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EDITOR'S NOTE: *The study of science is often underrepresented in discussions on education abroad and international exchange as traditionally these areas were established in humanities and social science disciplines. This article is the first in an occasional feature series on science in higher education, particularly on what education abroad and foreign student experiences have brought to developments in scientific specialties.*

IMMERSION

Sea-mester student Priscilla Sloan holding colony identification slate and measuring stick assisting in Elkhorn coral research in Green Island (Antigua). The measuring stick is used to record the width, length and height of elkhorn colonies.

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With unique education abroad experiences burgeoning in many disciplines and international students and scholars participating in programs and research, interest in studying marine biology firsthand in the world's oceans has steered many toward ongoing interest in the field and has launched careers in marine conservation BY NICOLE BRANAN

BRIGHT SUNLIGHT HITS THE pellucid turquoise ocean embracing Lombok, a 2000-square mile island east of Bali in south-central Indonesia. Krystle Chavarría, an undergraduate student from the University of California at Berkeley, spends most of her time underwater. Fishing nets and abundant sample containers attached to her scuba gear, she combs the vibrantly colored coral reefs for *amphiprion ocellaris*, also known as common clownfish. Whenever she sees a specimen, she cuts a tiny tissue sample out of the fish's fin. Back at Boston University, Chavarría will feed her 200-plus samples into genetic machines that will uncoil the fish's DNA, analyze it, and spew out the exotic species' genetic code. By comparing genetic signatures from different clownfish populations living among Indonesia's endangered coral reefs, Chavarría hopes to discern natural barriers in the ocean that keep the different populations from mixing. Identifying these invisible fences will help determine the most effective positions for future marine protected areas.

Chavarría is one of three students who set out to Indonesia last summer as part of Boston University's Diversity Project, a 10-week education abroad program for undergraduate students from U.S. institutions. The project combines fieldwork on Indonesia's coral reefs with cutting edge molecular genetic research at Boston University and gives students a taste of life as a marine scientist. "It was very eye-opening to learn what it felt like to be a researcher," Chavarría said.

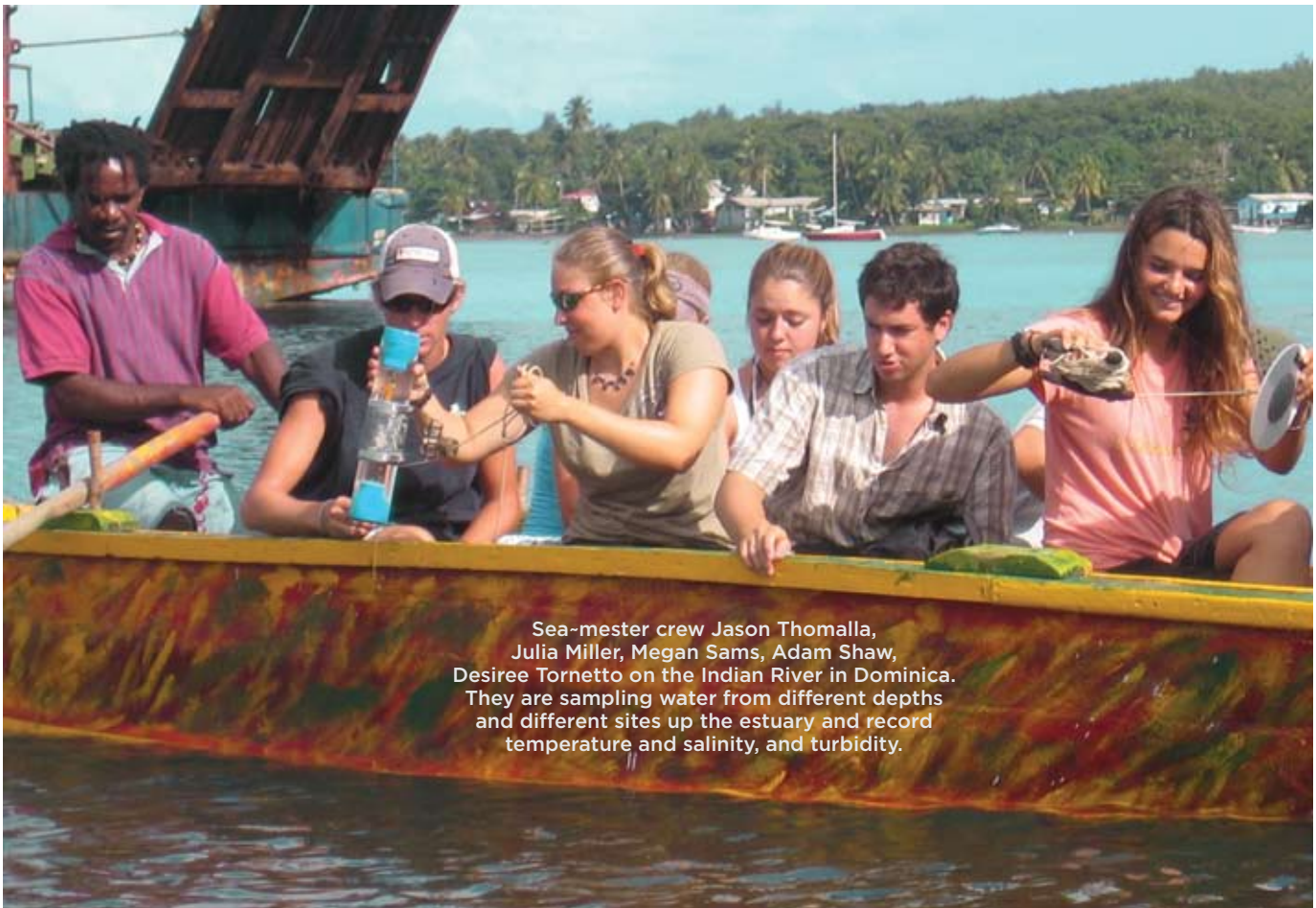
Initiated in 2005, the project is one of many education abroad programs that take students to diverse spots all over the globe to gain hands-on research experience by participating in marine expeditions. Besides contributing to current research in the field, these programs are intended to spark students' curiosity about the oceans. "The best way to get students interested in marine biology is to just take them out into the field," said Paul Barber, assistant professor of biology at Boston University and leader of the Diversity Project. "And it's hard to go to a place like Indonesia, put on your mask and snorkel, put your face in the water and not just be amazed—it's simply a beautiful place."

It seems only appropriate that students mix and mingle around the globe to study the oceans. After all, the world's waters are shared by all of us and problems within them could have global implications. Not only do our oceans' circulation patterns exert a profound influence on the planet's climate, they also provide the great majority of the world's fish supply. Large-scale disturbances of this vast ecosystem's delicate balance, caused for example by global warming and overfishing, could have disastrous consequences for the whole planet. And the clock is ticking; marine environments are degrading at an alarming rate, said Edith Widder, president and senior scientist at the Ocean Research and Conservation Association in Fort Pierce, Florida. "Marine research today is more important than ever because the health of our oceans is threatened more than ever," she said. Barber agrees and pointed out that Indonesia's coral reefs are one of the most threatened reefs in the world. "I don't think there is anything approaching a pristine reef left in Indonesia. If we have any hope of protecting these ecosystems at all we need more research, and more people need to go there to study those reefs," he said.

Boston University's Diversity Project is a step toward that direction. Barber and his students study genetic similarities and differences across different populations of various species throughout the Indonesian archipelago. The team found that some populations have distinct genetic fingerprints even though they live in close proximity—a condition that usually results in a uniform blending of genetic pools. By identifying these patterns, Barber and his students started to locate particular regions in the ocean through which different populations would not cross. Identifying these natural barriers is crucial for the design and implementation of future protective measures, commented Nancy Knowlton, director of the Center for Marine Biology and Conservation at Scripps Institute of Oceanography in La Jolla, California "We need to have a sense of where these natural barriers are in order to set up marine protected areas across the oceans—equivalents to our terrestrial national parks," Knowlton explained.

Preserving Oceans for the Future

Protecting the oceans' web of life is becoming an increasingly pressing issue. So far scientists have only explored about 5 percent of the roughly 139 million square miles of ocean that cover our planet, but an estimated 50 percent of all marine species have already gone extinct, said Widder. "We are destroying the oceans faster than we



Sea-mester crew Jason Thomalla, Julia Miller, Megan Sams, Adam Shaw, Desiree Tornetto on the Indian River in Dominica. They are sampling water from different depths and different sites up the estuary and record temperature and salinity, and turbidity.

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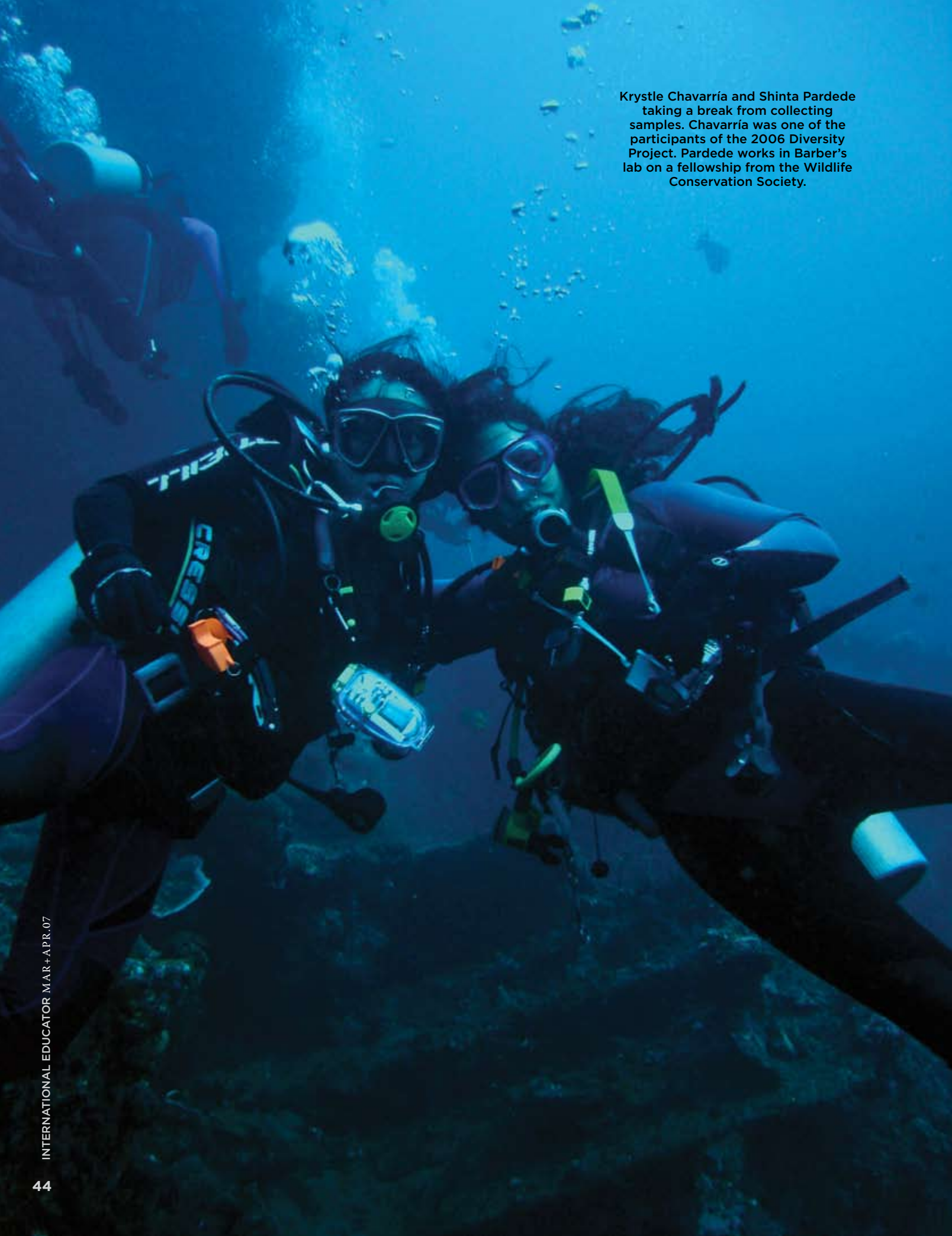
Sea-mester student Michael Birdsong carrying out an Invertebrate Belt Transect at Superman's Flight, St. Lucia. He is holding a 2.5 m measuring stick to aid estimation of the survey area.

can explore what's in them. It's like living next to the Garden of Eden and throwing trash over the wall without ever even looking to see what glorious things are in there."

One of the reasons for the rapid collapse of marine ecosystems is a burgeoning human population resulting in pollution of the oceans and an ever-increasing demand for seafood. "Destructive fishing practices are one of the major and best-documented human threats to the marine environment," said Fan Tsao, conservation scientist at the Marine Conservation Biology Institute in Bellevue, Washington. Deep-sea bottom trawling, usage of heavy fishing gear dragged across the seafloor to catch a large number of fish in little time, kills a lot of bycatch. "It's like collateral damage on the battlefield—a lot of innocent lives are lost," said Tsao, whose career began in her native Taiwan where she completed her undergraduate studies in ocean engineering. After spending one year as an international exchange student at the University of British Columbia, she decided to pursue a master's degree in marine affairs at the University of Washington. In her thesis work, Tsao explored the interface between social sciences and natural sciences, a combination that prepared her for her current job. At the Marine Conservation Biology Institute, Tsao is involved in devising marine policy recommendations for the U.S. government based on current research findings. The institute also works on raising the public awareness of marine conservation issues. The job can be challenging, Tsao points out, because it is often difficult to convey the severity of the situation. For example, a recent study by an international team of ecologists and economists projected the collapse of all seafood fisheries by 2050 if current fishing trends continue. "But when people go to their local store, they still see fish filet in the grocery section, so they simply don't feel that fish stocks are dwindling. People don't live in the sea, so they don't get to observe the decline of marine biodiversity directly," she said.

In addition to killing bycatch, bottom trawling also destroys the habitat of many marine species. The heavy nets break apart deep-sea cold-water coral reefs, such as those on the summit of Manning seamount, part of a 1,000-mile stretch of underwater mountains, almost a mile below the ocean's surface off the coast of New England. Thousands of years ago, cold-water corals began to settle on the rocky seamounts and gradually grew into the tremendous stony fortresses they are today. Lauren Mullineaux, senior scientist at Woods Hole Oceanographic Institution (WHOI) in Massachusetts, explained that, like their tropical cousins, deep-sea coral reefs provide shelter for a rich diversity of marine life, including abundant commercially valuable fish. That's why fishing trawlers like to gather in areas near those reefs. The New England oceanic mountain range is covered with large and ancient coral gardens that have attracted the interest of many marine scientists.



Krystle Chavarría and Shinta Pardede taking a break from collecting samples. Chavarría was one of the participants of the 2006 Diversity Project. Pardede works in Barber's lab on a fellowship from the Wildlife Conservation Society.

Foreign Students Study Marine Biology, Too

Last year, Nika Stagličić, at the time an undergraduate student at the University of Split in Croatia, came as a summer student fellow to WHOI to study Manning's diverse ecosystems. Since the Adriatic Sea flanking her home country Croatia is a shallow, semi-enclosed basin of the Mediterranean Sea, Croatia didn't offer any opportunities for her to study similar ecosystems. "I was delighted to get the chance to explore a segment of deep-sea ecology," she said. Every summer, WHOI hosts student fellows from the United States as well as many foreign countries. "It's good to have students from different backgrounds come to us and share their knowledge and experience," said Mullineaux. Stagličić commented, "The international atmosphere at WHOI increased my awareness of the importance that collaboration and exchange of experiences have in the sciences."

At WHOI, Stagličić analyzed information from images and data that Mullineaux and her team had collected on a previous deep-sea cruise to Manning's seamount. From that, Stagličić determined the spatial distribution, abundance, and size of bubblegum corals, pink tree-like structures with round branch ends. "To understand and predict how these deep-sea coral communities will react to disturbances, such as deep-sea trawling, we need to find out how quickly these corals reproduce and recolonize," Mullineaux said. Documenting the current and future status of individual species, such as the bubblegum coral, is an important step toward that goal. Widder commented, "If we want to prevent the continuing collapse of marine ecosystems, something that needs to happen in a big way is the implementation of major monitoring efforts worldwide."

Discovering Coral Reefs

Although scientists and fishermen have known about cold-water coral reefs for centuries, it was only with the development of submersible vehicles equipped with deep-sea cameras that scientists have been able to study them. Widder, whose passion for marine biology was sparked during a month-long study abroad program at the Lerner Marine Lab in Bimini when she was an undergraduate student at Tufts University, is one of the leaders in designing and inventing such submersible vehicles, instrumentation, and equipment. That's not an easy task, she explained, because deep-sea exploration vehicles need to withstand pressures of hundreds of atmospheres that the megatons of water several miles below the sea surface are exerting. "In many ways it's easier to explore outer space than to explore the deep ocean because in outer space you only have a pressure difference of one atmosphere between the outside and the inside of your exploration vehicle," Widder said.

Mysteries of the Ocean Floor

But the harsh conditions at the ocean floor also offer some unique opportunities. The chilling temperatures and the crushing pressures miles below the sea surface squash most gases into liquids. That's why some scientists had the idea to use the deep ocean as a carbon dioxide waste site. Miles below the surface, the greenhouse gas forms liquid lakes that rest quietly on the ocean floor. Pumping vast amounts of unwanted carbon dioxide into the abyss would slow the rise of the greenhouse gas in the atmosphere and mitigate the effects of global warming, proponents argued. But before deep-sea carbon dioxide sequestration could be pursued as a viable strategy, researchers needed to determine the impact of carbon dioxide-enriched seawater on deep-sea ecosystems. And so, in 2001, a research group at the Monterey Bay Aquarium Research Institute (MBARI) in Moss Landing, California, started to conduct the world's first deep-sea carbon dioxide experiments more than two miles below the Pacific's surface on the ocean floor off the coast of California. Among the trailblazers was Rachel Dunk, at the time a Ph.D. student at the University of Southampton in England and trainee in MBARI's 10-week summer internship program.

Since 1997, MBARI has been hosting summer interns to work on specific projects under MBARI staff supervision. "The program is designed to give the students an opportunity to experience something they don't get in college, and that is the real-life aspect of research and development," said George Matsumoto, senior education and research specialist at MBARI and coordinator of the internship program. As a private organization, MBARI's financial support comes from the David and Lucile Packard Foundation rather than from federal sources which is why the internship has no citizenship restrictions. So far, the program has drawn international students from such countries as France, Sweden, Canada, India, the Czech Republic, Australia, and the United Kingdom.

During several research cruises, Dunk and the MBARI team ventured out into the Pacific aboard the *Western Flyer*, one of MBARI's research vessels. From there, the team sent a remotely operated vehicle into the abyss to dispense about 10 gallons of liquid carbon dioxide onto the seafloor. Then MBARI researchers placed various marine animals in cages close to the carbon dioxide pool to study how the chemical affected their health. At the same time, Dunk conducted experiments that allowed her to measure how quickly the carbon dioxide leaked into the surrounding water. In the ship's control room the team watched their experiments on a high definition screen and in real time. "It was absolutely amazing to be sitting on the ship with our laptops and our equipment and to watch what we were doing more than two miles below. It was just the most unique way to do science," Dunk remembered. "And seeing what I had been studying dry in a classroom was really a thrill." The team found out that the carbon dioxide pool had a detrimental effect on some of the deep-sea marine biology. Carbon dioxide slowly leaked into the surrounding ocean, reacted with seawater, and increased the water's acidity, a condition that deep-sea marine life is particularly sensitive to.

But even without deliberate pumping of carbon dioxide into the seas, the compound's concentration in the ocean—and with it ocean acidity—have been rising steadily over the past few decades. The oceans pull megatons of the greenhouse gas out of the air every day

and scientists fear that the enormous extra amounts that human activities are forcing into the atmosphere might take a toll on marine life. "Anthropogenic carbon dioxide from the combustion of fossil fuels is altering the chemistry of the world's oceans," said John Guinotte, a marine biogeographer at the Marine Conservation Biology Institute. This is one of the reasons that the research community has recently shifted its focus away from direct carbon dioxide storage in the deep sea towards storage in depleted off-shore oil and gas reservoirs. "Now the question is: If we had a leakage from one of those sites, what would the worst-case scenario be?" said Dunk, who is now a lecturer and postdoctoral researcher at the University of York in England, and still an active research collaborator with MBARI. After her internship, Dunk returned to MBARI for a postdoctoral position, during which she worked on developing technology that can detect the small shifts in acidity that such carbon dioxide leaks would cause.

Overdoses of carbon dioxide don't only affect fish, they also impact coral reefs. When carbon dioxide reacts with seawater it forms carbonic acid, which is corrosive to calcium carbonate shells and skeletons, such as those corals are made of. Acidic water slowly dissolves the reefs' complex structures, making them weaker and slowing down their growth rates. "This process is similar to osteoporosis in humans," explained Guinotte, who studied coral reefs in the Coral and Timor Seas.

Global Warming Impacts Oceans

Mounting evidence suggests that global warming poses a threat to coral reefs as well. A small but constant rise in ocean temperature forces coral colonies to banish their symbiotic, food-producing algae. This process is known as bleaching because it turns the flamboyantly colored reefs ghostly white, explained Guinotte, who got his first study abroad experience when he went to Central Queensland University in Rockhampton, Australia, during his senior year at Kansas State University. After completing a master's degree he went back to join the Australian Institute of Marine Science in Townsville as a postgraduate researcher in 1999. Together with other scientists at the Institute, Guinotte began to unravel a mystery that had shocked the scientific community a year earlier, when a massive bleaching event wiped out an estimated 16 percent of coral reefs worldwide.

By analyzing satellite data, the team found that the bleaching was the result of several different factors. Wind conditions at the time were such that they largely prevented mixing of the water column, Guinotte explained. In addition to that, the water cover over the top of the corals was unusually low and an extremely sparse cloud cover let a lot of solar radiation reach the ocean, heating the top layer of water to such a high degree that many corals couldn't handle the temperatures. "It was kind of a perfect storm that came together."

Guinotte continued to work with coral reefs during his subsequent Ph.D. program at James Cook University in Townsville. By analyzing environmental data, such as sea surface temperature and salinity, he developed a model that could track down the locations of so far undetected coral reefs. Scientists have found most of the currently mapped reefs using satellite images. But these have a very limited range. "Most mapped reefs lie within the top 50 to 65 feet of water because that's all that can be seen with satellites," he explained. Using his model, Guinotte and his team discovered many undocumented reefs that lay outside the reach of satellites, some 200 feet below the water surface off the northwest shelf of Australia. "That's significant because a lot of these deeper reefs don't experience the really high temperatures that the shallower ones do, so they are less likely to bleach. That makes these areas great places for future marine protected areas," he explained.

Students Contribute to Marine Conservation Efforts

As conservation efforts of endangered coral reefs become more important, many marine biology education abroad programs have started to actively participate in them. One example is Sea-mester, a global study abroad program during which students live full-time aboard traditional schooners while sailing from island to island, country to country, or continent to continent in the Caribbean, the Mediterranean, or in Asia. Since its inception in 1998, Sea-mester has taken about 60 students every year across the globe. For the past five years, students aboard Sea-mester voyages have conducted coral reef surveys in St. Lucia for Reef Check, an international ocean conservation organization. "This work is valuable, especially to aid in monitoring the decline of coral reefs in the eastern Caribbean," said Jessica Fry, chief scientist and oceanography and marine biology instructor aboard *S/Y Ocean Star*, Sea-mester's Caribbean-based 88-ft schooner.

All of the 90 square kilometers of coral reefs around the West Indies island country of St. Lucia are threatened by human activities, such as overfishing, coastal development, and unsustainable land use practices, Fry explains. Sea-mester students play a vital part in an ongoing research project on elkhorn coral, the first coral species listed as threatened under the Endangered Species Act, a U.S. environmental law passed in the early 1970s. "The eastern Caribbean represents a significant gap in current elkhorn coral status information." Fry said. Together with researchers of the National Oceanic and Atmospheric Administration, Sea-mester students have helped set up permanent monitoring sites in the British Virgin Islands, St. Vincent and the Grenadines, and Antigua. Each site is marked with a metal stake, whose GPS position is recorded, and each coral colony within the area is marked with a small tag. Sea-mester visits each site 2-3 times a year and students record information such as colony size, percentage live coral, signs of disease, and bleaching. "No other current targeted monitoring efforts are known in this region," Fry said. As part of the elkhorn monitoring program, students are also involved in a mapping program. Equipped with underwater scooters and waterproof GPS units the students traverse the reef, marking the position of every elkhorn colony. "This gives us a good overall impression of the density of colonies in the area, and will allow us to monitor any dramatic changes in the future," Fry said.

Sea-mester isn't the only program during which students live

aboard a ship full-time. Since 1971, the Sea Education Association's (SEA's) Semester program at Woods Hole, Mass., has taken more than 6,000 students from colleges and universities across the country out into the open oceans. SEA Semester students begin the 12-week interdisciplinary program on shore at SEA's Woods Hole campus with six weeks of class work to study the chemistry, biology, physics, and geology of the oceans. During that time, students design their own research projects that they will later carry out at sea.

One of the many destinations of SEA Semester cruises is the Sargasso Sea, located in the northern Atlantic Ocean between the West Indies and the Azores. Because it isn't bounded by land, the Sargasso Sea doesn't receive any supply from nutrient-carrying rivers. In addition, the sea is centered in a subtropical convergent zone where water mixes slowly, leaving it nearly devoid of nutrients. "It's somewhat of a biological desert," said SEA staff scientist Gary Jaroslow. However, scientists have found 10 times more microscopic life in the Sargasso Sea than they could explain, given the dearth of nutrients that these plants need to grow. So researchers developed the theory that eddies, water currents that run separate from the main current, might act as a biological pump and make this ocean desert bloom. SEA Semester students have helped gather evidence to support this theory.

Eddies are like hurricanes inside the ocean, stirring up a vortex of water and material from the nutrient-rich depths of the ocean to the surface. To find and track them, SEA Semester students use acoustic Doppler current profilers, instruments that can measure the direction and the speed of water that is moving across the entire column. By analyzing the distribution of nutrients in and around eddies, SEA Semester students have been able to document that there is a relationship between the currents and the biology in the Sargasso Sea, Jaroslow said. Eddies pump up nutrients from the abyss, fertilizing the ocean and creating oases in the middle of the ocean desert.

SEA Semester has been the starting point for many careers in the marine sciences. Rick Murray, a 1983 SEA Semester alumnus commented, "My interest in doing oceanography and marine sciences as a career was definitely sparked during my SEA Semester. It was like 'Yeah, I want to be an oceanographer.' During his SEA Semester, Murray studied the submarine canyons coming off of Georges Bank on the edge of the North American continental shelf. "This was the first time that I could see how what you learned in the classroom could in fact actually be used in the real-world—and how the real-world experience is not exactly the same as the classroom experience," he remembered. Now an earth sciences professor at Boston University, Murray studies natural cycles of global warming over the last hundreds of thousands of years as recorded in the ocean. He and his colleagues collect samples from the ocean floor of the different layers of sediments that have settled there year after year. "These samples tell us how the natural system has behaved before men arrived on the scene," he explained. Murray's research has shown that current global warming trends are much too extreme to be part of a natural cycle. "What we are seeing now far exceeds the natural range."

Programs such as SEA Semester are crucial for students who want to pursue a career in the marine sciences. "The students learn that real-world research is different from textbooks—and that's very important," said Jaroslow.

Not Just for Science Majors

But such programs can be just as valuable for students of all majors. Understanding the impact that humans have on the world's oceans and learning how to manage their vital natural resources is essential for our global well-being, said Jaroslow. "I think that it is becoming increasingly important that the voting public has a basic understanding of the oceans." Widder agrees and pointed out that "we have to make people all around the world aware that this is an ocean planet that they live on. In terms of living space on the planet, the oceans represent more than 99 percent of our biosphere. And if we mess up our biosphere, we don't have any place to go."

The oceans have acted as a buffer in the past, producing oxygen and absorbing carbon dioxide from the atmosphere, but Widder is one of many scientists who believe that we have reached a tipping point. "We have overtasked the oceans, and now they need our help." **IE**

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