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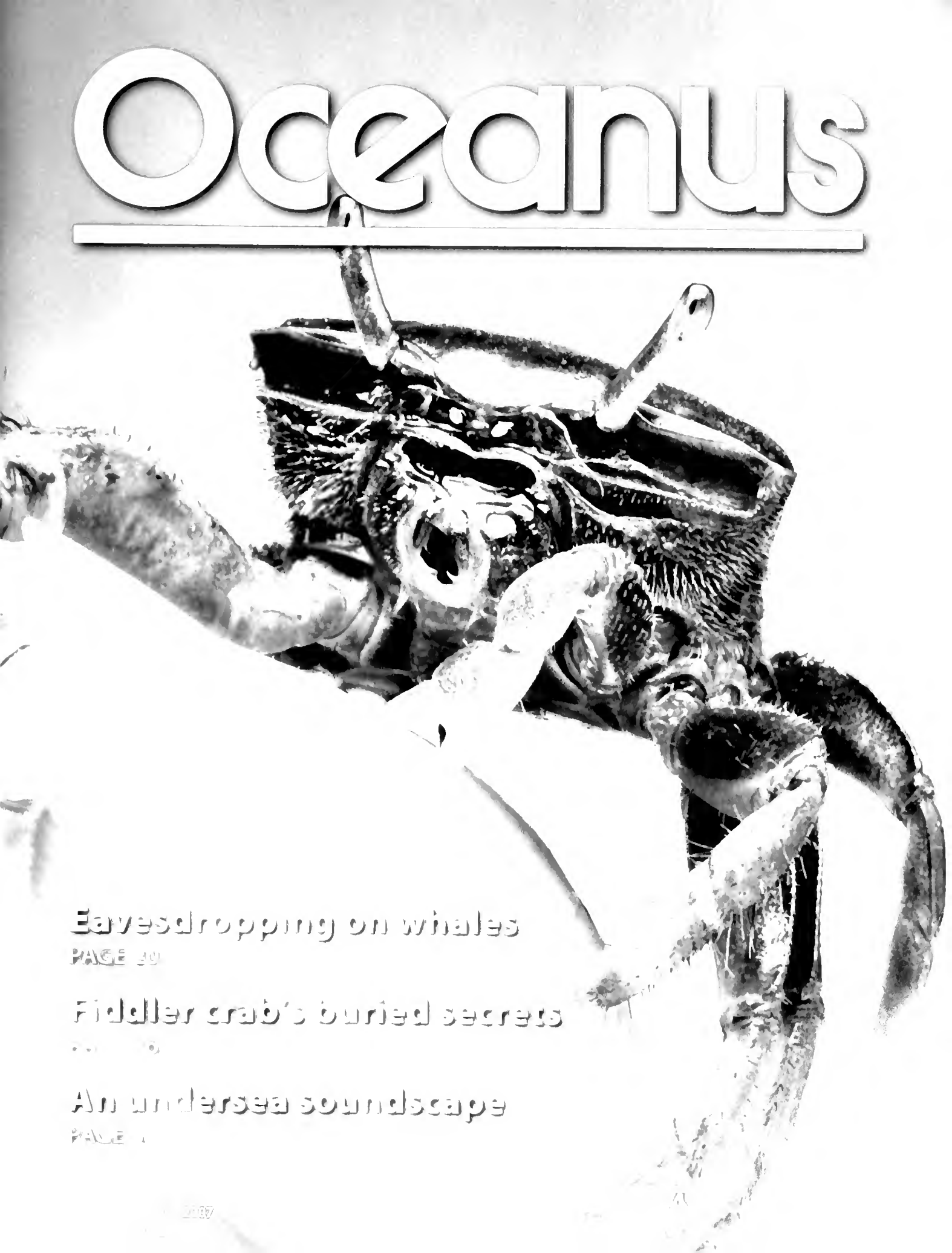

Eavesdropping on whales
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An undersea soundscape
PAGE 4


GARELICK FARMS

THROUGH THE LENS

◄ Scientific equipment, including an Ice-Tethered Profiler (the yellow instrument on the third pallet), is lined up on an icy runway in Resolute Bay, Canada, awaiting a flight to an ice camp/observatory near the North Pole in April 2007. WHOI researchers deployed the instrument atop a hole in a drifting ice floe. It measures properties of the ocean below and relays data back to WHOI via satellite.

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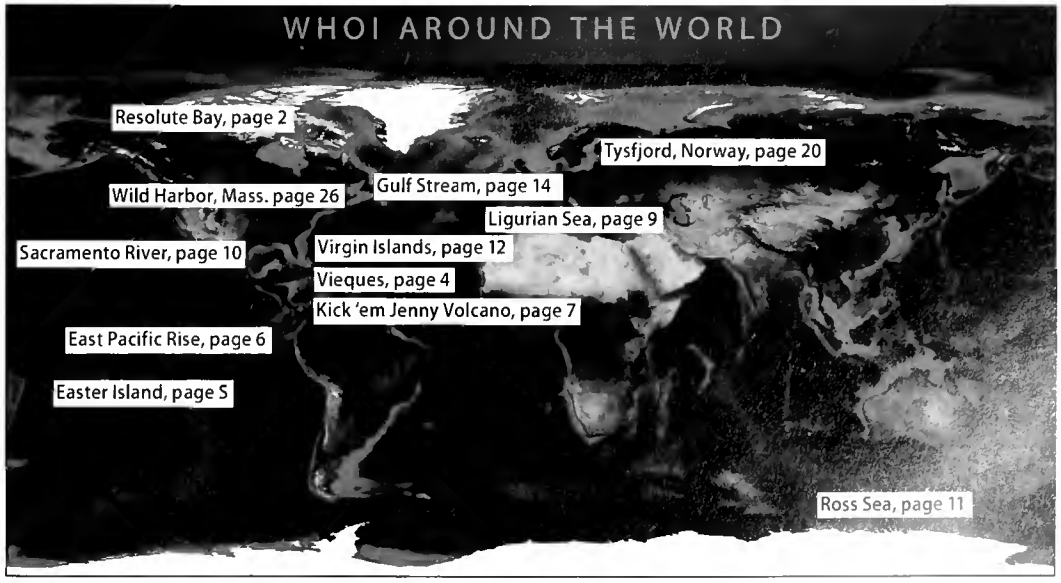
COVER: Fiddler crabs pointed the way to answering a question that long nagged scientists: Did oil spilled into a Cape Cod salt marsh from a barge that ran aground in 1969 still have impacts on wildlife living in the marsh? See story on page 26. Photo by Tom Kleindinst, WHOI.



Scientists unearth long record of past hurricanes

Jeff Donnelly, WHOI

Researchers extract and examine cores of sediment from Laguna Playa Grande in Vieques, Puerto Rico, to look for evidence of intense hurricanes.

Reaching down into the muck below a Caribbean lagoon, two geologists at Woods Hole Oceanographic Institution reached back 5,000 years to compile the longest record of strong hurricanes in the Atlantic region.

The record showed that the dominant forces spawning heightened hurricane activity appeared to be atmospheric conditions generated by weak El Niños in the tropical Pacific and strong West African monsoons, Jeff Donnelly and Jon Woodruff reported in the May 24, 2007, issue of the journal *Nature*.

Somewhat to their surprise, they also found extensive periods of intense hurricanes in the past, when ocean temperatures were cooler than they are now. Today, concerns about global warming have focused public attention on warmer ocean waters as a prime suspect for increased hurricane activity.

"Warm sea surface temperatures are clearly important in fueling intense hurricanes," Donnelly said. "Over the past several thousand years, ocean temperatures have never been as warm as they are now, so we have no analog to help predict how they will affect hurricane activity."

MIT/WHOI graduate student Jonathan Woodruff works to sink a coring tube into the sediments beneath Laguna Playa Grande.

"But our research demonstrates that the El Niño/Southern Oscillation and the West African monsoon are certainly important," he said. "Understanding how they will change in a warming world could be extremely important in determining the kind of hurricane activity we will see in the future."

Donnelly, an associate scientist at WHOI, and Woodruff, a doctoral student in the MIT/WHOI Joint Program, began reconstructing the history of Caribbean hurricanes in 2003 by driving 13-foot (4-meter) cores through the bottom of Laguna Playa Grande in Vieques, Puerto Rico. The lagoon is protected and separated from the ocean by dunes during all but the most severe tropical storms. But storm surges from intense hurricanes carry sand and bits of shells from the ocean beach over the dunes and into the lagoon, leaving telltale layers in the typically black, organically rich silt on its bottom.

The interspersed layers of silt and sand recorded long stretches of frequent hurricane strikes punctuated by lulls that lasted

Jeff Donnelly, WHOI

Laguna Playa Grande (left) sits behind a vegetation-covered barrier beach. Surges from intense storms carry sand and bits of shells from the ocean beach over the dunes and into the lagoon. Such "over-topping" events leave distinctive layers in lagoon sediments that identify hurricanes.

many centuries. The team then compared their new hurricane record with other climate influences, such as El Niño, the periodic diminishing winds and buildup of warm waters in the eastern tropical Pacific. Other researchers have established that El Niño can stunt hurricane activity by causing strong high-altitude winds that shear the tops off hurricanes or tip them over as they form.

The researchers also examined precipitation records from Lake Ossa, Cameroon, and discovered that when monsoon rains increased, intense hurricanes occurred more often on the other side of the Atlantic. Researchers have theorized that storms over western Africa generate atmospheric waves that move into the Atlantic and provide "seedlings" for hurricane development.

"If we have few El Niño events and a strong West African monsoon, combined with exceedingly high sea surface temperatures, we could experience an active hurricane period that is unprecedented in the last 5,000 years," Donnelly said. "Conversely, if we have more steady-state El Niño conditions, it may reduce—but not stop—intense hurricane activity in a warmer world."

— Mike Carlowicz and Lonny Lippsett

The research was funded by the National Science Foundation, the Risk Prediction Initiative, the National Geographic Society, the WHOI Coastal Ocean Institute, and the Andrew W. Mellon Foundation.

A hagfish by any other name would not smell as sweet

It's not hard to figure out how hagfish got their name, as they aren't exactly warm and fuzzy. Skinny, coated in gooey slime, and often found wriggling and eating in the guts of dead whales, they're not the sort of critter most people want to be associated with. When *Alvin* pilot Bruce Strickrott captured a specimen of the worm-like fish during a dive in the cold, inky Pacific depths in March 2005, he recalled thinking it was "cool ... but in a hideous sort of way."

About a year later, he learned scientists wanted to name it for him. It turns out that the fish he spotted swimming at a depth of 7,218 feet (2,200 meters) during an oceanographic expedition south of Easter Island was the first hagfish captured from a hydrothermal vent site. Morphological studies and genetic analyses confirmed what researchers had then suspected: The hagfish was a new species, and one of the deepest-dwelling of its kind.

Suddenly, Strickrott felt not repulsed but nearly paternal about the 18-inch-long fish he had withdrawn from the depths.

"It's a feather in my cap," Strickrott said of the announcement of his namesake hagfish, *Eptatretus strickrotti*. "It's recognition from researchers for my contributions to the advancement of science."

An article announcing the new species, by Peter Møller of the Zoological Museum of the University of Copenhagen and W. Joe Jones of the Monterey Bay Aquarium Research Institute, was published in the February 2007 issue of the journal *Biological Bulletin*.

The naming initiates Strickrott into a unique fraternity of at least a half-dozen pilots of the deep-sea submersible *Alvin* whose surnames are now intertwined with species of jellyfish, worms, nematodes, and slugs.

"Without *Alvin* pilots, many oceanographers could not get their jobs done, and we want to recognize the commitment of these dedicated people," said Jones, a genetics specialist who was in *Alvin* with Strickrott during the hagfish's capture.

"We saw this little thing swimming like a worm and I told Bruce, 'There is no way you are going to catch it,'" Jones said. Strickrott—who had logged more than 1,600 hours and 200 dives in *Alvin* since becoming a pilot 10 years ago—accepted the challenge. Within moments, he maneuvered the submersible behind the wiggling fish and then vacuumed it through a tube known as the "slurp gun" into a canister mounted on the sub.

"I was like, 'Man, this guy has skills and deserves recognition,'" Jones said. "The naming was a way to express our gratitude."

The find, Jones said, "reminds us that the oceans remain wide open for exploration and new discovery."

Strickrott, meanwhile, has taken good-natured ribbing about his namesake fish from "individuals who argue that the characteristics of a hagfish seem to match the persona of some *Alvin* pilots."

"Slimy bottom dweller," he deadpanned. "How fitting."

— Amy E. Nevala

The National Science Foundation funded the 2005 Easter Microplate Cruise.

Illustration Figure 1 from Møller, P.R., and ... Reproduced with permission from MBL, Woods Hole, MA

Seafloor seismometers—res

Undersea eruption traps devices on the bottom of the Pacific

NDSF, ROV *Jason*, WHOI, and NSF

An eruption that spread lava over nine square miles of seafloor trapped three ocean-bottom seismometers.

The two earthquake-monitoring instruments—each the size and weight of a small refrigerator—were glued to the ocean bottom by erupting lava that had flowed and hardened around them. If scientists could pry them loose, the payoff could be huge.

The instruments, called ocean-bottom seismometers (or OBSs for short), appear rather bulky, but they are designed for a sensitive job. Sitting on the seafloor, they record ground motions—from the tiniest flutters to major earthquakes. These particular seismometers, stuck 1.6 miles (2,500 meters) deep on the Pacific Ocean floor, may also have also been stuck at a particular moment in time, recording something scientists rarely have a chance to pinpoint: the precise timing of an undersea volcanic eruption.

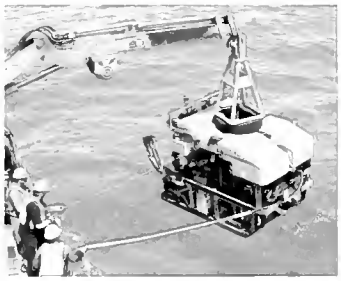


Photo by Tom Bolmer, WHOI

With its dexterous mechanical arms, the WHOI-operated robotic vehicle *Jason* was dispatched to knock loose hardened lava and extricate instruments trapped on the seafloor.

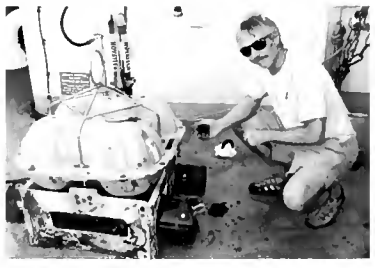
Did the eruption happen all at once or over a longer time period? Seismic spikes—recorded on Jan. 22, 2006, by two other OBSs that were not engulfed in lava and recovered a year ago—suggest the former. But geologists and chemists, analyzing fluid temperatures and rock samples to date lava flows from the eruption site, believe the eruptions occurred over several months in late 2005 into early 2006.

"It's a good, old-fashioned, friendly science debate," said marine geophysicist Maya Tolstoy from the Lamont-Doherty Earth Observatory of Columbia University. "We have two types of data, saying two different things. The recovery of the instruments could resolve the issue."

The seismometers survived the eruption because the nearly freezing temperature of water in the deep ocean (about 35°F or 2°C) rapidly quenches hot lava as it emerges from the seafloor.

"You couldn't throw an instrument like this into a lava flow on land and expect it to survive," Tolstoy noted.

In April 2007, researchers returned to the eruption site with the remotely operated vehicle *Jason*, hoping its pilots could use *Jason*'s mechanical hands to extricate three OBS instruments cemented to the seafloor by lava. Typically, one pilot controls both of *Jason*'s robotic arms. But in this case, the two pilots on the job, Tito Collasius and Bob Waters, decided that the situation called for a tag-team effort.



(Courtesy of Dan Fornari, WHOI)

Marine geologist Dan Fornari holds a chunk of fresh lava that came up with a seismometer rescued from the seafloor after an undersea eruption.

"One guy used one arm to knock off chunks of lava" that were stuck to the instruments, Collasius said. "The other guy was working to attach a float in case the instrument broke free and tried to float away."

Within 45 minutes, one instrument was free and rising to the sea surface, where it was recovered by the research vessel *Atlantis*. A second OBS was wedged into a lava flow and partly buried, but Collasius and Waters wiggled it from the lava and secured a float to it, said Dan Fornari, director of the Deep Ocean Exploration Institute at WHOI. A third OBS, however, was stuck too tightly between collapsed lava flows and could not be recovered.

"We worked for several hours trying to break ... the lava crusts around it and digging out the rubble, to no avail," Fornari said. "But we gave it our best shot."

When *Atlantis* docked in San Diego on April 27, Fornari ferried the two recovered instruments to the Scripps Institution of Oceanography. Engineers will determine if they can recover any data, which could speak volumes about the volcanic processes on the seafloor that shape our planet.

"Even though the instruments are pretty singed-looking in places," Tolstoy said, "the damage is quite minimal given what they went through."

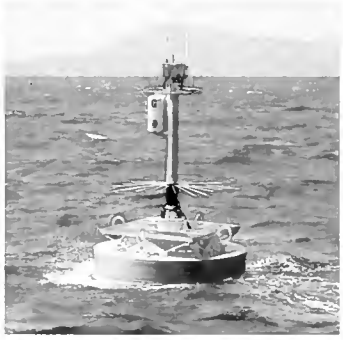
—Amy E. Nevala

The research was supported by the National Science Foundation Ridge 2000 Program.

cued and to the rescue

Buoy system atop underwater volcano offers early warnings of eruptions

A team led by the Woods Hole Oceanographic Institution installed a novel underwater earthquake-monitoring system atop Kick'em Jenny, an active volcano just off the north coast of Grenada in the Caribbean Sea. The new Real Time Offshore Seismic Station—deployed May 6, 2007, and being tested for the first time—sensitively detects rumblings from the submerged volcano and transmits data within milliseconds by high-frequency radio to a coastal shore station.



Spahr C. Webb, Lamont-Doherty Earth Observatory

A new buoy transmits real-time seismic data from the Kick'em Jenny volcano off Grenada.

"This is the first time that radio telemetry has been used to transmit data from an underwater seismic monitoring station," said Rob Reves-Sohn, a WHOI marine geologist who heads the project. It will allow scientists to observe the "inhaling and exhaling" of the volcano as it draws in and expels seawater, magma, and superheated fluids, he said. "By putting a seismometer right on the volcano, we will significantly improve our ability to detect precursory seismic activity before an eruption takes place" and help reduce hazards from bursts of volcanic gases or rocks from seafloor avalanches that can generate tsunamis.

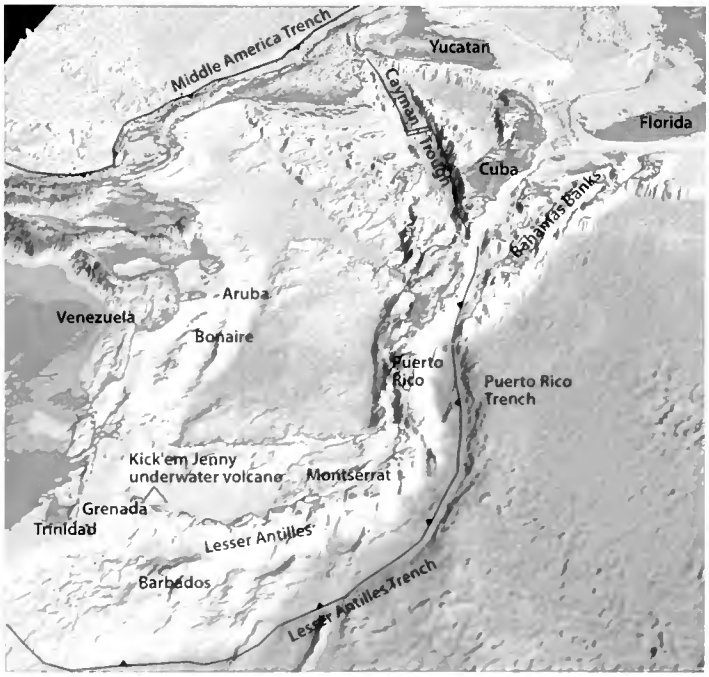
"The system essentially acts as a kind of doctor's stethoscope so we can directly listen to the pulse of the volcano," said Richard Robertson, director of the Seismic Research Unit at the University of the West Indies, who manages the region's seismic monitoring network. The WHOI research team is also coordinating with the National Disaster Management Agency in Grenada.

A key element of the real-time seismic system is a flexible, stretchy hose that connects instruments anchored to the seafloor with a buoy on the sea surface. The hose is designed to compensate for the movement of waves, tides, and currents, which are notoriously rough around Kick'em Jenny. It stretches more than twice its original length without snapping. Electrical conductors are spiraled through the hose's wall so that the wires straighten out, rather than break, when the hose stretches. Solar panels on the surface buoy provide power for radio transmitters that send data 4 miles (7 kilometers) to the shore station on Grenada.

The mooring system was developed by engineers Keith von der Heydt and Dan Frye of the WHOI Instrument Systems Development Laboratory, along with geologist Uri ten Brink of the U.S. Geological Survey in Woods Hole. Spahr Webb of the Lamont-Doherty Earth Observatory of Columbia University designed the seismometer.

Kick'em Jenny provides scientists with a unique natural laboratory to study the activity at a shallow submarine volcano that will one day emerge from the ocean as a new volcanic island. It has erupted at least 12 times since 1939, with the last major eruption occurring in 2001.

The National Science Foundation provided major funding for the project. WHOI and USGS provided additional funds.



(Uri ten Brink, U.S. Geological Survey)

The Kick'em Jenny submarine volcano, located offshore Grenada in the Caribbean Sea, has erupted a dozen times since 1939.

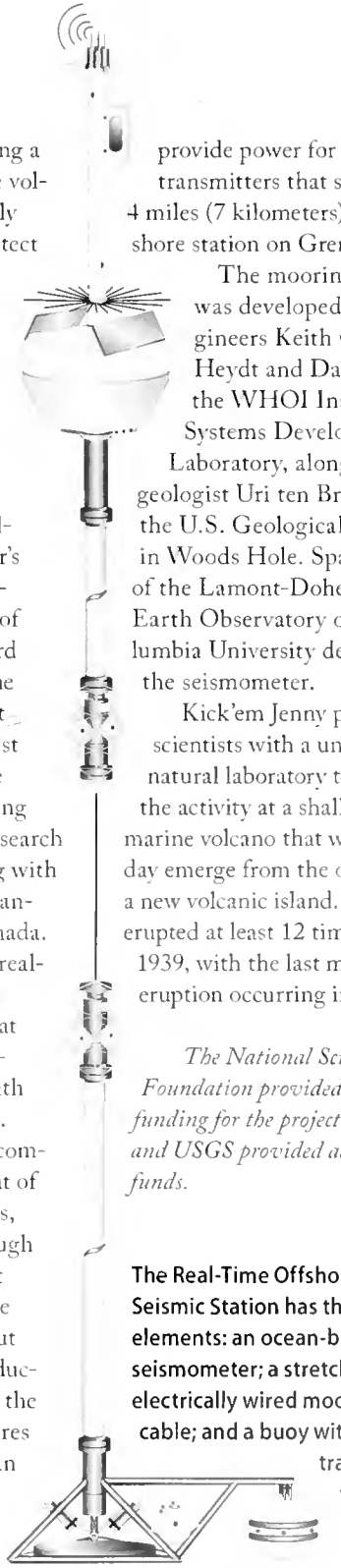


Illustration by E. Eg / Oceanwide Visuals

The Real-Time Offshore Seismic Station has three main elements: an ocean-bottom seismometer; a stretchy, electrically wired mooring cable; and a buoy with radio transmitters that send data to shore.

A rare chance to examine a rare leatherback turtle

A panoply of uncommon stories and specimens, from shrimp to whales, passes through Woods Hole Oceanographic Institution's Computerized Scanning and Imaging Facility. Another unusual subject arrived in May 2007, when a team of specialists from several institutions and agencies used the facility to conduct a necropsy on a 900-pound leatherback turtle.

The leatherback, an endangered species, was inadvertently caught in April off Jupiter, Fla., during a longline survey of Atlantic shark carried out every two to three years by the National Oceanic and Atmospheric Administration Fisheries Service.

The turtle was kept for a required 24-hour observation period before being confirmed dead, said Teri Frady of the NOAA Northeast Marine Fisheries Center. NOAA anticipates and accounts for this and other incidental catches when, as the federal Endangered Species Act mandates, it evaluates the total impact of fisheries on turtle populations.

The unintentional catch did have a positive side: It presented a rare opportunity to learn more about this species. With funding from NOAA, Jeanette Wyneken (in white), a turtle physiology expert from Florida Atlantic University, came to WHOI to lead the necropsy. It included WHOI biologist Darlene Ketten (in blue) and other WHOI staff, who used the high-resolution medical scanner to create precise three-dimensional visualizations of the leatherback's internal structure, which are impossible to obtain by dissection.

Tom Kleindinst, WHOI

A ridge too slow?

An international team discovered the first active hydrothermal vents ever found on an ultraslow-spreading mid-ocean ridge, which scientists had once thought would not be volcanically active. "It is a significant milestone," said WHOI geophysicist Jian Lin, who was U.S. coordinator of a Chinese expedition aboard the research vessel *Dayang 1* to the remote Southwest Indian Ridge in the Indian Ocean in early 2007. "People have been looking for active hot vents on ultraslow ridges for more than 10 years." In the past decade, some scientists began to hypothesize that slower-spreading ridges would have fewer vents but larger vent fields. "This cruise confirmed that hypothesis," Lin said. WHOI scientists used the autonomous underwater vehicle *ABE* to pinpoint the vent site, which is larger than a football field.

Gutsy, versatile bacteria

Six-foot-tall tubeworms living at seafloor hydrothermal vents have no mouths, but they do have symbiotic microbes in their guts. In exchange for a place to live, the microbes convert carbon dioxide into a form that tubeworms use for energy. WHOI microbiologist Stefan Sievert was part of a research team that discovered that these microbes can use two different biochemical methods to convert carbon, giving them metabolic flexibility to adapt to fluctuating conditions. Such bacteria likely played a role in the evolution of life on Earth, say scientists, who

D-tags record in-depth data of beaked whales in the depths

Which air-breathing animal holds the record for diving deeper and longer than any other?

Using digital tags temporarily suction-cupped to whales, researchers led by scientists at Woods Hole Oceanographic Institution tracked Cuvier's beaked whales diving to depths of nearly 6,230 feet (1,900 meters) and staying down for 85 minutes.

"These data establish beaked whales as the extreme breath-hold champions of all animals studied so far," said WHOI engineer Mark Johnson, who developed the "D-tags," which record whale movements, their echolocations, and other underwater sounds.

"Because these animals spend so much of their lives under water, we knew very little about them beyond what we could learn from stranded animals or see from research vessels," said WHOI biologist Peter Tyack, lead author of a paper published October 2006 in the *Journal of Experimental Biology*. "Now we know more about their behavior at depth than many of us had ever dreamed."

Tyack and Johnson worked with an international team, tagging seven Cuvier's beaked whales in the Ligurian Sea off Italy and three Blainville's beaked whales off Spain's Canary Islands. The research shines light on the mysterious world of beaked whales and should help answer questions about the possible impacts of sonar testing on the whales, which have been found stranded with symptoms of decompression sickness after naval exercises.

The D-tags show that when the whales dive deep in search of prey, they ascend slowly. The behavior is mysterious because breath-hold diving whales don't have to ascend gradually to avoid decompression as scuba divers would: Underwater pressure below about 330 feet (100 meters) collapses the animals' lungs, preventing gas from entering their blood, Tyack said.

After the whales surface from deep dives, the D-tags show that they stay close to the surface making shallow dives for up to several hours. It appears that the whales dive so long that they use up most of their oxygen stores and need to resort to anaerobic metabolism for part of their dives. This behavior suggests the whales may be resting to process lactic acid, a byproduct of anaerobic metabolism, before taking their next deep plunges, said Tyack—similar to "the way human athletes use gentle exercise to clear lactic acid from overworked muscles after an intense workout."

Photo courtesy of Peter Tyack, WHOI. Photo taken using a University of La Laguna permit.

A Cuvier's beaked whale breaches off the Canary Islands. Scientists and military officials are studying the whales' behavior, particularly their reaction to sonar testing, which may make them vulnerable to stranding.

Despite such physiological adaptations for deep diving, Tyack hinted that sonar may provoke behavioral changes that make whales vulnerable to stranding. In ongoing efforts to develop effective strategies to reduce whales' exposure to sonar in the future, Tyack, and colleagues will continue D-tagging experiments this summer off the Bahamas while Johnson will return to the Canary Islands for more data.

—Matt Villano

Research funding came from the Strategic Environmental Research and Development Program, the National Ocean Partnership Program, the Packard Foundation, the Canary Islands Government, and the Spanish Ministry of Defense.

reported their findings Jan. 12, 2007, in the journal *Science*.

New Orleans toxic gumbo

When New Orleans' levees broke after Hurricane Katrina, officials feared Lake Pontchartrain might be infiltrated with a "toxic gumbo" of water, polluted sediments, and sewage. Weeks after the flood, scientists from several U.S. Centers for Oceans and Human Health, including WHOI biologist Rebecca Gast, mobilized to sample mud and waters around the lake, looking for disease-causing microbes. In the May 2007 issue of the journal *Proceedings of the National Academy of Sciences*, they reported that the influence of contaminated floodwaters on Lake Pontchartrain was relatively short-lived, limited to coastal areas, and did not leave a lasting contamination or disease problem.

Mercury in groundwater

WHOI scientists have found that a surprisingly substantial amount of mercury enters the ocean from groundwater flowing out of underground aquifers near the coast. "This pathway for delivering nutrients and contaminants into the ocean has long been overlooked and ignored because it was difficult to quantify," said WHOI marine chemist Matt Charette, whose lab has advanced methods to detect mercury flowing out of aquifers. Charette and Sharon Bone, a former undergraduate summer student fellow at WHOI, published their findings May 2007 in the journal *Environmental Science and Technology*.

Antibiotics delivered for the first time to wild, wounded whales

For two weeks in May, the saga of two humpback whales, wounded and off-course in the Sacramento River, held the world's attention. Woods Hole Oceanographic Institution biologist Michael Moore was called in to join rescue efforts.

The mother and calf, straying from their migratory route along the California coast, were first spotted May 11 in the Sacramento River, which empties into San Francisco Bay. The media and public watched intently as the whales swam 90 miles inland into completely fresh water—where they dallied with no food, no room, and little tolerance for low salt levels.

Sarah Wilkin, NOAA

Windsurfers and scientists alike were surprised to find two injured humpback whales swimming astray in the Sacramento River.

Local, state, federal, and private organizations responded. Marine mammal experts tried to encourage the animals to swim back downstream with tactics that included broadcasting whale sounds, with little success. Ship traffic was diverted from their path, but concerns mounted: Both whales had serious wounds, likely from an interaction with a vessel, and the longer they stayed in the river the more their condition deteriorated.

Moore, a marine mammal veterinary and forensic biologist, is experienced in working with whales from small boats. With Jamison Smith of NOAA Fisheries Northeast Office, Moore helped to administer antibiotics to the whales with a new remote drug delivery device, which launched a syringe and stiffened foot-long needle into the whales' muscle tissue to deliver the drug.

"This was the first time we are aware of antibiotics being administered to non-captive large whales," Moore said.

The whales swam intermittently downriver to the bay, on their own schedule. "We think the drugs, along with their return to salt water, aided their markedly improved skin and wound condition," said Moore.

In the end, the whales left the bay unobserved, swimming through the Golden Gate into the Pacific on a foggy San Francisco night.

—Kate Madin

Funding for the drug delivery system, developed with the New Zealand company Paxarms, came from the National Oceanic and Atmospheric Administration through a contract with the Provincetown Center for Coastal Studies.

Old whale oil tells whale of a tale about pollution

It was the scientific equivalent of finding fine wine in an old cask.

Analyzing whale oil from the whaling ship *Charles W. Morgan*'s last voyage, in 1921, marine chemists at Woods Hole Oceanographic Institution found that the oil contained chemical compounds with properties similar to toxic PCBs and the pesticide DDT. Here's the surprise: Large-scale production of PCBs began in 1929 and DDT in the late 1930s.

The research demonstrates that so-called halogenated organic compounds are also produced naturally and "were bioaccumulating in marine mammals—just as PCBs do now—before Monsanto, Dupont, and 3M were making halogenated organic compounds for industrial use," said Emma Teuten and Chris Reddy. Their findings were published February 2007 in the journal *Environmental Pollution*.

In the past decade, routine analyses of animal and food samples, including marine mammals, human breast milk, and commercially available fish, have begun to uncover halogenated organic compounds that could not be easily traced to known industrial or natural sources.

Teuten's and Reddy's findings raise intriguing questions: "We do not know who makes many of these natural compounds, or why, or how toxic they are," said Teuten, who is now at the University of Plymouth in England. "We suspect that many of the compounds were and are made by bacteria, plants, and animals"—as chemical defense mechanisms against predators.

The whale oil samples had been preserved in the New Bedford Whaling Museum in New Bedford, Mass., where the *Charles W. Morgan* was built in 1841. It was one of the last whaling ships operating during the 19th and early 20th centuries and traveled on voyages throughout the world. The ship, now preserved and on public display at Mystic Seaport in Mystic, Conn., was once owned by the father of former WHOI Trustee Gratia "Topsy" Montgomery, who was one of WHOI's most generous benefactors.

Emma Teuten, WHOI

The *Charles W. Morgan*

—Lonny Lippsett

The research was supported by the National Science Foundation, the WHOI Ocean Life Institute, and The Camille and Henry Dreyfus Foundation.

Even in the oceans, living things need their vitamins

Tom Kleindinst, WHOI

WHOI biogeochemists Erin Bertrand (right) and Mak Saito found evidence that B_{12}, an essential vitamin for people, also plays a critical role in the ocean food web.

Your mother was right: You need your vitamins. And that turns out to be true for life in the oceans, too.

B_{12}—an essential vitamin for land-dwelling animals, including humans—also plays a vital and previously overlooked role in determining how microscopic plants will bloom in the sea, according to a new study led by biogeochemists at Woods Hole Oceanographic Institution.

These plants (called phytoplankton) have critical impacts on the marine food web and on Earth's climate. Via photosynthesis, they draw huge amounts of carbon dioxide, a greenhouse gas, from the air, incorporating carbon into their bodies. When they die or are eaten, much of the carbon is transferred to the ocean depths, where it cannot re-enter the atmosphere.

B_{12} contains the metal cobalt and can be synthesized only by certain singled-celled bacteria and archaea. Humans, animals, and many algae require B_{12} to manufacture essential proteins, but they cannot make it and must either acquire it from the environment or eat food that contains B_{12}, said the study's lead authors, Erin Bertrand and Mak Saito.

The scientists wondered whether the vitamin was also important in the ocean, where B_{12} and cobalt are both found in exceedingly low concentrations—especially around Antarctica, where the only nearby continent (a common source of metal particles blown into the sea) is largely ice-covered. Nevertheless, polar regions harbor some of the most extensive phytoplankton blooms in the world and are believed to play a significant role in exporting carbon to the deep ocean.

Yuanyuan Feng, University of Delaware

Two expeditions aboard the icebreaker *Nathaniel B. Palmer* explored the Ross Sea off Antarctica, where spectacular blooms of marine algae arise each spring and summer.

Bertrand, Saito, and colleagues collected water samples from three locales in the highly fertile Ross Sea off Antarctica during a 2005 expedition aboard the icebreaker *Nathaniel B. Palmer.* To one set of samples, they added B_{12} and iron (another essential nutrient for plant growth); to a second set, they added just iron; and to a third, they added neither. Samples stimulated with both iron and B_{12} showed significantly higher concentrations of plant life in general and greater concentrations of a particular type of marine algae called diatoms.

"The possibility that a vitamin could substantially influence phytoplankton growth and community composition in the marine environment is a novel and exciting finding," wrote Bertrand and Saito in the May 2007 issue of the journal *Limnology and Oceanography.*

In the Ross Sea, spectacular spring blooms of marine algae called *Phaeocystis antarctica* dissipate by summer and are followed by blooms of diatoms. The scientists' experiments—showing that adding more B_{12} benefits diatoms—indicate that *Phaeocystis* may have a competitive advantage over diatoms in the Ross Sea in spring, when populations of B_{12}-manufacturing bacteria and archaea (and therefore B_{12} supplies) are low.

Phaeocystis effectively monopolize the B_{12} supply by forming colonies cemented by sticky mucous that attracts B_{12}-making bacteria, the scientists theorize. In a symbiotic relationship, the algae get their required vitamin, and the bacteria get a steady supply of carbon made by the plants. When *Phaeocystis* die off, the bacteria are eaten or decomposed, and B_{12} is released back to the ocean, becoming available to be used by diatoms.

The finding underscores the complexities of the marine food web and raises questions about how climate change could affect the delicately balanced ecosystem—and vice versa.

—Lonny Lippsett

The National Science Foundation funded the 2005 Controls on Ross Sea Algal Community Structure expedition. Erin Bertrand was a Carl and Pancha Peterson Summer Research Fellow at WHOI and is now a graduate student in the MIT/WHOI Joint Program.

Lauren Anderson

Researchers in the Virgin Islands collect seaweed with algae that cause ciguatera fish poisoning.

Pilot study examines fish-borne poisoning

It is one of the most common illnesses from eating seafood, sickening more than 50,000 people a year, and it is on the rise around the world. Yet most people in the United States have never heard of it: ciguatera fish poisoning.

Ciguatera produces a variety of unpleasant symptoms, including vomiting, diarrhea, numbness, breathing difficulties, and bizarre reverse sensations of heat and cold. Recovery can take years. There is no reliable way to detect whether a fish has ciguatera without using elaborate toxin extraction methods and complex analytical instruments. In some places, people have tried using cats or other animals to test food, but this is far from reliable.

Dr Yasuwo Fukuyo, University of Tokyo

Single-celled, toxin-producing *Gambierdiscus* algae live on seaweed stalks that are eaten by fish.

Scientists know the cause: single-celled marine algae called *Gambierdiscus* living on seaweeds. They produce a substance that is transformed into a toxin when reef fish graze on seaweed and consume the *Gambierdiscus* cells; larger fish eat the grazing fish, passing the accumulated toxin up the food chain, eventually to people.

But scientists don't yet understand fundamental aspects of how, when, and where various strains of *Gambierdiscus* grow and live. Funded by the WHOI Ocean Life Institute's Tropical Research Initiative, a team of researchers launched a study of *Gambierdiscus*. They collected seaweed samples in the U.S. Virgin Islands in 2006 and 2007, bringing them back to the lab to isolate, culture, and analyze algal cells attached to the seaweed.

The team—WHOI Senior Scientist Don Anderson; Deana Erdner, a University of Texas marine biologist and former graduate student in Anderson's lab; and Robert Dickey, a U.S. Food and Drug Administration chemist—plan to map distributions of *Gambierdiscus*, genetically identify different strains, and analyze their toxins. The study aims to discover how strains and degrees of toxicity vary in different environments. Anderson hopes this pilot study will stimulate funding for research in collaboration with epidemiologists and neuropsychologists who would investigate the human side of the poisoning syndrome.

"Our research spans scientific fields, making it harder to place within funding agencies' traditional research categories," Anderson said. "The WHOI Tropical Research Initiative provided invaluable seed money that lets us begin this important cross-disciplinary research."

—Kate Madin

Ancient bridge reconstruction

Researchers have found evidence that the land bridge between Alaska and Siberia—believed to be the major route for human migration from Asia to the Americas—may have been cut off about 1,000 years earlier than widely thought. Extracting the longest piston core ever of seafloor sediments in the Arctic Ocean, WHOI paleoceanographer Lloyd Keigwin and colleagues analyzed and dated clues indicating that the Bering Strait flooded into the Arctic Ocean about 11,000 years ago. The finding, reported in the October 2006 issue of *Geology*, offers a key milepost for archaeologists reconstructing human history.

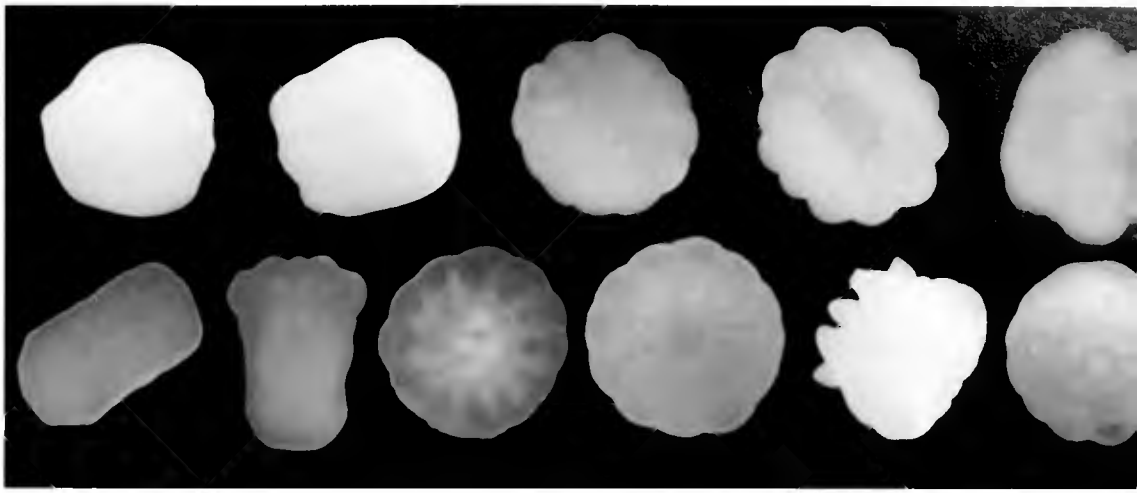
A conversation of narwhals

Individual narwhals, the Arctic whales with spiraled unicorn-like tusks, can make individual sounds that may help other narwhals recognize them or help them reunite with their group. Ari Shapiro, a biological oceanography graduate student in MIT/WHOI Joint Program (see page 20), and colleagues used digital-recording devices temporarily suction-cupped to two narwhals in Admiralty Bay on Baffin Island, Canada. "For the first time, we could really 'ride' with the animals as they were vocalizing and as they were moving," said Shapiro, who reported the findings in the September 2006 issue of the *Journal of the Acoustical Society of America*.

Forecast: Hotter summers

If greenhouse gas emissions continue to rise at current rates, average summertime high temperatures in the eastern United States could rise 10°F by 2080, and soar to more than 100°F in Chicago, Washington, and Atlanta, according to a study by NASA and WHOI researchers published April 2007 in the *Journal of Climate*. The team fed results from a computer model that simulates future global climate change into a separate weather prediction model that forecasts summer temperature variability in the eastern U.S. The global model alone failed to account for periods without enough rainfall on the East Coast, which cause temperatures to rise dramatically, said Rick Healy, an information systems specialist at WHOI and co-author of the study.

A lullaby for larvae



Rhian Waller, WHOI, and Susie Balser, Illinois Wesleyan University

WHOI biologist Rhian Waller watched the transformation of tiny, shapeless offspring of Antarctic deep-sea corals as they grew tentacles within 24 hours of brooding.

Like many babies, these tiny offspring arrived last spring amid much fanfare and a little trepidation. Never before had scientists witnessed the birth of deep-sea Antarctic corals, which unlike like their tropical, shallower-water cousins, normally live and breed in the icy, sunless depths, 165 to 6,650 feet (50 to 2,000 meters) below the surface.

Their parents had been collected in nets and placed in saltwater tanks onboard the polar research vessel *Laurence M. Gould*. Day and night, in the ship's laboratory, Woods Hole Oceanographic Institution biologist Rhian Waller watched with delight as dozens of the bright orange coral larvae crawled from the mouths of adult corals. Almost immediately, the small blobs, no bigger than peppercorns, began settling on glass tiles and black rocks.

"Every day the captain would come down and say, 'So, how are the babies?' " Waller said. "I was amazed how many people were excited about them."

Waller's work focuses on two cone-shaped corals, a sherbet-orange variety called *Flabellum thouarsii*, and a pale yellow coral called *Flabellum impensum*. Marine biologists knew some details about these corals' taxonomy, but practically nothing about the unusual way they reproduce: Adult females brood fertilized larvae in their mouths, then release them fully formed into the water to settle and grow. Starfish, sea urchins, sea cucumbers, and other marine Antarctic animals also use the technique to give larvae the best chance for survival.

"The environment is so harsh that we assume that this gives them a secure place to begin their lives," Waller said.

Though she had studied corals worldwide, it was her first trip to the remote Southern Ocean surrounding Antarctica, whose icy waters don't seem a likely home for colorful, delicate-looking corals.

"That's one reason I'm so fascinated by them," Waller said. "I'm particularly interested by how marine organisms reproduce and develop into adults in extreme environments, such as polar regions."

Waller hadn't expected to collect the corals, nor planned to bring any home, and no one had ever set a precedent for keeping deep-sea coral larvae alive. She packed them in a portable cooler that she jammed under airplane seats. During three layovers, she and colleagues replaced ice to keep the larvae cold and comfortable.

Tom Kleindinst, WHOI

Waller brought back larvae collected on a cruise off Antarctica to her lab at WHOI to continue to monitor their development.

Back at her lab at WHOI, she fed them copepods and cleaned their refrigerated saltwater tanks, and carefully observed them. After a month, they eventually died, but not before Waller learned a great deal about deep-sea coral larvae.

"From preserved specimens, we never could have learned that the larvae can blow themselves up like anemones when stressed; how long they take to settle on the bottom; the fact that they crawl, and morph into different shapes rapidly, and feed within a few days; that they feel out where they want to settle but do not have the capability to go very far," she said.

She worried it would be many years before she could acquire more specimens—the journey to Antarctica is expensive, long, and often grueling. But Waller was invited on three expeditions in 2008 and 2009 that will allow her to continue her investigations.

—Amy E. Nevala

The research was funded by a National Science Foundation grant and a U.S. Geological Survey-Woods Hole Oceanographic Institution Postdoctoral Fellowship.

Measuring a drop in the ocean

A quest to engineer tough but sensitive sensors for buoys at sea

Earth is often called the blue marble. But it's more like a marble cake: a swirling batter of air, sea, and dirt stirred by our spinning planet and baking under the sun.

Every day, sunlight streams into the atmosphere, reflecting off clouds and dust particles, warming the air, and making the wind blow. Heat from the sun evaporates water, leaving the sea surface cooler, saltier, and denser and setting currents in motion. Winds also whip whitecaps into currents. Falling rain makes the sea surface fresher and (depending where it lands) warmer or cooler.

All of these physical transactions combine to create our climate, and all of them change over every minute and every meter. Designing equipment to track climate dynamics—in minute detail and at levels of precision unmatched in the world—has obsessed Bob Weller and the Upper Ocean Processes (UOP) group at Woods Hole Oceanographic Institution.

Two decades ago, few researchers thought it was even possible to obtain such measurements in the roiling ocean, Weller said. The doubters, however, were "land-based people, who have the option of cleaning radiometers every day, and (their instruments) don't rock and roll like buoys do. So they had always been pretty skeptical of ocean data." Weller set out to change those perceptions.

The result of this obsession is an array of seven sensors called ASIMET (for Air-Sea Interaction Meteorology). The sensors measure heat, sunlight, wind speed and direction, precipitation, humidity, barometric pressure, air temperature, sea surface temperature, and salinity.

The $60,000 systems are currently bolted on a half-dozen ocean buoys and fastened to masts on the bows of a handful of research and volunteer commercial ships around the globe. Left alone for up to a year, the instruments send back enough data for Weller's team to calculate, minute by minute, exactly how much heat, fresh water, and momentum moves between air and ocean.

"The kind of attention that the UOP group puts on every parameter has been tremendous for the community," said Don Conlee, chief scientist for the National Data Buoy Center at the Stennis Space Center in Mississippi. "Woods Hole has helped to define what the achievable accuracy and quality can be, and it gives the rest of us a benchmark to aim for."

The ASIMET project began life in 1988 when scientists realized that large inaccuracies in sea-surface measurements were holding back advances in understanding ocean-atmosphere interactions. The ASIMET program, then called just Improved Meteorology (IMET), sought to create an integrated system of sensors that would simultaneously take measurements of all the various factors that computer-driven models needed to calculate climate.

By 1993, Weller's group was testing prototypes at sea. By 1995, the first generation of IMET was up and running. Seven sensors housed in plastic tubes shaped like tennis-ball canisters made the necessary measurements. The system drew about 7.5 watts of power and ran partially on solar panels.

Ever since, ASIMET designers have made continuous improvements to the system despite investigating plenty of dead-ends along the way. They fabricated a grating to create more space for instruments atop buoys, but they abandoned it after finding it disrupted airflow. Solar panels sounded like a good idea but were foiled by clouds and beaten by rough waves. Hourly broadcasts to satellites blasted instruments with static, drowning out measurements.

Eleven years later, ASIMET sensors are shielded inside titanium canisters and use 92 percent less power, freeing the system from dependence on solar panels. They measure more precisely than ever, too, yielding estimates of heat flux that are 90 percent more accurate than in the days before IMET.

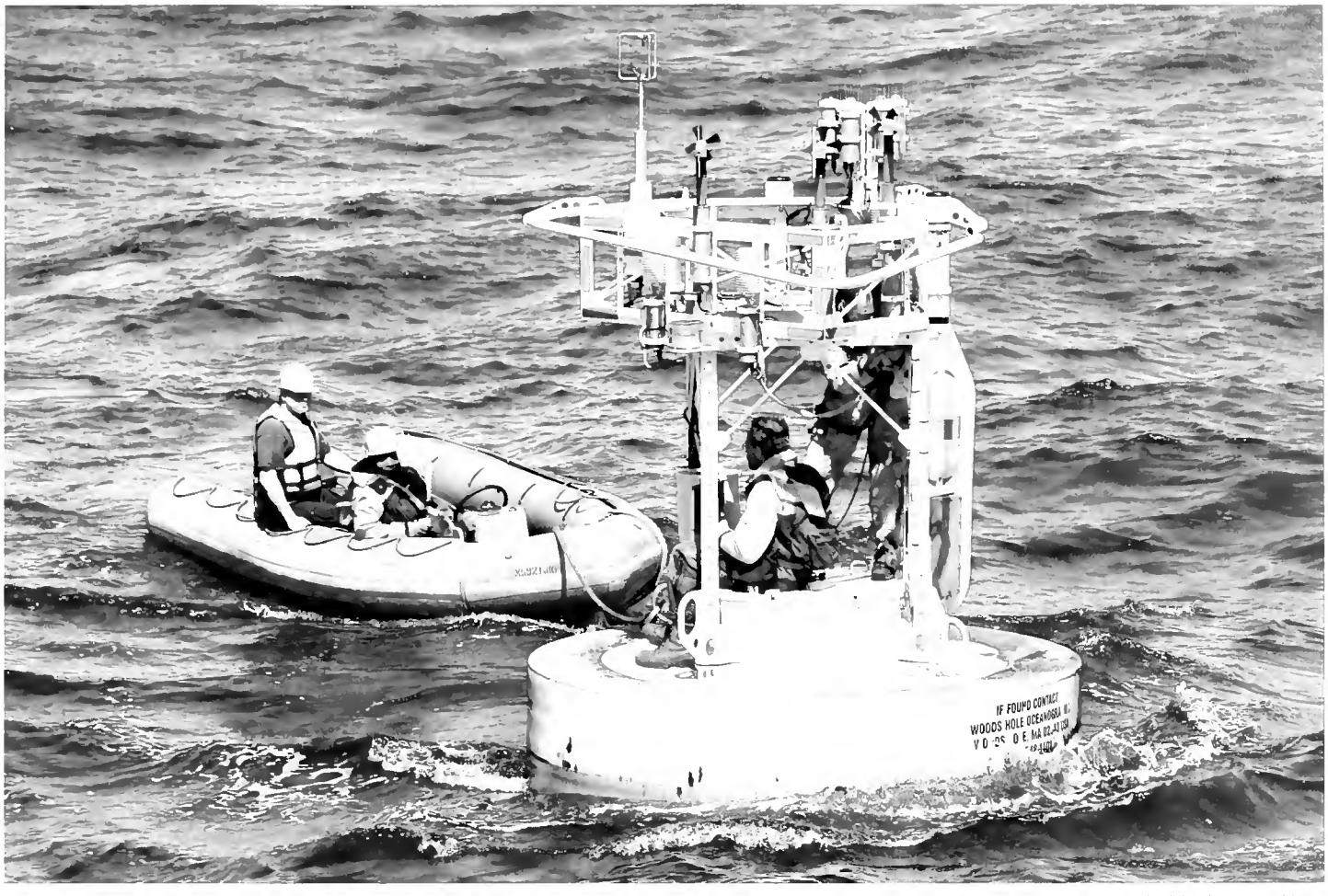
Leaving ASIMET systems alone on buoys in the open ocean introduced the team to brutal design challenges. One of the most painful lessons came in the early 1990s off Iceland. A buoy snapped loose after it began to pitch at the same frequency as storm waves, loading the buoy's mooring line with 7,000 pounds of pressure every 15 seconds. Now, a design program ensures buoy moorings are "detuned" before they go out. In his office, Weller still keeps the broken pear link that had connected that buoy to its mooring line.

A fully equipped ASIMET buoy is a far cry from a lobster trap or channel marker. The base is a 10-foot-wide puck of yellow Surlyn foam. From it rises a 10-foot scaffold that bristles with instruments. A thickened wind vane runs down one aluminum support, brandishing two satellite antennas and pointing the buoy into the wind.

On the tower top, 12 or more instruments cluster at the upwind edge where the airflow is least disturbed. Below, a watertight trapdoor leads to a hold stuffed with knee-high stacks of batteries. Sharing space are two microprocessors that control the instruments, archive the data, and send out hourly updates via satellite.

During weekly meetings, the UOP group hashes out equipment problems. With Weller consulting a whiteboard list of cruise deadlines, about a dozen men and women supply mooring, hardware, software, and logistical details. Brainstorming is fed by fresh donuts or, recently, an authentic German layer cake courtesy of Frank Bahr, a WHOI research specialist who oversees ASIMET deployments on volunteer commercial ships.

Even after 18 years of sweating the details, calibration is an incessant worry. It doesn't matter how accurate a freshly polished sensor is on the WHOI dock. It has to measure unflaggingly for a year at a time while it gets battered by waves, chilled in gales, or encrusted with salt and bird poop.



Members of the WHOI Upper Ocean Processes Group conduct at-sea repairs on an ASIMET buoy in the Gulf Stream that was probably damaged by a ship. ASIMET sensors measure heat, sunlight, winds, precipitation, humidity, barometric pressure, air and sea surface temperature, and salinity.

The team has three main approaches to the problem of consistent measurements: lab calibration (or "burn-in"), redundancy, and calibration at sea. Burn-in involves incessantly monitoring and retuning an instrument for six weeks on land before a cruise. All ASIMET deployments include at least two full sets of instruments, each set keeping an eye on the other. Technicians carry a third complete set on all cruises in case a sensor malfunctions on the way out. Before and after each buoy deployment, the researchers dedicate an entire day at sea to checking the buoy's instruments against the ship's onboard readings.

Now that the system is precise, reliable, and frugal with power, Weller dreams of deploying it on more buoys at more places around the globe. Although blanketing the ocean with thousands of ASIMET buoys isn't practical, Weller notes that buoys in perhaps 10 carefully chosen regions per ocean could lead to huge improvements in understanding how the ocean affects global climate.

Weller's wish list includes some regions he already has covered, such as the heart of the Gulf Stream and a perpetually overcast region off Chile. Other strategic sites include the region downwind of the Sahara, where windborne dust might be either blocking sunlight or heating the atmosphere; and the brutally rough Southern Ocean, where present buoy designs simply can't survive the winter.

For the future, Weller's group is still looking for the perfect radiometer, perhaps the system's most finicky sensor and one crucial to measuring both heat and light. Wind gauges are still unreliable in very light and very heavy winds. David Hosom, one of the original IMET engineers, now emeritus at WHOI, covets a $4,500 rain gauge that measures individual drops of rain. And the team is adding another crucial climate measurement: carbon dioxide. In October 2006, Weller and his group departed Chile to install a buoy equipped with a CO_2 sensor made by Chris Sabine at the NOAA Pacific Marine Environmental Laboratory in Seattle.

At their first stop, in a collaboration with the Chilean Navy Hydrographic and Oceanographic Service, the ship installed a tsunami-warning buoy. But a sharp-eyed observer sailing past at 75°W might notice some extra cylindrical instruments lining the buoy tower. With rising fuel costs cutting into research budgets, collaborating just makes sense, Weller said. "If you've already got a ship driving around doing tsunami buoys, why not put on some ASIMET instruments?"

—Hugh Powell

What does it take to break a whale?

The ship hit the whale with a force that snapped her 14-foot jawbone like a toothpick and left a four-foot-long crack in her skull. Known as 2150 among scientists, she was a young, fertile North Atlantic right whale—exactly the wrong whale to lose in an endangered population struggling to increase its numbers.

The call about 2150's death in the fall of 2003 sent Regina Campbell-Malone, a biology graduate student in the MIT/WHOI Joint Program, to Nova Scotia. On a wind-swept beach, she and her advisor, biologist Michael Moore, and a team of colleagues and volunteers performed a necropsy. They took photos and measurements and then carefully cut the whale apart to reveal internal injuries, marveling grimly over the extensive damage inflicted on the 45-foot animal.

"It got us to thinking: What exactly does it take to break a whale?" Campbell-Malone said.

Only about 400 North Atlantic right whales remain. Despite thick blubber, big bones, and an average adult weight of about 50 tons, these slow-moving whales have proved no match against fast-moving, metal-hulled vessels, whose shipping lanes intersect the whales' habitat and migration routes between Florida and New Brunswick, Canada. More than half of the 40 right whales found dead since 1970 were hit by ships, Campbell-Malone said. (The majority of the others died after becoming tangled in fishing gear.)

But in the world of commercial shipping, where time equals millions of dollars, simply asking vessels to slow down is not a straightforward matter. Propellers shred whales' skin and blubber, often causing the animals to bleed to death. But the blunt trauma caused by a moving ship's hull often leaves little to no external evidence. Instead, it breaks jawbones, ribs, and skulls, as Campbell-Malone witnessed with whale 2150.

She and other scientists needed specific data to provide recommendations to policy-makers for specific speed limits for ships. So she set out to determine and quantify the amount of stress whale bones can sustain before they break.

To conduct her research, Campbell-Malone first

Graduate student Regina Campbell-Malone put a 493-pound, 14-foot whale jawbone through a series of stress tests to develop recommendations for vessel speed limits aimed at preventing ship-whale collisions.

Photo by Tom Kleindinst, WHOI

needed bones. The skeleton from whale 2150 went to a Canadian museum. But several months later, a 53-foot right whale named Stumpy, who was pregnant with her sixth calf, washed up on a North Carolina beach after she was hit by a vessel. Campbell-Malone spent the next several years running Stumpy's 493-pound right jawbone through a variety of stress tests.

Her goal was to look at the bone outside and in. First, to measure its precise geometry (needed for computer models), Moore and Campbell-Malone hung it from a crane in a WHOI parking lot. Then they used a laser to scan the bone, which provided a more accurate 3-D view than measuring by hand. They anticipated that the pungent, 14-foot-long bone would draw attention, though some of it was a bit unnerving.

"Less than 20 minutes into this venture, we noticed that we were surrounded by three coyotes eagerly licking their chops," Campbell-Malone said.

Next the bone went to the University of New Hampshire (UNH), where colleagues hung 1,000 pounds of steel weights on the bone and rigged it with tiny sensors to measure strain. Even the bone's internal structure was not overlooked; Campbell-Malone squeezed cork-sized pieces of bone between metal plates to see how stress affects the bone's tissue and internal structure.

Then she helped collaborators at UNH to develop computer simulations of whales getting hit by vessels. This summer, plugging data into the computer models, she and colleagues at WHOI, UNH, and the University of Delaware will determine recommended speeds for various-sized vessels to avoid damaging or fatal collisions with whales.

Mesmerized as a child by Jacques Cousteau television specials, Campbell-Malone grew up in Buffalo, N.Y., "dreaming of becoming a marine biologist." But she was 20 before she saw the ocean for the first time.

"My parents encouraged me to do what I wanted, but they never thought of oceanography," she said. "It just wasn't on the map."

Kate Madin, WHOI

For a marine biology class she taught at Codman Academy Charter School in Dorchester, Mass., Regina Campbell-Malone brought students to Cape Cod for fieldwork at Waquoit Bay and a shark dissection at WHOI.

She explored a less-well-traveled path. After graduating from The State University of New York at Buffalo with a degree in ecology and evolutionary biology, she took a variety of jobs with institutions doing research in cancer, public health, and space science before coming to WHOI, where she was determined to pass along her knowledge to children and young adults. "I wanted a way to introduce them into science, a rather daunting, foreign area for many kids, especially since I spent so much time figuring out the path to get me into my field of study," she said.

While at WHOI, she has worked with dozens of elementary, junior high, and high school students, traveling to classrooms or bringing classrooms to WHOI.

"It's pretty remarkable that she takes the time to do this," said Julia Westwater, registrar of academic programs at WHOI. For most students, "just completing a Ph.D. program takes a terrific amount of time."

Campbell-Malone doesn't give standard lessons; instead, she literally plunges young people into science. Students from Dorchester, Mass., waded with her into Waquoit Bay and netted fish for a fish survey. She had fourth-graders in Falmouth wear special tinted glasses to understand how fish hide from predators in the dark ocean depths.

Another time she brought live clams and squids to a classroom for an invertebrate anatomy lesson. She was delighted when the high school students grew comfortable with the slime-coated creatures, their comments shifting over the course of a day from "Regina, this is nasty!" to "Can I work with you for the summer?"

Of the 536 people who have received Ph.D. degrees in the MIT/WHOI Joint Program's 40-year history, Campbell-Malone is the second African-American. Surprised about the lack of diversity in oceanography, she chaneled her energy into making a difference.

Each fall she speaks at an undergraduate minority fair in Boston on behalf of WHOI Academic Programs. She also sets up tours for students in the MIT Summer Research Program. "Their visit to Woods Hole gives our scientists access and exposure to a group of talented students from around the country who may have never considered a future that intersects with ocean science," she said.

Campbell-Malone said she is especially proud of Diversity Day, a daylong event launched in 2006 by Woods Hole science institutions to encourage conversation and celebrate the diverse people and cultures in the local community.

In the fall, she begins postdoctoral research at Brown University, where she leaped on an opportunity to teach an evolutionary biology class.

"To teach something well, you have to be able to explain it in different ways to different audiences," she said. "To do that, you have to really understand a concept. Often you don't know what you really understand until you have to teach it."

—Amy E. Nevala

The research was funded by the National Science Foundation, the Quebec-Labrador Foundation, MIT, the National Oceanic & Atmospheric Administration, and the Ocean Life Institute and Academic Programs Office at WHOI.

Photos courtesy of NOAA

Fish swim inside the cage of an open-ocean aquaculture project off Hawaii, while divers clean the outside.

New regulations proposed for offshore fish farms

WHOI-led task force recommended tough environmental standards

Newly proposed legislation to regulate large-scale fish farming in the oceans around the United States includes major recommendations from a blue-ribbon task force organized by Woods Hole Oceanographic Institution.

Established in the summer of 2005, the independent Marine Aquaculture Task Force was charged with examining the risks and benefits of offshore fish farming and recommending national policy to guide its development. The panel was established through a grant from the Pew Charitable Trusts and the Lenfest Foundation.

In January 2007, after 18 months of study and public hearings, the task force recommended strong national environmental standards to regulate offshore marine aquaculture and clear federal leadership by one agency—the National Oceanic and Atmospheric Administration (NOAA)—as opposed to the byzantine mix of agencies currently involved.

The new National Offshore Aquaculture Act of 2007—crafted by NOAA and introduced on April 24 by U.S. Rep. Nick Rahall (D-W.Va.), chair of the House Natural Resources Committee—specifically charges NOAA with establishing stringent standards and coordinating offshore aquaculture with efforts by individual states. Several national aquaculture programs proposed in the past decade have been criticized for a lack of environmental safeguards.

"The legislation is proposing environmentally sound standards," said Judy McDowell, chair of the WHOI Biology Department, who served as the science director for the task force. "That was the hope of the task force, and it seems to be happening."

Aquaculture—the farming of fish, shellfish, and aquatic plants—accounts for nearly half of all seafood consumed in the world today. The industry is growing rapidly as wild fish stocks decline. The federal government has proposed a fivefold increase in U.S. aquaculture production.

Seafood industry groups and researchers have been testing large nets, pens, and other apparatus for raising fish in deep-water environments, tens of miles away from the shore. Offshore aquaculture has some natural advantages over coastal fish-farming operations because open-ocean winds, waves, and currents can naturally remove excess feed and wastes. Moving offshore also reduces conflict with boaters and real estate interests.

But there are environmental and ecological questions, such as which species should be farmed and where, and what level of discharges from aquaculture facilities can be safely absorbed by the ocean. Some researchers are concerned that domesticated fish—and the medicines and disease outbreaks sometimes associated with high-density fish farms—could escape and compromise natural fish stocks.

The task force was chaired by Rear Adm. (ret.) Richard F. Pittenger, former WHOI vice president for marine facilities and operations. It included experts from scientific, policy-making, business, and conservation organizations. The group met with many stakeholders, balancing their opinions against the best available science.

"We listened to the fishermen and others whose lives and livelihoods are tied to the oceans," said task force member Arliss Sturgulewski, a former Alaska state senator. "Because of the potential impacts on fisheries-dependent communities, there is strong disagreement about whether marine fish farming should expand. But there is universal agreement that if it does go forward, it should be done with appropriate safeguards for and consultation with coastal states and communities."

"If we are going move offshore with aquaculture, we should do it right and make sure the right policies and regulations are in place," added Pittenger. "Modern agriculture developed without a lot of oversight and regulation, leading us to a lot of our current problems with pollution from fertilizers and pesticides. We don't want to repeat the same mistakes in the water."

In its report, the task force also recommended streamlining and simplifying permitting and application processes; market-based incentives for businesses to invest in sustainable, ecologically sound fish-farming projects; as well as funding and incentives for research, development, and deployment of technologies and techniques for sustainable fish farming.

—Mike Carlowicz

Eavesdropping on whales


time conversation

Researchers aboard the sailboat *Iolaire* search for orca whales in Tysfjord in Norway, north of the Arctic Circle. Orcas generally swim into Tysfjord in late autumn, following schools of herring that return to the calm, nutrient-rich fjord waters.

Here, in the expansive Tysfjord of northern Norway, Shapiro was set to use D-tags in the fall of 2006 to learn more about orca whales. But first, researchers in the inflatable had to track some whales.

Christoffersen, the pilot, passed along Shapiro's instructions to Jesper Jensen, clad against the cold in a fluorescent Mustang suit, who staggered against the howling wind and fought his way to the bow of the boat. Safely situated, Jensen bent down and grabbed a 7-meter (23-foot) long carbon-fiber pole. At the end of the pole, a D-tag was poised.

As Christoffersen positioned the boat alongside the whales, a huge male orca surfaced just out of Jensen's reach. After a few moments, another whale surfaced—another miss. The whales, probably feeding, were swimming around furiously in the water surrounding the boat.

Just then, as one orca was readying to descend, Jensen lunged at it and pulled the pole back. The D-tag was gone.

"It wasn't a clear hit, but it managed to stick," Jensen yelled into the radio. "We have successfully tagged our first whale."

The moment the tagged whale dove beneath the surface, a saltwater switch on the D-tag instructed the device to start collecting data. A hydrophone on the tag recorded every call and click the whale uttered or heard. Elsewhere on the D-tag, an accelerometer and magnetometer began recording the whale's depth and movements—raw data that ultimately would enable scientists to calculate every pitch and roll.

For years, fishermen and scientists alike have witnessed orcas swimming round and round schools of zigzagging herring in Tysfjord to gather them into a tight, wriggling mass. Then the whales slap their powerful tails on the corralled fish to stun them before devouring them one by one.

Researchers have dubbed this behavior "carousel feeding" but have only begun to understand how the whales manage an attack that clearly requires coordination, and possibly communication. For Shapiro,

Below deck on *Iolaire*, researchers take a break and warm up after hours in the cold, salty air. Geoff Magee (left) served as skipper of the ship.

D-tags offer a window into the depths of whale behavior.

"In the short term, I'm hoping to get a better sense of what goes on when these whales engage in collective feeding," Shapiro said. "Long term, we could end up learning something important about the ways in which whale communication impacts other aspects of their behavior."

Late autumn is a dark time in Tysfjord. The area is one of the most expansive fjord systems in all of Norway, comprising hundreds of waterways. Because it sits on the western half of the Scandinavian Peninsula more than 155 miles north of the Arctic Circle, there are fewer than six hours of direct sunlight each day.

Most mornings the sun didn't rise before 8:30 a.m., poking over a horizon of jagged, snow-capped mountains in a glow of sherbet pink and orange that reflected on the water below. Norwegians call the largest of these mountains *Stetind* (shtet-in), the "Anvil of the Gods," because of the way its summit forms a plateau 1,392 meters (4,567 feet) above sea level. They also voted the peak their national mountain in 2002.

This setting served as the backdrop for a 30-day window of field observations on orcas. Over that time, 15 researchers from the United States, Canada, Denmark, Finland, Greenland, Portugal, Japan, and the United Kingdom pitched in—eight on Shapiro's project and seven on another project coordinated by Patrick Miller, an MIT/WHOI Joint Program graduate and now a senior research fellow at the Sea Mammal Research Unit at the University of St. Andrews in Scotland.

Researchers in both groups passed the daytime hours at sea, working on separate boats. Shapiro's group used a 39-foot (11.9-meter) sailboat named the *Iolaire*. Though the boat had sails, Capt. Geoff Magee kept it under motor power the entire time to control its speed near the whales and minimize drift from frequent gusts off the mountains.

"You never know what the wind's gonna do around here," Magee explained one afternoon on a tour of the fjord system. "Better to be master of your own power, if you know what I mean."

The boat was property of Tiu Similä, a Finn who has been one of the most prominent whale researchers in northern Norway.

Matt Villano

Michael deRoos

Sanna Kuningas, University of St. Andrews

MIT/WHOI graduate student Ari Shapiro (top) prepares a D-tag, a digital recording device that records whale movements and sounds in the depths. Jesper Jensen (middle) prepares to affix the D-tag temporarily and harmlessly to a whale via a long pole and suction cups.

Similä is considered the "mother" of orca research in northern Norway, having brokered relationships among scientists, fishermen, and whale watchers for the better part of two decades. She was among the first to document carousel feeding and to compile a photo identification catalog of whales that frequent the Vestfjord area, which she made available to Shapiro, Miller, and the rest of the researchers from the beginning. Perhaps the boat's most appealing feature was a stove below deck, which made the cabin a great place to dry off after hours in the cold and salty air.

Back on shore, in the tiny fishing village of Korsnes, researchers shared two three-room cabins—modest vacation rentals with working kitchens. They dubbed one cabin the "eating hut" and used the common room there to host buffet-style meals for breakfast and dinner.

The other cabin, known as the "science hut," was where researchers went to study and tabulate data. When the weather was too lousy to go out on the water at all, Shapiro and Miller hosted classes there, including tutorials on how to download and analyze data from D-tags.

The group wasn't alone out there. Korsnes is a working fishing community, and occasionally one of the researchers would buy fresh cod from a fisherman right off his boat. About a 15-minute van ride away, an ecotourism lodge named the Tysfjord Turistsenter offered free wireless Internet, which researchers (and at least one intrepid journalist) used whenever possible.

Perhaps the strangest feature of the area was a lonesome ice cream truck that drove around at all hours of the day and night, blasting a catchy tune all the while. Even though the air itself was considerably below freezing, researchers hailed the truck frequently and enjoyed every last lick.

They were onto something—even for an ice cream fanatic like me, frozen goodies never tasted so yummy.

Shapiro's research in Tysfjord actually began in November 2005. That season, Miller, Shapiro, and a team of international collaborators deployed eight D-tags on eight different whales. The scientists shared the data. It was a good deal for everyone involved.

These first instruments recorded the sounds of all members of a group of whales, as well as the movements of the tagged individuals within the group. Five of the tagged animals engaged in carousel feeding.

"We were really enthusiastic about the data that first season," Shapiro said. "From what we had, we could see that the orcas engaged in complex behaviors that are coordinated at the group level and produced a rich vocal repertoire."

When fieldwork wrapped up in December of 2005, Shapiro and other researchers, including Tyack and Andy Solow of the WHOI Marine Policy Center, began exploring the D-tag data to identify movement and communication patterns.

By correlating the whales' sounds and movements, Shapiro is investigating how the marine mammals may communicate to coordinate their actions during feeding and other situations. He is also examining the different kinds of whale calls, their components and their sequences—in other words, the syntax of their vocalizations.

Heading into November 2006, the plan was to jump in and resume the study. But there was a problem: no whales. Generally, killer whales swim into Tysfjord in autumn following schools of herring that return to the calm and nutrient-rich waters of the fjord to find food. By November, the herring had not returned, so neither did the whales.

Anna Kumigas

Orcas swim in circles around schools of herring to herd them together. Then the whales slap their tails on the corralled fish to stun them before eating them—a behavior called carousel feeding.

Shapiro and the researchers felt handcuffed for nearly three weeks before they received word that the animals were sighted in the area; even then, reports had them 30 miles west, in Vestfjord, where winds and open water would have made D-tagging challenging at best. One night, over burritos in the eating hut, Miller put the frustration into perspective.

"When you study nature, you're always at her mercy," he quipped. "You can only do what you can do."

Indeed, science is like televised poker games: Hours upon hours of boring hands are edited out; we see only the exciting money hands. In the world of research, so too might scientists spend 30 days in the field for three or four good days that comprise the bulk of a published work.

Eager for data, Miller and his team eventually used their sturdy boat and hit the open water. Shapiro's team, on the other hand, waited things out in Tysfjord, passing time with transmission loss experiments. Using a speaker designed to broadcast tunes underwater for synchronized swimming, the crew repeatedly broadcast acoustic chirps into the water at various depths to gain a better sense of how sound travels in the area's waterways. These sounds were recorded by a D-tag suspended from the inflatable, which was positioned at varying distances up to 500 meters (545 yards) away. This grunt work established the audio background onto which whales add their calls.

The transmission loss experiments were conducted one day after another. One day, the rain was incessant. Another day, wind seemed to penetrate even the thickest fleece. Shapiro tried to keep the mood light with jokes and stories. At one point, he even handed out smiley-face pins as a token of camaraderie.

"I'm not as much the leader of this project as I am an equal to everyone else," he explained. "We're all in this together. When the whales finally get here, we'll celebrate together."

Finally, the whales arrived. Fishing reports indicated the whales had been moving in and out of the Tysfjord area for a few days, but researchers aboard the *Iolaire* hadn't spotted them near Korsnes yet. Miller's group saw them first. Shapiro and his team celebrated their successes graciously; now they wanted some of their own.

On Nov. 9, the whales made their way past Korsnes, darting across the horizon with *whooshes* as they surfaced to breathe. The water was so choppy that first day that neither the *Iolaire* nor the inflatable could get within tagging distance. Still, the mere sight of dorsal fins buoyed everyone's spirits.

"That first day we saw them it was like, 'Thank God, they're really here,' " remembered Andy Foote, a doctoral student at the University of St. Andrews. "Then it hit us—we have got to get those tags on."

Sea conditions were equally lousy on the morning of Nov. 10, but Shapiro's team decided they could not wait any longer. The *Iolaire* and the inflatable both pushed off from the dock at Korsnes and headed west into a steady wind. About an hour later, the inflatable motored up alongside some whales, and Jensen made his heroic lunge.

Back on *Iolaire*, Shapiro and his team were doing recordings of their own. From the first day of the season, the boat had been equipped with a homemade array of 12 hydrophones in a giant tube tailing behind the boat, specially designed to pick up sounds from the depths.

"I cannot tell you what a relief it was to get the tag on and start recording," Shapiro said. "Suddenly, everything we had worked for, all of our preparations—it all became worthwhile."

The speedy inflatable followed the tagged whale, but the wind picked up considerably, making it difficult to spot whales among the whitecaps. As if the task weren't difficult enough, the whales decided to pick up speed and started moving out of the area almost as quickly as they had come in.

Nevertheless, the boat pursued. After about 90 minutes, the vessel had lost track of the whales, but Mike deRoos, a Canadian researcher on the inflatable, picked up a constant string of very-high-frequency beeps, indicating the tag had come off. An hour later, the inflatable found the tag floating in the water, full of precious data.

"We sped back to the *Iolaire* as fast as we

possibly could," deRoos remembered. "It was like we had won the lottery or something."

Of course, the data remained raw until this winter, when Shapiro downloaded it and started making sense of what the D-tag recorded.

In the first stage of data processing, Shapiro listened to the hours of audio data from each tagged animal, denoting when calls, tail slaps, and echolocation clicks (sent out by and reflected back to whales to detect objects) occurred. Shapiro finished this step in February 2007.

Next, he'll go back through the record and analyze the calls—squeals, sirens, and bellows that whales make by moving air around in the chambers of their heads. Shapiro will attempt to correlate these sounds with behaviors to discern if orcas are communicating to coordinate their feeding. Still, comparing and contrasting thousands of calls won't be easy. The first step is to run a pitch tracker to extract fundamental frequencies—that is, digital traces of certain wavelengths of sound. Shapiro plans to use software developed for telephone speech by Chao Wang and Stephanie Senneff at the Computer Science and Artificial Intelligence Lab at MIT, and he has hired undergraduates to help him parse through the data.

Already, Shapiro said he has found that the whales increase their calling activity when they increase their movements during carousel feeding. Ultimately, he hopes to be able to identify certain call types and cadences and correlate them to certain cooperative feeding behaviors. Later, he'll analyze these vocalizations to see whether the whales flexibly arrange smaller subunits of sound to assemble longer calls in their vocal repertoire.

Whatever he finds, the research itself is a realization of one of Shapiro's lifelong goals. During his childhood years, he was always fascinated with animals and why they did the things they did. Later, as a high school freshman in the suburbs of Cleveland, Ohio, Shapiro once began a presentation about marine biology with a photograph of a killer whale.

"I started rattling off all of these facts about killer whales," he remembered. "Then I stopped and said, 'I don't want to grow up and become a killer whale; I want to study them.' "

Sari Oksanen, University of Jyväskylä

Researcher Sanna Kuningas atop *Iolaire* scans the fjord for dorsal fins and whale blows.

By the time Shapiro entered Boston College in 1997, he was convinced he'd focus on molecular biology. In his second year, he met Donald Griffin, a biology professor emeritus who had been Tyack's graduate student advisor at Rockefeller University. Griffin invited Shapiro to join him on a project studying a small group of Canadian beavers outside Concord, Mass. Shapiro jumped at the chance.

The next summer, he was accepted into the WHOI Summer Student Fellowship Program and worked in Tyack's lab under the direction of Miller, who was then a graduate student. After receiving a bachelor's degree in biology, Shapiro spent a year at the University of St. Andrews, where he obtained a master's degree in animal behavior for work that involved training gray seal pups.

"It was in graduate school that I really got hooked on the idea of studying marine mammals full time," said Shapiro, who participated in a couple of research projects during his time abroad. "I came back and thought, 'I can do this. I actually can do it.' "

He did do it. But first, Shapiro spent a year in New York participating in a program called Avodah: The Jewish Service Corps. During his stint there, Shapiro worked as a legal advocate representing clients on welfare who were homeless or precariously housed. Looking back, he recalls the time as one of the most formative of his life and says it was valuable to "take a year off from schooling and focus on others and on issues of social justice and equity."

The following year Shapiro joined the MIT/WHOI Joint Program. His first project involved communication among narwhals, toothed whales that are famous for their unicorn-like tusks. That research was published in the September 2006 issue of the *Journal of the Acoustical Society of America*.

The opportunity to study the killer whales of Tysfjord finally presented itself in early 2005. Representatives of the Norwegian navy contacted Tyack looking for guidance with experiments that would expose killer whales to controlled amounts of sonar activity. In exchange for advice and associated involvement, Tyack paved the way for Shapiro to research the same whales.

"We had a unique opportunity to go in there and study whales in a unique environment," said Tyack. "Ari took that responsibility seriously and has made the most of it."

While the Norwegian navy did not run sonar tests during the 2005 season, it did conduct them in 2006. Local fishermen and ecotourism operators were quick to blame the tests for spooking the herring and keeping whale sightings low. During my brief visit to Tysfjord, the locals met with researchers and navy officials at the Tysfjord Turistsenter in a heated discussion about the future.

While Miller and other scientists remained patient during the two-hour talk, many local boat captains and naturalists became animated when expressing their concerns to the navy about the long-term prospects of the area's nascent whale-watching business with no whales.

"If you drive the fish out and the whales don't come back, then what will we do?" asked one boat operator. "For you, it is an exercise. For us, it is a livelihood."

Nobody knows for sure yet what the impacts of future testing might be on the whales or on whale research in Tysfjord.

"The great thing about marine biology is that there are always new questions," said Shapiro, who expects to complete his Ph.D. in 2008. "I'd like to continue to study in Norway, but if I can't find my answers here, I'll find them somewhere else. The answers are everywhere. That's what makes this fun."

—*Matt Villano*

This project was funded by the Ocean Life Institute at WHOI, the National Geographic Society, the MIT Undergraduate Research Opportunities Program Office, and the National Defense Science and Engineering Graduate Fellowship.

In their own way, fiddler crabs (*Uca pugnax*) revealed an answer to scientists' nagging questions about coastal oil pollution.

Still toxic after all these years

Does oil spilled in 1969 still have impacts on wildlife? Ask a fiddler crab.

By Christopher Reddy, Associate Scientist
Marine Chemistry and Geochemistry Dept.
Woods Hole Oceanographic Institution

This is a story about persistence—of oil, and of people.

It began in 1969 when the barge *Florida* ran aground off Cape Cod, spilling 189,000 gallons of fuel. But it began for me in 2000, when Aubrey Hounshell just kept calling me and calling me, asking if he could come to Woods Hole Oceanographic Institution during the summer to do some science.

He was a 20-year-old undergraduate at the University of Hawaii, with less-than-stellar grades, particularly in my field, chemistry. Still, there was something about him that reminded me of myself at that age: someone perhaps a little rough around the edges, whom people had taken a chance on and given a shot.

So I let Aubrey come as a summer guest student in my lab, to get a taste of science, to test-drive it to see whether he might want to pursue it. Maybe it was his persistence, a useful attribute in the scientific endeavor, which often winds down long pathways, hits temporary dead-ends, segues serendipitously, circles around, and occasionally leads to an unexpected destination. That's what happened in this case.

I confess to having second thoughts when Aubrey arrived in Woods Hole. He was sporting long hair, a black leather jacket, an array of tattoos, and mirrored sunglasses that covered half his face.

For his summer project, we dispatched Aubrey to the Wild Harbor salt marsh in West Falmouth, which had taken a savage hit from the 1969 *Florida* oil spill. In its aftermath, WHOI biologists and chemists had taken advantage of the unfortunate incident. They brought to bear a full suite of expertise and technology to document the devastation to plants and wildlife and to learn how natural ecosystems respond to uninvited guests such as oil. And they found, contrary to prevailing ideas, that oil persisted in marsh sediments years after it disappeared from the water and beaches. We thought it might be an interesting scientific project for Aubrey to see whether, three decades later, oil remained in Wild Harbor.

I asked George Hampson, one of

Oil washed ashore after the barge *Florida* spilled 189,000 gallons of fuel off Cape Cod in 1969.

the WHOI biologists who had conducted the original research on the 1969 spill, if he could give us advice. "I'll try to find some funding to pay for your time," I said. George scoffed at my offer, accompanied us to Wild Harbor, and pointed out several locations, saying, "Look in those places."

Aubrey took cores of marsh sediments and helped analyze them. He was proud to be an author on the scientific papers we published documenting our surprising finding: Oil from the 1969 spill resided in the marsh in 2000.

This finding inspired a cascade of intriguing questions: How much oil from the 1969 spill actually remained? Where was it most concentrated? Which particular chemical components of the oil remained? Were these components toxic to life? Had bacteria decomposed the oil? Since Aubrey's summer discovery, my research group and many colleagues, armed with some of the most advanced chemical instruments in the world, have attacked these questions.

With colleagues from the United States Coast Guard Academy, we employed comprehensive two-dimensional gas chromatography to determine that the remaining oil was not substantially weathered or biologically degraded, as we expected; in fact, it hadn't changed much since the mid-1970s when most of the work at this site stopped.

Emily Peacock, a Boston University Marine Program student and a WHOI guest student, took 26 additional cores over a wider area of Wild Harbor. We analyzed more than 150 oil samples. With Andy Solow, director of the WHOI Marine Policy Center, we developed a statistical model that helped fill in the gaps where we didn't sample and create a map identifying where oil most likely remained in Wild Harbor. The map was essential to calculating how much oil was left in the marsh—about 100 kilograms (220 pounds). Not much, but was it enough to still have impacts on the ecosystem?

To answer that question, Helen White, a former MIT-WHOI Joint Program graduate student and now a postdoctoral investigator at Harvard, analyzed our Wild Harbor oil samples to see if they contained specific compounds, known as polycyclic aromatic hydrocarbons, or PAHs, which are suspected to be toxic to life. PAHs were

Graduate student Jennifer Culbertson used plaster of Paris casts of fiddler crab burrows to show that the crabs turned back when they came in contact with buried residual oil.

Helen White, WHOI

Wild Harbor appears pristine today, but oil from the 1969 spill still lies buried in marsh sediments.

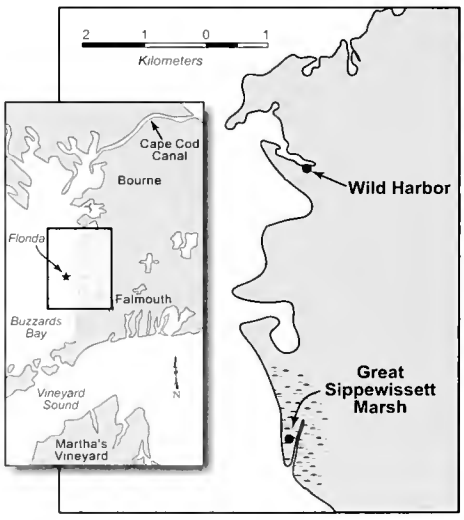
there, an indication (though not proof) that life in the marsh might still be affected by the 1969 spill.

Next we wondered if bacteria were still consuming and decomposing the remaining oil—a question explored by a postdoctoral investigator, Greg Slater, who is now an assistant professor at McMaster University in Canada. He had to build a special stainless steel device to collect sufficient amounts of marsh sediments to obtain and isolate infinitesimal amounts of bacterial biomass for analysis. Using the National Ocean Sciences Accelerator Mass Spectrometry facility (NOSAMS) at WHOI, Slater measured the radiocarbon content of phospholipids from bacterial cell membranes and found that bacteria in 2001 were not eating the oil.

Which led to the next question: Did bacteria merely stop eating the oil recently, after consuming the most easily digestible chemical components 10 or 20 years ago? For her Ph.D. dissertation, Helen White analyzed remnants of organic matter in the marsh, also using the NOSAMS facility. She showed that it was not created by bacterial degradation of the oil. Both Slater's and White's results revealed that bacteria degraded the most easily eaten oil compounds soon after the spill and then moved on to their more typical fare.

From our geochemical perspective, this flurry of research on Wild Harbor has added a wealth of valuable knowledge on oil spills. Yet, whenever I gave talks or was interviewed about the research, I was never able to answer the most frequently asked question: Does the oil still affect wildlife in the marsh?

My standard response had been that the levels of toxic PAHs we found suggest that wildlife would still feel impacts. This answer frustrated not only the audiences, but me, too. My saviors for this problem have been Jennifer Culbertson, a Boston University Marine Program Ph.D. candidate and WHOI guest student, and her advisor, Ivan Valiela, a noted marine ecologist from the Marine Biological Laboratory. When Professor Valiela approached me about studying the biological effects of the 1969 spill, I was thrilled with the prospect of working with him. I was such a junior scientist in another discipline, and he could address the questions that I could not answer.



Jack Cook, WHOI

Prevailing winds blew oil from the barge *Florida* into Wild Harbor in Falmouth, Mass., but not into Great Sippewissett Marsh.

He also had the ideal student in Jennifer. Before attending graduate school, she had worked on salt marsh restoration for the U.S. Army Corps of Engineers and was interested in salt marsh recovery from oil spills.

Jennifer then trumped our fancy geochemical data and provided irrefutable evidence that the oil from the 1969 spill still affects wildlife, in particular fiddler crabs. The research, published April 2007 in *Marine Pollution Bulletin*, showed that the crabs do not burrow as deeply in the areas still affected by oil as they do in oil-free areas in Wild Harbor or in a control site, Great Sippewissett Marsh.

Using only elbow grease and a few gallons of plaster of Paris, Jennifer and several summer students made casts of the crab burrows at these locations. Though I jest that our geochemical data were insignificant, Jennifer's fieldwork was guided by Emily Peacock's maps identifying oil hotspots in the marsh.

Jennifer found that in areas where Emily had found oil, there were fewer crabs, and

they moved more slowly—as if they were literally intoxicated from exposure to the residual oil. More significantly, Jennifer observed that in areas where oil concentrations were higher, the crabs stopped burrowing downward when they ran into oil, began to burrows sideways in the sediments, and then turned back up.

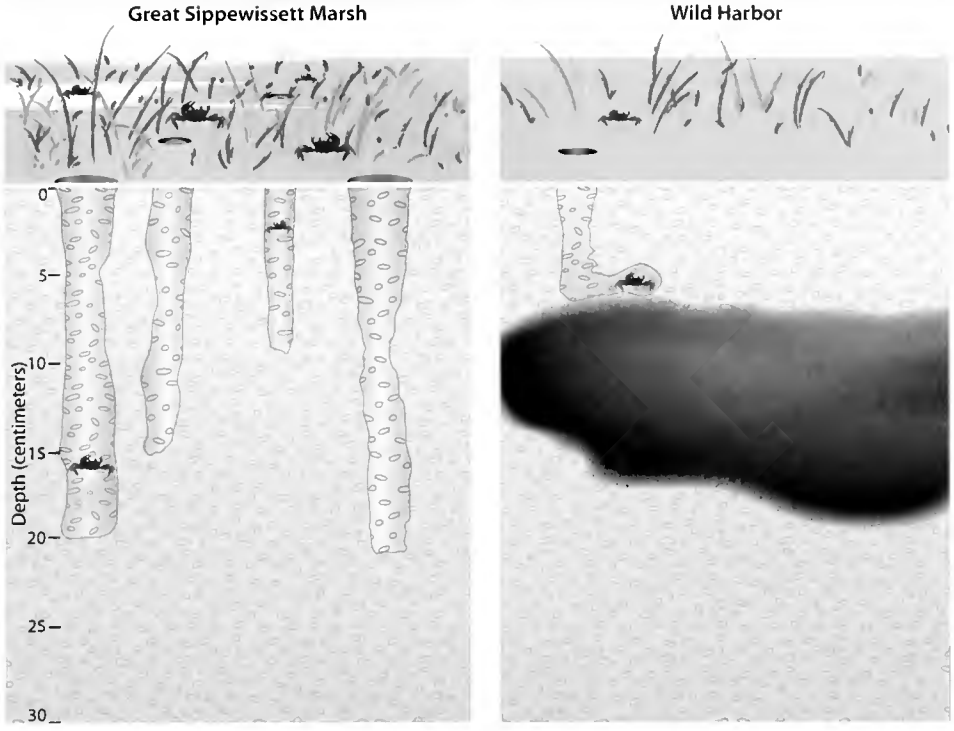
The crabs' inability to make normal deep burrows has direct implications for the crabs and other biota in the marsh. The crabs cannot hide as well from predators, such as raccoons, in shallow burrows. In addition, fiddler crabs normally play a crucial role in tilling the salt marsh, which helps provide oxygen to the roots of salt marsh grasses. Somewhat like the iron rods in poured concrete, salt marsh grasses provide strength and stabilize the marsh against erosion.

The consequences of these results are far-reaching. For example, this work provides direct answers to a high-priority item in the National Research Council's 2003 study *Oil in the Sea III*, which stated that more information was needed about the chronic biological effects resulting from petroleum hydrocarbons in sediments. Jennifer's experimental design was similar to research done within a few years of the spill by graduate students Kathy Burns of the MIT/WHOI Joint Program and Charlie Krebs of the Boston Univeristy Marine Program, who observed the same patterns for the crabs' burrowing capacity in oil-polluted sediments. Hence, Jennifer's results indicate that long-term exposure does not promote resistance, but chronically impairs these crabs.

This research will also help damage-assessment teams evaluating how to restore and rehabilitate oil-polluted locations per the Oil Pollution Act of 1990. This law states that the responsible party (the spiller), under the guidance of government scientists, must make every effort to clean up and return any ecosystem to its pre-spill status. Often the health of an ecosystem is gauged by its visual appearance. In the case of Wild Harbor, this would be misleading, because it now has a picture-postcard appearance.

Whoever would have known that only a few inches below the surface, a nearly four-decade-old oil spill would be wreaking havoc on these crabs? For me, I learned a valuable lesson that sometimes the finest chromatographs and mass spectrometers cannot outdo simple, old-fashioned, get-your-hands-dirty research.

Aubrey Hounshell, by the way, is now a disc jockey in San Francisco.



Scientists made plaster of Paris casts (below) of fiddler crab burrows in Great Sippewissett Marsh, which did not receive oil from a 1969 spill, and in nearby Wild Harbor, which did. The Sippewissett burrows were straight and deep. Burrows in Wild Harbor did not descend as far and were stunted. The crabs appeared to turn back when they encountered oil.

This research was supported by funds from the WHOI Sea Grant Program, the WHOI Coastal Ocean Institute, the U.S. Office of Naval Research, and the Hollis and Ermine Lovell Charitable Foundation.

A 3-D underwater soundscape

A large-scale experiment sheds light on sound in the coastal ocean

It was the largest oceanographic field experiment in the 76-year history of Woods Hole Oceanographic Institution. Most research projects employ one ship and a dozen or so researchers; this one involved a fleet of six research vessels, more than 50 scientists from 12 institutions, 62 moorings, 350 assorted oceanographic sensors, nearly 100 tons of equipment, as well as an airplane, space satellites, and a squad of robotic undersea gliders.

Over seven weeks in the summer of 2006, all of that inventory was focused on a 40-by-50-square-kilometer (24-by-31-square-mile) patch of ocean about 100 miles east of Atlantic City, N.J. The goal: to assemble a spatially three-dimensional, highly detailed picture of how sound waves travel through the complex, ever-changing medium of coastal waters.

Those who work in these complicated ocean waters need to know how their instruments operate in them. So a consortium of three sponsors from the Office of Naval Research (ONR)—representing interests in acoustics, physical oceanography, and vehicles—pooled funds, experimental resources, and scientists to attempt a large-scale experiment to collect the fundamental data needed to advance basic understanding of sound propagation in a 3-D coastal ocean. Adding the third dimension potentially *squares* the amount of equipment required, as well as the costs, so this was an ambitious undertaking, even with pooled resources, said Jim Lynch, an acoustics expert and senior scientist at WHOI, who co-led the experiment.

"Coordination of such a huge effort would be a small logistical nightmare, and we knew that a hurricane or fishing activity could wipe out the project at any time," Lynch said. "But the potential payoff was extraordinary. A look at the third dimension with fine resolution, acoustically and oceanographically, was worth a shot."

Unlike light, sound propagates efficiently through water, making sound the primary way for people to "see" beneath the waves. Sound is used by scientists, industries, navies, and others to communicate under water, to monitor the ocean's moving water masses, to get images of the seafloor and structures beneath it, and to localize and track sources of sound in the ocean.

Karen Johnson, WHOI

WHOI engineer John Kemp got his hands (and knees) dirty, leading efforts to deploy 62 moorings for the experiment. Above, he instructs WHOI Summer Student Fellow Wilken-Jon von Appen, one of six students involved in the expedition who, with help from the R/V *Knorr* crew, actually got to deploy a mooring themselves.

The Navy has long used sound to detect objects under water. During the Cold War, it deployed acoustic systems all across the Northern Hemisphere to monitor submarines that lurked in the deep ocean. In deep water, sound waves do not interact with the ocean bottom, and they propagate through large, stable, slowly varying oceanographic features. Shallow waters, however, are anything but stable, simple, or predictable, making it harder to understand how sound propagates through them.

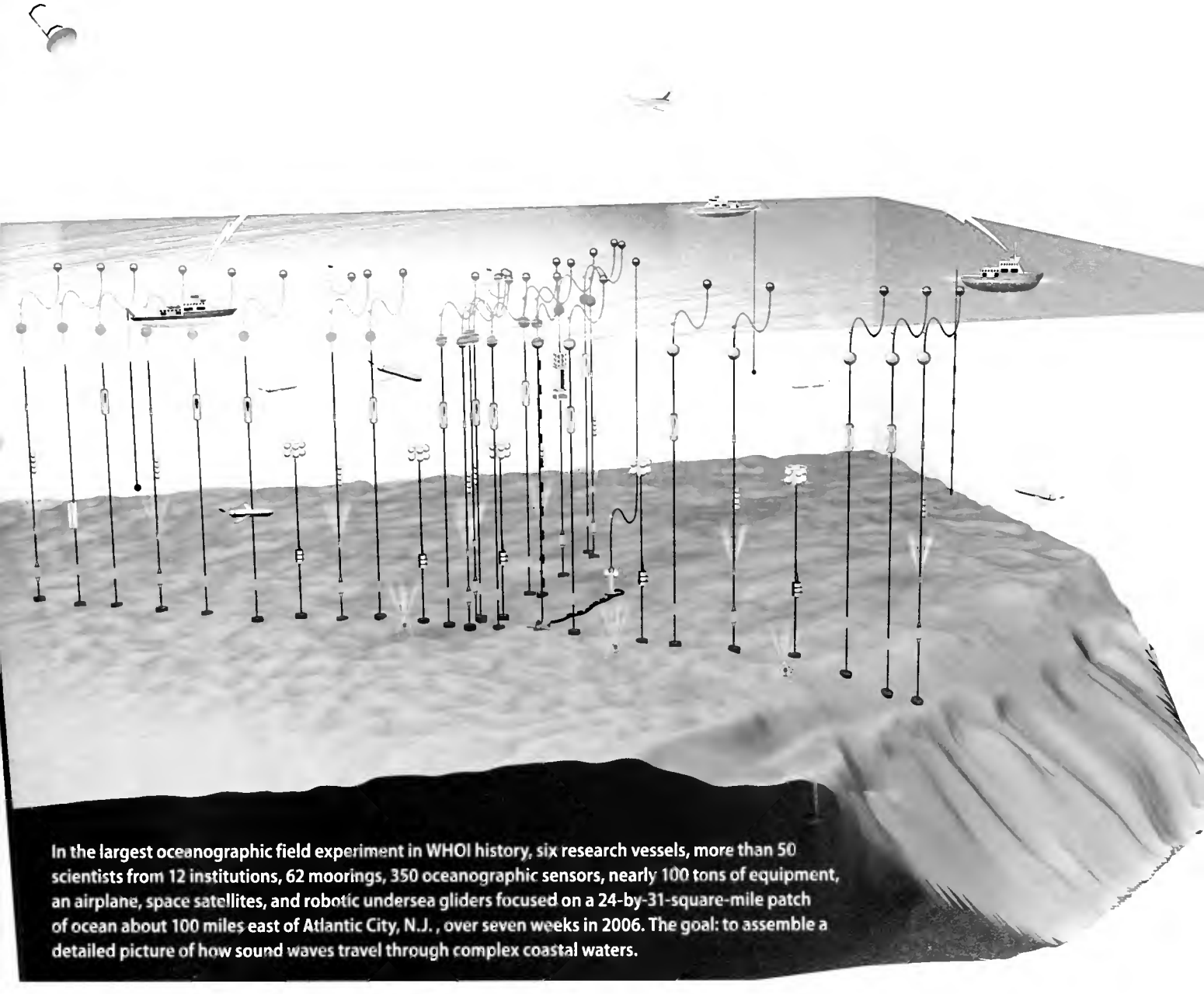
The first confounding factor in shallow water, almost by definition, is the ocean bottom, which significantly interacts with and reflects sound waves. Sound waves reflect differently off seafloors with different topographies and compositions.

The ocean also interacts with the atmosphere, and its surface is warmed or cooled by weather systems that change daily and seasonally. This produces water masses or layers near the surface that often have substantially different temperatures than deeper waters. These water masses change how sound travels through the shallow waters. The 10-to-50-meter-thick surface water masses are almost insignificant to sound in the deep ocean, which extends thousands of meters deep; but in coastal waters with depths of only about 200 meters, they have large impacts.

Shallow waters also have more water masses that don't mix and that constantly jostle against each other, creating the oceanic equivalent of atmospheric cold and warm fronts. Sound travels more easily through cold water, but refracts away from warm water. Some of these fronts are relatively stationary, fixed features, whereas others are swept along by currents and tides. Occasionally, swirling ocean eddies of various sizes travel through shallow waters, adding another layer of complication.

As if all this weren't complex enough, tides and topography in shallow water create waves *within* the ocean's interior—so-called "internal waves," which have important impacts on underwater acoustics (as well as many other areas of ocean study).

All this variable oceanography—coupled with complicated and irregular ocean bottoms, and topped off with a sea surface cluttered with ships and waves—serves to



In the largest oceanographic field experiment in WHOI history, six research vessels, more than 50 scientists from 12 institutions, 62 moorings, 350 oceanographic sensors, nearly 100 tons of equipment, an airplane, space satellites, and robotic undersea gliders focused on a 24-by-31-square-mile patch of ocean about 100 miles east of Atlantic City, N.J., over seven weeks in 2006. The goal: to assemble a detailed picture of how sound waves travel through complex coastal waters.

scatter, reflect, dissipate, interfere with, channel and generally increase the uncertainty of predicting how sound waves travel in shallow water.

Planning for the experiment began in 2001 at WHOI, the University of Washington, and other research institutions. Acousticians, oceanographers, geologists, oceanographic vehicle developers, and other scientists assembled their expertise and resources to conduct a concentrated acoustics and oceanography study in a rectangle of ocean off New Jersey, whose geology, currents, and water characteristics had already been well-studied over the past decade.

"This was an opportunity to continue building on that accumulated body of knowledge, using the latest technology and research advancements," said Ellen Livingston, program manager of the Ocean Acoustics Program at ONR.

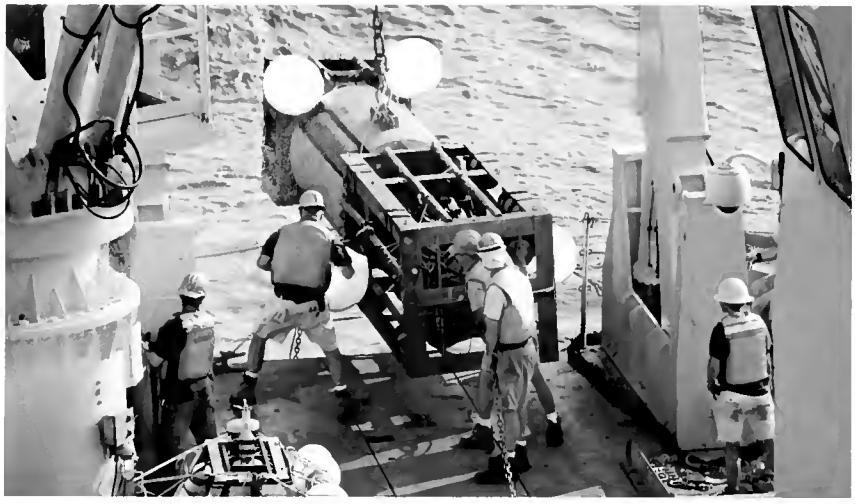
That area's proximity to WHOI made it convenient and affordable to study. Yet any fundamental shallow-water acoustics knowledge obtained there would be "transportable" anywhere in the world—to continental shelves in more far-flung locales, such as the Arabian Sea, for example.

Shallow Water '06 began in full on July 24, 2006, when WHOI engineer John Kemp and a team of mooring specialists finished loading the WHOI-operated vessel *Knorr* with nearly 200,000 pounds of equipment. That included some 90,000 pounds of anchors to secure moorings to the seafloor.

The moorings were mounted with instruments to measure temperature, salinity, currents, pressure, and other ocean characteristics. They also had devices to transmit and receive sound signals through the ocean and to record sounds emitted by shipboard sources, the ships themselves, and marine animals. The sounds produced for the experiment—an amusing assortment of chirps, whooshes, and beeps (including one that sounded quite rude)— were scrupulously kept below decibel levels believed to affect marine mammals, based on the latest research.

The team placed some moorings 100 meters apart and others several miles apart in a carefully arranged T-shaped pattern that stretched both along and across the continental shelf. At the junction of the "T," a 3-D array of oceanography sensors was deployed to examine fine-scale patterns of ocean internal waves, a key topic of interest for both Lynch and the experiment.

Things did not begin auspiciously. On the first mooring to be deployed, a critical microprocessor on the main acoustic receiver array malfunctioned, threatening to compromise the experiment. But the researchers managed to repair it at sea and went on to position 57 moorings over five days, in advance of other scientists arriving via research vessels. (Five other moorings came later.) The T-shaped mooring array, continually collecting ocean and acoustic data, served as the foundation for many researchers.



Karen Johnson, WHOI

The WHOI mooring group deploys a University of Miami mooring from R/V *Knorr*. The instrument transmits acoustic signals at multiple frequencies.

"We were on deck at 6 a.m., deploying about one mooring every hour and working until seven each night," said Kemp, the project's logistics coordinator. Karen Johnson, a cook aboard *Knorr* who also photographed the expeditions, said the carefully coordinated deployment of 200,000 pounds of equipment from the vessel's deck into the North Atlantic "suggested an orchestral arrangement. ... Watching Kemp and his group with their hand signals and synchronized movements was like watching masterful artists."

"I've been on expeditions with two or three other ships, maybe a few research instruments, and they were considered huge," said Kemp, a 28-year veteran at WHOI. "Other projects I've worked on were small potatoes. This project was nothing short of daunting."

Arthur Newhall, a project coordinator and acoustics data specialist at WHOI, said the project explored "at least four times the number of research questions we're usually dealing with."

Lynch joked that "we put so much equipment in the water, we probably raised mean sea level."

Success of the scientists' project rested critically on the security of the moorings, which Kemp feared would be dragged up by unsuspecting fishermen who flock to the region each summer for lobster, scallops, and tuna. The scientists alerted their fellow seafarers by both modern means (sending text messages to fishermen) and ancient, well-proven ways (marking the moorings with orange flags).

Another "traffic hazard" was fellow scientists. It wasn't unusual for two or more research vessels to be working in the area at the same time; they stayed out of each other's way using a Web site that tagged mooring positions and ship and glider tracks and gave daily updates of each other's research status and intended ship tracks. Each day, scientists and engineers aboard the various ships exchanged data via e-mail.

One report of a mooring dragged to the surface did have scientists briefly on edge, Kemp said. "It turned out that what the person saw wasn't our moorings, but actually a bunch of balloons that had been released from a cruise ship and were floating around," he said. "I'm happy to report that we brought back every mooring."

By mid-September, when Shallow Water '06 concluded, its participants were "both exhausted and deliriously happy," Lynch said. "Murphy took a few weeks off, and the sea gods and goddesses smiled on us. It was totally unbelievable. That much equipment, that many people, that many experimental components—and it all bloody *worked*!"

"WHOI did a great job of providing complex data-collection capabilities of the highest scientific standards," Livingston said. "That's not easy to do in the ocean, and WHOI made it happen."

The main acoustic array alone brought back six terabytes of data, Lynch said, and the other ocean sensors, acoustic arrays, aircraft, and satellites will likely double that. Over the coming years, this cornucopia of new observations should provide the grist for the acousticians, physical oceanographers, geologists, and engineers involved in Shallow Water '06 to make significant leaps in understanding the shallow-water environment.

"I think we're going to see things we've never been able to see before," Lynch said. "Let me use my own research as an example."

Although the ocean often scatters sound energy almost randomly to create a "messy" acoustic picture, he explained, regular ocean features—such as ocean fronts or internal waves— can trap sound, allowing it to propagate more efficiently and perhaps amplify local noise levels.

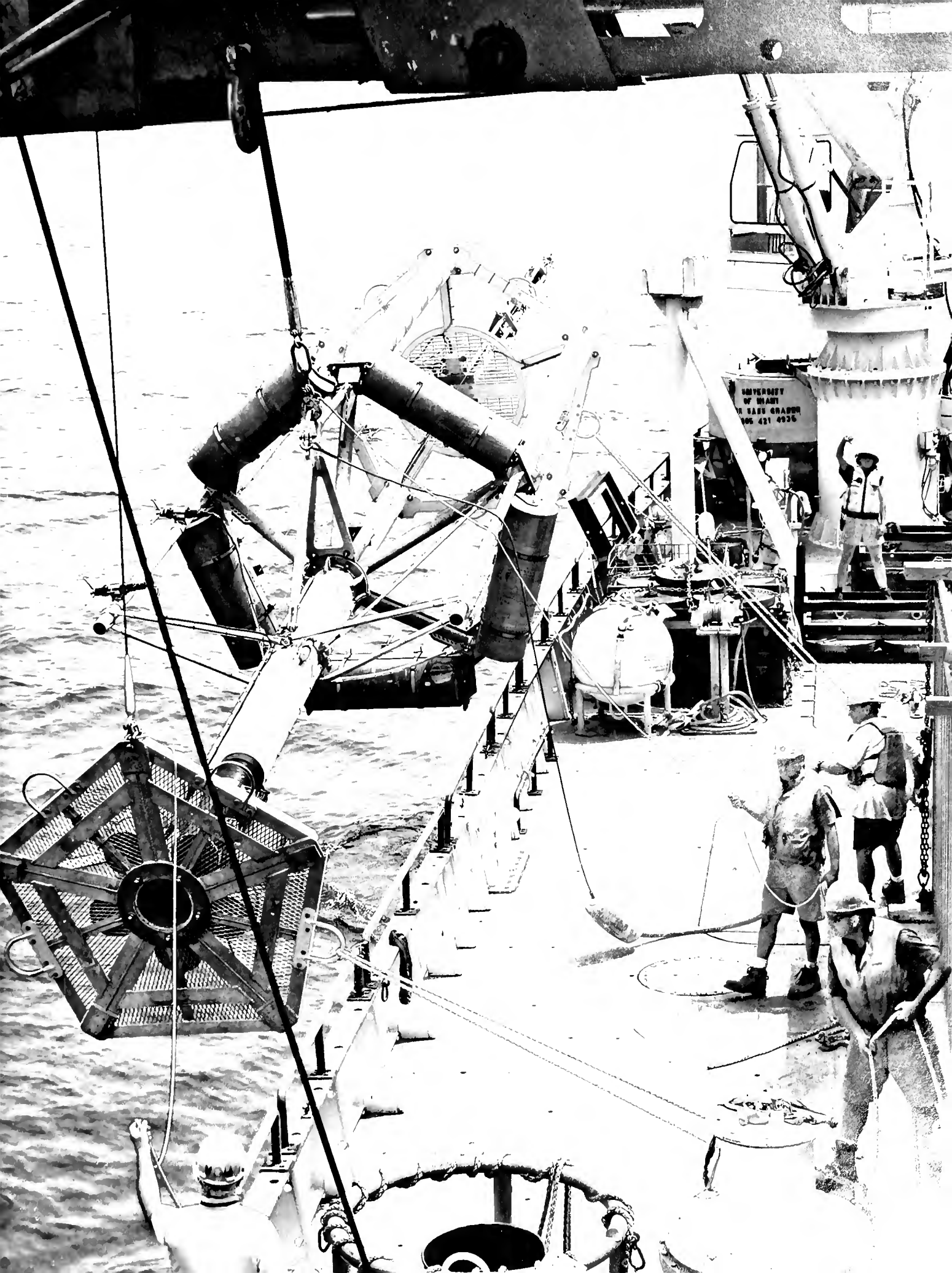
"This can affect the ranges over which marine mammals can hear and be heard and how well sonars can work," Lynch said.

In addition, curved internal waves can perhaps "bend the sound paths horizontally" to create both an efficient sound pipeline between the waves and also a rainbow dispersion pattern for sound that escapes the pipeline, Lynch said. "All this structure and variability in the shallow ocean should be quantifiable to a good extent, and it is our job to do this."

—Amy E. Nevala and Lonny Lippsett

Funding for this research was provided by the Office of Naval Research, the Defense University Research Instrumentation Program, Rutgers University, and the Naval Research Laboratory.

John Kemp (red vest, center right), along with members of the WHOI mooring group and the R/V *Knorr* crew, coordinates the deployment of a University of Miami buoy that measures air and water properties a few meters above and below the ocean surface.



Agreement opens door to Red Sea research

WHOI signed an agreement April 16 with officials of the planned King Abdullah University of Science and Technology (KAUST) in Saudi Arabia to consult on facilities and develop research projects on areas of mutual interest.

In consultation with the Washington Advisory Group and WHOI Trustee Frank Press, Saudi Arabia sent a visiting group from its state-owned national oil company, Saudi Aramco, to several U.S. institutions of scientific research and higher education in January 2006. Their charge was to explore establishing relations and developing research partnerships between U.S. institutions and the new Saudi university, to be built on the shore of the Red Sea, a relatively unstudied region.

Acting WHOI Director of Research Laurence Madin arranged a daylong program of talks by WHOI scientists on research topics applicable to the Red Sea location, as well as tours of WHOI facilities. During a second visit in March 2007, the Saudi delegation received more-detailed research proposals from scientists and later selected three areas of focus and proposed a memorandum of agreement.

Tom Kleindinst, WHOI

Officials of the planned King Abdullah University of Science and Technology in Saudi Arabia gathered with WHOI officials and scientists after signing an agreement to develop cooperative research projects.

The Saudi government agreed to fund three multipronged research projects by WHOI scientists: coastal hydrography, headed by WHOI physical oceanographer Amy Bower; coral ecosystems, headed by biologist Simon Thorrold; and fisheries and aquaculture economics, headed by Andy Solow, director of the WHOI Marine Policy Center. Other WHOI scientists participating in research in Saudi Arabian waters will include paleoceanographer Konrad Hughen, biologist Jesús Pineda, coral researcher Anne Cohen, and physical oceanographers Thomas Farrar and Steve Lentz.

Aramco is managing construction of the new university, which is expected to be completed within five years. But WHOI scientists will begin research in Saudi Arabia in 2007. WHOI participants visited Saudi Arabia in June to meet with Saudi representatives, evaluate field research sites, and view the new university's location.

Former chair of the WHOI Board of Trustees James Moltz and interim KAUST President Nadhmi Al-Nasr signed the memorandum of understanding.

G-8 science agency chiefs meet at WHOI

In an unusual honor, WHOI was selected to host the annual meeting of the Heads of Research Councils of the G-8 countries in May. It was the first time the group held its meeting at a research institution.

Leaders of the science-promotion and science-funding agencies of the world's eight largest democracies and economies (known as the Group of Eight, or G-8 Nations) meet in each country on a rotating basis to discuss global and science policy topics of common interest.

This year, Dr. Arden Bement, director of the U.S. National Science Foundation, officially hosted the science agency heads from Canada, France, Germany, Japan, Russia, the United Kingdom, and the United States (the Italian delegate was unable to attend)—plus the head of the new European Research Council, headquartered in Brussels, Belgium—in Fenno House at WHOI.

The next day, the group heard presentations from WHOI scientists on polar and International Polar Year research and on *Nereus*, a new underwater vehicle being developed at WHOI. They also toured the National Ocean Sciences Accelerator Mass Spectrometer facility on the Quissett campus.

Tom Kleindinst, WHOI

Bill Jenkins (right), director of the National Ocean Sciences Accelerator Mass Spectrometer facility at WHOI, gives a tour to the Heads of Research Councils of G-8 Nations, who held their annual meeting at WHOI.

Tom Kleindinst, WHOI

Pittenger Fellow studies seashells on the seafloor

Greg Dietzen, a Navy ensign studying how sound waves change when they reflect and scatter off sand dollars and other seashells on the seafloor, became the third MIT/WHOI Joint Program student to receive a Pittenger Fellowship.

The fellowship honors Richard Pittenger, former WHOI vice president of marine operations. It has been given annually since 2004 to a U.S. naval officer completing a degree in the graduate program.

Dietzen, who studied mathematics at the U.S. Naval Academy in Annapolis, said his WHOI advisors Tim Stanton and Andone Lavery introduced him to the field of undersea sound propagation. Sound can travel long distances in the open ocean, and acoustic signals are used for a variety of reasons, from tracking submarines to controlling robotic oceanographic instruments. Researchers want to understand how these sound signals change when they encounter waves, rocks, and even marine life—from whales to sand dollars.

Dietzen said that after he completes the Joint Program he expects to return to his native California to serve as an officer on a San Diego-based Navy destroyer. His career plans include work in the engineering department of an aircraft carrier.

Dietzen received the award at a ceremony at WHOI in June. Past recipients were Ensign Allison M. Berg (2004) and Ensign Colleen M. (Maloney) Bowers (2005).

WHOI scientists give testimony to Congress

Marine geochemist Scott Doney and marine policy specialist Porter Hoagland traveled to the nation's capital this spring to inform Congress about critical ocean issues: the effects of climate change and ocean acidification on living marine resources and issues surrounding the siting of wind power in the ocean.

"Climate change and acidification trends will accelerate over the next several decades unless there is deliberate action to curb greenhouse emissions," Doney said in his written testimony in May to the U.S. Senate Committee on Commerce, Science and Transportation's Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard. "Rising atmospheric carbon dioxide and climate change produce upper-ocean warming, sea-ice retreat, sea-level rise, ocean acidification, altered freshwater distributions, and maybe even stronger storms.

"... Further pressure will be put on living marine resources, such as fisheries and coral reefs that we depend upon for food, tourism, and other economic and aesthetic benefits. We have an opportunity now to limit the negative impact of climate change and acidification in the future."

In April, Porter Hoagland testified before a joint hearing of the U.S House of Representatives' Subcommittee on Fisheries, Wildlife and Oceans and Subcommittee on Energy and Mineral Resources Committee on Natural Resources.

In his written testimony, he said, "Like good cropland, ocean space with the right qualities (for wind farming) may be a scarce natural resource. As a consequence, ocean space useful for wind farming or other renewable energy production may have economic value. Further, ocean space may have value for other human uses, including commercial fishing, marine aquaculture, recreation, environmental conservation, shipping, among many others.

"... There is no private market for ocean space. Specialized institutions must be devised, if they do not yet exist, for allocating ocean space for renewable energy development. The existence of institutions to establish legal interests in ocean space and to provide a means for enforcement against any infringement of these interests is critical."

Read their complete testimonies at: www.whoi.edu/page.do?pid=7497.

Photo Up

WHOI marine geochemist Scott Doney (left) told a congressional subcommittee that greenhouse gasses are causing ocean acidification.

Hail to the latest harvest of MIT/WHOI graduates

WHOI honored and celebrated recent graduates of the MIT/WHOI Joint Program in Oceanography with an enthusiastic graduate reception in Clark Laboratory in early June, attended by previous and current graduates, friends and parents, and (in some cases) children. Among the students awarded degrees in September 2006, February 2007, and June 2007 were 23 doctoral recipients and 9 master's recipients, from all scientific departments. Two students received special recognition: Joy Lapseritis (Ph.D., biology) received the George P. Panteleyev award, given for committment to improving the graduate experience at WHOI, and Gregory Dietzen received the Richard F. Pittenger Fellowship given annually to a U.S. naval officer in the Joint Program (see page 35).

Tom Kleindinst, WHOI

Diane Poehls Adams receives a Ph.D. at MIT/WHOI Joint Program graduation exercises from Dean Jim Yoder, as WHOI acting President and Director Jim Luyten (center) and Associate Dean Jim Price look on.

An unusual feature of this year's graduating class was WHOI's first "legacy" student—Diane Poehls Adams (left), who earned a Ph.D. in biology. Her father graduated from the MIT/WHOI Joint Program in 1976 with a Ph.D. in marine geology and geophysics, and her mother worked at WHOI as a research assistant. Adams will begin a position at the National Instututes of Health this fall.

WHOI earns reaccreditation

WHOI has been reaccredited as a degree-granting institution by the organization responsible for accrediting New England colleges and universities.

The Commission on Institutions of Higher Education of the New England Association of Schools and Colleges (NEASC) accredited WHOI in its own right—as separate from MIT, its partner institution in the Joint Program—and with no review scheduled for 10 years instead of the normal five.

In the official letter of accreditation, NEASC Chair Judith R. Gordon commended WHOI for "its clear mission, comprehensive planning processes, exceptionally well-qualified student body, dedicated and highly competent faculty, and the unique repository of oceanographic legacy data maintained by the library," and applauded steps WHOI has taken to address gender and diversity issues.

The accreditation culminates an intensive process that includes a self-study, an on-site evaluation, and a formal review. Judith McDowell, associate dean of academic programs at the time, led the self-study and coordinated the accreditation process, which began during John Farrington's tenure as dean and continued after the appointment of James Yoder to that position. Eighteen scientific and administrative staff members from WHOI departments, the Academic Programs Office, and the MBL/WHOI library, served on the self-study committee.

Dean Yoder said the outcome "shows high regard by the commission for WHOI's education programs, for the MBL/WHOI library, and for the Institution's own strong support for its education mission."

For teachers, an inside track into ocean science

WHOI workshops for teachers offer a window into the world of current ocean research, and educators from all parts of New England come for the view.

This spring, Benjamin Walther, who recently earned his Ph.D. in the MIT/WHOI Joint Program, explained his geochemical work using fish ear bones (otoliths) to track American shad migration, and WHOI biologist Simon Thorrold discussed using otoliths to study tropical reef fish populations. Walther and Andrea Thorrold, coordinator for the New England Center for Ocean Sciences Education Excellence (COSEE-NE), gave teachers interactive DVDs they produced containing classroom lessons and an inquiry-based activity using actual otolith data. The workshop also featured WHOI physical oceanographer Peter Winsor speaking about using computer models and new polar profiling floats to study the fast-changing Arctic climate.

One teacher commented, "I appreciate listening to scientists explain current research. This is interesting to bring back to my classroom. The students feel that they have an inside track."

Dave Gray, WHOI

Teachers gets lessons on polar research from WHOI scientist Peter Winsor (blue jacket).

Teacher professional development workshops at the WHOI Exhibit Center are jointly sponsored by the WHOI Information Office and the WHOI Academic Programs Office, and Woods Hole Sea Grant, primarily supported by a generous donation from the Ducommun Foundation. COSEE-NE provided a supplemental grant to defray costs for teachers from underrepresented and underserved school districts in New England.

WHOI gets new skipper to lead Board of Trustees

Newt Merrill grew up sailing off the coast of New England, and like many who spend time on the water, he worried about the ocean's health. When he moved from New York to Boston for a banking job in 1991, a family friend suggested he turn his concern into action by becoming involved with Woods Hole Oceanographic Institution.

Bit by bit, Merrill said, he was drawn in, fascinated by the work scientists do to study the impacts of ocean pollution, map the seafloor, or address questions about the changing global climate. "Every time I went down to WHOI for a meeting, I came back having learned something," he said. "It recharged my batteries."

Merrill, in turn, donated not only financial support to the Institution, but also his time as a member of the WHOI Board of Trustees. In the past 14 years, he has participated on a half-dozen board committees whose actions have helped raise funds for the construction of the Institution's newest vessel, *Tioga*, and two new major laboratories. He also helped direct a capital fund-raising campaign that thus far has netted $160 million.

His involvement reached new heights on May 18, when he was elected chair of the WHOI Board of Trustees.

Merrill takes over as chair during a time of major transition for WHOI, said Tom Nemmers, WHOI director of board relations. The Board of Trustees—along with a committee of WHOI scientists and engineers—is in the process of choosing a new president and director for the Institution. They expect to make an offer to a candidate by fall.

The Institution is also implementing a new strategic plan that seeks more diverse funding sources for oceanographic research—from the state, private individuals, foundations, and corporations—to augment flat traditional federal funding.

"We're going through a sea change, but we're also riding a

Tom Kleindinst, WHOI

long wave of success," Merrill told the Trustees at their May meeting. In a later conversation, Merrill gave examples of those successes under the guidance of his predecessor, Jim Moltz, who served as board chair since 1998. Those included a major fund-raising campaign, now in its final phase, which resulted in the largest single donation in WHOI history: $28 million.

Merrill, 67, attended Harvard College and spent much of his career at The Bank of New York. He headed groups handling lending to large corporations, as well as leasing and investment banking activities. He worked three years as a senior executive vice president at the Bank of Boston until 1994, when he returned to The Bank of New York.

He retired in 2004. He and his wife, Polly, a former elementary school teacher, live in New York City and Lyme, Conn. He often sails with his three grown children, including offshore excursions from New England to Bermuda aboard his 42-foot sloop, *Finesse*.

Dan Stuermer, WHOI vice president of external relations, said Merrill's energy, commitment to fund-raising and his aptitude for consensus building make him a natural fit as chair. He likened Merrill's leadership skills to those of a good sea captain.

"He constantly looks around, assesses problems, and keeps things in order," Stuermer said.

—Amy E. Nevala

Vessels and vehicles managers appointed

Several longstanding members of the WHOI vessels and vehicles community have stepped into new management roles, while an engineer who joined Woods Hole Oceanographic Institution 37 years ago to help operate and maintain a then-fledgling vehicle known as *Alvin* has retired.

Tom Kleindinst, WHOI

Barrie Walden's career, which began in 1969 (five years after the submersible's first dive), included managing the care and support of *Alvin* as it carried scientists on more than 4,500 trips to the seafloor. In the 1980s, Walden began mentoring engineers on dozens of other high-tech marine projects, from drilling platforms to remotely operated undersea vehicles. Rick Chandler, an administrator hired by Walden in 1987, referred to him as "a rarity in today's business world: a combination of hands-off manager who earns respect by example, and an engineer with skills and knowledge second to none in the submersible industry."

Bob Brown is the newly appointed manager of *Alvin* operations. Brown has designed and managed projects in the *Alvin* group since 1997, after piloting the submersible for three years. He served in the U.S. Navy submarine force for 20 years, commanding three subs. He will continue to serve as project manager for *Alvin's* replacement, a submersible expected to dive to depths of 6,500 meters (21,325 feet)—2,000 meters (6,562 feet) deeper than its soon-to-retire predecessor.

Andy Bowen, who spent two decades designing, constructing, and operating remotely operated vehicles, became director of the Institution's Deep Submergence Group. Bowen helped propose and manage the creation of the current-generation vehicle *Jason*. He is also leading the effort to develop a new, $5 million remotely operated vehicle, *Nereus*.

Matt Heintz took over Bowen's position as manager of operations for the remotely operated vehicles group. Heintz, a mechanical engineer, piloted *Alvin* for 7 years before returning to work on land in 1999 to help design and build *Jason*.

Two WHOI-operated research vessels have new commanders. **Kent Sheasley**, who has sailed as chief mate for six years of the research vessel *Knorr*, became its captain. He succeeded **A.D. Colburn**, named the captain of another WHOI vessel, *Atlantis* (see page 42).

Building international bridges to explore mid-ocean ridges

In January 2007, WHOI scientists Jian Lin, who grew up in China, and Chris German, who grew up in England, became the new chair and co-chair of an international organization called InterRidge. The group helps coordinate research activities of roughly 2,500 scientists from 25 countries who study mid-ocean ridges. InterRidge will be based at Woods Hole Oceanographic Institution for the next three years.

"InterRidge helps facilitate partnerships to accomplish what any one country would be hard-pressed to do on its own," Lin said. "Cutting-edge ocean sciences in the 21st century require increasing international cooperation and resources. We are honored to have an opportunity to lead the international community in promoting and coordinating scientific research and exploration of the fascinating deep-ocean geological, hydrothermal, and biological processes along the global mid-ocean ridges." (For more information, visit interridge.whoi.edu.)

Courtesy of Dana Yoerger, WHOI

WHOI scientists Chris German (right) and Jian Lin (fourth from right) took part in an expedition, along with WHOI researchers Dana Yoerger (third from right), Al Duester, and Andy Billings, (sixth and seventh from right) aboard the Chinese research ship *Dayang I*, where they helped discover the first deep-sea hydrothermal vents along the Southwest Indian Ridge. In January, Lin and German became chair and co-chair of InterRidge, an international organization of mid-ocean ridge researchers, which will be based at WHOI for the next three years. Lin and German also won prestigious awards recently.

German and Lin collaborate closely on research and recently returned from an expedition to the Indian Ocean where they contributed to the discovery of the first deep-sea hydrothermal vents along the ultraslow-spreading Southwest Indian Ridge (see page 8 and read more on *Oceanus* online).

The two scientists also were honored recently for their outstanding contributions to understanding the makeup and dynamics of Earth's ocean floor.

German, a marine geochemist, was awarded a Doctor of Science (ScD), or "Higher Doctorate," by the Faculty of Earth Sciences & Geography at the University of Cambridge at a ceremony in England in May. The distinguished ScD degree is awarded after an assessment and approval process that can take as long as three years. The ES&G faculty have awarded only four ScD degrees in the past two years.

Lin, a marine geophysicist, was elected a Fellow of the Geological Society of America in recognition of his "innovative, significant, and continuing contributions to the understanding of global ocean ridge processes and earthquake interactions."

Long-distance call links inner and outer space

Tim Shank and Sunita Williams placed one of the most unusual long-distance phone calls of all time on Jan. 26, 2007. It traveled over a few time zones and through the ocean, the atmosphere, and outer space.

Shank, a WHOI biologist diving to the Pacific Ocean floor in the *Alvin* submersible, and Williams, a NASA astronaut aboard the International Space Station, spoke for roughly 30 minutes about the joys, perils, and challenges of exploring outer space and inner space. The event was broadcast to tens of thousands of viewers on the WHOI and NASA Web sites, as well as NASA TV. Children from around the world submitted more than 400 questions for the two explorers.

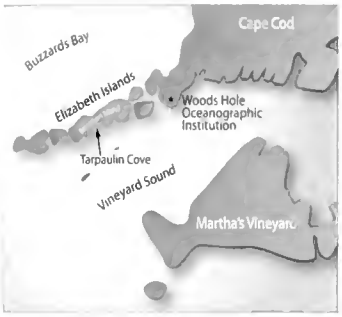
Tim Fuentes, WHOI

NASA

"Hey, what do you think about switching jobs?" Williams asked at one point. "I'd love to do your job and see what's living on the ocean floor. How about coming up here sometime?"

Shank replied: "I would love to do that."

It was the first-ever link-up between a deep-ocean submersible and a spacecraft, but it won't be the last for Shank and Williams, as they hope to give a joint public talk about their adventures sometime this fall in Woods Hole. Listen to a recording of the conversation at www.whoi.edu/sbl/liteSite.do?litesiteid=13252.



E. Paul Oberlander, WHOI

Vessels rendezvous at sea to evacuate an injured mate

Into the frigid darkness, following two days of stormy weather, Woods Hole Oceanographic Institution's coastal research vessel *Tioga* left port shortly after 10 p.m. on March 6, with sea spray freezing immediately on its railings and windows. It was headed for a rendezvous with its big-sister ship, *Knorr*, which had been thundering home since the previous morning, against 35- to 40-knot storm winds and 20- to 25-foot seas that relentlessly pounded its bow.

Knorr had to evacuate its third mate, Derek Bergeron, who had injured his hand March 4 during a rescue boat exercise on a research cruise 300 miles southeast of Cape Cod. Heading home, *Knorr*'s captain, Kent Sheasley, turned the ship northwest, right into the teeth of a fierce storm. The ship, which normally makes 11.5 knots, averaged only 6.5 knots. It had accumulated about three inches of ice from freezing spray.

Because *Knorr* was coming from Bermuda, a foreign port, docking at WHOI would have required hours of official protocols, which threatened to compromise the research cruise. Ken Houtler, *Tioga*'s captain, and a crew of volunteers agreed to meet *Knorr*. Meanwhile, Mike Brennan, WHOI marine personnel coordinator, had located a mate, who was flown in from California to relieve Bergeron.

The 279-foot, steel-hulled *Knorr* finally arrived at 9:30 p.m. March 6, and the 60-foot, aluminum-hulled *Tioga* headed out. Everyone was dressed in exposure suits against the biting cold.

"Normally," Sheasley said, "transfers of this kind would be done using a smaller work boat, as any contact, even slight bumping, of two large vessels can do some serious damage, usually to the smaller vessel. But the process of launching a work boat would have been dangerous as well, given the weather conditions, especially the cold. Captain Houtler decided he would maneuver the *Tioga* alongside the *Knorr* and conduct the transfer directly."

The two captains decided to rendezvous in Tarpaulin Cove on the east coast of Naushon Island, about half a nautical mile from the beach. "It's fairly deep in there," Houtler said, "and *Knorr* could get up inside, which provided a good lee"—protection from the waves and winds.

"There was approximately 2.5 knots of current running through Vineyard Sound at that point," Sheasley said, "so the *Knorr* had to hold against that current and the wind, and also block those effects as much as possible for the *Tioga*. Unfortunately, the *Tioga* still had less than ideal conditions to bring a vessel her size alongside the *Knorr*."

"The ships were moving; there's no way to stop that," Houtler said.

"It's not like pulling a car alongside another," said WHOI Marine Operations Coordinator Liz Caporelli, who was aboard. "Boats can't put on the brakes. They can only stop a motion with a reverse motion."

"For eight minutes—a long time when it is happening," Sheasley said, Houtler "held the *Tioga* within two feet in any direction. The *Knorr* had to maintain a solid position to not add to the dynamics Captain Houtler had to contend with."

"Dock to dock, it only took *Tioga* an hour, but while the boats were together, it was a long time," Houtler said. "It was tense, a little sweaty."

A ladder from *Knorr* was lowered three to four feet down to *Tioga*, and crew members above and below firmly held onto the transferee's arms and shoulders as the vessels bobbed asynchronously in the waves.

Bergeron was taken straight to a hospital. He subsequently was examined by orthopedic specialists to treat his fractured metacarpal bone.

Knorr returned to work. "On the way out," Sheasley said, "the weather had eased, and what winds and seas we had were behind us, making a much easier ride than on the way in."

Healed and declared fit for duty, Bergeron went back to work on *Knorr* on April 23.

— Lonny Lippsett

Tom Kleindinst, WHOI

Ken Houtler (at the wheel), captain of *Tioga*, and mate Ian Hanley.

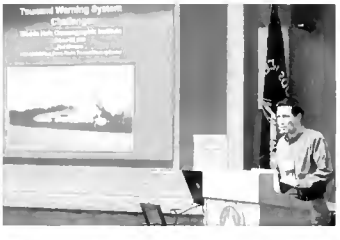
Tom Kleindinst, WHOI

Kent Sheasley, captain of R/V *Knorr*.

Morss Colloquia focus on tsunamis, flooding, and climate change

Woods Hole Oceanographic Institution launched a new program, hosting three "Morss Colloquia" since October 2006. Enabled by a generous grant from Elisabeth and Henry Morss Jr., the public colloquia concerned "issues of global importance that are connected to human society and involve some aspect of science."

In October, hazard management officials, scientists, and coastal managers assembled to consider "Lessons from the 2004 Indian Ocean Tsunami." Organized by WHOI marine policy researcher Di Jin and geophysicist Jian Lin, the colloquium included Stephen Atwood of UNICEF, who was director of emergency operations for the 2004 tsunami; Philip Berke, a University of North Carolina professor who conducted research on post-tsunami recovery efforts by inhabitants; and Emile Okal, a Northwestern University professor who has conducted extensive earthquake and tsunami research worldwide.



Tom Kleindinst, WHOI

WHOI scientists Jian Lin (above) and Di Jin brought together earth and social scientists to learn lessons from the 2004 Indian Ocean tsunami.

Tom Kleindinst, WHOI

WHOI paleoceanographer Jerry McManus leads public panel discussion on ancient and future climate change.

"The Morss Colloquium brought together two traditionally separated research communities—natural and social scientists, along with emergency response personnel—to discuss a major issue, and it offers the promise of doing multidisciplinary research in the future," Lin said.

WHOI biologist Rebecca Gast organized a colloquium in November 2006 focusing on lingering biological and public health effects of Hurricane Katrina. Floodwaters from the September 2005 disaster damaged New Orleans' infrastructure, including waste dumps and sewage treatment facilities, putting citizens at risk of bacterial and viral infections. In the months following the flood, researchers from WHOI, the Marine Biological Laboratory, and four other institutions teamed with colleagues from Louisiana State University to study the microbiological impact of the storm.

At the Morss Colloquium, hosted by the Woods Hole Center for Oceans and Human Health, Gast and the research team gathered to share and compare results on the presence, abundance, and fate of pathogens and toxins in the water and sediment of Lake Pontchartrain. The workshop and public event allowed scientists to compare their findings and assemble them into a publication that appeared May 2007 in the *Proceedings of the National Academy of Sciences.*

In January 2007, the third Morss Colloquium convened researchers from four continents to discuss research on a period in Earth's history whose climate resembles today's. Organized and led by WHOI paleoclimate scientist Jerry McManus, the public presentation was titled "Fire and Ice—Climate Changes of the Past … and Future?"

Approximately 400,000 years ago, Earth had just emerged from an ice age (much the way it did 10,000 years ago) into a so-called interglacial period with relatively stable climate (much like our climate today). A key difference, however, is that no human activity had impacts on the environment then, as it clearly does now. At the Morss-sponsored public debate in Woods Hole, researchers discussed what this interval in our geologic past can tell us about our climate future.

Tom Kleindinst, WHOI

WHOI biologist Rebecca Gast (left) organized the Morss Colloquium on the public health impacts of Hurricane Katrina.

WHOI meets WhOI on www.Whyville.net

Whyvillians have a problem: Harmful algae are threatening their beaches and coastal ecosystem. To investigate, understand, and mitigate the problem, citizens are turning to the Whyville Oceanographic Institution (WhOI), with its boats, its underwater laboratories, and other resources for exploring the ocean.

This interactive experience is part of a new partnership between the developers of Whyville.net, a leading educational Web site for youth, and the Woods Hole Oceanographic Institution. To learn more about how nutrients can fuel plankton blooms, Whyvillians must collect samples from the virtual ocean, use the laboratory to identify the species and nutrient at the root of the problem, trace the nutrient to its source, and stem the nutrient flow by restoring a virtual wetland.

"One of our biggest challenges as a research institution is conveying our work to the public," said WHOI Associate Scientist Sonya Dyhrman, who helped create the new feature. "Whyville.net is an excellent tool for communicating information about the oceans, and their significance to our everyday lives, in a unique and entertaining format."

WHOI scientists win a boatload of honors for pioneering research

Tom Kleindinst, WHOI

Ralph A. Stephen was named a Fellow of the American Acoustical Society, the premier international scientific society in acoustics. He was cited for "for contributions to seafloor elastic wave propagation."

Stephen is a senior scientist in the WHOI Geology and Geophysics Department. The ASA has nearly 7,000 members in theoretical and applied fields, ranging from physicists, engineers and oceanographers to architects, musicians, and speech and hearing researchers.

Tom Kleindinst, WHOI

Nobumichi Shimizu was elected by peers as a Fellow of the American Association for the Advancement of Science (AAAS). Shimizu was selected for his pioneering work in the development and application of secondary ion mass spectrometers in the field of geochemistry and for furthering our knowledge of mantle differentiation.

Shimizu is a senior scientist in the WHOI Department of Geology and Geophysics, as well as founder and director of the Northeast National Ion Microprobe Facility. AAAS is the world's largest general scientific society, and publisher of the journal *Science*.

Tom Kleindinst, WHOI

Jim Ledwell won the 2007 Alexander Agassiz Medal by the U.S. National Academy of Sciences. Ledwell, a senior scientist in the Department of Applied Ocean Physics and Engineering, specializes in the use of chemical tracers to observe currents in the ocean.

Established in 1913, the Agassiz Medal is awarded every three years to an individual scientist for original and fundamental contributions to oceanography. The academy cited Ledwell for his "innovative and insightful tracer experiments using sulfur hexafluoride to understand vertical diffusivity and turbulent mixing in the open ocean."

To measure the mixing and stirring effects of eddies and internal waves, Ledwell "marks" parcels of water by releasing harmless dyes or chemicals from ships and then measures the subsequent dispersion (sometimes for several years). Such work aids oceanographers in understanding the circulation of the ocean and the transport of nutrients, plankton, and pollutants in ocean ecosystems—all of which are important to marine life and to the ocean's role in climate change.

Past WHOI recipients of the Agassiz Medal include Henry Bigelow, Columbus Iselin, Alfred Redfield, Fritz Fuglister, John Steele, and Henry Stommel.

Lauren Anderson

Don Anderson was recognized by two groups for his research expertise and leadership in chronicling and analyzing blooms of the harmful algae *Alexandrium* in New England waters. The Massachusetts Marine Fisheries Advisory Commission awarded Anderson its 2005 David L. Belding Award, which is given to "the individual who has done the most to promote conservation and sustainable use of the Commonwealth's marine resources."

The U.S. Food and Drug Administration gave a Group Recognition Award to the Paralytic Shellfish Management Group, a federal advisory body on which he serves. The FDA cited the group for "exceptional performance in controlling shellfish resources of the Atlantic Ocean rendered unsafe by the hazardous algal bloom of 2005." Anderson is a senior scientist in the WHOI Biology Department and director of the WHOI Coastal Ocean Institute.

Tom Kleindinst, WHOI

John A. Whitehead won the 2007 Stommel Award given by the American Meteorological Society, the nation's leading professional society for scientists in the atmospheric and related sciences. He was also named a Fellow of the Society, an honor given to only a limited number of members each year in recognition of outstanding contributions to the atmospheric or related oceanic or hydrologic sciences, or their applications, during a substantial period of years.

Whitehead was cited "for his fundamental contributions to geophysical fluid dynamics and physical oceanography, for which his laboratory and observational studies of rotating hydraulic flows have been particularly illuminating."

The Stommel Award, named after the renowned WHOI oceanographer Henry Stommel, is granted to researchers in recognition of their outstanding contributions to the advancement of the understanding of the dynamics and physics of the ocean. Whitehead is a senior scientist in the WHOI Physical Oceanography Department.

Captain A.D. Colburn of the research vessel *Atlantis*

Of sons and ships and science cruises

Woods Hole Oceanographic Institution has had an unbroken line of three ships named *Atlantis* that date to the Institution's founding in the early 1930s. Arthur D. Colburn III, better known as A.D., who was recently named master of the modern-day *Atlantis*, is continuing another tradition: His father, Arthur D. Colburn Jr. (Dick), was the last captain of the first *Atlantis*. A.D. himself spent 13 years as a mate on *Atlantis II* when procedures for diving the submersible *Alvin* from a large research vessel were first developed. Then he took the helm of R/V *Knorr* from 1995 until early this year. A.D. and Dick are two of many mariners who have worked their way up on WHOI ships, devoting their careers to the success of the Institution's seagoing operations.

Is there a seagoing tradition in your blood?

Yes, and also a WHOI tradition. My father's career was my most immediate influence. I have vivid memories of the *Atlantis* crew stopping by the house. As a little kid in pajamas, I picked up on the camaraderie and mutual respect. It was obvious they were doing something they all liked, and they were pretty proud of it.

WHOI Archives

Dick Colburn, A.D.'s father, and last master of the first *Atlantis*.

My mother's father, David Atwood, spent his professional life sailing for commercial enterprises. During family summers in Maine, we were always on the water. My mother also worked from 1945 to 1957 for geophysicist Brackett Hirsey at WHOI, where she met my dad.

My wife Karen's family also has a maritime history, and she and several relatives have worked on the Institution switchboard. Her father, Buddy Baker, was supervisor in the WHOI carpenter shop. So she knew what she was getting into with me!

When did you make your first WHOI cruise?

I must have been about six or seven years old—my dad took me along on the last *Atlantis* shipyard transit. A couple of years later, he took the helm of WHOI's small coastal vessel *Asterias* to spend more time at home with the family. Once when a WHOI scientist needed the boat in Casco Bay, Maine, but couldn't afford to pay for its transit, Dad bought the fuel and took my brother, my grandfather, and me along—Woods Hole to Somme Sound, Mt. Desert Island, with fog all the way. Mom and my grandmother drove up to collect the rest of us while Dad carried on with the science program.

A decade later, I was a cadet at Massachusetts Maritime Academy in Buzzards Bay. Dick Edwards, who was then WHOI Marine Superintendent, arranged for me to fulfill part of my required "sea term" aboard *Knorr*. Captain Emerson Hiller was a good mentor, and little did I know that I would one day be sitting in his chair.

Was that your goal when you were a cadet?

I thought I'd follow the path of my Atwood grandfather, who graduated from Mass Maritime in 1920 and went on to commercial ship work. I tried it for a while, but the shipping industry was in a downturn at the time. So I returned to work on WHOI ships.

One summer, I faced a decision: work for the Steamship Authority in Woods Hole parking cars on ferries or relieve as a second mate on *Knorr*. I went deep sea, and I've never regretted it.

Tell us about a memorable cruise.

To the Labrador Sea in 1997, with Bob Pickart as chief scientist. Our goal was to measure the sinking of cold, dense water in the Labrador Sea—a phenomenon that drives world ocean circulation and one that requires true winter weather. A lot of people thought the obstacles—the ice, the cold, the stormy weather—would be insurmountable and predicted the cruise would not turn out well. I had more confidence because early in my career I had some experience working in the Labrador Sea for an oil company.

It was a very tough cruise, but we just worked at it real hard. We focused on the safety of the people aboard first and also keeping the ship out of harm's way. There was a constant watch for dangerous ice. We spent many hours chipping ice off the ship's superstructure with the wooden mallets we brought along for that purpose, with crew members clipped into safety lines on icy decks.

The ship and crew performed extremely well in some really nasty weather conditions. At the beginning of the cruise, we expected to spend as much as a fifth of the 47-day cruise hove to and unable to work, so we cautiously estimated we could make measurements at 60 to 80 stations. In the end, despite taking on everything the Labrador Sea could throw at us, we made more than 160 stations and brought home a fine data set for the scientific party.

Any other *Knorr* stories?

In 2001, we were off Somalia, and I truly believe we saw pirates out there. The scientists needed to stop to do measurements of the flow through the choke point between the horn of Africa and Socotra Island. We sighted a fishing-type vessel that did not have any active fishing gear. The boat set a course to intercept. We actually bluffed them and came to a screeching stop. They turned and headed for the coast. I think it was that *Knorr* has a certain "naval" look to it.

Every transit up and down the Bosporus is just amazing. It's gorgeous, exciting, and busy. The ship traffic is organized into alternating northbound and southbound convoys. There are ships all around you, a tenth of a mile away, with perhaps one overtaking on the starboard side as somebody else approaches on the port side.

On one cruise there, the scientists wanted to sample the very deepest, coldest, most dense water flowing from the Black Sea, and that meant we had to go into the center lane, so to speak. Well, they didn't find exactly what they were looking for. The scientists wanted to move farther to port, into the deepest, middle part of the channel.

By this time, the southbound convoy is en route, and the pilot wants to know "What are you doing stopped in the middle of the Bosporus?" and alerts the coast guard. We did manage to get the samples and get out.

What are some of the major challenges of the job?

Keeping to timetables. Trying to fulfill the scientific mission, while balancing weather conditions and transit times to get to your next port. Convincing the chief scientist that we can't do just one more thing because the ship can't do 14 knots to make its scheduled transit time through the Panama or the Suez Canal on time. Sometimes it gets right down to the last hour!

Scientists have gone to great lengths to secure their limited, precious time at sea, and sometimes they say they would like to do something. I've found that once you've demonstrated a consistent desire to do things well to the best of your ability, if you look them in the eye and say, "No, it's unsafe or impractical," you won't get a contentious response.

What would you rate as your strengths as a captain?

Team building and mentoring are some of the things I both enjoy and think I've had some success at doing. Fostering a positive learning atmosphere and supportive network in the small community aboard a ship. Maintaining an open dialogue between the deck, the engine room, and the scientists, it's possible to accomplish amazing things—*and* arrive on schedule at the next assignment. You know, a "can do" attitude—right up to the limits of safety and common sense. It allows everyone to work well together another day.

What changes have you seen over your career?

Ship-to-shore communication is the major change. Going further back, my dad would have said, "I remember leaving Woods Hole, maybe heading for Bermuda—you would be in single-sideband radio contact for a day or so and then lose it. When you got to Bermuda, you could receive telexes through the agent, and then depart once again over the horizon, with no communication."

When I joined *Knorr* in the late 1970s, Captain Hiller was a ham radio operator. He worked with Kent Swift in Falmouth, a guy named Bud Santos in Barnstable, and another contact on the West Coast to help those at sea keep in touch. People would line up outside the captain's cabin waiting to do the occasional ham-radio patch.

Now, with e-mail, we sometimes have "virtual" chief scientists in their laboratories onshore who can be in such tight contact with the ship that they can request that we change course or to try to close up on a certain feature. Recently, when we were working about 60 miles off the California coast, many aboard the ship were in cell phone range the whole time. E-mail also allows us to keep better in touch with our families.

Is the seafaring lifestyle hard on the family?

Do you mean, "What would draw somebody to choose going to sea over a desk job?" You really need to be willing to spend the time away to gain significant blocks of time ashore. You're able to have six weeks or two months off straight, and that affords you opportunities with family and children that you can't do easily on a 9-to-5 job.

Tom Kleindinst, WHOI

We had busman's holidays: We love to go boating. With my wife and two daughters as infants in tiny life jackets, we'd get out in Great Harbor in a skiff, or a little later in a little bigger boat, go over to Tashmoo for a picnic.

My schedule may have not been optimum from many people's viewpoint, but from my perspective, it's worked out quite well, and from the input of my children, who are now 21 and 18. When I looked at a shore job about five years ago, they said, "What do you mean— you're going to be home nights and weekends? But then you won't be captain." I took that as positive reinforcement of what I had chosen.

My wife, Karen, has obviously been key. Without her support, strength, and understanding, this career would not have worked out.

Did you consider doing anything besides going to sea?

A musician. That never panned out, but I always carry my guitar when I'm shipping.

—Vicky Cullen

AN EIGHT-TENTACLED HUG— "Most octopuses will let you get close, maybe even touch them, but normally they'll try to run once the manipulator gets close," said *Alvin* pilot Bruce Strickrott. Instead of swimming away, this female octopus grabbed the submersible's robotic manipulator arm, used for picking up samples of seafloor rocks and organisms. Strickrott and Penn State biologist Chuck Fisher encountered the octopus 7,500 feet (2,300 meters) down in the Gulf of Mexico in May 2006 and collected it for Janet Voight to study. Voight, an octopus specialist and curator at Chicago's Field Museum of Natural History, said the animal may have become disoriented and thus acted docile after her paper-thin skin absorbed sulfide and other chemical-laced fluids leaking from seafloor cracks, called cold seeps. In addition to the invertebrate's large size, the octopus's bright orange color is unusual among octopuses living at depths below a half-mile (800 meters), Voight said. "Normally they are kind of purple." This wasn't the first time Strickrott encountered an odd deep-sea creature (see page 5). Photo by Bruce Strickrott, WHOI.