



2024

# Wave Makers

THE IMPACT OF  
YOUR UNRESTRICTED AND  
RESEARCH ACCELERATOR GIVING

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# A Message from WHOI President and Director Peter de Menocal

**Breakthrough ocean science and technology, unparalleled marine operations, and vibrant education programs—these are the hallmarks that set WHOI apart and make us the thriving world-class research institution we are today.** Discovery and fundamental science are at the core of WHOI’s mission. At WHOI, ocean scientists, engineers, and technicians work together to advance our knowledge of the ocean—and apply this knowledge to some of the biggest problems facing society today.

As we wind down the fourth year of our seven-year capital Campaign for Our Ocean Planet, your unrestricted giving this year has been extraordinarily impactful. Your generosity has enabled WHOI leadership to launch new programs and drive growth across all scientific disciplines. This strategy is at the heart of WHOI’s Vision 2030, and thanks to supporters like you, it is working.

In the coming year, we will announce the public phase of our comprehensive campaign. In preparation for that, WHOI is doubling down on fundamental science and exploration and expanding our impact on the world, all while staying true to our core values of scientific excellence, integrity, and independence.

Unrestricted giving provides crucial support to advance WHOI’s mission and our vision for the future. By providing flexible funding that can be deployed where it is most needed, you have enabled this institution to quickly respond to new opportunities, launch some of our most successful programs, and nurture the next generation of ocean leaders.

In the pages that follow, you will see how your support has enabled WHOI research, innovation, and exploration over the past year. With your help, our scientists are mapping the path of pollution, deploying smart cameras that can help ships avoid whale strikes, and making new deep-ocean discoveries from the *Alvin* submersible. You will also meet some of our promising new hires, who will help us push the frontiers of ocean science for years to come.

We could not be more grateful to our supporters who understand the value of unrestricted giving. Thanks to you, we will continue to expand WHOI’s distinctive capabilities to advance ocean science for the global good at a pace commensurate with the urgency of today’s global challenges.

With sincerest appreciation,

A handwritten signature in black ink that reads "Peter de Menocal". The signature is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

Peter de Menocal

On the cover:

A North Atlantic right whale mother and calf. These whales are critically endangered, with fewer than 400 individuals remaining. To help, WHOI scientist Dan Zitterbart and his collaborators have invented a thermal infrared camera designed to mitigate vessel strikes that are a leading threat to right whales, humpback whales, and other large whales. Story on page 5. NOAA Permit #17355, © Woods Hole Oceanographic Institution

# RESEARCH HIGHLIGHTS

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# Mapping the Potential Path of a Proposed Release of Wastewater into Cape Cod Bay

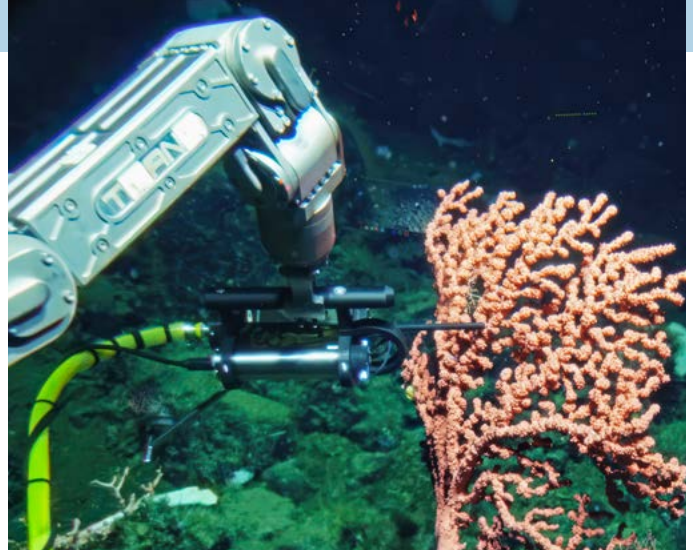
**Last July, the National Oceanic and Atmospheric Administration's Sea Grant Program provided rapid-response funding to WHOI Sea Grant to study the pathways of circulation in Cape Cod Bay.** The call for action came in response to nearby Pilgrim Nuclear Power Station's proposed release of 1.1 million gallons of radioactive wastewater into the area. Soon, Principal Investigator Irina Rypina and her collaborators will publish findings that will provide crucial understanding of where surface waters travel. While this study alone won't allow experts to draw conclusions about the full impact on the health and safety of humans and animals in Cape Cod Bay and surrounding waters, WHOI's research into the Bay's water transport

pathways will help predict the potential path of wastewater. "Some radioactive contaminants will move largely with ocean currents, but others are more inclined to end up accumulating with seafloor sediments, which is a concern especially with bottom-dwelling and filter-feeding organisms," says Ken Buesseler, a WHOI marine chemist. According to Matt Charette, WHOI's Sea Grant director and a senior scientist in the Marine Chemistry Department, this study will have lasting impact, providing essential information to regulators in their consideration of permit requests going forward, as well as for responses to potential incidents such as oil spills or harmful algal blooms. ■

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“SOME RADIOACTIVE CONTAMINANTS WILL MOVE LARGELY WITH OCEAN CURRENTS, BUT OTHERS ARE MORE INCLINED TO END UP ACCUMULATING WITH SEAFLOOR SEDIMENTS, WHICH IS A CONCERN ESPECIALLY WITH BOTTOM-DWELLING AND FILTER-FEEDING ORGANISMS.” — WHOI MARINE CHEMIST KEN BUESSELER

# New Sensor Reveals Deep-Sea Corals Produce Reactive “Superoxide”



**Just like us, corals breathe in oxygen and eat organic carbon.** And, just like us, as a byproduct of converting energy and oxygen in the body, corals produce reactive oxygen species (ROS), a family of chemical compounds that are naturally made by cells during cell division, while fighting off pathogens and performing other physiological functions.

SOLARIS, a novel deep-sea sensor designed by WHOI scientist Colleen Hansel, has helped answer the question of whether healthy, deep-sea corals produce a particular type of ROS, called superoxide. Superoxide is highly reactive and known for influencing ocean ecology, organism physiology, and driving chemistry in the ocean, including the breakdown of carbon and the bioavailability of metals and nutrients. SOLARIS revealed that deep-sea corals and

sponges do produce the ROS superoxide and showed that these chemicals have a string of previously unknown effects on ocean life and chemistry in the deep sea. Superoxide is not easy to detect in the ocean. This highly reactive chemical lasts just seconds in the water. But when scientists deployed SOLARIS from the *Alvin* submersible, the tool enabled them to take direct measurements of superoxide produced by deep-sea corals found within California’s Monterey Bay National Marine Sanctuary. The sensor detected superoxide in large healthy corals, providing essential insights into the metabolism of deep-sea species. Future research will deploy SOLARIS in other regions to better understand how superoxide impacts both ocean chemistry and ecology. ■



# Puzzling Over a Mollusk Mystery

**WHOI's Becky Gast, a marine microbial ecologist, and Arun Venugopalan, a marine virologist and WHOI Sea Grant post-doctoral investigator, are pondering a unique problem affecting Wellfleet on Cape Cod, home to one of the largest hard-clam aquaculture production areas in the U.S.** The problem is hemocytic neoplasia, a leukemia-like form of cancer that spreads among clams through seawater (the disease cannot spread to humans).

The scientists are working with Roxanna Smolowitz, a veterinarian and biology professor at Roger Williams University (RWU), who first saw hard-clam neoplasia in the early 1990s while researching a marine parasite called QPX, or Quahog Parasite Unknown, that was causing mass mortalities in the shellfish. Then, nearly ten years later, Smolowitz saw clams floating at the surface. "We picked them up, brought them into the lab, and saw they had leukemia-like neoplasia," she says.

The discovery prompted Smolowitz and her team at RWU to investigate the disease. She secured funding from WHOI Sea Grant and the Northeast Regional Aquaculture Center at the University of Maryland, with support from Barnstable County in Massachusetts, and soon contacted the Gast Lab for help.

Gast had heard about transmissible cancer in Tasmanian devils, but until Smolowitz reached out, she hadn't known it to be a problem for hard clams. "I thought it was a fascinating project, and I was surprised at how many different bivalves are affected by the disease," says Gast.

According to Smolowitz, neoplasia outbreaks are hard to contain, particularly since the clams live in close quarters and the disease spreads from clam to clam. The disease, however, is only contagious among hard clams and does not cross species, which is why it is not infectious or harmful to people.

The fact that there is no public health threat may be common knowledge to scientists, but there is still a

huge mystery surrounding hard-clam neoplasia that has researchers stumped: What, exactly, causes it?

In the Gast Lab, Venugopalan has been running diagnostics on the samples with the goal of trying to help determine whether the cancer is viral or genetic. He says that if it is a marine virus that is transforming normal cells into neoplastic ones, there could eventually be the option of selectively breeding a new, virus-free strain of clams.

Venugopalan is trying to determine the severity of an individual clam's cancer. He examines blood samples under a microscope. Since the cancerous cells are roughly 1.5 times larger than the normal cells, he can quickly quantify the number of each and from that determine the severity. "It's the equivalent of being able to indicate things like 'stage-3 or stage-4 cancer' which we often hear with human diagnoses," Venugopalan says. He is also performing genetic sequencing on DNA-RNA from the blood samples so he can compare the genetic changes and mutations between the normal and neoplastic cells, which may hint at the underlying causes of the disease.

Smolowitz, too, is conducting genetic analysis in her lab at RWU, comparing the genes of surviving clams to those that died to see if there is a particular gene that is important for resistance. "We can't treat them with antibiotics or cancer drugs," she says. "But if we can understand what strains are more susceptible or less susceptible and then find a genetic component to the resistance, we've got a whole new ballgame."

So far, the Smolowitz and Gast labs have helped determine that there are multiple cell lines involved in hard-clam neoplasia, a discovery that Smolowitz feels could be significant.

"If there are multiple lines of neoplastic cells out there, that indicates that there's some additional infectious agent present in the water," she says. "That hints at the idea that the disease could be viral." ■





# Smart Cameras May Help Ships Prevent Whale Strikes

**A team of WHOI innovators is currently testing a thermal infrared camera they designed to help mitigate vessel strikes—one of the leading threats to large whale species such as endangered North Atlantic right whales and humpback whales.\***

The camera offers hope of augmenting or replacing more limited vessel strike prevention methods, such as using marine mammal spotters aboard ships and planes, as well as passive buoys that provide information on a two-hour time delay.

“Our concept is simple,” says Dan Zitterbart, who invented the camera with fellow WHOI engineers Alessandro Bocconcelli, Daniel Gomez-Ibañez, Bob Petitt, and Fred Thwaites. “We have a thermal imaging scanner that scans the surface for whale exhalations, or blows. If a whale surfaces and blows, its thermal signature can be recorded by the camera.”

Mounted on ships and coupled with AI, the system can alert captains to the presence of whales several kilometers away within seconds, enough time for most vessels to slow down or change course. Unlike with human observation, these cameras don’t require ambient light, so they can spot whales around the clock.

Zitterbart, who received a 2019 Young Investigator Program award from the Office of Naval Research for his work

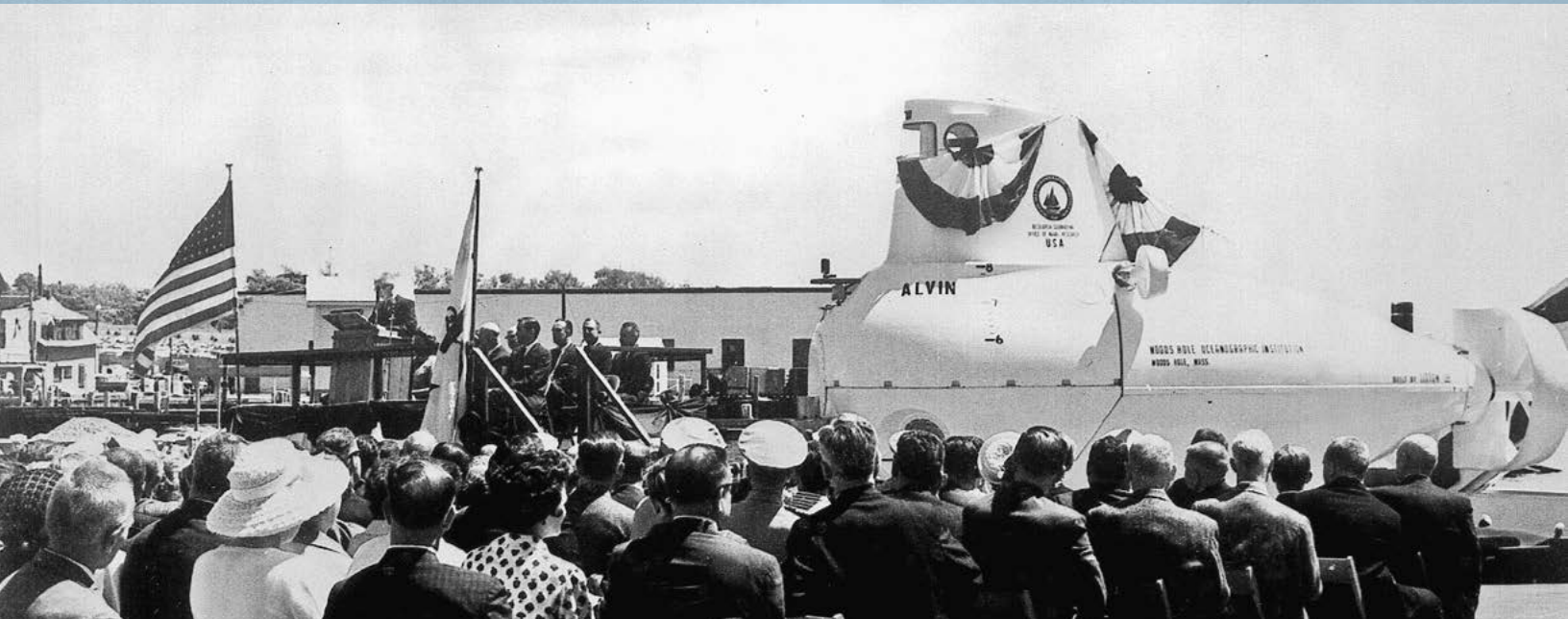
on whale detection, first developed a thermal imaging system to protect marine mammals from underwater noise during scientific seismic surveys. However, there were drawbacks to this design. “The cameras provided a 360-degree view, making the system prohibitively expensive,” says Zitterbart. “So, we narrowed the field of view and installed miniature cameras and stabilizers and reduced the cost and the weight of the system enough to install on small vessels.”

Recently, Zitterbart partnered with Matson Navigation to further improve the camera’s performance by enhancing and improving detection ranges to allow for effective whale strike mitigation.

Over the past year Zitterbart and his collaborators have successfully built three new miniaturized camera systems for installment on Matson cargo vessels, including the *M/V MANULANI*.

If all goes well, the cameras could be a potential game changer for both whales and vessel operators. “Thermal imaging systems are a powerful tool in real-time whale detection,” says Zitterbart. “Used alone or in conjunction with acoustic monitoring, this technology could significantly reduce the risk of vessel strikes.” ■

\*U.S. Marine Mammal Commission



# Celebrating Sixty Years of Deep Ocean Research, Exploration, and Discovery with Human-Occupied Vehicle *Alvin*

**On June 26, 2024, the human-occupied submersible *Alvin* celebrated 60 years of helping scientists expand human knowledge of the ocean and inspiring countless individuals to learn more about its connection to our planet and to society.**

In its more than 5,200 dives, *Alvin* has provided over 3,000 researchers with unprecedented access to the deep ocean, enabling extensive observation as well as data and sample collection. It has supported publication of groundbreaking peer-reviewed scientific studies, enabled development of new tools to further oceanographic research, and has fostered the early careers of many scientists and engineers. Operated by the Woods Hole Oceanographic Institution (WHOI) and funded by the National Science Foundation (NSF), the U.S. Navy via its Office of Naval Research, and the National Oceanic and Atmospheric Administration (NOAA), *Alvin* is the only publicly funded human-occupied vehicle available to the U.S. scientific community for in-person exploration of the ocean's upper hadal region, located at depths of 4,000 to 6,000 meters (13,000 to 20,000 feet).

"For 60 years, the deep-submergence vehicle *Alvin* has unveiled the ocean's mysteries for the scientific benefit of society as a whole," said Chief of Naval Research Rear Adm.

Kurt Rothenhaus. "The Office of Naval Research is proud of its history with *Alvin* and Woods Hole Oceanographic Institution and looks forward to future discoveries and innovations."

"*Alvin's* long and extraordinary history is a testament to the importance of ocean research and exploration," Rothenhaus continued. "In its first 60 years, it has transformed our view of life, responded to national emergencies, and inspired us all. I look forward to the remarkable discoveries it will make in its next 60 years."

## A Few Career Highlights

- ▶ 1964 – Commissioned in Woods Hole, MA
- ▶ 1977 and 1979 – Discovered Hydrothermal Vents and New Life Forms
- ▶ 1985 – RMS *Titanic* Wreck Exploration and Documentation
- ▶ 2010 – Deepwater Horizon Oil Spill Exploration
- ▶ 2010-2014 – Major Upgrades for Deeper Dives to 6,500 Meters (21,325 feet)
- ▶ 2020 – More Upgrades and Access to 99% of the Ocean Floor
- ▶ 2023-2024 – New Coral Reef and Hydrothermal Vent Discoveries (Galapagos Marine Preserve and eastern tropical Pacific Ocean) ■



# STUDENTS IN ACTION

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# Crowdsourcing a Handheld Carbonate Analyzer

**Ocean acidification has profound impacts on ocean chemistry, biology, and ecosystems.** It stems from increasing levels of atmospheric carbon dioxide that lead to more carbon dioxide dissolution in seawater, which creates more bicarbonate and hydrogen ions (lower pH), but fewer carbonate ions in the water. Gauging the current state of this “carbonate system” is crucial for understanding the impacts carbon dioxide has in our oceans and reveals how ocean acidification alters the ocean’s chemistry—but existing tools for this work are expensive and cumbersome.

WHOI Joint Program Ph.D. student Jonathan Pfeifer is prototyping a new tool that will empower citizen scientists



Jonathan Pfeifer explains a new tool for enabling citizen scientists to help gauge the effects of ocean acidification.

around the globe to contribute valuable data on the ocean’s carbonate system. “This user-friendly carbonate sensor could significantly transform carbonate chemistry research by eliminating many existing barriers to entry,” he says.

Pfeifer is using crowdsourcing to create a “democratized” tool that enables researchers and individuals to more readily study the effects of ocean acidification in local waters. The device will be accompanied by a mobile app that controls the instrument and handles the calculations required to determine the critical parameters of the carbonate system in the water sample. ■



## MIT-WHOI Students Attend COP28

**For the second year running, a group of MIT-WHOI Joint Program Ph.D. students** were official members of the WHOI Delegation to the annual UN climate conference, traveling to Dubai, UAE, in December 2023 to attend COP28. Split into Week 1 and Week 2 cohorts, eight students joined WHOI faculty mentors Chris Picuch and Sarah Das in this transformative experiential learning opportunity. Students shared their expertise speaking on panels at the Ocean Pavilion, met with policy makers and stakeholders from around the world, and engaged with a wide variety of finance, technology, and non-profit organizations, all working on addressing ocean-related problems and solutions. As part of their Observer status, they also attended international negotiation sessions, hearing firsthand from a diverse set of delegates, including those from the Global South, Global Youth, and Small Island Developing States (SIDS), hammering out global agreements to advance climate action. WHOI is now preparing to attend COP29 in Baku, Azerbaijan. ■

U.S. Senator Ed Markey (D-Mass.) shot a video for his social media channels at the Ocean Pavilion in Dubai with MIT-WHOI Joint Program students. Pictured L to R: Lulia Ștreangă, Michael Dotzel, Kate Lane, Lina Taenzer.



# Antarctic Krill Face an Uncertain Future

**Krill are tiny, shrimp-like crustaceans that move in prolific swarms across the ocean—some nearly ten miles long—numbering in the trillions globally.** They're a key food source for a broad range of marine species from seabirds to fish, seals, gigantic baleen whales, and yes, humans. Today in the Antarctic, however, they're swimming away from something much more threatening than a voracious blue whale: climate change.

It is estimated that Antarctic krill (*E. superba*) have retreated over 275 miles (442 kilometers) south since the 1970s, closer toward the interior of the Antarctic Peninsula. They are in search of sea ice, which provides juvenile krill with shelter from predators and winter storms and supplies them with a vital source of food—phytoplankton. But lately that sea ice has been dwindling.

"If you're krill, you have to swim way farther to meet your needs if you're just moving around in the water column," says MIT-WHOI Joint Program Ph.D. student Henry Holm, who studies energy in the Antarctic food web. Sea ice, he says, helps trap and concentrate phytoplankton into briny ice pockets that juvenile krill can then mine for an easy meal. Global warming, marine heatwaves, and more extreme and frequent storms have chipped away at Antarctica's annual sea ice, which contracts by roughly 10% each year—equating to 60 million Olympic-sized swimming pools-worth of water. Gone with that ice is a buffet of phytoplankton trapped inside, which juvenile krill need in order to grow.

"If you form less sea ice during the winter, then you have less opportunity for this incredible reservoir of [food] and energy," says WHOI marine chemist Ben Van Mooy, Holm's advisor. "For krill, it's like having to go farther and farther away for the 'hunting ground.'"

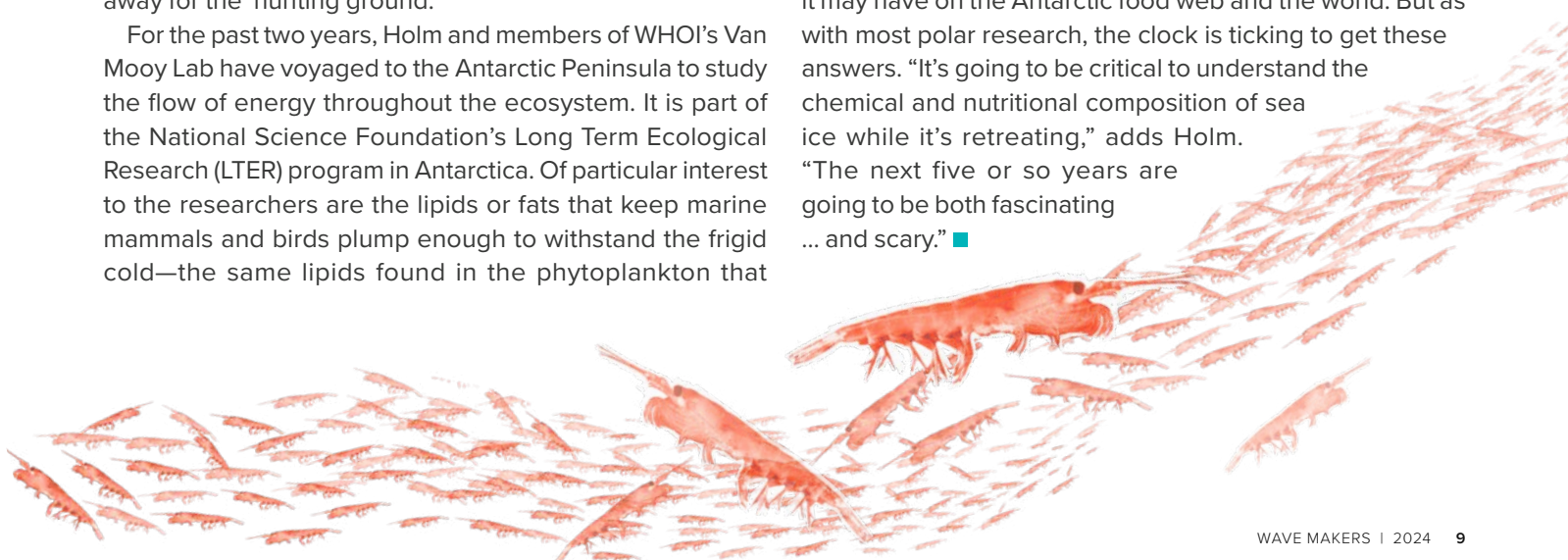
For the past two years, Holm and members of WHOI's Van Mooy Lab have voyaged to the Antarctic Peninsula to study the flow of energy throughout the ecosystem. It is part of the National Science Foundation's Long Term Ecological Research (LTER) program in Antarctica. Of particular interest to the researchers are the lipids or fats that keep marine mammals and birds plump enough to withstand the frigid cold—the same lipids found in the phytoplankton that

krill eat. Estimating how much of the nutrition krill—and, therefore, the Antarctic food web—are losing from the loss of sea ice is something Van Mooy and his lab are working hard to figure out.

"We're trying to understand the chemistry behind the energy at the base of the food web that feeds the krill," says Van Mooy. "And that hasn't been done before." In fact, it is estimated that nearly 40% of the dry weight of krill is fat from consuming their prey. That's fuel for the long, global migration of nursing humpback whales, or for fledgling Adélie penguins about to hit a growth spurt. Without krill, many of these species and their predators would likely face starvation. If sea ice continues to contract south due to warming seas, it stands to reason that future generations of krill could eventually run out of places to find food where they have historically thrived.

Their disappearance, however, could have broader consequences that extend beyond the Antarctic food web. In addition to supporting the base of a rich food web, krill are also an important cog in the ocean's ability to sequester carbon. By eating phytoplankton that trap atmospheric carbon dioxide, they may be keeping the worst of global temperature rise at bay. Unlike more gelatinous creatures, like salps, krill produce dense fecal pellets, which are especially efficient at sending carbon to deeper waters, accounting for 67% of the carbon transport that happens in the upper layers of the oceans during the summertime.

For Holm, the Van Mooy Lab, and other members of the LTER program, this pathway for carbon transport only underscores the team's need to better understand how the disappearance of sea ice will impact krill, and the ripple effect it may have on the Antarctic food web and the world. But as with most polar research, the clock is ticking to get these answers. "It's going to be critical to understand the chemical and nutritional composition of sea ice while it's retreating," adds Holm. "The next five or so years are going to be both fascinating ... and scary." ■



# Historic Hurricanes Can Predict Storm Intensity

**In August 2024, the North Atlantic Atmospheric Association reaffirmed predictions of a “highly active” Atlantic hurricane season due to near-record sea surface temperatures and potential La Niña conditions.** So far, Hurricanes Helene and Milton have caused hundreds of deaths and billions of dollars of damage. Researchers at WHOI are working to refine our understanding of past hurricane events to improve predictive models that inform how coastal communities prepare for the future.

Hurricane records in the Atlantic only go back about 150 years, but paleoclimate data derived from tree rings, ice cores, and other sources stretch back much further. To reconstruct thousands of years of hurricane history and make connections with long-term climate trends, researchers have looked for evidence of past storms in sediment cores. Flooding from strong storms can sweep coarse sand and shells into new areas, creating distinctive layers in otherwise muddy soil. But that work has focused on frequency of past hurricanes, not their strength or impact on the landscape. Lily Sanborn, an MIT-WHOI Joint Program doctoral student in the Coastal Systems Group at WHOI, is working to change that.

Advised by WHOI scientist Jeffrey Donnelly, Sanborn is working with Northeastern University researchers Jim

Chen and Samuel Muñoz to simulate how different properties of storms and coastlines change the way that beach sediment is moved by floods during a hurricane.

“Coastal communities are vulnerable to hazards associated with beach erosion and flooding during major hurricane events,” Sanborn says. “We rely on models that can predict the likelihood of future hurricane recurrence and provide the basis for coastal planning and management strategies.”

The first step of this project was to literally get their hands dirty. The researchers pulled up vertical cores of mud and muck from the bottom of coastal ponds in southern New England.

“When a hurricane strikes a coastline, it produces waves and storm surge, which often induce flooding,” Sanborn says. “These floods tend to erode sediment from the shore, pick it up, and carry it landward.”

Floods wash sediment from the beach into coastal ponds, where it settles to the bottom as a thin layer of sand amongst the mud. Sanborn and her colleagues can examine plant fragments and other organic matter mixed into the sand to estimate when each storm occurred using radiocarbon dating. The core sample becomes a vertical timeline written in mud. Sanborn can see how sediment was moved and distributed during each storm event. For more recent major hurricanes, the researchers can match these sediment measurements to aerial images showing how the region’s coastal geometry has been rearranged by storms.

All this information can then be combined with instrument data on wind speed, storm track, and water level to calibrate new computer models. Thus, the past becomes a window into the future.

“Determining the probability of major hurricane events in the future requires knowledge of the frequency of hurricane recurrence in the past,” Sanborn says. “Using historic data, we can adjust the characteristics of the storms and of the beaches that we’re interested in to explore how overwash patterns could change in different scenarios.” ■



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DETERMINING THE PROBABILITY OF MAJOR HURRICANE EVENTS IN THE FUTURE REQUIRES KNOWLEDGE OF THE FREQUENCY OF HURRICANE RECURRENCE IN THE PAST.” —MIT-WHOI JOINT PROGRAM DOCTORAL STUDENT LILY SANBORN

# Can the Ocean Twilight Zone be Fished Responsibly? A Scientist Asks the Fish

**“We’re leveraging the skills of the tuna and the swordfish as information collectors, as ocean samplers, and oceanographers, because they have the ability to collect information that we don’t,” says WHOI Joint Program student Ciara Willis.**

Willis is studying the importance of the ocean twilight zone to ocean apex species such as tuna and swordfish, and vice versa. One answer she found by examining the fishes’ stomach contents and tissues is that they are seeking sustenance.

Willis’s advisor, WHOI biologist Simon Thorrold, was first drawn to the little-studied ocean twilight zone (also known as the mid-water) after tagging studies revealed that top predators were spending much more time in deep water than previously thought. The discovery set Willis on her current path.

The ocean twilight zone located at ~200 to 1,000 meters (~600 to 3,000 feet) below the surface, is a primary food source for many large open ocean animals and plays a key role in carbon sequestration processes. With the rise of aquaculture and nutraceutical industries that depend on fish meal and fish oil, there is interest in harvesting this ocean realm.

“There is a truly immense number of fish in the mid-water,” Willis notes, estimating that amount to be about 10 billion tons, plus countless other species. However, little available data exists on how commercial fishing of the ocean’s mid-water might impact economically important surface fisheries like those for tuna and swordfish. Scientists have long known that both species depend on the twilight zone to some extent—but exactly how much they need it and what exactly they need it for is still largely unknown. Such baseline

data is essential to knowing whether the ocean twilight zone can be fished responsibly.

To investigate the interactions between top ocean predators in the surface ocean and the biomass in the twilight zone, Willis has investigated both the stomach contents and the liver and muscle tissues of tuna and swordfish. She and other researchers have identified unique chemical signatures of the food web of surface waters and the twilight zone enabling them to compare these signatures in tissues of the predators. The tissue composition helps reveal where they have been eating and, in this case, whether prey species were residing primarily at the surface or farther down.

So far, the findings show that swordfish get just over a third of their carbon from the twilight zone, despite spending half of their lives there—likely because they eat large amounts of squid in surface waters. But bigeye tuna, who spend only 16% of their time down below, get two-thirds of their carbon from mid-water species. For yellowfin tuna, it is even more dramatic: They spend just 3% of their daily time in the ocean twilight zone but get half their carbon there. Given this discrepancy, says Willis, it appears likely that yellowfin tuna are foraging at night on twilight zone fish and invertebrates that are migrating into surface waters to feed.

This baseline information will prove valuable to the fishing industry and regulatory agencies as commercial interest increases. Understanding these dynamics is essential as the ocean continues to undergo massive and rapid changes resulting from climate change, large-scale fisheries harvest, and other pressures on global fish stocks, something Willis’s research is helping to assess. ■



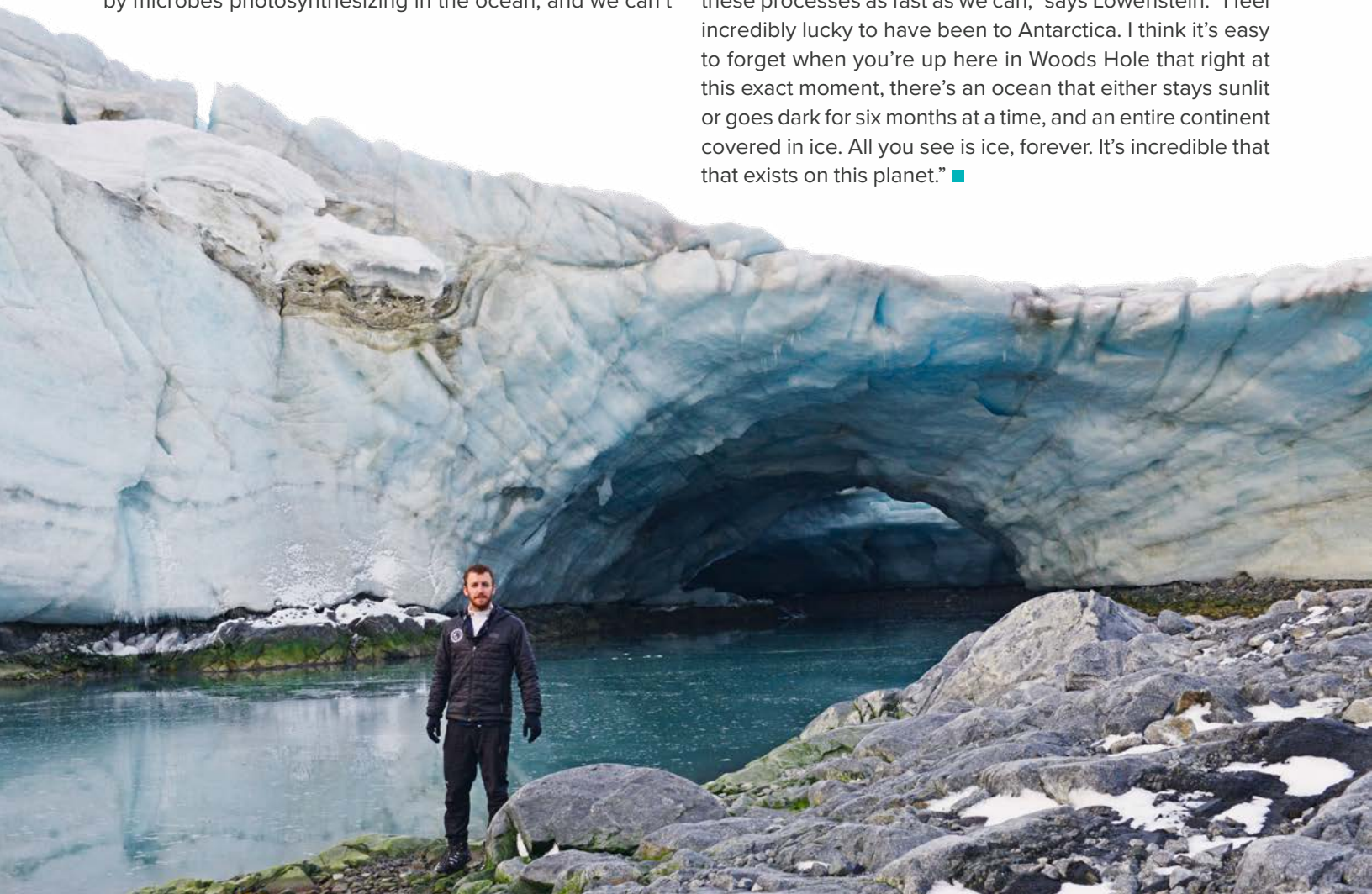
# Researching Small Scale Processes with Big Global Impact

**A big part of Dan Lowenstein's research happens on the West Antarctic Peninsula, a region of the Southern Ocean that is one of the fastest warming places on Earth.** The National Science Foundation's Palmer Station Long-Term Ecological Research (LTER) program has been running there for over 30 years, cataloging what is happening to this quickly changing ecosystem. Lowenstein has been to Palmer Station three times, from six weeks to six months. He says most of his job while there is filtering lots of water samples to bring back and analyze in his lab in Woods Hole.

"I'm most interested in the stuff in the water that you can't see, at least without a microscope: the microbes capturing carbon through photosynthesis and releasing it through respiration. In the ocean, they're the base of the food chain, the base of the carbon cycle. And that is the aspect that I find most compelling—these processes happening at such a small scale, but with global impact," says Lowenstein. "Something like 50% of the oxygen on Earth is produced by microbes photosynthesizing in the ocean, and we can't

even see it, but all of the fundamental chemical cycles on Earth are governed by the interacting metabolisms of these unseen little creatures," he adds.

Lowenstein wants to understand how the changing light levels throughout the day affect microbial rhythms and energy storage. In most of the ocean, there is a daily oscillation of energy in phytoplankton because of the solar cycle. "They take sunlight and make fats and sugars during the day, then they burn it to rebuild all of their cellular machinery overnight. But when it's sunny for almost 24 hours, how much carbon and energy are they able to fix? How much fixed carbon will be able to sink down to be sequestered on the sea floor? How much carbon will be available to krill, and then to penguins and whales?" Lowenstein wonders. He also believes that if it is theoretically an unchanging ecosystem, we need to establish a baseline for how the ecosystem works. "But at the same time, we've got rapid climate change, so it feels even more critical to understand these processes as fast as we can," says Lowenstein. "I feel incredibly lucky to have been to Antarctica. I think it's easy to forget when you're up here in Woods Hole that right at this exact moment, there's an ocean that either stays sunlit or goes dark for six months at a time, and an entire continent covered in ice. All you see is ice, forever. It's incredible that that exists on this planet." ■



# RECENT HIRES

## SCIENCE STAFF

### **NARE KARAPETYAN, APPLIED OCEAN PHYSICS AND ENGINEERING**

Nare Karapetyan is a roboticist whose research focuses on planning and exploration problems with heterogeneous multi-agent systems, with particular applications in the aquatic domain. She aims to develop more efficient, task-oriented exploration techniques for environmental monitoring and survey operations. She often draws inspiration from human expertise in performing specific tasks and strives to incorporate similar reasoning into the algorithms she develops for surface and underwater robots. Karapetyan was a postdoctoral associate at the Maryland Robotics Center at University of Maryland. She received her Ph.D. in computer science from the University of South Carolina where she worked in the Autonomous Field Robotics Laboratory. Prior to her Ph.D., she received her M.S. in computer science from American University of Armenia and a B.S. in applied mathematics from Yerevan State University. Since 2022, she has served as an associate editor for the RA-L and IROS editorial boards. She joined WHOI as an assistant scientist in December 2023.

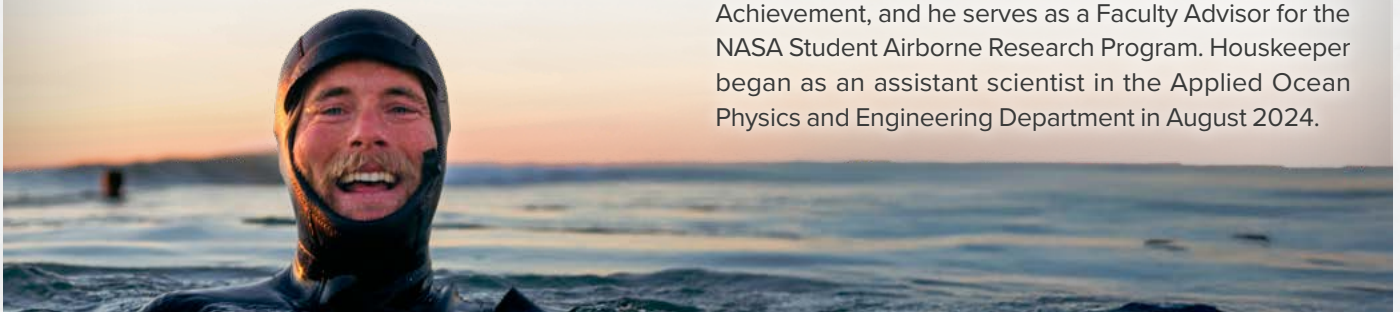


## SCIENCE STAFF

### **HENRY HOUSKEEPER, APPLIED OCEAN PHYSICS AND ENGINEERING**

Henry Houskeeper is an optical oceanographer investigating the dynamics of the oceanic light environment and its role in organizing marine ecosystems. He combines theory and field radiometry to better quantify oceanic light flux in the visible and invisible spectral domains, and he leverages field characterizations of bio-optical relationships to improve satellite or airborne remote sensing of changes in the surface ocean. He

graduated with a B.S. in biology from the University of California, Santa Cruz in 2012 and obtained a Ph.D. in ocean sciences at the University of California, Santa Cruz in 2020. He served as a postdoctoral researcher at the University of California, Los Angeles until 2023, when he joined Woods Hole Oceanographic Institution as a Weston Howland Jr. Postdoctoral Scholar. Houskeeper has been recognized with three NASA Honor Awards for Group Achievement, and he serves as a Faculty Advisor for the NASA Student Airborne Research Program. Houskeeper began as an assistant scientist in the Applied Ocean Physics and Engineering Department in August 2024.





SCIENCE STAFF  
**GIL AVERBUCH,**  
**APPLIED OCEAN PHYSICS**  
**AND ENGINEERING**

Gil Averbuch is an assistant scientist whose research focuses on Earth and planetary acoustics and seismo-acoustics. Specifically, he is interested in how acoustic and seismic waves propagate in a coupled solid Earth-ocean-ice-atmosphere system and how we can use them to study the sources that generate them and the properties of the media they propagate through. For example, his research projects cover topics such as using seismo-acoustic observations in Antarctica to study the dynamics of sea ice, icebergs, and ice shelves; studying how underwater sounds interact with sea ice in polar regions; assimilating acoustic data in weather prediction models to improve forecasts; and developing methods to study Venus's seismicity and internal structure using airborne acoustic measurements. Averbuch obtained his B.Sc. and M.Sc. in geophysics from Tel Aviv University in 2014 and 2015. In 2020, he completed his Ph.D. at the Delft University of Technology in the Netherlands. He then spent two years as a postdoctoral researcher at Southern Methodist University in Dallas (2020-2022) and another year as a postdoctoral scholar at WHOI (2022-2023). He became an assistant scientist at WHOI in September 2023.

ADMINISTRATIVE STAFF

**CHRISTY TALLEY,**  
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Christy Talley joined WHOI in April 2024 after nearly twenty years at Boston University (BU), where she served as associate general counsel, deputy general counsel, and the interim vice president of compliance services. Prior to joining BU, she worked in the Boston office of Ropes & Gray. Christy is a graduate of Southwest Missouri State University and Cornell Law School.





# RESEARCH ACCELERATOR

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# The Power of the Research Accelerator Fund

## LETTER FROM THE INTERIM VICE PRESIDENT FOR SCIENCE AND ENGINEERING

**As I write, our thoughts are with the millions of people still reeling from the recent devastation wrought by hurricanes Milton and Helene.** College friends of my wife Tiffany and mine have been displaced in a hotel for over a month, waiting still for a decision on whether they will ever be able to live in their home again.

High-intensity storms like these are stark reminders of the ocean's critical role in our lives and planet and of the urgent and complex problems each of us is facing. At WHOI, we are more dedicated than ever to providing critically needed ocean knowledge. Our pledge is to do this with equal parts creativity, courage, and commitment—along with WHOI's unique cutting-edge capabilities.

Your gifts to the Research Accelerator Fund are empowering WHOI scientists and engineers to work at the accelerated pace the world needs right now. The stories that follow highlight some of the work you have supported this year. These projects include an Ocean Vital Signs Network to gauge ocean health, AI and deep machine learning that are enabling us to analyze giant datasets, and innovative efforts to restore declining kelp forests and coral reefs.

Since the Research Accelerator funding model was established in 2019, your generosity has provided more than \$16 million in endowment and over \$5 million in current-use funds that are driving ocean science and innovation for the benefit of people everywhere.

From August 15, 2023 to August 15, 2024 alone, the Research Accelerator Fund provided \$7.4 million to WHOI scientists and engineers—funding that leveraged an additional \$20 million-plus from external agencies, many for multi-year projects.

Thank you for believing in the WHOI Research Accelerator Fund. Now more than ever, the world needs breakthrough ocean science and technology for addressing urgent problems related to climate change and pollution, supporting healthy habitats and thriving wildlife, and to open new possibilities for human lives and livelihoods. Together, we are making an impact.

Sincerely,

A handwritten signature in black ink, appearing to read 'Ben Van Mooy'.

Benjamin Van Mooy

Interim Vice President for Science and Engineering

# Using Soundscapes to Enhance Coral Larvae Settlement and Restore Hawaiian Reefs

**A healthy coral reef is noisy, full of the croaks, purrs, and grunts of various fishes and the crackling of snapping shrimp.** Research suggests that larval animals use this symphony of sounds to determine where they should live and grow.

Using this knowledge, WHOI scientists recently discovered that replaying healthy reef sounds could potentially be used to encourage coral larvae to recolonize damaged or degraded reefs. A reef that has been degraded—whether by coral bleaching, disease, or direct human impacts—cannot support the same diversity of species and has a much quieter, less rich soundscape. But the research showed that broadcasting the soundscape of a healthy reef at a degraded reef caused coral larvae to settle at significantly higher rates. The tool they invented for this work is known as the *Reef Acoustic Playback System*.

“What we learned is that you can actively induce coral settlement by playing sounds,” says Nadège Aoki, a WHOI Joint Program Ph.D. student and first author of a paper on the research. “You can go to a reef that is degraded in some way and add

in the sounds of biological activity from a healthy reef, potentially helping this really important step in the coral life cycle.”

This summer, WHOI collaborated with The Nature Conservancy-Hawaii, the State of Hawaii’s Department of Aquatic Resources, NOAA’s Hawaiian Islands Humpback Whale National Marine Sanctuary, and the Maui Ocean Center to apply this new method of re-populating reefs. The work focused on restoration aquaria settings with the Maui Ocean Center’s “coral ark,” and this knowledge base is allowing the scientists to refine and optimize methods for field trials scheduled for 2025. Aoki led the research project, which included several other graduate and undergraduate students, affording multiple opportunities for training the next generation of female scientists. ■

Healthy Coral Reef, Solomon Islands.  
Tracey Jennings / Ocean Image Bank



# Launching a First-of-its-Kind Ocean Vital Signs Network

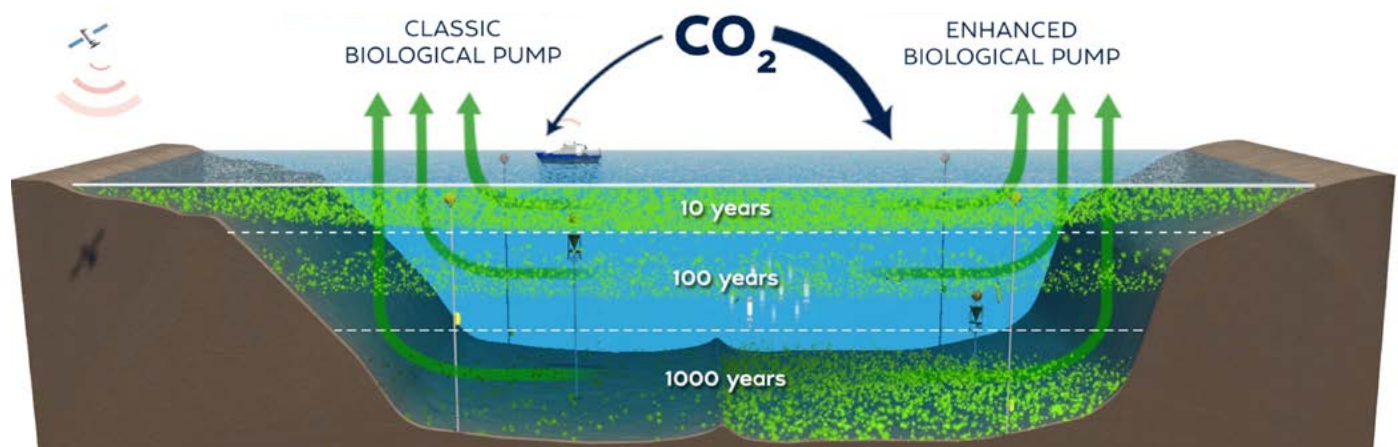
“WHOI is committed to increasing observations and knowledge of the oceans and to providing solutions to the greatest challenges facing ocean health. Understanding how carbon moves through the ocean remains a fundamental challenge for the scientific community, and we’re able to deploy great minds and technology to accelerate understanding.” —WHOI PRESIDENT AND DIRECTOR PETER DE MENOCAL

This year, WHOI formally launched the **Ocean Vital Signs Network (OVSN)**—a flagship initiative created to quantify the movement of carbon in the ocean—and to better understand the complex relationships between ocean health, the ocean’s carbon pumps, and its biology, chemistry, and circulation patterns. The initiative will unlock a new generation of ocean insight and innovation, improving climate forecasting and creating the necessary tools to track potential impacts of ocean-based carbon dioxide removal (CDR) and other human activities on the marine environment. Project leaders include WHOI scientists Susan Wijffels (Physical Oceanography) and David Nicholson (Marine Geochemistry), who are co-chairs, and Emanuele Di Lorenzo, chair of Earth, Environmental, and Planetary Sciences at Brown University, serving as external advisory board chair.

The project’s scientific goals are: (1) track and quantify carbon as it moves from the atmosphere through the ocean; (2) quantify the effects (intended or not) of efforts to enhance carbon uptake in the ocean; and (3) identify and measure key ocean vital signs—measurements that can be used to assess the health of entire marine ecosystems.

Generous philanthropic support enabled the development and planning of OVSN, convening dozens of WHOI experts from across the institution to frame the scientific agenda, identify key knowledge and technology gaps, and develop an implementation roadmap. This spring, a series of workshops and seminars kickstarted the first stage of the project, building momentum to tackle this complex challenge. Following a competitive call for applications, the project leadership team selected four new projects to fund and move forward: (1) a scalable underwater sensor for dissolved inorganic carbon; (2) enabling persistent observations of phytoplankton on a commercial ship in the North Atlantic; (3) a glider-based biogeochemical observing network for the Gulf Stream; and (4) evaluating the shortcomings in current models and observations and implementing regional models that will inform on the future design of a scaled OVSN regional system to track carbon in the northwest Atlantic.

As OVSN moves forward, WHOI is actively seeking partnerships with others beyond Woods Hole to create a diverse set of global partners and sponsors. Widescale collaboration will help build a more complete understanding of Earth’s ocean and climate, while charting a path toward sustainable ocean solutions. ■



# Using AI and Deep Machine Learning to Analyze Vast Datasets from the Ocean Twilight Zone

**The Ocean Twilight Zone lies between ~200 and 1,000 meters (~600 and 3,000 feet) beneath the ocean's surface.** It is home to some of the most abundant animal life on Earth but has been a challenging place to explore.

Over the past few years, however, new technologies are making the twilight zone more accessible than ever before, helping scientists unravel new information about its inner workings. Cutting-edge autonomous vehicles, animal tags, cameras, and acoustic systems can now collect massive amounts of information from the zone's deep waters in a short period of time, cranking out multiple terabytes of data in a single deployment. The relative ease of gathering this much information is a boon for scientists trying to understand the twilight zone, but raises new challenges: how does one extract meaningful science from such sprawling datasets?

WHOI researchers Heidi Sosik and Joel Llopiz have adopted powerful new tools to help. Using AI-driven deep machine learning, they have created computer software that can analyze staggering amounts of data and highlight subtle patterns that would take humans decades to reveal.

Sosik uses these AI techniques extensively in her work. As the lead scientist for WHOI's Ocean Twilight Zone project, she studies plankton, the tiny organisms that make up the base of the zone's food web and is revealing how those tiny creatures fit into the twilight zone's ecosystem. It is a complex question. In addition to providing food for larger animals, plankton also play a part in moving carbon from the surface into deep water, which ultimately helps to regulate global climate.

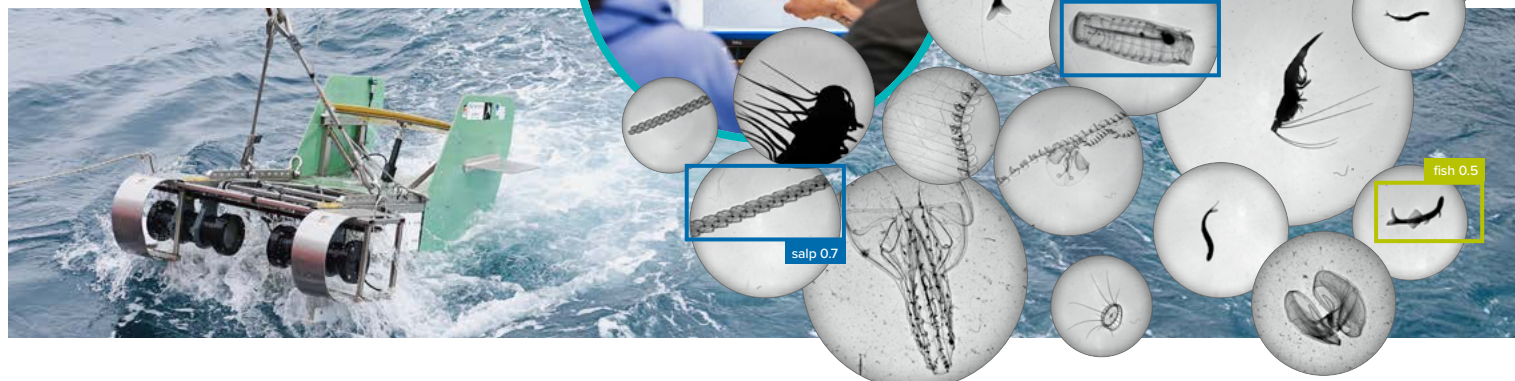
To understand more about how these organisms work in the twilight zone—where

they go, how much they reproduce, which animals are eating them, and so on—Sosik has to figure out not only the estimated number of plankton at different depths throughout the day, but also the specific species they represent. She has developed two new technologies that work in concert to achieve those goals. The first, a high-speed towed camera system, can record 15 frames per second, capturing millions of images of plankton, small fish, and gelatinous animals that pass in front of its lens. The second technology, a specially designed neural network algorithm, can then sort through those images, flagging individual organisms and grouping them by species or genus.

“The AI is used mostly to find targets in images, and to classify what kind of organisms they may be. In some cases, we can even use it to tell us whether those organisms are alive or dead or being eaten by something else if that's evident in the image,” Sosik says.

It is a vast improvement over the way plankton biologists had to work just a generation ago, Sosik adds: “Before high-volume imaging and AI, the best we could do was to pull a discrete water sample from the ocean and have a human look at it through a microscope.

This technology is a game changer for our field.” ■



# Restoring the Forests of the Seas

**Kelp forests provide numerous benefits to nature and people around the world.** They form the backbone of the ecosystems in which they are found, providing habitat and food for thousands of species. However, recent research suggests changing ocean conditions including marine heatwaves have led to the loss of kelp in regions including on the U.S. West Coast, off of California. With further declines anticipated, WHOI assistant scientist Tom Bell joined up with scientists from The Nature Conservancy; University of California, Los Angeles, and the University of California, Santa Barbara in an effort to track kelp growth and survival over time. In 2020, the group pioneered an automated technique to map kelp forest density using satellite imagery that led to an innovative online visualization tool ([kelpwatch.org](http://kelpwatch.org)) to improve kelp forest mapping and monitoring.

Today, Bell is working toward interventions for restoration of degraded kelp forests. “Interventions are possible and increasing both in California and globally, but they require further understanding and must be grounded in science,” he says, adding that restoring kelps can only succeed with knowledge of the conditions they need to thrive. The new project is creating a forecasting tool for predicting future states of California’s kelp forests and to enable timely kelp restoration decision-making. It also aims to identify monthly and seasonal factors in the environment that help or hinder kelp restoration and create methods to forecast the best timing and location for kelp restoration. “It’s similar to the rainfall and temperature forecasting tools that farmers use to strategically plant and harvest crops,” says Bell. ■



“

**INTERVENTIONS ARE POSSIBLE AND INCREASING BOTH IN CALIFORNIA AND GLOBALLY, BUT THEY REQUIRE FURTHER UNDERSTANDING AND MUST BE GROUNDED IN SCIENCE.”**—*WHOI ASSISTANT SCIENTIST TOM BELL*



# A New Way to Discover Life in the Ocean's Deepest, Darkest Places

**If we want to learn more about the limits of life in our solar system, the ocean's deep trenches and troughs are a great place to start.** Known as the hadal zone, which ranges from 6,000 - 11,000 meters (3.7 - 6.8 miles) deep, this ecosystem is home to animal life that is specially adapted to extreme pressure, darkness, and island-like habitats. All the species scientists find can tell us more about where to look for life beyond our planet. We just need to catch more of them. That is where Johanna Weston comes in. As a deep-sea biologist and WHOI postdoctoral scholar, Weston identifies and studies animals living at extreme depths. In just the last five years, she has discovered four new species of shrimp-like creatures called amphipods, mainly by using baited traps that lure in opportunistic scavengers. But to find other kinds of life, she says she'll have to come up with a new method of capturing species.

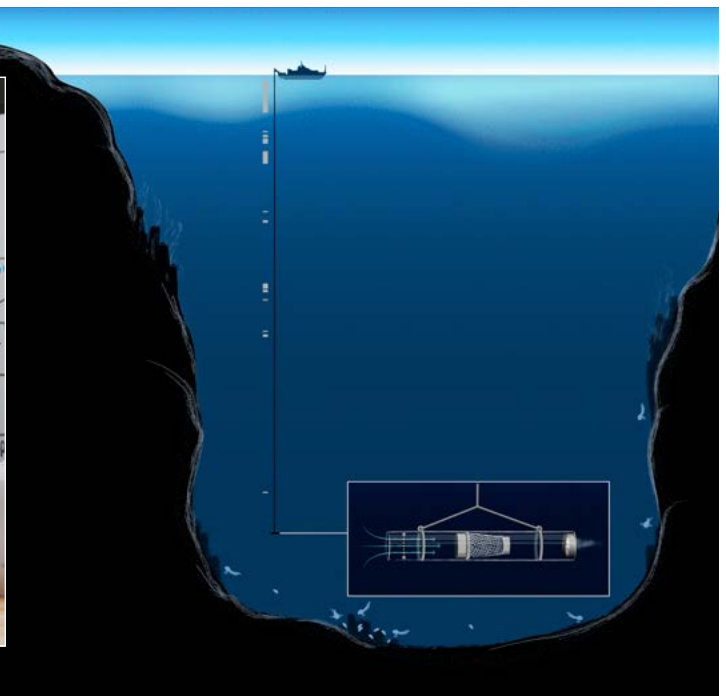
"Using baited traps, we collect hundreds of amphipods and maybe one fish," says Weston. "I'm trying to solve the issue of collecting different animals at different life stages to learn more about this ecosystem."

To this end, she is designing a new, vacuum-powered sampler at WHOI's Ocean Innovation Hub in the George and Wendy David Center, known as AVAST (short for Autonomous

Vehicles and Sensor Technologies). The sampler will actively draw in passing marine life at depth in a similar way to that of another suction-based device, called the McCrane Pump, that WHOI researchers use to collect larvae at shallower-but-still-extreme ecosystems, like hydrothermal vents. The new hadal sampler would be the first rated for much deeper missions, while integrating cost-effective materials, including a small electric motor and computer, a flowmeter to measure the rate of suction, a thruster to draw water through a fine mesh net capped off by a 3D-printed tail, plus a titanium frame to safely house the electronics and battery.

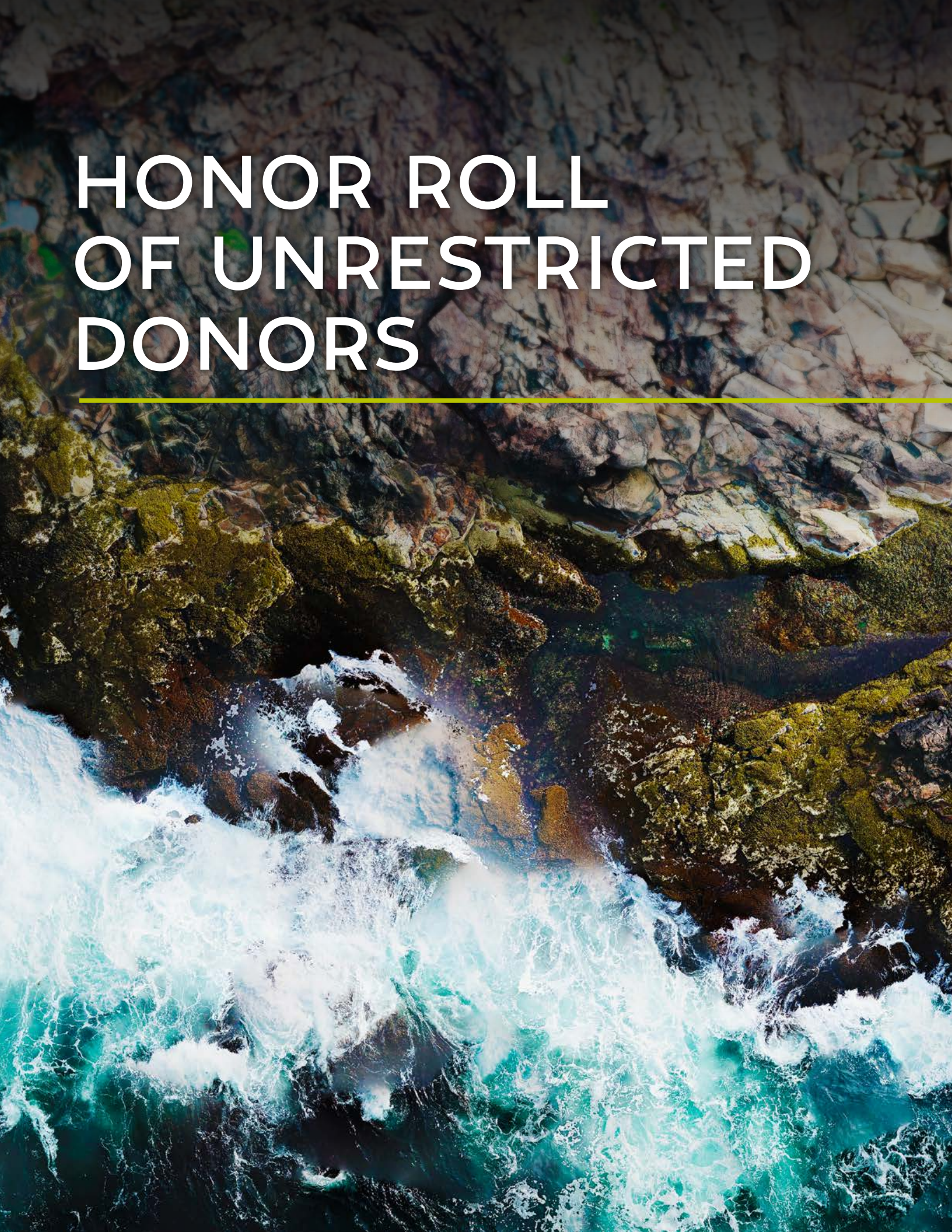
"A part of this long-term vision is that the housing can be a lot smaller and cheaper as it's basically a net in a tube," Weston says. Weston and her postdoctoral advisor, Kirstin Meyer-Kaiser, aim to field test a prototype design this year. If it works, they could start catching larval and small, juvenile-stage cephalopods, crabs, and snails. Catching them could also give scientists insights into how humans are impacting this mysterious ecosystem.

"These organisms have been adapted for millions of years to a precise set of environmental conditions," Weston says. "But now there's a question about how climate change (and pollution) could be affecting the deep ocean." ■



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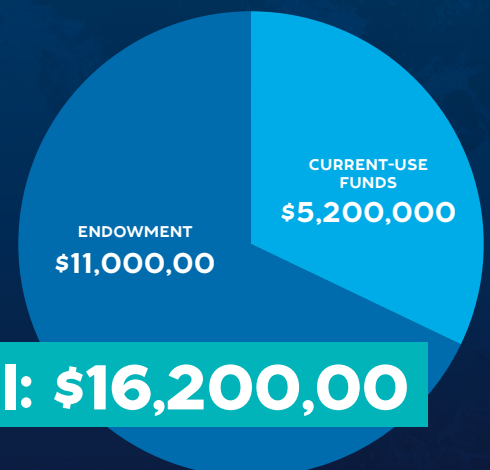
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