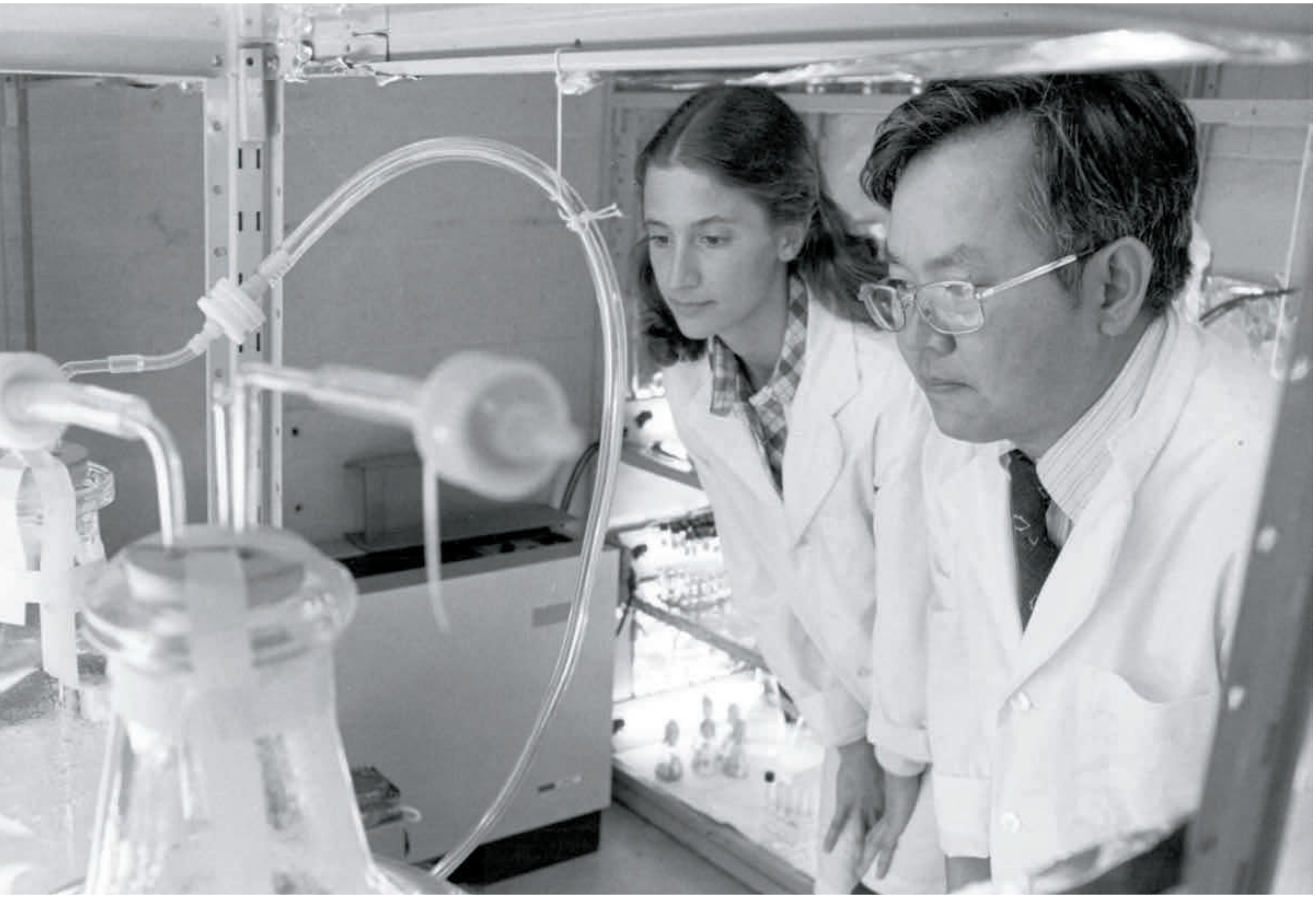
"The compounds are thought not to be made for growth or reproduction but instead for defense, to ward off grazers or other competitors," says Bertin. "And because marine cyanobacteria are so old, they've had a long time to have their genes mutated and duplicated and diverge, so they make all of these interesting molecules."

Like Rowley, Bertin aims to extract new molecules from these blooms of cyanobacteria and test them for potential therapeutical use against a wide range of diseases. He and colleagues from Texas A&M University are collecting buckets of algae from the Gulf of Mexico, where the blooms are largely cyanobacteria, for analysis in his URI lab. He has already identified 21 new molecules and has begun testing them for anti-cancer properties.

Bertin is also curious about the genetic architecture of the chemical compounds he is working with. He believes their structure will help him learn more about how the cyanobacteria produce them.

"When you look at some of the molecules ... from the bloom, they have the same general carbon backbone, the same core structure, but then they have little deviations," he says. "I'm fascinated by what's controlling it, and I'm quite certain it's genetically controlled."

A better understanding of that molecular architecture may enable scientists to engineer uniquely structured genes to build new compounds that could be used



Professor Yuzuru Shimizu, right, was the first URI faculty member to study the potential of marine organisms for biomedical applications. Photograph courtesy of URI

as therapies for a variety of diseases.

But it all begins with collecting and analyzing these buckets of blooming algae. So Bertin is seeking partnerships with scientists in distant corners of the globe who could regularly collect samples for him. He is particularly interested in finding partners whose work takes them to the waters off Australia and in the Red Sea, where cyanobacteria commonly bloom. He is already collaborating with scientists in Italy who identified molecules in a sponge in the Mediterranean Sea that were very similar to some of the molecules he found in the Gulf of Mexico.

"The ultimate goal is to build a library of pure compounds and then try to ... see where they might be therapeutically relevant," Bertin says.

While the research by Bertin and Rowley primarily focuses on seeking marine microbes that may help combat human diseases, they are also addressing diseases that affect creatures living in the marine environment. One of Rowley's newest projects aims to manage or prevent diseases common to shellfish.

He says that diseases are one of the most significant limiting factors in the successful farming of shellfish. And while some aquaculture farms use antibiotics to reduce disease outbreaks, their use can lead to the same kind of antibiotic-resistant bacteria that are causing so many problems for people. So he is trying to identify naturally occurring microbes that could serve as probiotics to combat disease.

"Probiotic agents are microorganisms—most often a bacterium—that can promote the health of a host organism," Rowley explains. "It might do that by breaking down molecules or providing nutrients to the host or by promoting disease resistance. In aquaculture, it might even help to promote water clarity."

ABOVE

The answers to preventing marine diseases affecting oysters and shrimp could come from beneficial bacteria that fight off pathogens.

OPPOSITE

Matthew Bertin is studying cyanobacteria blooms, like this one, for their ability to fight diseases such as cancer.
Photograph courtesy of NASA

Working with URI professors Marta Gómez-Chiarri and David Nelson and research associate Kathleen Castro, Rowley is seeking to understand the mechanisms by which these organisms provide a benefit to their hosts and how best to provide the organisms to farmed shellfish.

According to Gómez-Chiarri, the process is somewhat simple. Using a sterile swab, she rubs the shell of an oyster and cultivates whatever bacteria are collected. Then she drops a small amount of the various bacteria on a plate with a disease-causing pathogen, and any bacteria with antibiotic properties will kill the pathogen around it. The researchers have identified two microorganisms—one collected from healthy oysters in Narragansett Bay and one from a sponge found in the Narrow River, which flows through North Kingstown, South Kingstown, and Narragansett—that could be used as probiotics against the common oyster disease vibriosis.

"We tested [the probiotic] with the larvae of oysters because they're especially susceptible to the disease," says Gómez-Chiarri. "We treated them with the probiotic and then introduced the pathogen, and we had a high survival rate. The next step is to try to understand how they do it. It's not clear how probiotics work."

The other challenge is that the probiotics have to be alive to do what they do, which will make mass production difficult.

"It's one thing to produce enough of the probiotic to test in the lab, but at a hatchery it has to be administered every day, so we need to produce a lot of it and figure out how to preserve it," Gómez-Chiarri explains. "The one from the sponge survives well when dried and made into a powder, but the other one is more complicated. We've applied for a grant to produce it in larger quantities and test it at commercial hatcheries."

Similar studies of probiotics for disease prevention at shrimp farms are also promising, though early efforts targeting the shell disease that infects wild lobsters in southern New England have not yet proved successful.

All the researchers agree that there will not be just one solution to the problems of antibiotic resistance, infectious diseases, or disease outbreaks in aquaculture farms. Each problem will probably require numerous approaches from a wide variety of scientists from different disciplines.

"But at the end of the day, I hope the research we conduct here is going to contribute to finding solutions to some of the problems we face today and those we may face in the future," Rowley says. Besides the outcomes of the research itself, "the work we do is … training the next generation of scientists who will be responsible for the well-being of our planet and our people into the future."

A LIFETIME UNDER THE WAVES

JON WITMAN AND THE WITMAN LAB

by **Emily Greenhalgh**

Portrait by **Dana Smith**

THE WORD "LAB" MAY SUGGEST WHITE COATS, microscopes, and petri dishes. But for Jon Witman and the members of his lab at Brown University, the word has a completely different—and wetter—connotation.

The group of 10 spends much of their time together as a lab in the field, most frequently in the iconic Galápagos Islands.

"I work closely with all my students underwater," says Witman, a marine ecologist, who has been a member of Brown University's Ecology and Evolutionary Biology Department since 1994 and whose research focuses on seafloor communities such as corals, mussels, and urchins.

"You'll be hard-pressed to find someone this far along in their career that spends as much time underwater as he does," says Robbie Lamb, Witman Lab Ph.D. candidate, who studies fish communities that live in the water column.

Witman, who began diving off the coast of New Jersey when he was 16 years old, has worked under six of the Earth's seven oceans. (It would only take Antarctica's Southern Ocean to complete the set.) He also lived in an underwater sea base for two weeks, studying corals and sponges on a deep-sea reef.

"Since I've joined the lab, he's taken me on some of those adventures," Lamb says.

A Long-term Perspective

For the last 18 years, Witman and his students have spent at least three months a year studying marine biodiversity in the Galápagos, which Witman says has the highest functional diversity level in the entire world. The members of his lab say they're lucky to be able to use the island chain as a living laboratory.

Witman and a changing group of students have gone to the same 12 sites every eight months since 1999. In some of their most-studied areas, Witman and his students have set up permanent quadrats. Placed randomly within an interesting habitat, scientists can identify and record the different species in the area, gaining a representative sample.

"You can investigate the way ecosystems *should* work in the rest of the world," Lamb says of the Galápagos. Coming back year after year has allowed these researchers to watch the pristine ecosystems shift and change as the entire Earth shifts and changes.

Lamb says that you can't really call anything baseline in the Galápagos. "It's just too dynamic," he says. "But we have Jon's long-term perspective to draw on. He's really got a sense of what's normal, what patterns are repeating, and what's never been seen before."

Since 1999, Witman has followed the Galápagos ecosystems through three full El Niño-Southern Oscillations, ENSO for short. ENSO is a naturally occurring climate pattern across waters in the tropical Pacific. It comprises a warm phase (El Niño) and a cool phase (La Niña). ENSO may be naturally occurring, but the magnitude of the variability is getting larger as Earth's climate warms.

Jon Witman displays some of the specimens he has collected while diving.

The question becomes how far outside of the mean can these observations go until they are no longer able to recover.

Witman recalls the first time he saw the devastating effects of bleaching on the reefs he knew so well during a research trip in January 2008. "Seeing the first large-scale coral bleaching in the Galápagos, in places that I knew like the back of my hand, absolutely blew me away." Witman says the reefs looked like "a snowfield underwater."

An Undersea Life

The Galápagos weren't Witman's first experience with a troubled ecosystem. As a New Jersey high school student, he volunteered at the Sandy Hook Marine Laboratory. During the 1960s, it was legal (and commonplace) to dump sludge and sewage off the New York and New Jersey coasts.

"Starting from six miles out, the water would go from olive green to black as far as you could see," says Witman. "There was a place called the acid grounds that would dry the monofilament [single-strand fishing line] to white."

Inspired by these experiences, Witman started his college career at Franklin & Marshall College in Pennsylvania but left to conduct a year-long independent study in New Zealand. He studied animal-sediment relationships in New Zealand's Blueskin Bay Estuary. That year stuck with him.

"This experience taught me how to do science, and it helped develop my world view of ecology and sense of belonging to a global human community," he says. After that, he took a long break from his undergraduate studies, using the academic hiatus to work and dive on underwater salvage operations.

"When I took a year and a half off, I was young, and I was exploring," says Witman, adding that even if he wasn't sure what form his future career would take, his path was "always directed toward the ocean."

Witman went on to finish his undergraduate career and go straight through to complete his Ph.D. at the University of New Hampshire.

Protecting Another World

The graduate work took him closer to home in waters off the Northeast United States. Cashes Ledge is an underwater mountain range and kelp forest located in the Gulf of Maine, about 80 miles off the coast of Gloucester, Massachusetts. It boasts an enormous amount of biodiversity. Scientists believe the area was formed by the same geological event that created the White Mountains.

Marine biologist and conservationist Sylvia Earle calls Cashes Ledge, which comes within 30 meters of the surface, the "Yellowstone of the Atlantic Ocean."

Witman started working on Cashes Ledge in the mid-80s, a time he calls the "Sputnik Era for marine

“WE NEED AREAS THAT ARE PERMANENTLY PROTECTED”

ecology.” There was a big funding push by the federal government to use ships and submarines to study offshore and deep areas in the Gulf of Maine. Today, although there are significantly fewer funding opportunities than there were in the 1980s, Witman still studies on Cashes Ledge, getting there at least once a year, and he tries to bring students with him.

“I believe there’s a trend for fewer graduate students working underwater. It takes longer to get your data and it’s harder,” says Witman. “But it’s great

Determining what role different species play in ecosystems is important for managing oceans, Witman believes.
Photograph by iStock.com/LFPuntel

to bring students to a marine location and show them how to work underwater and how to ask the questions and get the answers about what's important to marine life."

Fiona Beltram, a Brown University senior who has been a member of the Witman Lab since her first day of freshman year, has joined the research teams in the Galápagos twice so far. "It's just such a cool experience to be able to have," she says. "When suddenly that piece of random classroom information becomes relevant when you're underwater … that's really, really important."

Lamb, too, has been lucky enough to benefit from Witman's drive to bring students to the field. In addition to joining him in the Galápagos, Lamb has visited the waters near the remote Easter Island and the rich Cashes Ledge area.

"Going down through this murky water, I see this fluid, wavy movement, and I see this kelp forest that stands about 15 feet high," says Lamb, describing the first time he visited Cashes Ledge as "descending into another world."

Witman has been working for years to get the U.S. government to list the Cashes Ledge area as a National Marine Monument—the equivalent of a national park in the ocean. "A farmer doesn't harvest their seed crop," says Witman. "We need these refuges, we need areas that are permanently protected."

A protected area in the Gulf of Maine could be especially important. Where ocean temperatures worldwide have risen at an average rate of 0.12°C every decade since 1980, sea surface temperatures in the Gulf of Maine are warming 99 percent faster than those on the rest of the planet.

Burning the Library

Trying to get Cashes Ledge declared as an underwater monument was "very much a politically active process, which as a scientist, you're sort of averse to," says Lamb.

But, Witman says, "with all of the human impacts, it's like we're burning the library of ocean biodiversity before we even know what's in the books. We need more exploration."

To really manage the oceans properly, Witman believes we need to understand three key things: Which species are the keystones of the community? How does biodiversity affect how ecosystems function? And perhaps most importantly: How is this all being altered by us as humans?

He recalls that when he was advocating for the

protection of Cashes Ledge, people were amazed at the photos of the area's biodiversity. "It's kind of astonishing ... People had no idea that there was all of this spectacular marine life just 100 miles away," says Witman.

"We don't really know what the biodiversity of the ocean is," he says. "And my God, that's ridiculous!"

That passion for exploration, and the importance of sharing your knowledge with those outside of science are things he passes on to the students in his lab. "What's the point of your trying to improve our relationship with nature and the world and creating a sustainable planet if no one is informed by your information?" he says. "It's much better to hear it from someone who is passionate about it than to read about it in a textbook."

The Tuna and the Whale

When he started his undergraduate work in marine ecology, the type of work he was drawn to—environmental and anthropogenic—was frowned upon. At a time when the field of ecology focused on ecological theory rather than human impacts, Witman's kind of research was referred to as "applied ecology."

"Luckily the field has come full swing to realize that working on human impacts on the marine ecosystem is tremendously important," says Witman.

It's a message he works hard to pass onto his students. Work in the field, he says, is not always an easy road. "But I always tell my students that to find something you're passionate about and reasonably good at ... if you can line up those two axes, you've absolutely got it made."

ABOVE
Witman compares Cashes Ledge in the Gulf of Maine, which includes a kelp forest, to a "seed crop."
National Geographic Creative/Alamy Stock Photo

OPPOSITE
Marine iguanas, which live only in the Galápagos, are threatened by climate change.
Photograph by Thomas P. Peschak

Witman calls himself lucky. Not just for the places he's traveled and the work he's done, but for being able to share that work with his students. "I've had a wonderful career I'm passionate about," he says. "and I just love being on the ocean and underneath it."

Witman's approach has certainly had an effect on his students. Lamb describes Witman's mentorship with a metaphor from marine biology. On one end of the continuum, he says, is the tuna that puts out 200,000 tiny eggs, of which only a few will survive. On the other end is a whale that has one baby every few years, but it puts tremendous energy into the development of that baby.

"Jon is the whale," says Lamb. "He's willing to sacrifice perhaps some of his own professional legacy in the volume for the quality of having well-developed, well-trained scientists coming out of his lab. I'd say that's his calling card."

"WE DON'T REALLY KNOW WHAT THE BIODIVERSITY OF THE OCEAN IS," HE SAYS. "AND MY GOD, THAT'S RIDICULOUS!"

POLYMER TIDES

Two Rhode Island artists find inspiration—and raw materials—at the shoreline

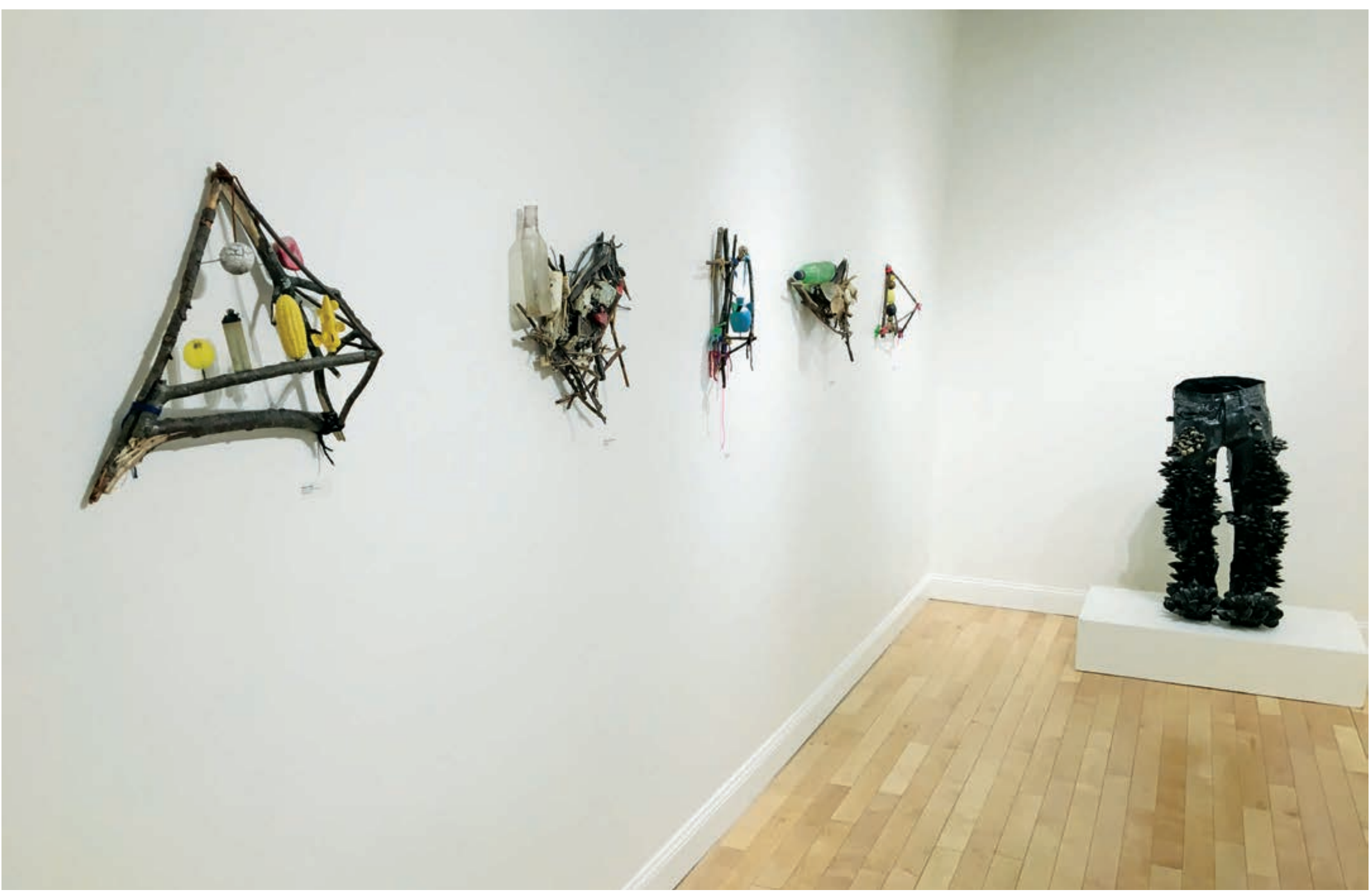
by **John Taraborelli**

ABOVE
Joan Wyand confronts challenging social issues in a variety of media, including shoreline debris.

OPPOSITE
Wyand's assemblages and Scott Lapham's found sculptures comprise the *Polymer Tides* exhibit at AS220.

THE RHODE ISLAND SHORELINE HAS INSPIRED generations of artists—you can scarcely browse an art fair anywhere in the state without seeing evidence of it—but where many are moved to paint watercolors of lighthouses or take pensive photographs of sunsets over the bay, Joan Wyand and Scott Lapham are inspired by different muses. Lapham is known primarily as a photographer and Wyand as an avant-garde performance artist, but both found something new to say through sculptural work that tells stories of a shoreline in peril.

In a classically Rhode Island turn of events, both Wyand and Lapham spent time in 2016 scouring the shore in East Providence, roughly a half-mile from each other, gathering the raw materials for what became their joint exhibition at AS220's Project Space gallery, *Polymer Tides*—and neither was aware of the other. The two were eventually brought together by AS220 Gallery Director Neal Walsh, and their combined work is surprisingly cohesive for two artists working in isolation.



Scott Lapham,
Perfectly Preserved Sea Shore

Polymer Tides, which ran from November 4-25, 2017, is a collection of three-dimensional, collage-like sculptures made entirely of materials collected along the shoreline. The pieces are immediate and unsettling, and the realization quickly hits you: All that junk was in our water. Plastic bottles are by far the number one offender, but human-generated, inorganic bits of all sorts mix with organic matter to create startling reminders that things we throw away don't necessarily go away.

Despite the similarities, however, Wyand and Lapham's interests and approaches came from different directions, making their eventual convergence even more interesting. Wyand, who has worked with trash as fodder for other types of creation in the past, finds wonder in the possibilities of reusing what others have discarded.

"I just kind of fell in love with this stuff. It's like the shoreline was this vintage store," she recalls thinking. "Why are these things even here? Why aren't we reusing them?"

So, she began reusing what she found, assembling pieces of driftwood, plastic bottles, and other detritus into playful sculptures. The intent is not to gloss over the damaging effects of litter in our tidewaters but to reframe the idea of waste. One of her goals is to remind viewers that if we, as a society, were more serious about reusing waste materials, most of that junk wouldn't have found its way to the shoreline to begin with.

"I want people to stop thinking of it as [only] a problem," she explains. "There's material out here. How can we use it?"

For his part, Lapham approached the shoreline more as a documentarian.

"I started looking at the tideline as a sample of what's really in our environment," he says. "There's beauty in the way the sun and tides have arranged things."

Naturally, he tried photographing what he found, "but it just looked like trash," he notes. His desire to show people exactly what he was seeing led him to a novel approach: preserving sections of debris directly at the shoreline with an epoxy resin so that they can be displayed on a wall just as they were found. Lapham did not arrange or construct the material into these pastiches of plastic bottles, twigs, and shells, he only selected which areas to preserve.

"When people realize I didn't construct the sculptures, they kind of do a double take," he says. "That's what I was hoping for. We all know what it is—putting it on a wall allows a different kind of reflection."

That two artists coming from different points along the shoreline can find such remarkable continuity speaks volumes about their creative processes, but the loudest and clearest message is about the tragic ubiquity of our wastefulness in one of our state's most precious places.

See more of the artists' work at scottlaphamprojects.format.com *and* joanwyand.com.

Two pieces from Joan Wyand

SEAFOOD LOVERS ON A MISSION

Exploring New England fish markets through citizen science

by **Kate Masury** & **Sarah Schumann**

Your mission, should you choose to accept it, is to eat local seafood once a week for 26 weeks.

Every Sunday, you and 88 other individuals will receive an assignment containing four randomly generated New England seafood species. No two lists are the same. You will each have seven days to visit up to three retail locations where seafood is sold. At each location, you must record whether or not the four species are present.

If you find one of your four species, you must buy it and take it home. If you find more than one, you must make a choice.

Once home, you must prepare your purchased seafood, feed it to your family, and closely monitor your enjoyment of the dish.

Should you or any of your family members feel particularly delighted with the seafood you devoured, you shall share a photograph of it on social media for everyone to admire.

Good luck.

Thus began a six-month adventure for a group of 89 intrepid strangers who volunteered for the "Eat Like a Fish!" project coordinated by Jeremy Collie at the University of Rhode Island Graduate School of Oceanography and the nonprofit organization Eating with the Ecosystem.

The rationale for the project was both economic and ecological. New England's marine ecosystems are home to an astounding array of species, but only a thin slice of these can be found in our seafood markets. Some are not harvested due to lack of demand, while others are harvested and shipped elsewhere. Disproportionately selective harvest patterns can disrupt ecosystem dynamics, while seafood export can mean a loss of potential economic value to the region.

These concerns prompted the research team to wonder: What local species are found in the marketplace? Why do shoppers choose certain species over others? And most importantly, when people take the time to try new local seafood species, do they like them?

Recognizing that no one is better qualified to answer these questions than shoppers themselves, the research team rounded up an eclectic group of New England seafood lovers and sent them on a mission.

Participants included a children's book illustrator from Rhode Island, a student from Maine, a carpenter from Connecticut, and an ice-cream production manager from Massachusetts. But they all had one thing in common: a curiosity to learn more about New England seafood. Armed with a wallet and a shopping bag, they set off on a fishing trip—not at the beach or from a boat, but at seafood shop counters, in grocery store aisles, and under the tents of their local farmers markets.

Between May and November 2017, citizen scientists made almost 3,000 visits to over 300 markets around New England. They cooked and ate over 1,000 fish, representing 50 different local species.

Their "data" was mouth-watering. Kelp noodles with white wine. Whole poached weakfish with lemon and garlic. Grey sole on couscous. Parmesan-encrusted striped bass. But it also provided important observations that together tell a story about the New England seafood retail marketplace. And for participants themselves, the experience was transformative.

Seafood counters favor monotony over exploration

The delivery of each week's "fish list" was an exciting moment for citizen scientists, and they reveled in the prospect of tasting unfamiliar local species like cunner, John Dory, butterfish, and skate. But all too often, they found nothing local at the seafood counter but cod, haddock, and lobster.

One week, after searching for blue crab, swordfish, spot, and conch—and encountering blank faces at the seafood market—Debbie Proffitt of Rhode Island exclaimed, "It's really been enjoyable to research the different species, but it's too bad I can't find them to try them!"

Zachary Miller-Hope, who lives along the Saco River in Maine, echoed this sentiment, after striking out on his fish list several weeks in a row. "It is disappointing that I have so few options available to me," he said, "when I live and work within minutes of the Gulf of Maine."

A successful expedition requires an expert guide

Participants who got the most out of their adventure were those who formed close relationships with knowledgeable fishmongers. The best fishmongers were able to answer questions about the type and origin of the seafood on sale at their counters and were eager to provide tips on preparation. Some even saved citizen scientists' contact information and notified them when interesting species arrived at market.

ANDREW McCARTHY DISCOVERED THESE RAZOR CLAMS FOR THE PROJECT.

"Asking the fish counter about where their fish comes from was an adventure in itself," said Jayne Martin of Connecticut, who discovered that the evening-shift seafood sales person at the Big Y was a New York City fish buyer by day, a post which had equipped him with a wealth of information about the fruits of the local sea, which he was keen to share with fellow enthusiasts.

Daryl Popper stumbled across a similar treasure in Massachusetts:
I went on an adventure to Cape Ann with my mom in celebration of Mother's Day, and we had a blast cruising through Gloucester in search of whiting, weakfish, striped bass, or swordfish. We met locals along the way who pointed us in the direction of Turner's Seafood, just outside the town center. We met with the team at Turner's and discovered that their swordfish was fresh from off the coast of Cape Cod. They were excited to learn about our project, and they encouraged me to return so they could share more local information about the boat and the fishermen that work hard to provide native fish to their markets.

But not all sales teams were as animated or informed.
"Fish is a big part of my diet and my life," explained Taylor Feuti of Maine, a former commercial fisherman. "One thing I am surprised by is the actual lack of knowledge of some of the shop workers I buy the fish from. None of them knew what tautog was (which I find is common north of Cape Cod) or conch, which is one of my favorites and another one I have trouble finding."

Nor did many vendors know where their fish was from. "I have been frustrated by the inability of our local grocery stores to tell me anything beyond country of origin for the fish that they sell," lamented Barbara Rotger of Massachusetts. "Much of it may be from New England, but they are unable, or unwilling, to share this information."

Advancing into uncharted territory
For many participants, the citizen-science project was an opportunity to step outside their seafood comfort zones. They found new favorite fish, gained confidence in their seafood cookery, and even overcame previous bad experiences and negative perceptions about certain species by giving them another try. For some, this project was the first time they had ever tried cooking seafood at home.

Conversions and revelations were common. For example, Connecticut participant Deborah Mager's feelings towards scup (also known as porgy) changed from skepticism to fanaticism as she got to know it a little better. "Porgies have the reputation of being called a trash fish and being bony. A woman standing next to me when I asked for the fish gave me a look that made me feel like I was buying 'trash fish,' and I have to admit I felt a tinge of embarrassment for purchasing it." But after overcoming her doubts and taking it home (where her husband valiantly scaled it), she wrote, "I have to tell you, this is a 'trash fish' that you should be eating right now! Porgy meat is white, meaty, mild and very similar to flounder meat, and tastes great!"

A lifelong quest
Returning to daily life after a challenging journey sometimes leaves adventurers feeling hollow. But for this corps of citizen scientists, the mission doesn't need to end just because the project is over.

Reflecting on her experience, Rhode Island participant Sherri Darocha "spent a little time looking back on all of the fish recipes that I've prepared so far, the new-to-me species that I've been lucky enough to find, and all of the great little seafood shops I've been introduced to as my search region has expanded." This prompted her to feel a mixture of fondness and unquenched yearning:

At the inception of Eating with the Ecosystem, I had no doubt that I would find, prepare, and marvel at my brilliance with new, exotic, local species of seafood each week! It would be a great excuse to seek out specific ingredients and expand my culinary horizons. I never dreamed that most weeks it would be so challenging to find even one fish on my list. I've got lots of pent up fish envy that will only be soothed by finding species that have eluded me, like cunner and red hake (and dozens of others). I have no doubt that I will continue the quest even after the study has concluded.

Eating with the Ecosystem will be using the results from the project in ongoing work to educate consumers about eating a diversity of species.

RECIPES

OVEN-STEAMED WHOLE BLACK SEA BASS

by **David Ford** (citizen scientist, Rhode Island)

Ingredients

- 1 whole black sea bass, about 2-3 pounds, gutted and scaled
- 1 cup rice wine vinegar
- 1 cup low-sodium soy sauce
- ¼ cup fish sauce
- ¼ cup sesame oil
- ¼ cup plus 2 tablespoons olive oil
- 2-inch piece ginger, minced
- 6 garlic cloves, minced
- 3 jalapenos, sliced
- 1 bunch scallions, green parts only, roughly chopped
- 1 bunch cilantro, chopped
- 2 tablespoons sesame seeds, toasted
- Sea salt and black pepper (Tellicherry preferred) to taste

Preparation

Set oven to 450 degrees.

1. Prepare the steaming sauce. In a bowl, whisk together rice wine vinegar, soy sauce, fish sauce, sesame oil, ¼ cup olive oil, ginger, garlic, jalapenos, half of the chopped cilantro, and half of the chopped scallions. Pour into an ovenproof casserole dish. Liquid should cover the bottom at least half an inch deep.
2. Heat casserole dish on stovetop until sauce begins to bubble. Remove from heat.
3. Place fish in casserole dish and let marinate for 10 minutes.
4. Remove and shake off liquid. Set a rack large enough to hold the fish over a casserole dish. Rub rack with olive oil. Place fish on rack.
5. Cut two diagonal slits on each side of fish. Spoon sauce into slits, and place a few chopped scallions into each slit.
6. Form a loose tent with aluminum foil over casserole dish.
7. Steam fish in oven for 10-12 minutes. Cooking time will vary with thickness of the fish. Flesh should look opaque, there should be no pink at the bone, and there should be little resistance when flesh is probed gently with a table knife.
8. Remove fish from oven and place on platter. Reserve steaming sauce for serving on the side.
9. Make the topping. Place a skillet or wok over high heat and add 2 tablespoons olive oil. When oil looks hazy, add remaining scallions and toss to coat. Sprinkle lightly with salt and pepper. Stir-fry until slightly charred, about 2 minutes. Set aside for serving.
10. Using two forks, separate fish from carcass. Remove and discard skeleton.
11. Scatter charred scallions, remaining cilantro, and toasted sesame seeds over fish.
12. Serve steaming sauce on the side.

Tip

Check that all the steaming liquid does not evaporate while in the oven. Add water if needed. This recipe would work well for any small whole fish.

ROASTED MAHI MAHI WITH LEMON, PARSLEY, GARLIC OIL AND GARLIC SCAPES

by **David Ford** (citizen scientist, Rhode Island)

Ingredients

- 1½ pounds fresh mahi mahi fillets
- Olive oil for baking and frying
- Sea salt and black pepper (Tellicherry preferred) to taste
- 1 bunch garlic scapes, ends trimmed
- 6 garlic cloves, minced
- 1 lemon, juiced
- 1 bunch parsley, chopped
- 1 lemon, cut in wedges

Preparation

1. Set oven to 450 degrees.
2. Brush fillets with olive oil on both sides. Liberally sprinkle salt and pepper on each side and rub into the flesh with the backside of a soup spoon.
3. Lightly coat a baking sheet with olive oil, and arrange fillets and garlic scapes on sheet.
4. Roast for 10 minutes or until reaching desired doneness.
5. Meanwhile, pour enough olive oil in a pan to cover the bottom and heat until just shimmering. Add garlic and gently cook a few minutes. Do not let garlic brown. Stir in half of the lemon juice. Remove from heat.
6. Lay roasted fillets on a serving platter. Scatter chopped parsley on fish and drizzle with remaining lemon juice. Place garlic scapes on top.
7. Serve with leftover cooking oil and lemon wedges on the side.

Tip

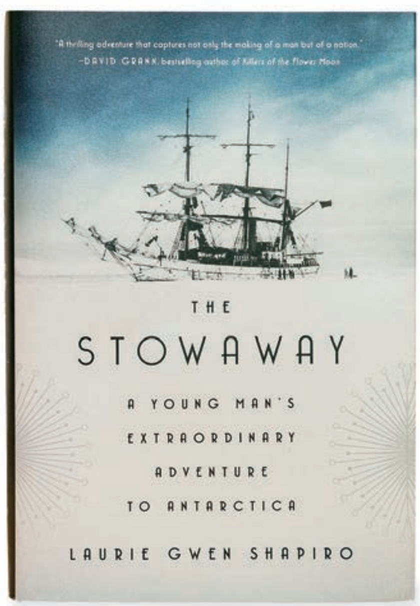
The garlic sauce is served on the side to allow spooning the desired amount on the fish when served. The garlic scapes add crunch and visual appeal to the fish. This recipe would work well for most fresh filets of fish.

The Stowaway

A YOUNG MAN'S EXTRAORDINARY ADVENTURE TO ANTARCTICA

by Laurie Gwen Shapiro

Reviewed by **Monica Allard Cox**



THERE WAS A TIME WHEN ANTARCTICA, not the deep ocean, was considered "the last frontier on Earth left to explore," and in 1928, the man determined to do so—and to cement his fame, if not his fortune—was Cmdr. Richard Evelyn Byrd.

By then, the explorer and retired naval officer had already suffered public setbacks—Charles Lindbergh narrowly beat him in 1927 as the first to fly nonstop between New York City and Paris, and his claim to have been the first to fly over the North Pole in 1926 was called into question by those who thought he had fudged his coordinates.

Still, according to Laurie Gwen Shapiro's recent book, *The Stowaway*, his exploration of the North Pole, his carefully cultivated charisma, and his ambitious plan to be the first to fly over the South Pole captured the imagination of 17-year-old William Gawronski —otherwise destined to join his father's upholstery business. Gawronski was determined to accompany Byrd on the trip, even if he had to stow away on board to do it.

The tale of this rebellious son of Polish immigrants is made possible, in part, by Byrd's own public relations efforts about the Antarctic expedition, which were needed to attract financing to cover the costs of the voyage. Part of that fundraising included selling the exclusive rights to the story of the expedition to the *New York Times*, which would send a reporter, Russell Owen, along on the trip for exclusive coverage. He was tasked with filing regular stories on the voyage, with the understanding that they highlight the romance and heroism of the crew, particularly Byrd. Owen wrote about the determined young Gawronski, who secured a place on one of the ships in the flotilla with the blessing of Byrd, who was impressed with his persistence in sneaking aboard after several previous attempts in which he was discovered and sent packing.

The Stowaway relies on those articles and on family scrapbooks, correspondence, and books written by some of the crew after the voyage, as well as on interviews with Gawronski's widow and son, to round out his biography. As there was much less written about Gawronski than his more famous crewmates and expedition leader, there are some gaps in his history that the author has tried to fill in—imagining his feelings for his unnamed first girlfriend, or what he might have gotten up to in shore stopovers in places like Tahiti and New Zealand.

Yet Shapiro includes details that give a sense of the era in which the expedition takes place, from the minute—such as the now-quaint advertisements by some of the voyage's corporate sponsors—to the revealing, such as describing the unabashedly racist news reports about a black stowaway, Bob Lanier, who also secured a place on one of the ships, at least for a time.

But the story also demonstrates the reasons, many legitimate, Byrd was considered an American hero, as well as reveals his personal foibles, all the while piecing together the history of his unlikely crew member Gawronski, who eventually, the tale reveals, becomes one of the youngest captains in World War II and spends 30 years in the Merchant Marines. The behind-the-scenes look at the voyage from the point of view of one of its most junior members captures the ethos that drove exploration in the era between two world wars, and what the aftermath of their feat meant for the sailors at the very beginning of the Great Depression.

UNIVERSITY OF RHODE ISLAND RESEARCH & SCHOLARSHIP PHOTO CONTEST

This image of a sea squirt embryo was one of the entries in the University of Rhode Island Research & Scholarship Photo Contest. It was taken in Dr. Steven Irvine's lab, where researchers are looking at how temperature affects the development of the embryo, which has implications for climate change.

Photograph by Rose Jacobson

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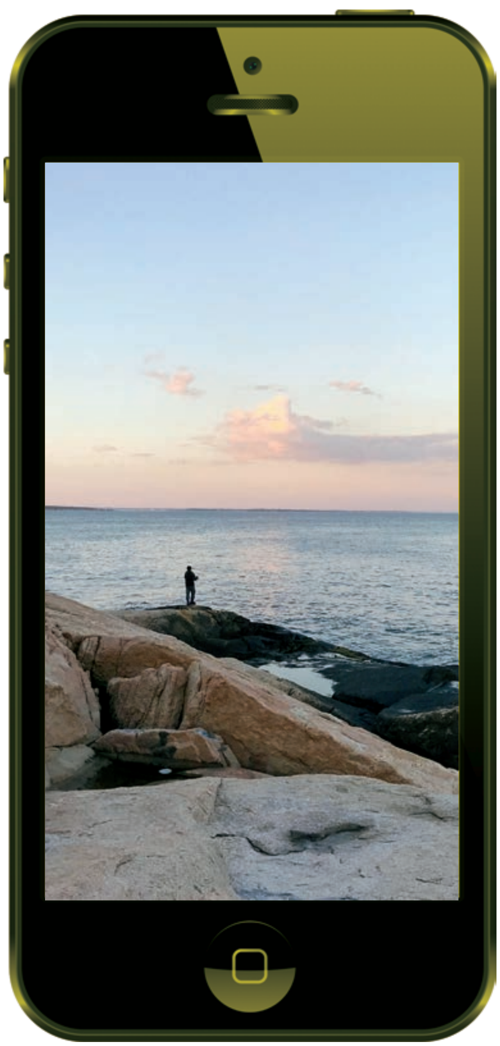

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