Alvin's pilots:

Driving the famed deep-diving sub

Where currents collide

Nafanua, Eel City, & the Crater of Death

THROUGH THE LENS

◄ Dolphins cavort amid steep waves and "sea smoke" off Cape Hatteras. The "smoke" is created when cold winter air meets the relatively warm waters of the Gulf Stream. WHOI Research Associate Chris Linder took this photo on a research cruise in January 2005 (see page 22).

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Corrections from June 2005 issue:

A map of the Caribbean on page 19 mislabeled the Bahamas as the Virgin Islands.

A caption on research to carbon-date wood from a shipwreck on page 7 should have said that the ship is purported to be—not is—the pirate Blackbeard's flagship.

Oceanus

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RESEARCH NEWS

OCEAN TECHNOLOGY

STUDENTS AT WORK

OCEAN POLICY

WHOI AROUND THE WORLD

AROUND WHOI

A CONVERSATION WITH...

FEATURES

Stace Beaulieu, WHOI

NOTE FROM THE EDITORS

The birth of Woods Hole Oceanographic Institution in 1930 arrived simultaneously with berths for scientists aboard *Atlantis*. The newly commissioned research vessel provided United States researchers with their first access in a half-century to the open oceans. Together, the ship and the institution heralded a new era of exploration that has helped revolutionize our understanding of the oceans, the seafloor, Earth's climate, and life on our planet.

Much has changed over the past three-quarters of a century, but some things have not: WHOI still provides exceptional access to the sea, and WHOI scientists, engineers, technicians, and students still resolutely head into the field—to the seafloor in the submersible *Alvin* (page 26); into rough winter seas off Cape Hatteras aboard R/V *Oceanus* (page 22); in "dormitory" boats along channels of the Danube Delta (page 20); or even, just for fun, in "unboats" to celebrate our 75th anniversary (page 32).

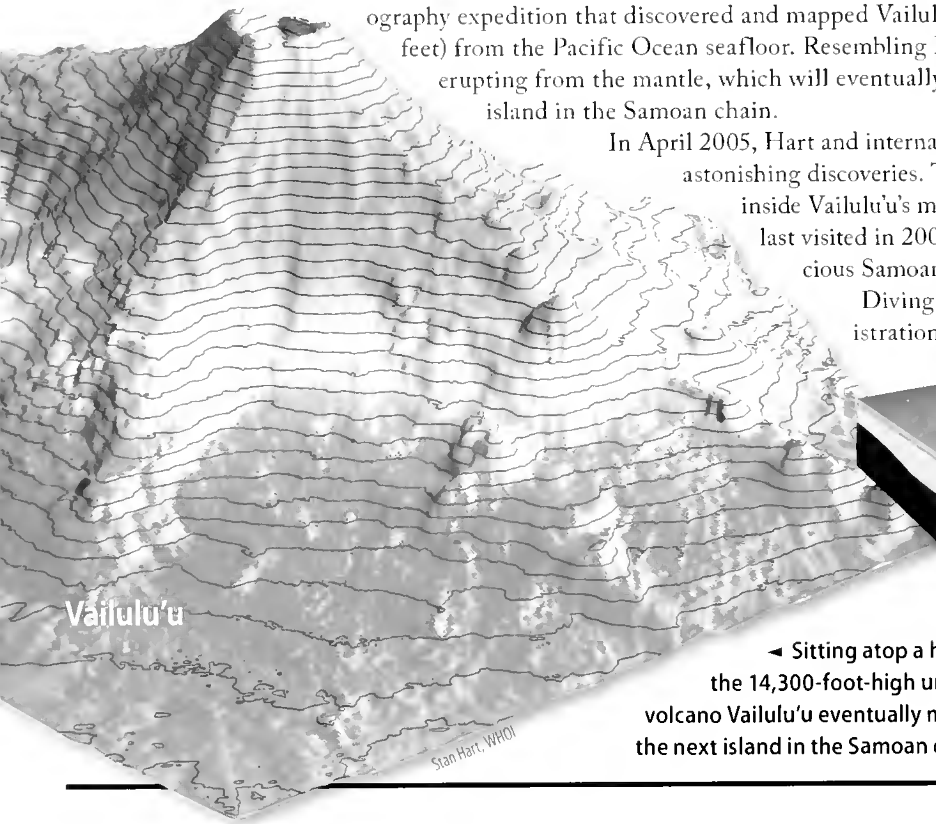
COVER: **Carl Wood (left), R/V *Atlantis* steward, and Ken Feldman, a shipboard technician, are also certified swimmers who help launch and recover the WHOI-operated deep-diving submersible *Alvin*. In the famed submersible's 41-year history, only 35 people—with an underwater brand of the "right stuff"—have become *Alvin* pilots (see page 26).** Photo by Mark Spear, WHOI.

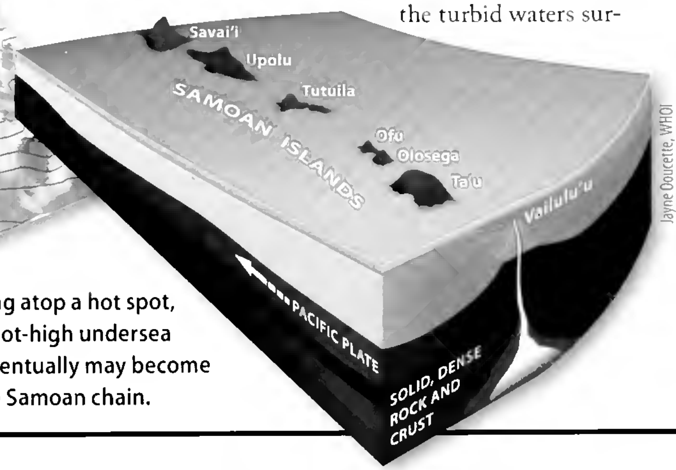
Nafanua, Eel City, and the Crater of Death

In 1999, WHOI geochemist Stan Hart was co-chief scientist of a joint WHOI-Scripps Institution of Oceanography expedition that discovered and mapped Vailulu'u—an active volcano rising 4,360 meters (14,300 feet) from the Pacific Ocean seafloor. Resembling Mount Fuji, it sits atop a hot spot, fueled by magma erupting from the mantle, which will eventually build the volcano high enough to become the next island in the Samoan chain.

In April 2005, Hart and international colleagues returned to Vailulu'u to make more astonishing discoveries. They found a dome-shaped volcanic cone—growing inside Vailulu'u's milewide caldera—that didn't exist when the scientists last visited in 2001. This new volcano, named Nafanua after the ferocious Samoan goddess of war, stood 300 meters (1,000 feet) high.

Diving in the National Oceanic and Atmospheric Administration's manned submersible *Pisces V*, scientists explored the turbid waters sur-





◄ Sitting atop a hot spot, the 14,300-foot-high undersea volcano Vailulu'u eventually may become the next island in the Samoan chain.

Red tide is gone for now, but will it return next year?

The bloom of toxic algae that blanketed New England waters from May to July 2005 and halted shellfishing from Maine to Martha's Vineyard is over. But scientists are now wondering if there will be an encore.

Before washing out of coastal waters, *Alexandrium fundyense*, the microscopic marine plant that caused so much trouble, likely left behind a colonizing population in southern New England. A team of algae specialists from Woods Hole Oceanographic Institution has found evidence that *Alexandrium* produced cysts—a hardy, seed-like form of the plant that can lie dormant in seafloor sediments until growing conditions are favorable again.

"We have to determine if *Alexandrium* has taken another giant step down the East Coast," said WHOI biologist Don Anderson. "Will *Alexandrium* flourish off Massachusetts? I have good reason to believe it will."

Vice Adm. Conrad Lautenbacher, administrator of the National Oceanic and Atmospheric Administration (NOAA), announced in July that the agency has awarded $540,000 to WHOI to return to sea in September and October 2005 to survey the cyst population. WHOI researchers also will continue their genetic studies of the algae and their computer modeling of how *Alexandrium* develops and spreads in coastal waters. In spring 2006, the WHOI team will assess ocean conditions with an eye toward predicting if and when the algae might resurface in southern New England waters.

"This work comes at a critical time," said Lautenbacher, "because we would like to be able to forecast future blooms so that coastal managers can mitigate the impacts on the public and the economy."

The 2005 bloom was the most widespread and intense since 1972. In most years, *Alexandrium* grows to toxic levels in Penobscot Bay and Casco Bay in Maine and in Canada's Bay of Fundy. In 2005, concentrations of toxic algae reached levels 40 times the norm for southeastern New England, as the plants spread to Cape Cod Bay, Massachusetts Bay, Nantucket Sound, and Buzzards Bay—waterways not usually affected by such blooms. Shellfish beds in Massachusetts, Maine, and New Hampshire, as well as 15,000 square miles of federal waters, were closed for more than six weeks at the height of the seafood-harvesting season.

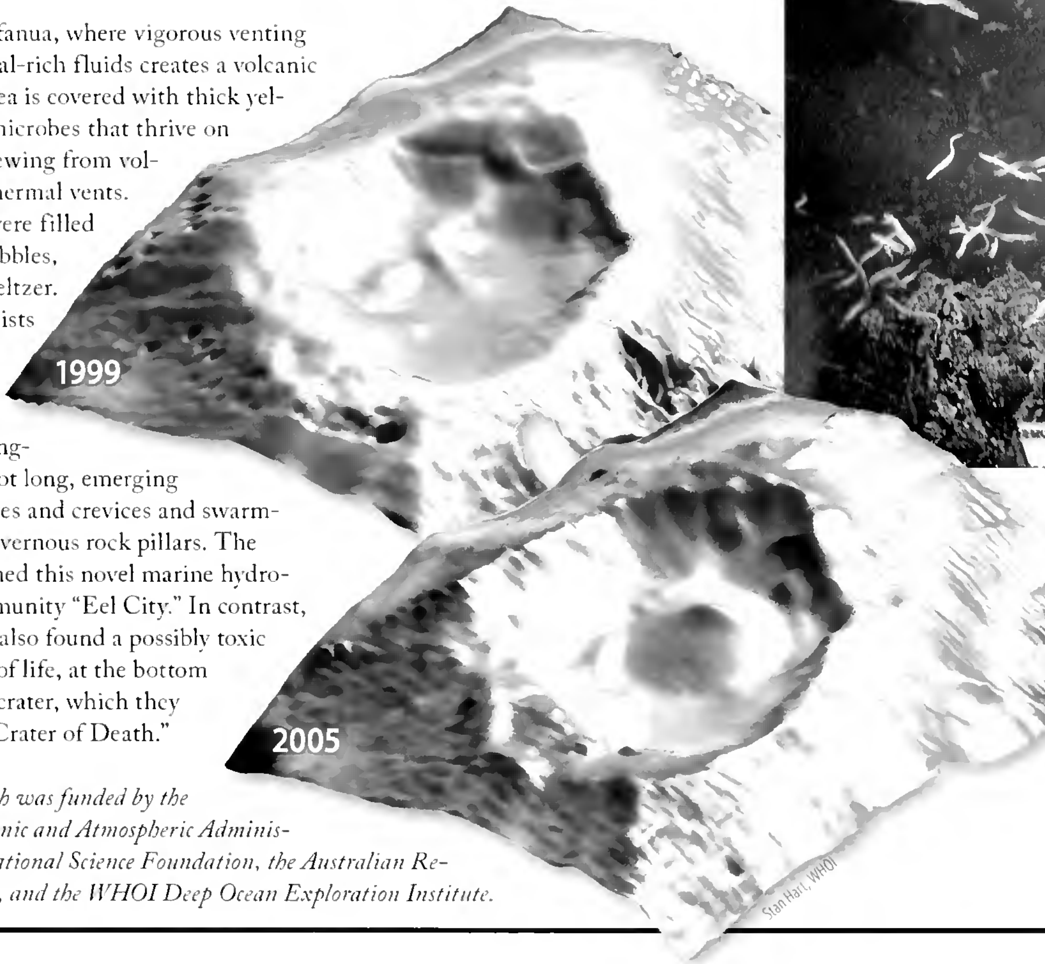
Kevin Chu, regional administrator of the NOAA National Marine Fisheries Service, noted that in spite of high risks, no one was hospitalized by this year's bloom, due in part to timely observations from WHOI, the Massachusetts Division of Marine Fisheries, and federal, state, and local monitoring agencies. "WHOI has been essential in helping us determine where and when we should close fisheries," Chu said.

rounding Nafanua, where vigorous venting of hot, mineral-rich fluids creates a volcanic "fog." The area is covered with thick yellow mats of microbes that thrive on chemicals spewing from volcanic hydrothermal vents. Some areas were filled with large bubbles, fizzing like seltzer.

The scientists also found hundreds of greenish-white eels, ranging up to a foot long, emerging from rock caves and crevices and swarming around cavernous rock pillars. The scientists named this novel marine hydrothermal community "Eel City." In contrast, the scientists also found a possibly toxic zone, devoid of life, at the bottom of Vailulu'u's crater, which they dubbed the "Crater of Death."

The research was funded by the National Oceanic and Atmospheric Administration, the National Science Foundation, the Australian Research Council, and the WHOI Deep Ocean Exploration Institute.

Hawaii Undersea Research Laboratory



Stan Hart, WHOI

◄ **Maps of the caldera (left) atop Vailulu'u, in 1999 and 2005, show a new volcano growing inside called Nafanua, where scientists found "Eel City" (above).**

"The major concern now is if *Alexandrium* will come back," said Bruce Keafer, a WHOI biological oceanographer. "The cysts dropped during the termination of this bloom are a concern. Massachusetts Bay contained very few cysts in 2004, but the 2005 bloom may have changed that."

Keafer and colleagues will remap areas they surveyed in the fall of 2004, looking for differences in the number of cysts buried in seafloor sediments. Historically, large beds of cysts have been located near the Bay of Fundy and off Casco Bay, near Portland. This fall's expedition will determine if the cyst distribution has moved south and if it could lead to subsequent outbreaks.

"I don't think there is any question that there are cysts here now in southern New England," said Anderson. "The question is: Will conditions allow them to stay and bloom, or will they wash out?"

— *Mike Carlowicz*

This research was funded by NOAA's Center for Sponsored Coastal Ocean Research, the WHOI Coastal Ocean Institute, the National Science Foundation, and National Institute of Environmental Health Sciences.

Judy Kleindinst, WHOI

◄ **Physical oceanographers Dennis McGillicuddy of WHOI (left) and Jim Manning of NOAA's Northeast Fisheries Science Center collect water samples during a May expedition aboard R/V *Oceanus* to examine coastal waters for toxic *Alexandrium* cells and the nutrients that allow them to flourish.**

On the seafloor, a parade of roses

WHOI

Tim Shank was a 12-year-old shortstop on North Carolina ballfields in 1977 when scientists in the submersible *Alvin* made a startling discovery near the Galápagos Islands: Lush communities of animals thrived on the sunless seafloor, living on chemicals venting from the volcanic ocean bottom.

Two years later, Shank still wasn't paying much attention to the news when returning scientists, looking out *Alvin*'s view ports, saw rows of slender white tubes with blood-red worms poking out of their tips. The scene resembled a field of giant long-stemmed roses, so scientists christened the vent site "Rose Garden."

"It wasn't until college that the animals and geology of hydrothermal vents really caught my eye," Shank said. As he pursued a career in marine biology, Shank began learning about the famous Rose Garden, where scientists first learned of the amazing ways that vent animals adapt to live in their extreme environment.

Adam [illegible]ule, WHOI

▲ Three generations of scientists have returned to the Galápagos Rift since 1977 to find three generations of hydrothermal vent communities, which they named Rose Garden, Rosebud (above), and Rose Bowl.

In 2002, now a biologist at Woods Hole Oceanographic Institution, Shank co-led an expedition back to Rose Garden to see how the animals, geology, and vent fluid chemistry had changed since scientists last visited it a decade before.

But over several *Alvin* dives, it became disappointingly apparent to Shank that Rose Garden had been paved over by erupting lava. His dashed hopes were partially allayed when, nearby, researchers found tiny tubeworms, thumb-sized mussels, and other new life that probably arose in the aftermath of the eruption that destroyed Rose Garden. In homage, they named this new vent site "Rosebud."

This spring, Shank returned to Rosebud to continue learning about the conditions that foster life at vent sites and that shift the demographics of animals living in vent communities. Celebrating his 40th birthday at sea, Shank found that the communities at Rosebud were in full bloom, maturing into midlife.

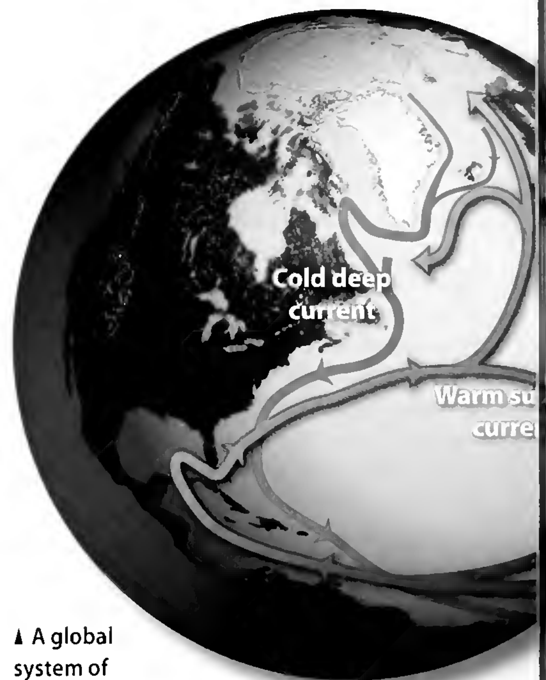
Then, during the 2005 expedition's final dive, researchers in *Alvin* came across a concave, ring-shaped area on the seafloor about 10 meters (33 feet) in diameter. White crabs crawled its perimeter, and anemones and mussels populated its center. The shape of the vent site—and its lineage—suggested what the expedition would name it: "Rose Bowl."

"It was one of those times when you say, 'Oh, if I only had one more dive, I know I could learn so much more,' " said WHOI volcanologist Adam Soule, who was in *Alvin* when Rose Bowl was found. "I'm already looking forward to going back someday."

So is Shank.

—*Amy E. Nevala*

Funding for the 2005 expedition to the Galápagos Rift came from the National Oceanic and Atmospheric Administration's Ocean Exploration Program, the WHOI Deep Ocean Exploration Institute, and the National Science Foundation.



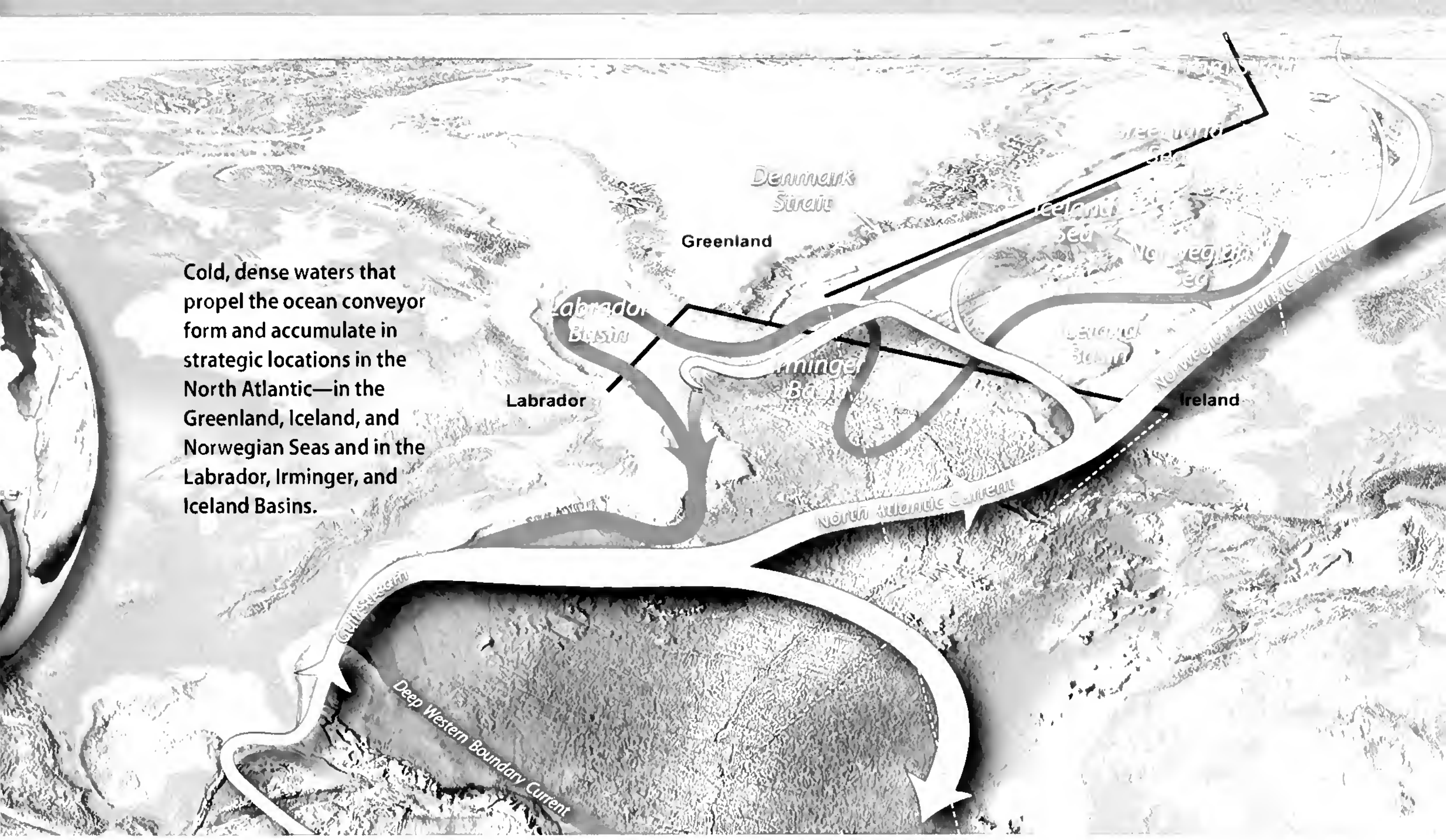
▲ A global system of currents, often called the "ocean conveyor," carries warm surface waters from the tropics northward. At high latitudes, the waters cool, releasing heat to the atmosphere and moderating wintertime climate in the North Atlantic region. The colder (and denser) waters sink and flow southward in the deep ocean to keep the conveyor moving.

Rapid freshening of North Atlantic could cool northern winters

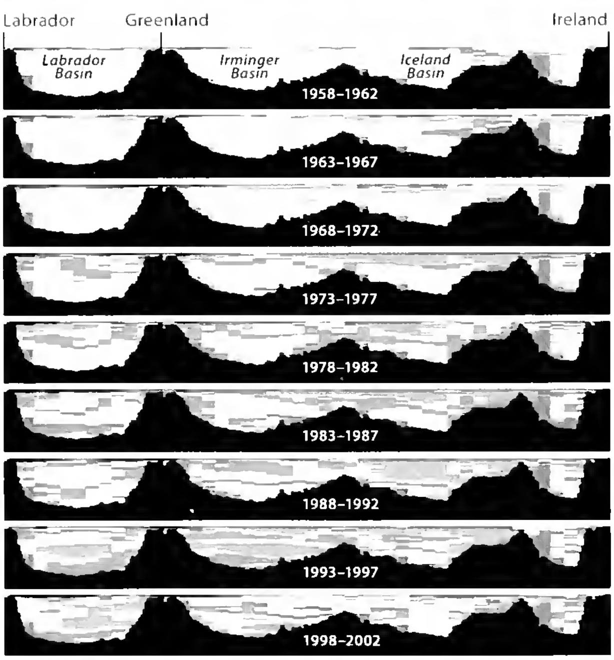
Large and climatically sensitive regions of the North Atlantic Ocean have become less salty since the late 1960s, a trend that could alter global ocean circulation and spur climate changes by the 21st century.

Reporting in the June 17 edition of the journal *Science*, Ruth Curry of Woods Hole Oceanographic Institution and Cecilie Mauritzen of the Norwegian Meteorological Institute analyzed salinity data collected over the past half-century throughout the Greenland, Norwegian, Iceland, Labrador, and Irminger Seas in the North Atlantic.

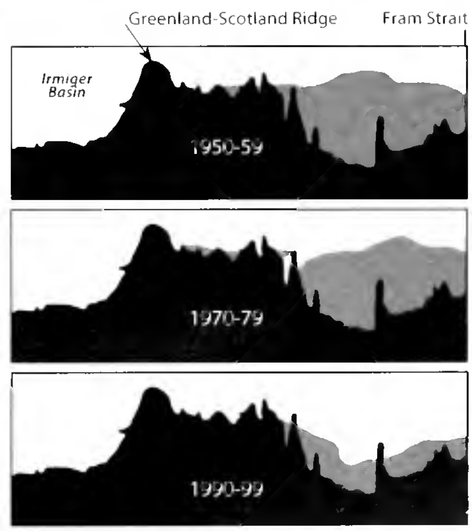
Cold, salty (and therefore relatively dense) waters form in the North Atlantic and drive a global ocean circulation system, often called the ocean conveyor, which plays a big role in regulating Earth's climate.



Cold, dense waters that propel the ocean conveyor form and accumulate in strategic locations in the North Atlantic—in the Greenland, Iceland, and Norwegian Seas and in the Labrador, Irminger, and Iceland Basins.



◄ A new analysis of salinity measurements over the past 55 years shows that waters in critical North Atlantic locations have been getting fresher—fed by melting glaciers and increased precipitation associated with greenhouse warming (saltier waters are red, orange, and yellow; fresher waters are blue and green). Continued freshening of the North Atlantic could slow the ocean conveyor, diminishing the amount of heat transported northward and significantly cooling areas of the Northern Hemisphere.



▲ Of particular concern are changes in the Greenland, Iceland, and Norwegian Seas, where dense waters accumulate (darker blues represent denser waters). A density contrast between these waters and those in the North Atlantic drives water southward across the Greenland-Scotland Ridge in the Denmark Strait. As excess fresh water accumulates in the northern seas, the density contrast of waters north and south of the ridge will diminish. The southward flow of dense waters will decrease, the ocean conveyor will weaken, and the North Atlantic region will cool.

"If you put too much fresh water in the right places in this part of the world, it can actually alter a portion of the ocean circulation that transports heat from the tropics up toward the North Pole," Curry said.

The increased inflow of fresh water comes from increased precipitation and melting glaciers, associated with greenhouse warming.

"Given the projected 21st-century rise in greenhouse gases, we cannot rule out a significant slowing of the conveyor in the next 100 years," Curry said. "We want to know exactly how fast that whole system is changing. It seems to be tipping out of balance as a consequence of global warming."

The study was funded by the National Science Foundation, a WHOI Independent Study Award, and the Norwegian Research Council.

Team finds rocky shipping hazard off polar station

For five frigid weeks in April and May 2005, a team of scientists and engineers sat in inflatable boats off the coast of the western Antarctic Peninsula, steering clear of sharp rocks and sea ice, enduring cold feet, and anxiously watching both the weather and a variety of animals that swam near the small boats—including humpback whales, penguins, and leopard seals.

"There were several leopard seals right by us that were as long as the 14-foot boat," said WHOI biologist Scott Gallager. "We saw one leopard seal toss a penguin in the air and catch it as it came down."

One early morning, members of another research group witnessed two large leopard seals attack a fur seal with such force that they nearly cut it in two. The team was mindful of being in low, air-filled craft susceptible to sharp teeth. "Everyone kept an eye on them," Gallager said, "and backed off carefully if a seal approached."

The team's objective was to meticulously chart the ocean floor near the United States' Palmer Research Station—to help select a suitable site for a new underwater observatory that they will install next year. But in the process, dodging dangers, they serendipitously found another potential danger that research ships had unknowingly been dodging for years.

To make a new seafloor chart of the area, the team—Gallager, co-principal investigator Vernon Asper of the University of Southern Mississippi, and WHOI engineers Keith von der Heydt and Gregory Packard—used a portable depth sounder with GPS, deployed over the sides of the boats, and a WHOI-built REMUS autonomous underwater vehicle equipped with sonar. Doggedly following a fine-scale grid pattern in and out of coves on the rugged shoreline, they took more than 180,000 depth readings at 50- and 100-foot (15- to 30-meter) spacing in waters extending several kilometers around Palmer.

The new chart is the most detailed and comprehensive ever compiled for this area, and the first made in 50 years. It shows deep, glacier-carved troughs extending from land to seafloor and several likely sites for the new long-term observatory, known as the Polar Remote Interactive Marine Observatory (PRIMO). The observatory, which will continuously monitor currents, animal life, seawater chemistry, and other aspects of the fertile marine ecosystem, must be installed in waters deep enough to avoid being scoured by icebergs, yet close enough to Palmer Station to be connected to a power- and data-carrying electrical and fiber-optic cable.

The chart also revealed a huge surprise: a number of previously unmapped submerged rocks, including a set of sharp rocky pinnacles that pose hazards to ships. Some of the pinnacles rise nearly 100 meters (330 feet) from the sea bottom to just 6 meters (20 feet) below the sea surface. The rocks are close to routes generally taken by ships traveling to and from Palmer Station.

"Ships navigate in and out of Palmer by sighting on visible rocks and sticking to the route they have always used," Gallager explained. "These rocks couldn't be seen, and no one knew exactly where they were."

The previous chart of the area was made in the mid-1900s by single, widely spaced depth soundings. Some underwater hazards were marked on an even earlier chart, but the team found that chart to be off by nearly a mile, and no sure guide to ships.

"When you think of all the ship traffic that has passed through the area over the years and the often hostile weather conditions," Gallager said, "you realize how skillful and lucky the crews have been."

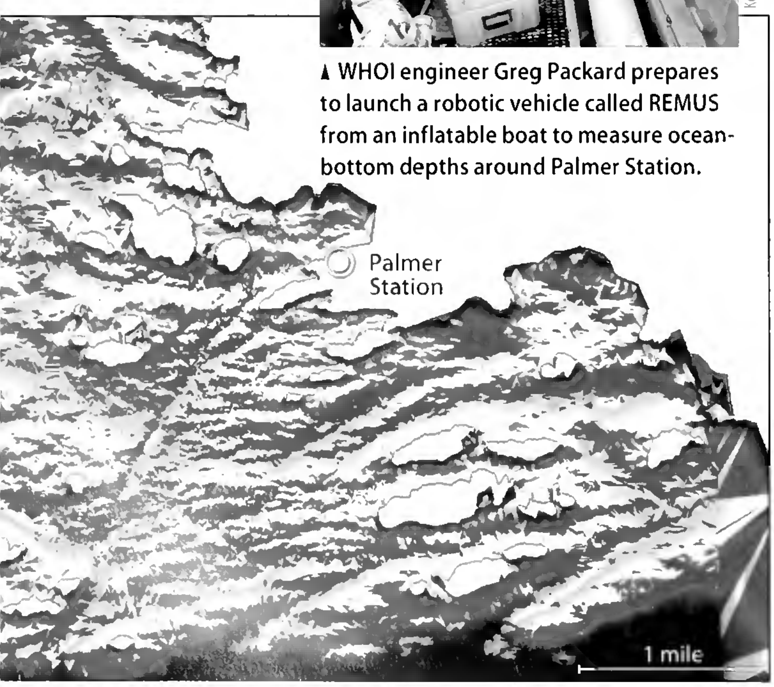
Personnel at Palmer Station and the captains of the U.S. polar research ships *Nathaniel B. Palmer* and *Laurence M. Gould* were interested in the new findings. The researchers left copies of their chart with the station and each ship, and the *Gould* and *Palmer* now use modified routes to and from the station.

—Kate Madin

This work was funded by the National Science Foundation, Office of Polar Programs.

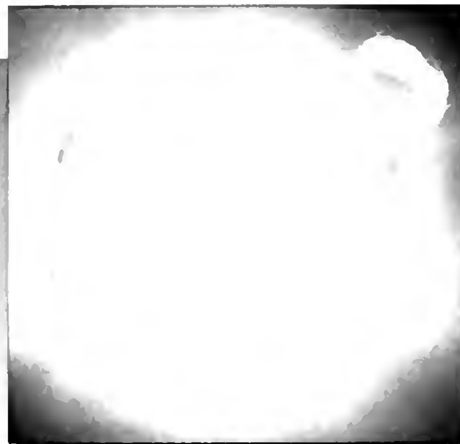
Keith von der Heydt, WHOI

▲ **WHOI engineer Greg Packard prepares to launch a robotic vehicle called REMUS from an inflatable boat to measure ocean-bottom depths around Palmer Station.**



Scott Gallager, WHOI

◄ **A new computer-generated map of the seafloor around Palmer Station, Antarctica, based on more than 180,000 soundings, shows seafloor troughs scoured by receding glaciers.**



European Space Agency and NASA

From ancient [illegible] omens, new da[illegible]vity

The ancient Romans [illegible] ens for signs of what might happen on [illegible] to historical docu-ments, an aurora in th[illegible] nd soldiers was [illegible] appear in the sky in [illegible] he fall of Juli[illegible] Another celestial [illegible] presaged the [illegible] rusalem by Titu[illegible]

Becaus[illegible] teors we[illegible] mans and [illegible] served th[illegible] recordin[illegible] longsi[illegible] of earth[illegible] cords ha[illegible] WHOI [illegible]

Auro[illegible] rn ligh[illegible] flares fr[illegible] t stir u[illegible] sphere. [illegible] ly firew[illegible] e with [illegible] of sunspo[illegible] ace of our [illegible] ree centu[illegible] observatio[illegible] shown that [illegible] pots and s[illegible] a rhythmic [illegible] n, with the n[illegible] r of sunspot[illegible] waning in a[illegible] ear cycle. But with onl[illegible] ears of ob-servations, sci[illegible] can't say whether this cy[illegible] cent or abiding in the life[illegible] 5-bil-lion-year-old sun.

In the late 1970s, astron-omer Richard Stothers of NASA's Goddard Institute for Space Studies analyzed classical writings from 467 BC to 333 AD, particularly Livy's history of Rome. He found dates and descriptions of celestial events that sound much like "great auroras"—northern lights that extend to middle l[illegible] intense periods of solar act[illegible] year cycle of solar ac-[illegible]

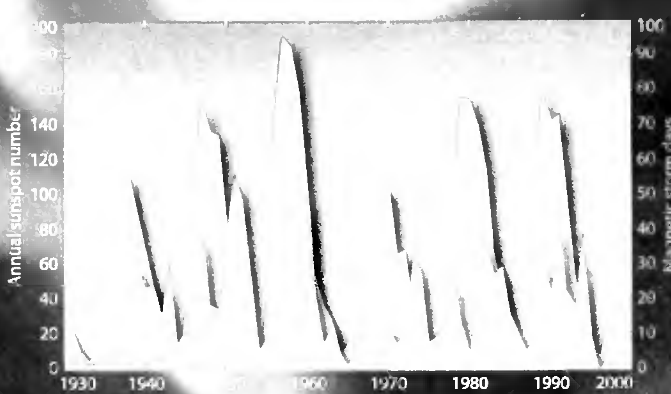
[illegible] ers' paper and felt com-[illegible] is. He filed the problem [illegible] e back to it. In late 2003, [illegible] kindling the urge.

[illegible] low, who is trained in math-[illegible] e WHOI Marine Policy [illegible] riosity, and interesting sta-[illegible] kinds of fields."

[illegible] cal methods to the dates Sto-[illegible] Rome. In a paper published in [illegible] *Letters* in April 2005, Solow con-[illegible] activity cycle seen by Stothers. But [illegible] ng that the cycle of solar activity and [illegible] was bimodal—that is, it has two peaks. [illegible] ng jibes with modern observations that auroras occur in an 11-year cycle, but their peaks of activity tend to lag behind peaks of the sun-spot cycle (left).

For space physicists and earth scientists, establish-ing the stability of the 11-year pattern is important because solar variability is linked to past climate changes. By find-ing both the solar and auroral cycles, Solow has provided twice as much confidence that the ancient solar cycle mir-rored the modern one.

—*Mike Carlowicz*



▲ Studies of sunspots (ye[illegible] curve on chart), geomagnetic storms (red curve), and auroras (back[illegible]ground image) show an 11-year cycle of waxing and waning solar activity that can be verified back to the Greek and Roman empires. (Data provided by Joe Allen, SCOSTEP.)

To decipher odd elephant calls, call in a whale expert

▲ Calimero, a male African elephant, learned to imitate the sounds made by female Asian elephants he was housed with in a zoo.

Stephanie Watwood had no reason to expect that two elephants would cross her path. Nor did she anticipate their surprising vocal impersonations.

Not that Watwood was unfamiliar with leviathan-sized mammals. As a biologist at Woods Hole Oceanographic Institution, she studies whale and dolphin communication. Marine mammals are known to use sounds to forage for prey, broadcast their identity, and establish social bonds. They even learn to make new sounds by imitating what they hear—a process known as "vocal learning."

"We know that humpback whales, for example, sing during the breeding season," Watwood said. "They learn songs from each other, and the songs change. All the whales within an area will imitate one another and help spread the changes in songs from year to year.

"It's an ability that's not very common among animals," she said. "Songbirds and parrots have this ability, and bats, cetaceans, and pinnipeds (such as seals and walruses), and that's pretty much it."

At least until the elephants showed up in her lab.

It happened this way. Joyce H. Poole, a researcher at the Amboseli Trust for Elephants in Kenya, was studying vocal behavior in African elephants. Like whales and dolphins, elephants have strong social structures, and they use low-frequency sound to communicate over wide expanses.

"Joyce had friends who were running an orphanage for elephants, and they had heard this female elephant, Mlaika, making strange sounds, so Joyce went to check it out," Watwood said. "Sitting near the elephant compound, Joyce could hear trucks in the far distance. When she was listening to Mlaika, instantly Joyce said, 'Wow, she sounds like those trucks I'm hearing!' "

Meanwhile, another elephant communication researcher, Angela S. Stoeger-Horwath of the University of Vienna, had discovered a male African elephant named Calimero living in a zoo with female Asian elephants—a different genus and species. He didn't make any normal male African elephant sounds. Instead, he mimicked the chirping calls of his female roommates.

Stoeger-Horwath shared her findings with Poole, and they agreed: These elephants seemed to have learned to imitate unusual sounds. Then they remembered hearing a lecture by Peter Tyack, a WHOI biologist and an expert on vocal learning in marine mammals. That's how two elephant researchers in Europe and Africa ended up in contact with Watwood in Woods Hole.

The elephant researchers sent Tyack numerical data on the elephants' calls. Watwood had analyzed similar data sets of marine mammal sounds. Funded by WHOI, she compared the frequencies and durations of Mlaika's and Calimero's calls with the sounds of the trucks and the Asian elephant females. The work of Poole, Tyack, Stoeger-Horwath, and Watwood demonstrated for the first time that elephants can also imitate vocal sounds.

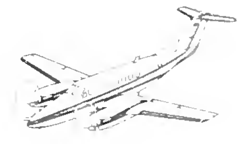
Mlaika's and Calimero's sounds did not exactly match the trucks and Asian elephants, Watwood said, but clearly they were trying hard to mimic those sounds to the best of their abilites.

"Truck sounds are very low frequencies, well within the range of sounds that elephants produce," Watwood said. "The truck sound that Mlaika imitated was a lo-o-o-o-o-ong sound—much longer calls than she normally would make.

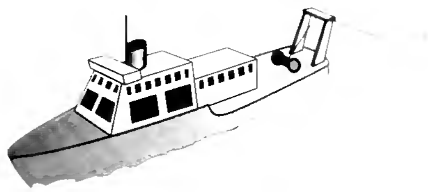
"Calimero is much bigger than an Asian elephant female, and he called at a lower frequency than females would," Watwood said. "But he put more vocal energy in frequencies that were much higher than a typical elephant of his size would make. He was doing his best to sound like a smaller elephant."

—*Kate Madin*

▲ WHOI biologist Stephanie Watwood, who studies the sounds whales make to communicate and forage under water, applied her expertise to decipher elephant calls.



An experiment to dye for



WHOI scientists are exploring a [illegible] technique to reveal [illegible] movements of water in the ocean, using harmless fluorescent dyes and airplanes equipped with Light Detection and Ranging instruments. To detect motion, LIDAR [illegible] pulses of [illegible] light, which [illegible] the flowing dye to fluoresce.

An officer and a graduate student

Long-standing MIT/WHOI program offers master's degrees to naval officers

Six hundred eighty-two students have earned master's and doctoral degrees since the MIT/WHOI Joint Program in Oceanography/Applied Ocean Science and Engineering began in 1968. After shaking hands and accepting their diplomas, 61 of them took off their academic robes and put their Navy uniforms back on. Nine more will do so in the next two years.

Through a special "memorandum of understanding" between the U.S. Navy and the MIT/WHOI Joint Program, several naval officers enroll each year for a 27-month mission into the oceanographic community. Before arriving in Woods Hole, each officer must run a gauntlet of two evaluation committees (naval and academic). A rare few are accepted.

"It's a good investment for the Navy," said Dick Pittenger, a rear admiral, 37-year Navy veteran, and retired vice president of marine operations for WHOI. "There is so much technology and so much need to understand the ocean environment. The Navy trains sailors, but this program educates them."

Since World War II, WHOI and MIT have had long-standing relationships with the Navy, training officers and developing technologies that helped save lives and win battles. The Joint Program has always allowed a few officers to apply and enroll, but the relationship was not formalized until the 1980s.

Then-Secretary of the Navy John Lehman thought the Navy would be reinvigorated by having its officers learn more about oceanography. Together with Adm. James Watkins, chief of naval operations, Lehman announced a Navy initiative that included new ships for the academic research fleet (WHOI received *Knorr* and *Atlantis*), the establishment of Navy-funded research chairs (WHOI physical oceanographer Bob Weller held one from 1999 to 2003), and formalized educational arrangements with several non-military institutions.

The MIT/WHOI connection was made by Arthur Baggeroer, then-director of the Joint Program, Charles Hollister, WHOI dean of graduate studies, and Adm. Rick Seesholtz, oceanographer of the Navy. Their 1984 proposal to admit at least three Navy officers to the program each year was met with skepticism and some resistance

◄ **Nine U.S. Navy officers are pursuing graduate degrees in the MIT/WHOI Joint Program through a special arrangement between the institutions.**

(Back row, from left)

Lt. Benjamin Jones, Class of 2006
Experience: helicopter pilot for six years
Research: analyzing the acoustic spectra of "bio-sonar"—that is, what beaked whales "see" when bouncing echoes off prey
After grad school: will join the Meteorology and Oceanography Command

Lt. j.g. Brendan Gotowka, Class of 2005
Research: contributing to the Mine Burial Prediction program, which examines how the movement of seafloor sediments can cover and uncover explosives
After grad school: nuclear power training school and submarine warfare

Lt. Cmdr. Carl Hartsfield, Class of 2005
Experience: 15 years of active duty as a nuclear-trained submarine officer, including two tours on fast attack submarines and one tour at the Pentagon
Research: developing a navigation method for REMUS autonomous underwater vehicles that uses a single ship-mounted beacon instead of an expensive acoustic field placed on the bottom of the ocean
After grad school: will become second-in-command of the ballistic missile submarine USS *Nevada*

Ensign Matthew Watts, Class of 2006
Experience: served for three years as enlisted sailor before entering the U.S. Naval Academy
Research: working to create a mechanical fish that will mimic the fast startle response observed in fish.
After grad school: training as a surface warfare officer in Pearl Harbor

(Front row, from left)

Ensign Colleen Maloney, Class of 2006
Research: studying the properties of underwater sand ripples on the continental shelf and how they are remodeled by storms (part of the Mine Burial Prediction program)
After grad school: training as a surface warfare officer in Little Creek, Va.

Ensign Kathryn D'Epagnier, Class of 2007
Research: interested in underwater vehicles
After grad school: training as a surface warfare officer

Ensign Maria Parra-Orlandoni, Class of 2007
Research: would like to work with autonomous underwater vehicles
After grad school: training as a surface warfare officer in San Diego

Ensign Allison Berg, Class of 2006
Research: using portable Sonic Detection and Ranging (SODAR) instruments to study the winds from the ocean's surface to roughly 200 meters altitude
After grad school: training as a surface warfare officer on the destroyer USS *Momsen*

(not pictured):

Ensign David Farrell, Class of 2007
Research: to be determined
After grad school: flight school in Pensacola, Fla.

MIT/WHOI officer-graduates who made a difference

Rear Adm. Jay M. Cohen
Cohen's military experience included tours as a submarine commander and as deputy director for operations for the Joint Chiefs of Staff. Since 2000, Cohen has served as chief of naval research.

Capt. Wendy Lawrence
Lawrence served for 11 years as a helicopter pilot before being selected for astronaut training by NASA. She made space shuttle flights in 1995, 1997, and 1998 and trained for duty on the Russian space station *Mir*. In July 2005, she lifted off on space shuttle *Discovery* in the nation's first return to space since 2003.

Rear Adm. Craig E. Dorman (retired)
A one-time Navy SEAL, Dorman spent time as director for anti-submarine warfare in the Space and Naval Warfare Systems Command. From 1989 to 1993, he served as the sixth director of WHOI. He is now vice president for research at the University of Alaska.

Rear Adm. Paul Sullivan
In 1998, he became director of the Navy's Deep Submergence Branch, and then moved to director positions on the United States Strategic Command staff and the chief of naval operations staff. He is now commander of the submarine force for the U.S. Pacific Fleet.

Read more at www.oceanusmag.whoi.edu.

in the Woods Hole community. Today, the students are key contributors to research, particularly in the WHOI Department of Applied Ocean Physics and Engineering.

"I get the best ocean engineering degree in the world," said Lt. Cmdr. Carl Hartsfield, the senior officer among the current students. "My MIT advisor, Arthur Baggeroer, is a trusted technical advisor to the chief of naval operations and other senior admirals, and a developer of the sonar improvements that put the hunt back in U.S. Navy submarines. My WHOI advisor, Chris Von Alt, developed REMUS, the first operationally deployed Navy autonomous underwater vehicle (AUV). I have been neck-deep in autonomous submersible design theory, up to my arms in their associated electronics, and deployed to do WHOI AUV operations in the deep ocean. Where else could I do that?"

"As the Navy becomes ever more reliant on cutting-edge technology," added Lt. Ben Jones, "it needs operators (for instance, pilots) and commanding officers who have an understanding beyond the user's manual level of knowledge on the gear we hunt the enemy with. In a program like this, a naval officer can learn about new technology and applications, as well as the physical, biological, and chemical details of the marine environment we work in."

"Officers work side by side with very smart colleagues at MIT, with its diverse subject offerings, and at WHOI, with its special knowledge and access to the oceans," said Baggeroer, now Ford Professor of Engineering and Secretary of the Navy/Chief of Naval Operations Chair for Ocean Science at MIT.

The participation of Navy officers also "adds diversity to the student body," said John Farrington, WHOI dean and vice president for academic programs. "They bring a different perspective on how the ocean works. They also have different goals in life, and they are quite focused because they have a limited time here."

Civilian students and scientists grow to better understand their military counterparts, and they form intellectual and professional bonds that can last a lifetime.

"On a WHOI expedition last summer, I suggested a submarine trick-of-the-trade," said Hartsfield. "We gained 20 decibels of signal and prevented a large-scale halt in operations. It is this give-and-take interaction between the renowned scientist and the professional naval officer that makes this program so irreplaceable."

—*Mike Carlowicz*

In and out of harm's way

Shipping lane changes proposed to prevent collisions with whales

Just a few more miles or a few more minutes. That's what scientists and some federal managers think it would take to improve the plight of the highly endangered North Atlantic right whale.

No more than 350 survive, and ship strikes are a leading cause of death for the whales, which live near and migrate through high-traffic coastal waters. Researchers are proposing that the U.S. government adjust shipping lanes around some ports and slow ships in other East Coast waters.

The "ship-strike reduction strategy" would reroute ships away from key breeding and feeding grounds; in other places, it would establish seasonal speed limits within 30 miles of the coast, perhaps slowing ships to 12 knots, about half the normal speed of many container ships and cruise ships.

The U.S. National Marine Fisheries Service announced in June that it intends to prepare an environmental impact statement as part of the process of implementing new shipping regulations. Conservationists and some researchers say the measure is long overdue; some maritime interests say the plan has as many potential negative impacts as positive ones.

For instance, shifting ship traffic closer to the coast could reduce the risk of a ship striking a right whale in Cape Cod Bay by 40 percent, said Hauke Kite-Powell, a research specialist in the WHOI Marine Policy Center (MPC) who recently delivered a research report on the matter to the Provincetown Center for Coastal Studies. For nearly five months a year, a significant number of northern right whales congregate in the nutrient-rich waters of Cape Cod Bay, Massachusetts Bay, and the Gulf of Maine. Hundreds of vessels pass through the area each year, making it likely that several ship-whale encounters take place annually.

▲ **Ship strikes threaten the survival of the North Atlantic right whale.**

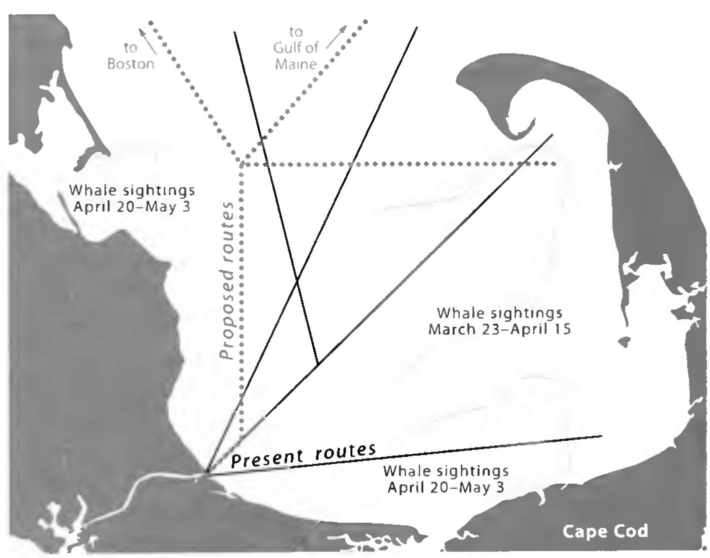
Kite-Powell is now working with Amy Knowlton and Moira Brown of New England Aquarium (NEAq) to study how right whales respond to ships and how changes in ship speed might increase the odds that ships or whales could get out of the way. He also has worked with MPC colleague Porter Hoagland to study the economics of ship-strike management.

"If there is a reasonable place to move the shipping lanes—as Canadian managers recently did in the Bay of Fundy—then it makes sense," said Kite-Powell. "It also could make sense in Cape Cod Bay. But for most of the East Coast, there is no good way to reroute ships. Speed limits might be the only way forward in the near term."

Changing the shipping regulations would likely increase costs by $10 million to $15 million per year for commercial operators. But Kite-Powell points out that the changes could disproportionately affect certain ports, such as Boston, which has right whales crowding its shipping lanes for nearly five months a year.

In related research, WHOI biologists Hal Caswell and Michael Moore, NEAq scientist Scott Kraus, and 11 other researchers reported in the July 22 issue of the journal *Science* that ship strikes and fishing gear entanglements are killing North Atlantic right whales at a rate exceeding a level that allows the population to grow. In a statistical analysis and call for action, the researchers noted that the situation may be more dire than they can observe directly, with many whales dying out at sea and out of sight.

—Mike Carlowicz



► **Endangered right whales congregate in Cape Cod Bay, particularly from December through May, while an average of seven passenger or cargo vessels pass through the area each day. Using five years of data on right whale sightings (red indicates more frequent sightings), researchers have proposed seasonal changes to shipping lanes to reduce ship-whale collisions. Solid lines indicate current shipping routes; dotted lines represent proposed, whale-friendly routes.**

A whole new kettle of fish

New legislation and task force to explore open-ocean aquaculture

▲ **Divers clean the outside of SeaStation 3000, an open-ocean aquaculture project operated by the University of Hawaii. The 15-by 24-meter (50-by-80-foot) cone-shaped steel-and-mesh cage lies two miles from Honolulu and 12 meters (40 feet) below the surface, out of the way of ships.**

With most of the world's fisheries already fully exploited or overexploited, the wild catch will not meet increasing worldwide demand for seafood—which the U.S. Department of Commerce projects will triple by 2025. The United States also imports nearly 70 percent of the seafood Americans consume, resulting in an $8 billion shellfishing industry trade deficit.

A solution, according to the Bush administration, is to greatly expand fish farming, or aquaculture, particularly in the open ocean. But researchers and conservationists see both benefits and threats to the environment as the fishing industry converts from wild harvests to domesticated operations.

In June, the Commerce Department submitted legislation to Congress to develop aquaculture in offshore waters. It is part of a "U.S. Ocean Action Plan," the administration's response to the *Ocean Blueprint for the 21st Century*, the 2004 report of the U.S. Commission on Ocean Policy.

The bill authorizes the National Oceanic and Atmospheric Administration (NOAA) to establish a system to issue permits and collect fees for aquaculture operations within the U.S. Exclusive Economic Zone—the strip of federally controlled waters from 3 to 200 miles (370 kilometers) off the coast. The proposal also authorizes NOAA to establish environmental regulations if "existing requirements are inadequate" and to support research and development programs for fish farming.

In anticipation of the legislation, The Pew Charitable Trusts and The Lenfest Foundation awarded $600,000 to Judy McDowell, WHOI biologist and director of the Woods Hole Sea Grant Program, to direct a Marine Aquaculture Task Force. The independent panel of leaders from science, industry, and conservation groups has been asked to develop a set of policy recommendations on open-ocean aquaculture.

"Opening our oceans to aquaculture holds great promise and great risk," said Dick Pittenger, the retired vice president of marine operations for WHOI who was named chairman of the task force. "The challenge is to see if we can protect the environment without inhibiting the growth of the industry."

As the ocean commission noted last year, the federal government has inconsistent laws and regulations for managing ocean waters. "What is the process for giving exclusive legal rights over a piece of federal ocean real estate?" said Hauke Kite-Powell, a research specialist in the WHOI Marine Policy Center who is studying governance issues. "How do you decide among competing interests? How much say should states have? What can we learn from other offshore management regimes, such as minerals, oil, and gas?"

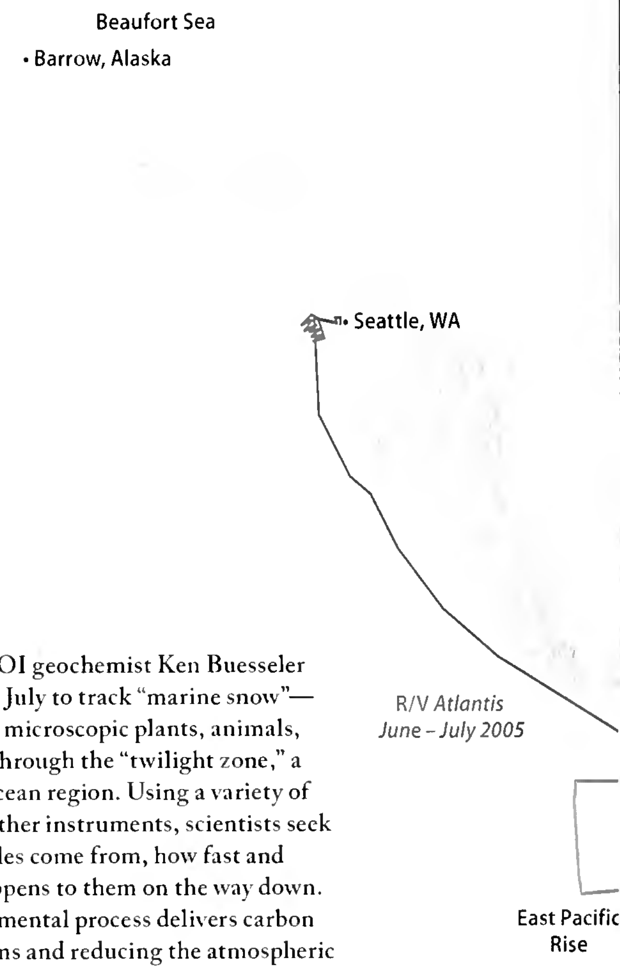
Offshore aquaculture has some natural advantages over coastal fish-farming operations because open-ocean winds, waves, and currents can naturally remove excess feed, disperse wastes, and maintain water quality. Offshore operations also don't conflict with recreational and real estate interests.

But there are environmental and ecological questions, such as which species should be farmed and where. Some researchers are concerned that domesticated fish—and the medicines and disease outbreaks sometimes associated with high-density fish farms—could threaten natural stocks of fish.

The task force will conduct public hearings and fact-finding trips to regions most likely to be affected by a boom in aquaculture. Members also will review scientific literature and interview representatives of industry, government, and environmental groups. They plan to issue a report by the fall of 2007 and to contribute, if asked, to congressional hearings on aquaculture legislation.

"The task force will recommend a suite of science-based standards for guiding offshore aquaculture," said McDowell. "If open-ocean aquaculture is going to happen, let's make sure the right policies and regulations are in place."

—*Mike Carlowicz*



On top of the world

Beaufort Sea—A huge freshwater reservoir collects in the western Arctic Ocean and gets trapped by a wind-driven cyclonic current called the Beaufort Gyre. WHOI oceanographer Andrey Proshutinsky has theorized that if the winds and the gyre weaken, large volumes of fresh water can leak out of the eastern end of the Arctic Ocean into the North Atlantic, having large impacts on ocean circulation and climate. Using a variety of instruments to measure ocean, ice, and atmosphere, WHOI researchers explored this remote and hostile sea in August—part of a multiyear effort to determine its critical role in global climate.


Chris Linder, WHOI

Marine 'snow'

Northwest Pacifc—WHOI geochemist Ken Buesseler led an international cruise in July to track "marine snow"—tiny particles of decomposed microscopic plants, animals, and fecal pellets—that rain through the "twilight zone," a dim, deeper, little-studied ocean region. Using a variety of nets, particle catchers, and other instruments, scientists seek to learn where marine particles come from, how fast and deep they sink, and what happens to them on the way down. This little-known but fundamental process delivers carbon to the deep, feeding organisms and reducing the atmospheric buildup of the greenhouse gas carbon dioxide.


Mark Gall, NIWA

Current affairs

Offshore Japan—The Pacific Ocean equivalent of the Gulf Stream is the Kuroshio Current. This strong, warm, northward-flowing current leaves the Japanese coast to flow eastward into the North Pacific as a free jet—the Kuroshio Extension. Here, warm Kuroshio waters encounter cold, dry air masses coming from Asia, triggering intense air-sea heat exchanges that affect regional storms and climate and, indirectly, fisheries. In June, WHOI physical oceanographers Nelson Hogg and Steve Jayne led a cruise to redeploy instrumented mooring arrays to measure currents and water properties that will reveal the dynamics of the Kuroshio Extension.

Steven Jayne, WHOI

Where the whales are

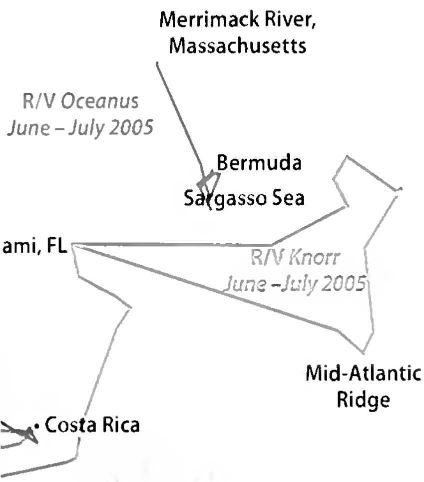
Barrow, Alaska—WHOI biologist Carin Ashjian and colleagues spent five weeks this summer studying the coastal ocean off Alaska, where bowhead whales migrate to feed on dense aggregations of zooplankton. Aboard a 44-foot boat, the researchers made transects across the continental shelf to locate and measure plankton, oceanic currents, fronts, eddies, and nutrients—with an eye on how these factors influence plankton concentrations. The research will help assess the vulnerability of the delicately balanced ecosystem to environmental changes.


Ev Sherr, Oregon State University

At the river's end

Merrimack River—WHOI scientists Rocky Geyer and Jim Lerczak explore the dynamics of estuaries, where rivers tumble into tides, salt water mixes with fresh, and detritus washed from the land churns with material imported from the sea. How will an estuary respond to a sewage or oil spill? A drought or storm? To rising sea level? To answer these questions, the scientists have been studying three dramatically different estuarine settings: the Hudson River in New York and the North River and Merrimack River (aboard R/V *Tioga* in July) in Massachusetts.

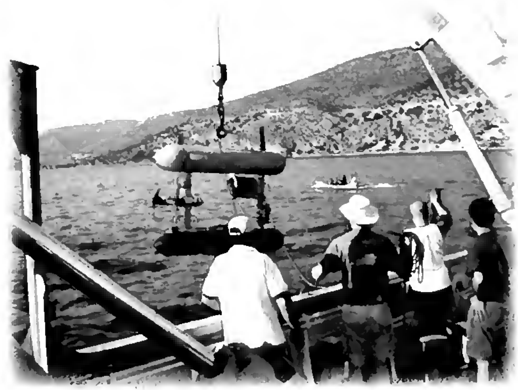
Jim Kent, WHOI



Stirring the oceanic pot

Sargasso Sea—They should be watery deserts, devoid of the nutrients needed to spur the growth of marine plankton. Yet some open-ocean regions nevertheless are biologically productive. From June through September, researchers from six institutions worked in tandem on R/V *Oceanus* (WHOI) and R/V *Weatherbird II* (Bermuda Biological Station for Research) to find out why. Led by WHOI oceanographers Dennis McGillicuddy and Jim Ledwell, the team investigated the role of swirling circular currents, or eddies. Early results indicate that the turbulent stirring of the ocean pulled nutrients up into light-filled surface waters and fueled phytoplankton blooms.

Valery Kosnyrev, WHOI



Brian Bingham, Franklin W. Olin College of Engineering

Bronze Age shipwrecks

Aegean Sea—Civilization blossomed dramatically during the Bronze Age 3,000 to 5,000 years ago; major clues to explain this critical turning point in human history lie at the bottom of the ocean—in artifacts aboard shipwrecks. In July, Brendan Foley, Hanu Singh, and other WHOI scientists strengthened a collaboration with Greek archaeologists and marine researchers to demonstrate how underwater vehicles such as WHOI's SeaBED can be used to find and study ancient shipwrecks beyond the depth of divers. Working near the island of Chios, they located, mapped, and photographed ancient (through not Bronze Age) Greek and Roman wrecks.

Amy Nevala, WHOI

Oceanographic 'telecommuting'

Mid-Atlantic Ridge, off Venezuela—Over 20 years, WHOI geophysicist Debbie Smith has been chief scientist of a research cruise four times, directing and coordinating scientific activities aboard ships. In June, she did it for the first time from her office, as a "virtual" chief scientist. She used a new system called HiSeasNet, which allows high-data ship-to-shore communications in real time. On her office computer, Smith received bathymetric, magnetic, and gravity information from R/V *Knorr*, which she used to guide the ship as it mapped the seafloor in a study of unusual deep-sea earthquakes off South America.

Settling on the seafloor

Deep in the ocean, larvae search for 'home, sweet home'

People may search for a long time, but they know it when they see it—the right job in the right town, or the right house in the right neighborhood. Then they settle down, set up shop, and put down roots.

At the bottom of the ocean, tiny larvae of deep-sea animals, floating through the black depths, make a similar quest. The offspring of tubeworms, giant clams, and other organisms that form thriving communities of life around seafloor hydrothermal vents must find the right conditions for them to settle down, live, grow, and reproduce.

How they do that has remained a mystery. In the 28 years since tubeworms and other organisms were discovered living in volcanic areas along mid-ocean ridges, scientists have been puzzling over how they survive there. Woods Hole Oceanographic Institution biologist Tim Shank calls the vent sites "Earth's largest chemosynthetic community," where inhabitants live without sunlight and instead convert chemicals from vent fluids into energy and nutrient sources.

"There's no other place on the planet like this," Shank said, "yet we know little about how young organisms move around, assemble, and form new communities."

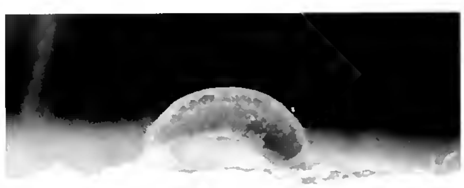
Understanding the factors that determine why larvae settle is a key first step to understanding the bigger picture of how seafloor life has developed across the wide expanse of the ocean throughout time.

In a similar way, scientists have studied how and why human populations developed and moved out of Africa, crossed the Bering Strait into the New World, or later journeyed across oceans via ships during the colonial era. Over the short term, social scientists also seek to understand the factors that cause demographic shifts—from urban to suburban communities, for example, or from the U.S. East Coast to the Southwest.

Equivalent population movements occur on the seafloor, and they all begin with organisms finding places to accommodate their basic needs. For larvae of hydrothermal vent organisms, those factors include basalt (volcanic seafloor rock) on which to settle, and the right acidity and temperature of seawater.

To begin learning exactly why larvae prefer one swath of seafloor to another, Shank and fellow WHOI biologists Stefan Sievert and Stace Beaulieu teamed up last year using a grant from the WHOI Deep Ocean Exploration Institute. They began in February 2004 by deploying small basalt

▲ Scientists placed experimental basalt panels in the center of a tubeworm colony on the seafloor and retrieved them months later to see what larvae settled on them.



Stace Beaulieu, WHOI

▲ A leech was among the organisms WHOI biologist Stace Beaulieu found on a basalt panel placed near hydrothermal vents on the Galápagos Rift.

panels as an experiment at a hydrothermal vent site called Tica Vent on the East Pacific Rise. This mountainous undersea area is located about 3,700 kilometers (2,000 nautical miles) west of Central America.

► Scientists (left to right) Stace Beaulieu of WHOI, Naomi Ward of The Institute for Genomic Research, and Breea Govenar of Pennsylvania State University wear gloves to keep panels (used to collect colonizing seafloor larvae) free of human bacteria that could contaminate experiments.

Amy Nevala, WHOI

During three cruises in 2004 to the East Pacific Rise, the science team began a series of studies that was repeated this spring at the Galápagos Rift, located off the Galápagos Islands near the equator, to see how microbes and larvae settle over time.

Traveling to Tica Vent on the research vessel *Atlantis*, the biologists worked at a lush and thriving community of giant tubeworms and mussels. Using the submersible *Alvin*, they placed 17 pre-cut, 4-inch squares of rock basalt previously collected from the site. The squares acted as seafloor petri dishes, growing microbes and providing a settlement surface for larvae in their natural surroundings.

"Microbes might coat the surface of the basalt and serve to indicate to the larvae that a particular spot is good for settling," said Beaulieu. She suspects they may act as a conditioner for larval settlement, in the same way that a paint primer brushed on walls allows subsequent paint layers to adhere better.

Nearby sensors monitored the temperature and chemistry of the vent fluid, including acidity and hydrogen sulfide levels, for a clearer picture of how the vents influence the larvae's settlement.

The scientists returned to collect and replace the squares over the following four, nine, and 13 days, as well as on later expeditions after two and nine months. This allowed time for the microbes and larvae to settle over different time spans.

"To the naked eye, the squares recovered after four, nine, and 13 days looked relatively bare," said Beaulieu. To peer closer, she headed to the ship's lab to use a special microscope to photograph where larvae settled on the squares. The lab's temperature was set at 2°C (35°F) to prevent seafloor microbes and the larvae that settled and metamorphosized—known to scientists as "recruits"—from rapidly decomposing, and thus fouling the research.

That's why Beaulieu packed winter clothes for the trip to the equatorial Pacific. Using forceps, Beaulieu plucked out tiny recruits, one by one, and placed them in tubes.

"For up to nine hours after *Alvin* returned from the dive, we labored at the scope," she noted. "While many scientists and crew were deep asleep, we were sequestered in the bio lab's walk-in freezer, forceps at hand.

"It can be difficult to take photos through a microscope on a rocking ship," she added.

Unlike the recruits, microbes are too small to pluck off. So after Beaulieu was finished, the squares were frozen for subsequent studies to identify organisms by their DNA. To do that, the scientists first needed to extract DNA from the samples.

"This is especially exciting because it's the first time it has been done," she said. Back at WHOI in February 2005, Beaulieu developed a technique using a jewelry- and tool-cleaning machine. It sends ultrasonic waves to the surface of the squares, which break up cells that may have accumulated there. DNA is then extracted into a liquid solution that is purified to remove other organic compounds, such as proteins.

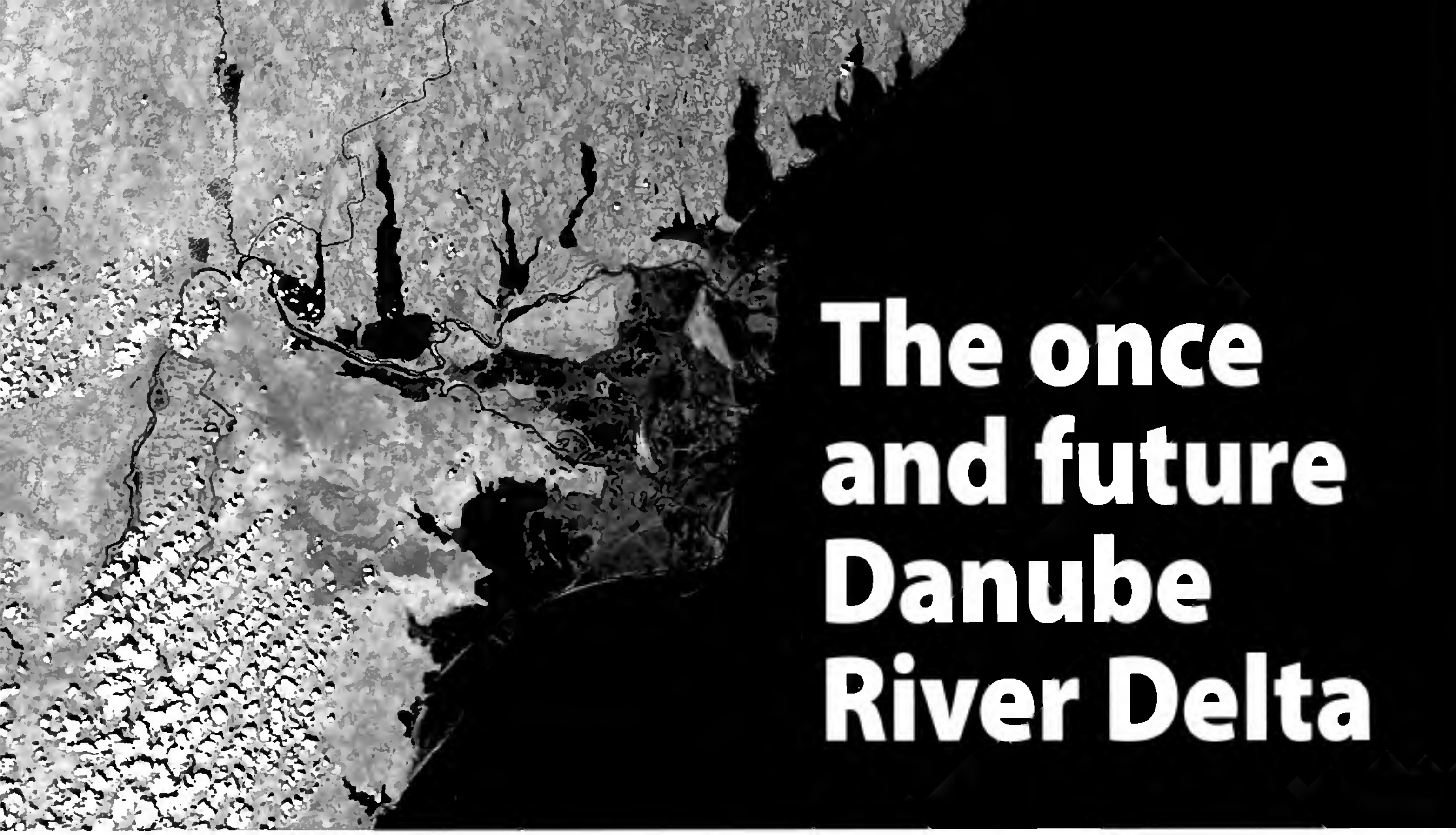
With relatively pure DNA in hand, Sievert has begun analyses to identify microbes that may have colonized the larval panels, while Beaulieu and Shank search for DNA to identify larval recruits plucked from the basalt surfaces.

To the naked eye and even under a microscope, "the surfaces sometimes appear to be clean, with no settled larvae," Beaulieu said. "But now we're developing techniques that tell us 'Not so fast—it appears that somebody is home, after all.' "

—*Amy E. Nevala*

► WHOI biologist Stace Beaulieu packed winter clothes for an expedition to the tropical Pacific Ocean to work in a shipboard lab set to 2°C (35°F). The cold prevents decomposition of microbes collected from the seafloor.

Lauren Mullineaux, WHOI



The once and future Danube River Delta

Past changes in World Heritage site offer lessons for proposed river projects

"The Danube Delta is like the Everglades," said Liviu Giosan, who grew up near the Romanian wetlands. More than 300 bird species and 45 freshwater fish species make homes in the fertile labyrinth of marshes, dunes, and channels.

The triangle-shaped, sediment-rich region at the mouth of the Danube River is also rich with human history. The area has been settled since the Stone Age, and the ancient Greeks, Romans, and Byzantines built trading ports and military outposts along the coast. A traditional maritime culture persists on the delta, and the United Nations has declared the region a World Heritage site.

The Danube Delta is also a great place for a geologist to study how the coast stretches, contracts, and undulates with time and human interference.

The Danube is Europe's second-longest river and a major artery for trade and transportation. Starting in the Black Forest in Germany, it winds 2,850 kilometers (1,770 miles) through nine countries before pouring into the Black Sea from Romania and Ukraine. A proposed project to dredge several arms and channels of the river for shipping will fundamentally alter the delta, said Giosan, a coastal geologist at Woods Hole Oceanographic Institution.

"We have experience from other parts of the world with the damage that occurs from altering rivers and wetlands," he said. "Why not learn from that?"

▲ WHOI coastal geologist Liviu Giosan (second from right) and colleagues from his native Romania disembark from their "dormitory" boat to collect ancient sediments that will help them reconstruct the geological history of the Danube Delta.

The delta—named for its resemblance to the Greek letter Δ—serves as a sieve filtering fresh water and sediment from the European interior before it reaches the salty sea. Buried in the sediments lies a geologic record of a moving, changeable shoreline that has shaped human history; in recent years, history has been shaping the river. For several years, Giosan has been working with geographer Emil Vespremeanu of Bucharest University and WHOI geologist Jeff Donnelly to dig into the Danube's secrets.

They traveled in small "dormitory" boats from Tulcea, where the roads end, to a base station near the Black Sea coast. They cruised small canals and arms of the river to take sediment cores from old beach ridges, and they used sonar to chart the shape of

► **The Danube River is a major European transportation artery, winding through 1,770 miles and nine European countries before pouring into the Black Sea through a vast, environmentally sensitive delta system.**

the seafloor near the mouth. Blending field geology with computer modeling, they are reconstructing the forces that changed the flow and structure of the delta in the past and figuring out what this can tell us about how the delta could change in the future.

"We need to understand the river mouth, where a delta is built," said Giosan. The traditional understanding of deltas holds that the river carries all the mud and sand deposited at the river mouth. But Giosan questioned this old assumption, and he and his colleagues are showing that not all the sediment is brought by the river. Waves, currents, and tides also help build the delta from the seaward side by moving and depositing sediments at the coast.

In fact, the river can serve as a natural barrier to the flow of water and sand that builds and erodes the coast. Evidence suggests that the ancient port of Istria may have been shoaled behind a barrier beach when changes in river flow through the delta brought more sand southward along the Black Sea coast. Preliminary findings by Giosan and colleagues also suggest that the Danube Delta may be much younger than previously thought.

"The construction of a delta is a delicate balance between river discharge and coastal currents and waves," he said. And that balance is in peril.

In the 1860s, European leaders internationalized the Danube region and dredged one navigable channel through the delta—called the Sulina arm—to open the European interior to bigger ships. For 150 years, Europeans have established commissions and written treaties to protect and exploit this vital waterway.

As with so many rivers around the world, the Danube has been dredged, dammed, and altered for centuries. It now delivers just 30 percent of its original load of water and sediment to the delta. "When a river no longer brings new sediment to maintain the shoreline," Giosan said, "it becomes imperative to understand how fast the coast will erode under the waves."

The imperative became clear in 2004 when the former Ukrainian government unveiled plans to revive inland ports by dredging a 170-kilometer (105-mile) shipping channel along the Chilia arm of the Danube, on the border with Romania. To date, a 3-kilometer (1.8-mile) canal has been carved through ecologically sensitive territory, prompting protests from environmentalists and the governments of Romania, the United States, and the European Union.

The controversy prompted Giosan to send testimony to the International Commission for the Protection of the Danube. "Any major modification in one region of the delta will affect the other parts," wrote Giosan. "Dredging the Chilia arm for a deep-water navigation channel will most likely change the water and sediment regime all along the Danube-influenced Black Sea coast."

Giosan believes that an improperly designed project could fundamentally change the flow through the delta. Increasing the water flow through Chilia would significantly increase the sediment load in that arm and increase erosion along the coast. At the same time, it could deplete other arms of needed fresh water and delta-building sediment, allowing salt water to penetrate the wetlands and turning fertile habitat into a brackish wasteland.

The technical details of the Ukrainian project are sketchy, and Giosan and colleagues hope the new government might reconsider the project long enough to get an impact study requested by the international scientific community. Perhaps scientists' voices can be heard before the dredges are sent in.

—*Mike Carlowicz*

This research was funded by the WHOI Coastal Ocean Institute and a WHOI Independent Study Award.

Courtesy of Liviu Giosan, WHOI

◄ **Liviu Giosan (left) of WHOI, and Emil Vespremeanu (in blue) and Ionutz Ovejanu (yellow) of the University of Bucharest use an auger to bore holes into a swale and collect samples in the Danube Delta.**

Where currents

◄ Veteran seagoing WHOI researchers Craig Marquette (left) and Will Ostrom deploy a mooring with tiny temperature probes from R/V *Oceanus* during a gale off Cape Hatteras—where the warm, salty Gulf Stream (red, orange, and yellow in map above) collides with a cold, fresh, southerly coastal current (dark blue).

Nineteen days at sea in the 'graveyard of the Atlantic'

I leaned on my shovel last February, taking a break from clearing our mailbox from a fresh mound of snow. My neighbor sauntered over with a wry grin on his face.

"So, you just got back from a cruise, huh? Some life you have—we're here digging out from the blizzard of the century, and you're off on a cruise!"

I just smiled. I didn't want to shatter my neighbor's image of me as a globe-trotting dilettante. The real story included relentless North Atlantic storms battering our ship, instrument retrievals in the dead of night with blue water washing over the rail, science gear shattered by 20-foot waves. I would rather have been shoveling.

On Jan. 15, 2005, our small science party set out on R/V *Oceanus* for the tumultuous waters off the coast of North Carolina—aptly nicknamed "the graveyard of the Atlantic." Led by Woods Hole Oceanographic Institution physical oceanographer Glen Gawarkiewicz, our objective was to study the confluence of southward- and northward-flowing currents that meet at Cape Hatteras. Here the mighty Gulf Stream—warm and salty—breaks away from the coast and heads to Europe—but not before it converges with the "shelf-break jet," a strong current at the edge of the continental shelf that carries cold, relatively fresh water from the Arctic and North Atlantic Oceans.

The two water masses have different densities, so they don't blend seamlessly into each other, but rather collide. Like low- and high-pressure air masses in the atmosphere, these water masses form "fronts," or boundaries, which continually interact and move in response to passing weather systems.

The shifting of these oceanic fronts creates the equivalent of "weather" within the ocean. They stir up nutrients from the deep to fuel phytoplankton blooms that feed fish and marine mammals. They steer pollutants coming on and off shore. They set up air-ocean temperature gradients that create fog.

To begin to map the dynamics of the oceanic weather in this region, Gawarkiewicz co-led a cruise in August 2004 to take

measurements of current speed and direction off Cape Hatteras, as well as water temperatures and salinities, which can distinguish various water masses.

But just as the atmosphere's dynamics change with the seasons, so do the ocean's. Now it was time to learn how the water masses mix and create new water masses under the influence of winter cooling and stormier seas.

During our three weeks riding the waves, I kept a journal with pen and camera. These entries will give you an idea of what it's really like on the high seas off Cape Hatteras in winter.

Jan. 15, 2005: Weather was clear and cold as we steamed south through the Elizabeth Islands. When I told people at WHOI where this cruise was headed, most responded, "Cape Hatteras, in winter?"—followed by a look of acute disbelief and sometimes a sad shake of the head. I know it's going to be rough, but how bad can it be?

Jan. 17: Just east of North Carolina, the seas could best be described as lumpy. Massive blobs of seawater lurch into the ship, causing it to heave and buck unpredictably. Will Ostrom, a veteran WHOI mooring technician, sways in time to the rolls as I careen into the bulkheads. Will is happily typing away on his computer in the main lab while I stare at the wall fighting nausea. When exactly do I get those "sea legs?" Time to pop the Dramamine.

Jan. 18: Tired and wet from putting moorings in the water. Since there are only six scientists and technicians aboard, it was an all-hands operation to get the instruments overboard safely. We deployed a variety of moored instruments: 30-meter (98-foot) lines of tiny temperature probes; a heavy chain mooring, 80 meters (262 feet) long, with temperature probes; several instruments called CTDs to measure conductivity, temperature, and depth; and a large meteorological buoy. The moorings were placed at strategic locations and will be picked up at the end of the two-week cruise.

Each deployment requires a slightly different procedure. Some take 15 minutes, others several hours. Water sloshed across the deck continually as we worked—attaching instruments to the mooring lines, moving heavy anchors, testing acoustic release equipment. My duty involved standing at the starboard rail holding the acoustic release transducer cable over the side while Craig Marquette, an engineer from the WHOI Physical Oceanography Department, tested the releases. For whatever reason, the waves seemed to be drawn to that location. My survival suit was soaked with salt water by the end of the day. Cold salt water.

Jan. 19: We have commenced towed vehicle operations, the heart of the project. A wing-shaped vehicle, 2 meters (6 feet) long, called the Scanfish will collect temperature and salinity data as we tow it behind us.

The Scanfish "flies" or undulates behind the ship, giving us a two-dimensional picture of water properties from the surface down to 100 meters (330 feet). Since we don't have to stop the ship to sample, we are able to measure a large parcel of ocean in a short time.

Brian Kidd from the University of Delaware is our Scanfish expert. In the shallow, placid waters of Delaware Bay, the "fish" flies beautifully. Out here in the towering waves and fast currents of the Gulf Stream, it's not doing so well. Brian has bags under his eyes. He's been standing an evening watch and working all day to fix the equipment problems that cropped up overnight.

"We're running out of parts," he confides between yawns. "We have never gone through this many spares." Looks like we might have to make a port call.

Jan. 21: I go outside to feel a cold wind in my face. A thick fog billows over the waves, caused by the cold northerly air passing over the balmy waters of the Gulf Stream. This "sea smoke" is one of the most beautiful things I have ever seen. The wind whips the fog over the wave crests as dolphins surf the 20-foot rollers (see page 2). I fight my way up to the bridge for a better look.

As the sun sets, the waves and mist turn gold. The wave crests look like distant mountain ridges. Chief Mate Diego Mello, a Coast Guard veteran, joins me on the flying bridge. "In all my years at sea I've never seen anything like this," he tells me. I feel like the sea has given us a little reward for our determination.

Jan. 22: We pulled into Morehead City, N.C., to pick up some parts for our battered Scanfish and to escape the storm that has just started burying New England with a record-setting snowfall. Thirty-five foot waves are forecast for the Gulf Stream.

Is it only a coincidence that the New England Patriots are playing in the AFC championships this weekend—something we couldn't watch at sea? Or perhaps it is a morale-boosting decision by the captain and chief scientist?

I'm glad we are not riding this storm at sea, and—back home—my wife is glad, too.

Jan. 26: The familiar hum of the engines was absent when I woke up. After two weeks on the ship, you become attuned to every sound and motion. A quiet ship meant that we weren't Scanfishing anymore.

The hum and whir of the propellers started up again. The sound of waves slamming into the side of the ship resumed, as did our wild rolls from side to side. Hmm, we must have just finished a CTD cast and are moving on to another station.

One of the most traditional ocean instruments, the CTD is encased in a metal frame called the rosette, which is lowered over the side using the ship's winch. In rough seas, two people use slip-lines to keep the 408-kilogram (900-pound) instrument package steady when it's off the deck. The last thing you want in rough weather is for the CTD to become a wrecking ball. It made for a long night, but the constant activity made time go faster.

Jan. 28: I asked Chris, our steward, why we haven't had pizza on the cruise. He replied that the ingredients would slide off in the oven.

Our definition of bad weather has changed. Now, 8- to 12-foot seas are considered "calm conditions," and anything higher is simply "messy." Work continues night and day. When it's too rough for the Scanfish, we resort to CTDs. No pizza for us tonight.

Jan. 29: I was heading up to the main lab today when I heard a series of faint whistles and clicks. Initially I thought I must be suffering from one of those "adverse reactions" from exceeding the daily limit of seasickness medication. But when I saw Brian Kidd's expression, I knew I wasn't the only one. "Are those dolphins?"

We stepped out on deck and saw several dozen dolphins swimming and leaping out of the water next to the ship. I watched them until sunset. They seemed delighted to find something to play with out in the cold dark ocean.

Jan. 30: Winds have increased to storm force—again. Too rough for Scanfish, too rough for CTDs, too rough for pizza, and too rough for reading in my bunk.

As the ship rolled heavily in the swell, portholes in the main lab alternated between views of the sky and views beneath the waves. As the water swirled around the round porthole, I had an uncanny feeling like I was in a giant steel washing machine.

Sleeping is difficult. With just the right pillow placement, I have managed to wedge myself into my bunk. The sounds of waves crashing into the hull are far from soothing.

This evening we steamed past the moorings to check that they were still there. The anemometer on the guard buoy is dangling from a single mounting bracket—the other one must have broken off. We are hoping it lasts the night.

The forecast for tomorrow looks a little better: only gale-force winds. We can't wait any longer to get the moorings. If we don't start pulling them up soon, we might have to head home without them. And then who knows when we would be able to get our precious data?

▲ From left : A research expedition aboard R/V *Oceanus* battled high seas and rough weather off Cape Hatteras in January 2005; WHOI engineer Craig Marquette secures the door to the wet lab after recovery of a CTD (on deck); Chief Scientist Glen Gawarkiewicz relays information from the bridge to the fantail; Gawarkiewicz, Will Ostrom, and Brian Kidd (right to left) recover the Scanfish, a towed vehicle that measures temperature and salinity.

Jan. 31: Not a good day. In the darkness of early evening, one of the mooring lines got sucked into the propeller as we were retrieving it. It tore the line in half and sent the bitter end zinging back on deck. We are thankful no one was hurt.

The remainder of the mooring line appears to be wrapped around the propeller. I can hear the swish-swish of the line hitting the hull from my stateroom. We have been waiting for a break in the weather to retrieve our largest mooring. Maybe tomorrow.

Feb. 1: Successfully retrieved the large guard buoy mooring. Unfortunately, the anemometer didn't make it. King Neptune claimed it in the last storm, and with it, all of our wind data.

All the other instruments were retrieved safely, and Craig and I immediately set to downloading the data. After all this hard work, it sure is nice to see those data plots come up on my screen—phew! Almost a 100 percent return from the instruments that made it back. Chief Scientist Glen is ecstatic. We feel like we have won a battle.

Feb. 3: Finally, heading for home (just as I was getting my sea legs, too!). Despite the rough conditions, we managed to make some unique high-resolution measurements of this energetic current system—five Scanfish grids, 71 CTDs, and 11 days of moored instrument data. That data will tell an interesting tale of what goes on beneath the waves as winter storms rage overhead.

Postscript: After arriving in Woods Hole, divers cleared the sundered mooring line from *Oceanus*'s propeller. Attached to the line was a single temperature probe, which valiantly collected data all the way back to port.

Alvin's pilots

A tight-knit group with the 'right stuff'


WHOI Archives

▲ Bill Rainnie, one of the first *Alvin* pilots, stands aboard R/V *Lulu*, *Alvin*'s former tender, in the late 1960s.

Forty summers ago off the Bahamas, two men climbed inside a 23-foot white submarine named *Alvin* and drove it to a depth of 1,829 meters (6,000 feet), a dive that certified them as the first pilots of the world's deepest-diving research sub.

Bill Rainnie and Marvin McCamis never became household names the way astronauts Buzz Aldrin and Neil Armstrong would four years later when they rocketed into space. In 1969, when newspaper headlines heralded the moon landing, *The New York Times* called *Alvin* "a curiously shaped midget submarine, [that] somewhat resembles a chewed-off cigar with a helmet."

But in the four decades that followed, *Alvin* has safely transported more than 8,000 researchers on more than 4,100 dives to some of the blackest, coldest, and most remote places on Earth—to depths of 4,500 meters (14,764 feet).

While the United States has maintained a small fleet of space shuttles since 1981, *Alvin* is the country's sole research submarine capable of diving to such depths. Some 75 space shuttle pilots have flown missions, but since 1965, the job of driving *Alvin* has gone to just 34 men and one woman. Mechanically minded and adventurous, *Alvin* pilots are the ocean's equivalent of astronauts.

Their skills have allowed scientists worldwide to explore the ocean depths, map undersea volcanoes and valleys, examine previously unknown ocean life, gather water, rock, and biological samples, and see firsthand the ruined decks of the *Titanic*. They view sights that—though still on Earth—are nevertheless extraterrestrial, and they bear witness to revolutionary scientific discoveries.

Larry Shumaker, now 73 years old, was a pilot in 1977, the year scientists first identified hydrothermal vents on the seafloor near the Galápagos Islands. Their finding would change ideas about where and how life could exist.

"I felt like Alice in Wonderland," Shumaker said. "I remember the shimmering water coming from the vents and the unusual animals that humans had never seen before. Of course, now scientists have identified many of these animals (including tubeworms, white shrimp, and giant clams). But at the time it was all so weird and new."

Former pilot Tom Tengdin was amazed by the tall seafloor rock formations, called black smoker chimneys, that were discovered in 1979. Belching black, scalding, mineral-rich fluids into the ocean, the smokers transformed scientists' understanding of the Earth's crust and the ocean's chemistry.

"Video doesn't capture the black smokers," he said. "When you're down there among them, you can almost hear them roar."

Pilots are more than deep-sea bus drivers who ferry scientists from surface to seafloor. Most have engineering degrees, and their certification with the U.S. Navy includes drawing—from memory—dozens of the sub's intricate hydraulic, ballast, electrical, and mechanical components and systems. They are solid swimmers; every launch and recovery requires assistance in the water. They are all mechanics as well as pilots; if anything breaks during an expedition, there are no fix-it shops at sea.

Just maintaining the sub's electronic and mechanical components requires at least five hours of work daily. Every three months—or every 25 to 30 dives—*Alvin* undergoes maintenance and inspection. And every three to five years, *Alvin* undergoes a six-month overhaul and modernization at

to guide a submersible on the seafloor

Mark Spear, WHOI

Woods Hole Oceanographic Institution. The pilots help clean, examine, and reassemble every component of the sub.

"Not to make it sound too dramatic—because the sub is very solid—but we're constantly working hard to make sure that the sub comes back up to the surface," said pilot Anthony Tarantino.

At sea, daily chores begin before dawn, when the entire group rises to check the submersible's equipment and ensure that the batteries are charged. They test electronic gear, from radios to temperature gauges and depth-readers. They make sure *Alvin*'s cameras work and video recorders are loaded with tape. They add a total of 377 kilograms (832 pounds) in ballast weights—stacks of steel plates—to each side of the sub. These make *Alvin* heavy enough to sink to the seafloor.

Then the glory begins, when two scientists slip into the sub's 2-meter (6-foot) sphere, huddle against tiny view ports, and turn to the day's pilot who will take them to the seafloor. When the sub resurfaces in the evening, another pilot hoses corrosive salt water off *Alvin* and its components. Meanwhile, tomorrow's pilot meets with scientists to plan strategies for the next day's mission.

Piloting *Alvin* comes with modest fame. Children's books describe the team of six or seven *Alvin* pilots and pilots-in-training that accompanies the sub on each expedition. Teenagers send e-mail messages to their support ship, the research vessel *Atlantis*, asking about the two- to four-year, at-sea training process. Strangers on airplanes and parties who ask "What do you do?" grow wide-eyed at their response.

"People have two reactions," said Anthony Berry, a 26-year-old in his third year of pilot training. "They are either impressed, or they think I'm crazy. They say, 'Why would you want to go to sea for months at a time and go into the pitch black sea in a tiny sub?' "

For every 40 applications to the *Alvin* group, one person is accepted into the pilot training program, which requires worldwide travel and up to eight months a year at sea. But for all the work involved in getting into the pilot seat, piloting *Alvin* isn't a career. Some of today's pilots may not be around when *Alvin* is retired and replaced in 2009 by a new submersible, now being designed, that can dive to 21,320 feet (6,500 meters).

Most stay an average of five years before family, other job opportunities, or the lure of driving something smaller than a 15,875-kilogram (35,000-pound) submarine beckons from shore. Still, every pilot has a story of why they went to sea and what happened during their time inside *Alvin*.

▲ ***Alvin* has safely transported more than 8,000 researchers on more than 4,100 dives.**

"We've all gone through the same path, and the guys who make it are definitely solid," Tarantino said. "You're looking at a bunch of guys who rely on each other. I'd place my life in any of their hands."

—*Amy E. Nevala*

▲ "How do you prepare for dives? Ever get scared in the sub?" Current *Alvin* pilots answer these and other questions in interviews on the pages that follow. From left, Anthony Berry, Mark Spear, Patrick Hickey, Bruce Strickrott, Anthony Tarantino, and Gavin Eppard.

Gavin Eppard

Amy Nevala, WHOI

After working for a month as a telemarketer in high school, Gavin Eppard decided to avoid a career involving office cubicles. "I can't handle fluorescent lighting," said the 34-year-old Honolulu native. He went on to jobs as a dive master and graphic designer before first going to sea as an intern on R/V *Atlantis* with the Marine Advanced Technology Education Center. Several other internships at sea followed while he took technology classes at Monterey Peninsula College in California. To become WHOI's newest *Alvin* pilot in the spring of 2005, he has spent approximately eight months a year at sea since June 2001. He is the 35th person to complete pilot training for operation of the 41-year-old submersible.

How do you prepare mentally and physically for a dive?

I get a good night's sleep, then do stretches in the morning because I know I'm going to be cramped in the sub all day. Mentally, I prepare by reviewing the scientists' objectives and talking with them frequently to make sure I am totally clear on their needs.

Ever get scared in the sub?

No. We do all the maintenance, and we trust each other completely to troubleshoot any problems that may come up. I never, ever question the integrity of the sub because of the experience of the guys working on it.

What is the one thing that can make a dive truly awful?

Food poisoning. Or seasickness. That has happened a few times—not to me, but to others with me in the sub.

How do you keep in shape at sea?

If we don't watch it, it is easy out here with all the good, homemade food to become the "round" shape. I like the rowing machine on the ship because it is safer than the treadmill in heavy seas. Plus our job is physically demanding; we're climbing six flights of ladders (stairs) several times a day as we go from place to place on the ship. In ports we're often loading or offloading tons of equipment.

What questions are you most often asked about your job?

"Have you dived on *Titanic*?" (No, but I'd like to.)

"What do you do if you have to pee while diving?" (Go in a bottle.)

"Does it take long to decompress after a dive?" (We don't decompress; the atmosphere in the sub is the same as on the surface.)

Whom would you most like to invite to dive with you in *Alvin*?

The president of the United States. I would like him to see why science and exploration is important, and why funding is critical to our success.

Mark Spear

Amy Nevala, WHOI

Mark Spear grew up in Cedar Rapids, Iowa, but annual family vacations to the Florida Keys ultimately shaped his life. "By age 6, I knew I'd live and work on the ocean," Spear said. "After high school I ran across a scuba magazine advertisement promising 'high pay, travel, and adventure.' I saw my ticket out of the Midwest." After graduating from a diving school in California, he spent 10 years as a commercial diver with Oceaneering International. On one project he worked and lived for 36 days in a deep-diving saturation complex located 980 feet below the surface. He left in 1988 to earn a mechanical engineering degree from California Polytechnic State University, then went on to work for Applied Technologies. When he wasn't working, he was sea and surf kayaking near his home in San Luis Obispo.

Did your love of the outdoors influence you to become a pilot?

While I loved my job, there was something confining about working in an office. Plus I missed being at sea. I wanted to utilize my underwater experience along with my engineering experience. So one day I did an Internet job search with the key words "oceanographic and engineering." One of my first hits was the position I have now with the *Alvin* group.

What was your initial reaction to seeing *Alvin*?

I was—and still am—blown away. I was amazed with the simple yet elegant design solutions utilizing basic physics principles to deal with the incredibly deep work environment.

How far into your training were you before your first dive?

I worked with the group for eight months before I had my first pilot-in-training dive, with Expedition Leader Pat Hickey. It was October 2003 on the East Pacific Rise. At first I just got to observe, and that meant seeing what Pat was like in the sub. As many people know, he swears and yells. A lot. It's just part of how he pilots the sub, and it's a job he does extremely well. Still, I was sort of pushing myself back in the corner, cringing. Then all of a sudden he stopped swearing, looked at me, and said—really sweet— "OK, it's your turn." I was fumbling a little, and I was worried that he would start screaming. But he didn't raise his voice once, and he was very encouraging.

Is piloting the sub like driving a car?

No. A car basically goes forward and reverse on solid ground. The sub, however, goes up and down and sideways. It tilts forward and back. It rocks side to side. It spins on a dime. All this happens in a moving water column. Speed is another difference. *Alvin* only goes about 2 miles per hour, but weighs many times more than a regular car. Because of the inertia of the sub's large mass, you have to be careful not to run it into cliffs and other deep-sea features.

Bruce Strickrott


Amy Nevala, WHOI

Bruce Strickrott, who hails from Maryland and New York, earned his sea legs in the U.S. Navy. After joining at age 20, he participated in the Gulf War, where he operated radars, monitored surface-to-air missile defense, and provided anti-aircraft warfare support on a naval vessel. After six years, he went back to college for a degree in ocean engineering from Florida Atlantic University. During his job search, he found WHOI's Internet advertisement seeking *Alvin* pilots. "When I went to Woods Hole for the interview, I saw the research vessel *Atlantis II* there. Then I saw *Alvin*. And at that moment I said, 'Man, I want this job.' "

Have you ever been scared in the sub?

Every once in a while I'll jump or get startled, like when the sub bumps into something. Otherwise, we do everything possible to keep us out of dicey situations.

What three skills must every *Alvin* pilot possess?

Attention to detail is probably the most important skill. Piloting the sub is about moving up and down safely, dealing with atmospheric pressure in the sub, doing science, checking systems, making sure data are being collected properly. With all that to do, the second skill is keeping your wits about you, staying calm, and making decisions in a logical way. The third? Keeping a sense of humor. Of course, the technical skills are obvious, but without humor down there, we're doomed.

Of the 35 people who have piloted *Alvin*, only one has been a woman. Few have been minorities; there has never been a black *Alvin* pilot. Why do you think there aren't more women and minority pilots?

I don't think it's a hiring philosophy; we have had minorities. I think it's a reflection of a larger problem of not having enough women and minorities in science and engineering fields.

What do you do when you are not on the ship?

We usually get 10 days to three months off at a time for vacation. In the winter I ski as much as possible. Otherwise I do normal things that people do. I go to weddings, visit family, and spend time at the office in Woods Hole.

What person, dead or alive, would you most like to invite on a dive in *Alvin*?

Jules Verne (author of *Twenty Thousand Leagues Under the Sea*). Tell me he wouldn't get the biggest kick out of it.

Patrick Hickey


Christopher Knight

Patrick Hickey has spent more time under water—at least 175 days of cumulative dive time—than most astronauts have spent in space. On May 23, 2003, he made his 500th *Alvin* dive to the seafloor, becoming the second pilot to make that many dives in the four decades of the sub's operation. Hickey, who grew up in Calgary, Canada, never thought he would stick around long enough to see the day. "I started with WHOI as a break from my career as a submersible pilot, remotely operated vehicle operator, and occasional commercial diver in the oil and gas industry," he said. He's since extended that sabbatical indefinitely. He joined the *Alvin* group in 1987 and expects to pilot his 600th dive in 2006.

Does it get boring to go to the seafloor, after so many dives?

In areas that I have visited many times, it can get monotonous. For me it's like making the same drive to and from work each day. But there are still vent fields I find very interesting. My favorite part is when we run across something really unusual. Once off the coast of California near a military base we found test torpedoes on the seafloor.

Do you have advice for people interested in becoming a pilot?

Electrical and mechanical experience is essential; so is learning principles of physics, mechanics, acoustics, and electronics. Having a science background helps, too; I have benefited from knowing about marine geology, chemistry, and biology.

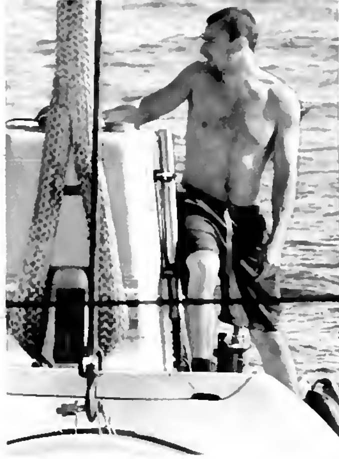
The sphere in *Alvin* is close quarters that can make for an intense experience. Does that spur close or strange relationships with the two observers?

For the most part we all get along well in the sub, but it can trigger some strange relationships. There are times when close quarters have definitely preyed on pilots' nerves, especially where hygiene is concerned. We have been ready to dive and have had to ask people to go take a shower.

***Alvin*, now 41 years old, will be replaced in 2009 with a new, deeper-diving vehicle capable of reaching more than 99 percent of the seafloor. What do you look forward to about the new sub?**

The increased visibility. The basic vehicle components won't change, but we'll have better fields of view. They are adding two more side view ports, for a total of five view ports. That means no matter where you look you'll be able to see most of what is surrounding the sub. The total size inside the sphere is going to increase by about 4 inches, which may not sound like much, but it will actually increase the sphere by 30 percent. It will increase in size from 5 feet, 8 inches to 6 feet, 2 inches. That's good news for our taller pilots.

Anthony Berry


Amy Nevala, WHOI

"My mom got me the job," Anthony Berry said of the first summer he spent volunteering in a chemistry lab at WHOI, where his mother worked. Summer after summer through high school and college, he returned to WHOI labs, combing through mud samples, learning how to build underwater vehicles, and helping to rewire *Alvin* during a maintenance overhaul. After earning an electrical engineering degree in 2001 from Worcester Polytechnic Institute in Massachusetts and searching for a job that was "cool, different, and adventurous," he joined the pilot training program. Now 25, he is the program's youngest pilot-in-training. "The ideal pilot has an engineering degree and a few years of experience outside WHOI," Berry said. "I think it helped my application that I had been hanging around the place since I was 16."

What did your mom say about you becoming the pilot of a submersible, a job requiring you to go to sea for eight months a year?

She was supportive of the job. It was the ship that worried her. She said, "You're going to work on *Atlantis*? You're going to get so seasick!" She had been on the ship once and had spent the entire week sick in her bunk. She hasn't been back on the ship since. Fortunately, I don't get seasick very often.

You've had about 15 dives in *Alvin* as you train to become a pilot. What has been your favorite experience in the sub?

It actually involves swimming during an *Alvin* recovery. We were in a tropical location, I forget where, but it was warm and raining so hard that it hurt. The ocean was glass smooth except for the drops hitting the surface. In the middle of this, I'm swimming around the sub, and a pod of pilot whales emerges. I was so close I could reach out and touch them.

If you weren't doing this, what would you do?

Drive a bulldozer. But I like helping the scientists understand the oceans. So the bulldozer dream is a distant second.

—*Amy E. Nevala*

Pilots have stayed with the *Alvin* group an average of five years before moving on to write books, start engineering companies, design and operate deep-sea instruments, fly planes, act in Shakespearean plays, build homes, and become parents. Read about the lives of 12 former pilots, including a 73-year-old who recalls that his first dive made him feel "like Alice in Wonderland."
Visit oceanusmag.whoi.edu/v44n2/former.html.

Becoming an *Alvin* pilot:

Like many boys who spend their youth throwing baseballs in Massachusetts parks, Anthony Tarantino dreamed of playing for the Red Sox. When not pitching, he liked to take apart his toys and put them back together, which ultimately led to a career in engineering. After graduating from Wentworth Institute of Technology in Boston, he worked for seven years at two engineering firms. In 1999 he went to Hawaii for a snorkeling and scuba vacation. "There were all sorts of interesting things in the water," he said. "I remember thinking on the flight home, 'Gee, it would be kind of interesting to do something where I would see some cool stuff in the water.' Being from Massachusetts, I knew a little bit about *Alvin*. As a shot in the dark, I pulled up WHOI's Web page, saw a job ad, looked at the skills they were looking for, and said, 'I can do all that stuff.' "

Tell us about the *Alvin* pilot training program. What skills do you need?

It helps if you have an engineering background, because the sub is very complex. You start off as an *Alvin* technician, and your job is basically to help out and do as much as you can. In the meantime, you're looking and listening, gathering as much information as possible, and trying to learn about how the day-to-day operations go, as well as what makes the sub work. The first couple of months you're here, you're feeling it out.

What do you mean by "you're feeling it out"?

The lifestyle. This job has a few unusual features. Being out here for eight months of the year. Dealing with the fact that the people you work with are the people you live with and the people you play with is another big factor. Being away from your family for so long. I don't have a house or an apartment. I have my stuff in my sister's house in boxes. When I'm on vacation, I'm either traveling or bumming a room in my sister's house, or even my parents' house. So it's a nomadic lifestyle. None of us is married. It can be very difficult to hold a relationship.

Assuming you like the lifestyle, what happens next?

Well, while you're trying to decide whether you fit into the program, the *Alvin* group is doing the same thing with you. If you've proven yourself, one day they come up to you, and they say, "We've talked about it, and we think you're ready. You're a PIT now."

A PIT?

Pilot-in-training. Every fifth dive, there's a pilot-in-training dive. A PIT will go down with a pilot and one observer. We accomplish the day's science mission, and at the same time, train our pilots. There's no simulator for *Alvin*. There's really no other way to learn. I made 16 PIT dives before I made it to pilot. Some people have more.

Anthony Tarantino

Amy Nevala, WHOI

What are the next steps?

There's a checklist of systems on *Alvin* that you have to learn. There are probably 200 electrical, electronic, and mechanical systems—from the system that scrubs out carbon dioxide from the air in the sphere to the variable ballast (VB) system that allows you to control the sub's buoyancy. You have to be able to draw a mechanical diagram of each system and know it thoroughly. Then you have to go in front of a pilot and display your knowledge of each system—how it works, why it works, and how to maintain it. Once you've completed all the systems, you begin the process.

The process is just beginning?

The process includes four oral examinations. The first one is with three to five scientists who ask you about safety and about your ability to complete scientific dive objectives. After that, you have a review board with all the *Alvin* pilots on board. You stand in front of a whiteboard, and everyone else sits around the table asking you questions. They'll say, "OK, draw the VB system." You draw it out, and then they start asking you all sorts of questions about it. I think I was in there two days, for four to five hours at a time. That was tough.

And then?

After that, there are two more reviews. They send you back to Woods Hole, and you have the same type of oral examination with the deep-submergence engineers back at the office. These are the guys who know all the technical bits about the sub that you might deal with on a daily basis. They expect you to have dug into them and know them. They just grill you. These guys have been around for years. They know the history of *Alvin*, and they expect you to know that, too. They'll ask questions like "Why is this *Alvin* system the way it is?"

Once you get past that, you still have one more hurdle to jump?

You have to go before a Navy review board. You get sent to the Navy's deep-submergence facility in San Diego and sit down in front of an admiral and a group of submarine captains, and they grill you on a bunch of situations. Once you get past them, you're blessed, and you get to dive. You've earned your Navy deep-submergence dolphin (an insignia pin), and you've made it. You do your first solo dive, and it's fantastic, and you get out of the sub, and the guys dump a bunch of goop on you. It's sort of a traditional initiation rite.

Is there a big celebration?

When you get into port after the cruise is done, it's traditional for the new pilot to throw a party for everyone on board. I did mine in Manzanillo, Mexico, and it was a load of fun. You get roasted by the guys, and they give you gag gifts.

—Lonny Lippsett

Amy Nevala, WHOI

▲ **The WHOI-operated research vessel *Atlantis* serves as support vessel for *Alvin* operations. During each recovery, two certified swimmers help bring the submersible back to the ship.**

Shichun Huang, MIT

Cartwheeling grad student earns Panteleyev award

Margaret Boettcher knows a fast stress reliever: turn upside down. "Handstands and cartwheels make people happy," said Boettcher, who has taught fellow WHOI graduate students and postdoctoral researchers her relaxation methods—even on geology field trips to volcanoes.

Her contributions (cartwheeling and otherwise) to graduate student life were recognized this spring when she received the Panteleyev Award, given annually to a graduating student in the MIT/WHOI Joint Program who best exemplifies the commitment to improving the graduate education experience at Woods Hole Oceanographic Institution.

"She has always been helpful to other students, taking the time to explain whatever questions came her way about research, problem sets, and the finer points of doing a cartwheel," wrote one student in a letter nominating Boettcher.

The award is named for George P. Panteleyev, a graduate student who in 1995 was swept overboard and lost in an accident on a research cruise on the Ob River in Siberia.

Boettcher, 29, received the award at a reception for graduates June 1 in Woods Hole. She continues her research at WHOI as a postdoctoral investigator working with Associate Scientist Greg Hirth in the Department of Geology and Geophysics. She studies the frictional behavior of ocean faults where earthquakes occur.

Joyce, Evans give testimony on oceans to Congress

WHOI scientists Rob Evans and Terry Joyce testified June 8 before the House Subcommittee on Fisheries and Oceans, chaired by Wayne Gilchrest (R-Md.) in a continuing effort to help educate the U.S. House of Representatives on the oceans.

"While many understand that the ocean supports diverse marine species," said Rep. Gilchrest in his opening statement, "it may not be as obvious how the Earth's climate is affected by ocean circulation patterns or, in turn, ocean circulation is affected by the geology of the ocean floor. Everything in this 'terrarium' is ultimately intertwined.... This subcommittee is doing its part to promote oceans today by highlighting ocean science."

Jayne Doucette, WHOI

▲ Shoveling and splashing toward a finish line ringed with spectators in Woods Hole, WHOI employees and students revived a tradition this summer: the Anything-But-A-Boat Regatta, which was first run to celebrate WHOI's 50th year in 1980. "The rules are simple," according to a 1980 WHOI newsletter: "no commercial boats, no commercial boat power, no boats over 20 feet, no boats." Twelve "unboats" with goofy names and dubious engineering took part. One named "Watergate" was made with a stockade fence atop blocks of foam. The fellow who delivers water cooler refills to WHOI remarked on a sudden temporary dearth of empty bottles that week. The teams vied for prizes, including the coveted "Rubber Ducky" award for the first-place finisher and the "Finding Nemo" award for unboats that "just didn't float."

Photo Op

▲ Terry Joyce (left) and Rob Evans testify before Congress.

Evans, an associate scientist in the Department of Geology and Geophysics, and Joyce, a physical oceanographer and director of the WHOI Ocean and Climate Change Institute, each presented highlights of their fields and left behind written testimony.

Evans described interactions between the seafloor and oceans, from the deep sea to the coastal ocean. He covered tsunamis; the effects of sea level rise and other processes on shoreline erosion; and seafloor features from mid-ocean ridges and seamounts and their distinctive biological communities to deep-sea vents and their unique interplay of geologic, chemical, and biological processes. He also mentioned methane hydrates—a vast potential energy resource on the continental shelf—and other marine economic resources.

Joyce highlighted ocean-atmospheric oscillations in the Pacific and Atlantic Oceans and their far-reaching effects on weather patterns and fisheries; the roles of the Gulf Stream and the global ocean circulation system in long-term and abrupt climate change; and the ocean's role in hurricanes.

The WHOI scientists joined five other scientists in giving testimony on topics that included marine mammal research, harmful algal blooms, and the structure and function of marine ecosystems. The audience included congressional staffers, members of other federal agencies, the public, and the media.

"This was a basic fact-finding hearing," said Terry Schaff, WHOI director of government relations. "Our participation not only demonstrates our leadership in these areas, we hope the session also leaves members and staffers better-educated about the oceans."

Read the testimony at: resourcescommittee.house.gov/archives/109/fcwo/060805.htm.

Anderson addresses UN ocean commission

Senior Scientist Don Anderson of the WHOI Biology Department was invited to deliver the Bruun Memorial Lecture in June at the 23rd annual meeting of the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Social, and Cultural Organization (UNESCO).

The keynote lecture is named for noted Danish oceanographer Anton Frederick Bruun, the first chairman of the IOC. The lectures address important developments in solid Earth studies, physical and chemical oceanography, meteorology, and marine biology.

In his lecture at UNESCO House in Paris, Anderson spoke about the ecology and oceanography of harmful algal blooms (popularly known as "red tides"), as well as interdisciplinary approaches to their research and management.

MIT/WHOI Joint Program alumna Laura Kong, director of the International Tsunami Information Center, presented the N.K. Panikkar Memorial Lecture 2005 on a "people-centred tsunami warning system and the challenge of building preparedness."

Heidi Sosik

Building an automated underwater microscope

Heidi Sosik studies marine phytoplankton—the community of microscopic plants that essentially make all the food for all the ocean. Like an anthropologist documenting an undiscovered society, Sosik wants to learn everything she can about the living things in her community—their seasonal activities, nomadic habits, and nutrition. She is also part engineer, building and tinkering with gadgets that promise to bring the microscopic world of phytoplankton into focus.

Sosik is the first scientist to receive a joint fellowship from two WHOI Ocean Institutes, the Coastal Ocean Institute and the Ocean Life Institute. This summer and fall, she and colleagues are testing a new instrument, the Imaging FlowCytobot, at the WHOI Martha's Vineyard Coastal Observatory (MVCO).

Very few people are aware that the majority of the world's plants live in the ocean. Why are they so important?

Phytoplankton are like the grass and trees of the ocean. They're just as important to the planet as land plants, but basically invisible—unless you go looking for them with tools and technologies such as the ones I use. It's easy to forget that they're there, but it would be a disaster for us if we forgot, and thus neglected to take care of the ocean—a huge portion of the planet.

The water over the continental shelf harbors an entire ecosystem. Phytoplankton are plant-like cells that feed larger plankton organisms and the offspring of larger animals. And this begins a web of interactions from plankton to the fish, whales, and birds that feed on them.

What we're after is a better understanding of what factors in the environment determine where and when different kinds of phytoplankton grow and bloom.

What are some of those ecologically important factors?

Phytoplankton are photosynthetic, so they need sunlight to make organic matter. And they need nutrients, essentially fertilizer. All the compounds that you read on the side of your breakfast cereal box—iron, vitamins, and nitrogen—phytoplankton need those things, too.

Typically, nutrients are concentrated in the deep waters of the ocean. But a variety of ocean circulation patterns causes water masses to well up from deeper regions. These processes bring deep waters, along with nutrients, into the shelf region at different times of the year. It's an absolutely natural fertilization process that's critical for the ecosystem.

The ecosystem also recycles: Phytoplankton are eaten by other organisms that produce waste that contains nutrients, and those become available again for the phytoplankton—much as manure fertilizes a garden.

Some areas of the coastal ocean have been exposed to too many nutrients—which run off from septic systems, lawns, and agriculture, or which are deposited in rain because we put nitrogen into the air. This overnutrition causes the problem of eutrophication, in which rampant algal growth depletes oxygen levels in the water.

What has prevented you from obtaining a clear picture of this dynamic ecosystem?

Answers have eluded us because we had to go out in boats, take single water samples, look at them through the microscope, and meticulously identify each cell—and then you have just *one* sample. The show-stopper was not having continuous observations of ongoing changes.

What's really exciting about our new technology is that we can now watch and record the community changing along with the environment, at the same time, in a natural system. There's still a big puzzle to tease out, because many factors contribute to the changes we see. Now, we can get this fabulous information we need to solve the puzzle.

How do these instruments work?

For many years, my lab group has collaborated closely with Rob Olson's group at WHOI to develop a submersible instrument we call the FlowCytobot to count and identify tiny phytoplankton in the water. It's a laser-based system that "sees" single cells—on the basis of red light that the chlorophyll in phytoplankton emits when it's exposed to blue or green light. FlowCytobot has been operating almost continuously at the Martha's Vineyard Coastal Observatory since 2003, and it works great. But we discovered toward the end of 2003 that we had a big problem.

Phytoplankton are diverse, from species too small to see with microscopes to others visible to the eye. We designed the FlowCytobot specifically to look at the smallest phytoplankton out there. But the mixture of plankton species changes during the year. By fall, the ecosystem is dominated by phytoplankton called diatoms, many of which were too big for our instrument to measure.

These population changes are as dramatic as succession on land, where over decades marsh changes to grassland and then to forest. In plankton communities, such dramatic succession happens every year over a few months. It's critical that we understand what causes these shifts, because if something changes so that the winter diatom blooms don't occur, for example, that could have serious implications for the rest of the ecosystem.

So could you adjust FlowCytobot to also identify diatoms?

It turns out that it's not possible to make one instrument that does a good job measuring both the smallest and largest phytoplankton. For diatoms, we needed a way to count cells in larger volumes of water and to take pictures through a microscope, along with the red fluorescence measurements.

We were experimenting with this dual ability in the lab, and colleagues would ask when we were going to build it into a submersible instrument. But it requires so much power, and generates so much data, we at first didn't think we could put it under water. The idea that you could have an autonomous underwater microscope, and actually run it continuously—we just laughed. But after our experience working at MVCO, it occurred to us that it wasn't that far-fetched. We had had success with the first FlowCytobot, and we knew we had power available. Within a year, we came around to realizing we could do this.

So now there are two instruments, and they work together. The original FlowCytobot counts and measures fluorescence of small cells; then the Imaging FlowCytobot does the same thing for large diatoms, and also takes microscope photographs for identification.

How did you solve the power and data problems?

There's no doubt in my mind that we wouldn't have gone down the path of building the imager if we didn't have the Martha's Vineyard Coastal Observatory. We can plug our instrument into its seafloor node, which is cabled to shore. The cables provide essentially unlimited, continuous power- and data-transmission capabilities.

FlowCytobot and Imaging FlowCytobot at MVCO will let us look at the entire community from the smallest cells to the largest. If everything works—and we're crossing our fingers!—we should get data that capture this dramatic shift from the late-summer, small-cell "field of grasses" to this bloom of large organisms in the fall—the "trees." It will be really interesting to see how that shapes up.

Over the next 10 to 20 years, we envision employing instruments for continuous, long-term monitoring of plankton, nutrients, and oceanographic conditions at a network of several coastal observatories spanning the U.S. East Coast. Then, scientists from many oceanographic disciplines—biology, physical oceanography, and chemistry— can begin to piece together the bigger picture, over time and space. We'll be able to see the effects of climate change on the ecosystem, for example, or how changes in one region affect other coastal areas.

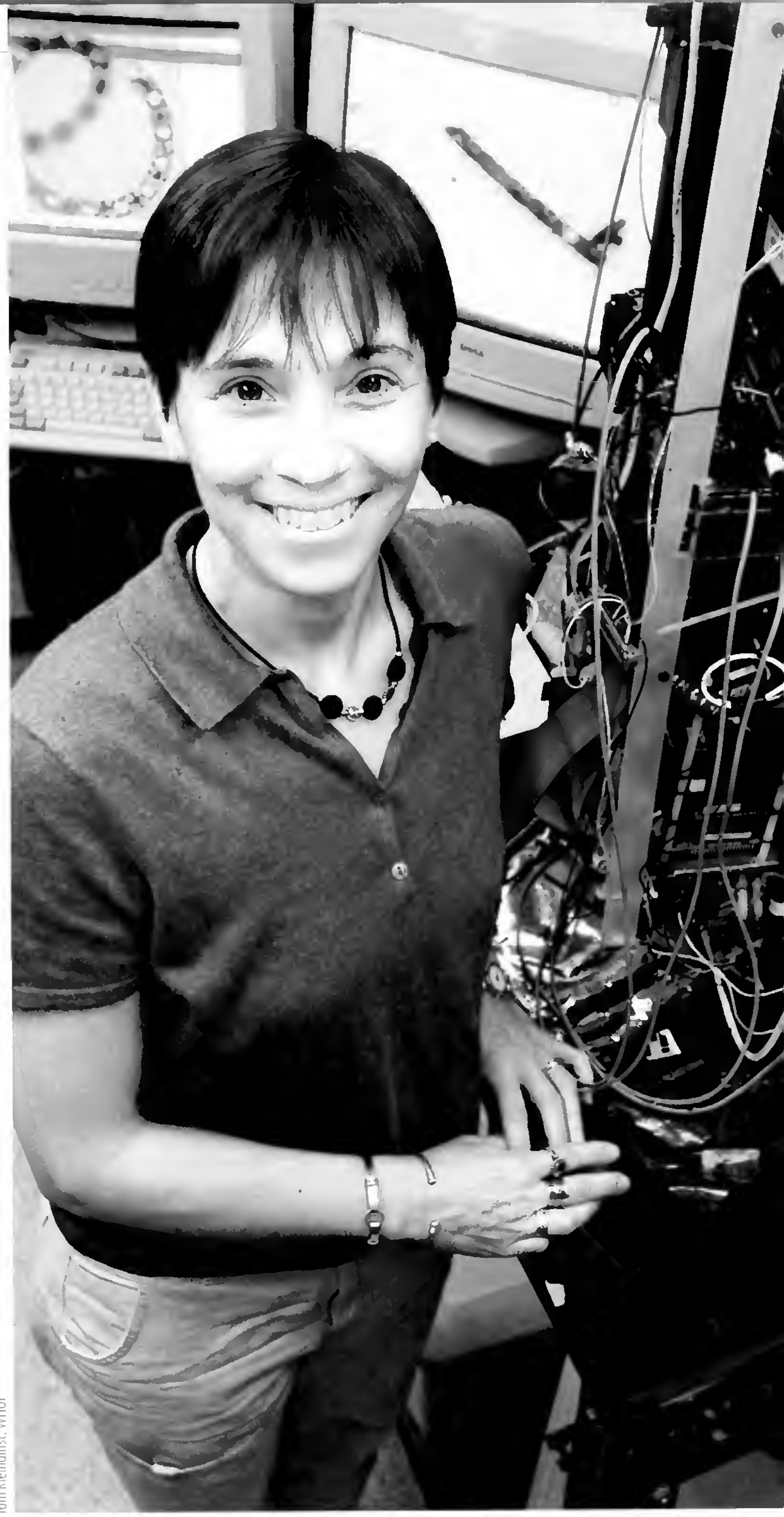
We've been surprised at how difficult it has been to get federal funding for instrument-development work, but support from the WHOI Coastal Ocean Institute and the WHOI Access to the Sea program is helping us install our instruments at MVCO this summer. We think that a successful proof-of-concept deployment will make us poised to be competitive to solicit future funding from national agencies.

What sorts of applications might this research have?

We are very interested in the basic question of what regulates phytoplankton communities. For example, the timing and occurrence of the winter plankton blooms are very important for other species that rely on them as a food source—fish and invertebrates. If the bloom fails one winter, then you may get low survival of fish. We're all hopeful that, down the road, the kind of basic information we are collecting will allow us to do a better job of managing fisheries and other coastal resources.

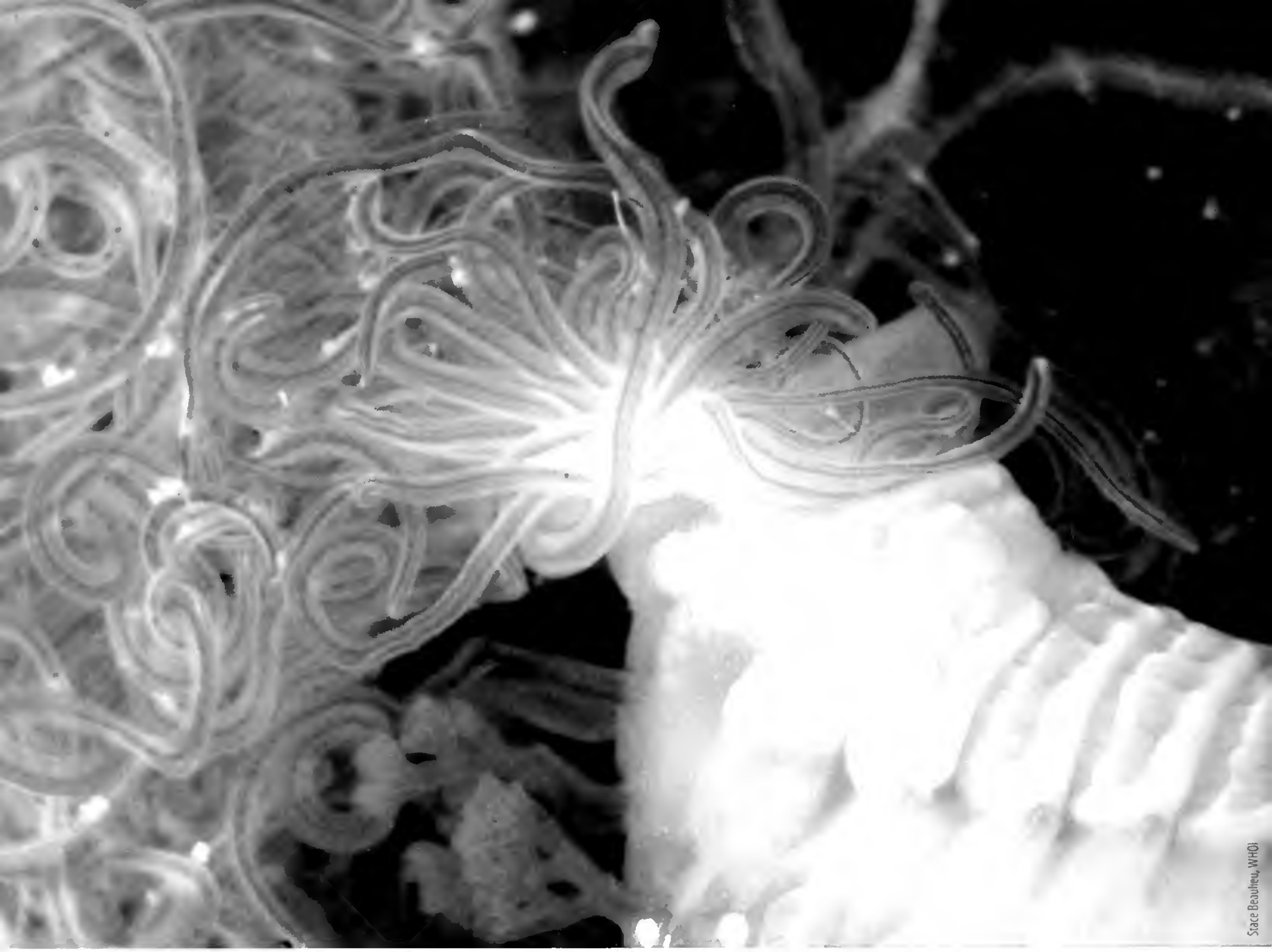
First, we need to have a better understanding of the ecosystem's natural variations. Only then will we be able to be smarter about how to manage human activities in the coastal ocean.

—*Kate Madin*



Tom Kleindinst, WHOI

"If we want the tools to look at these organisms, we have to invent and build them ourselves. You can't buy them anywhere."



▲ Under a microscope, a deep-sea worm's tentacles—used for feeding—look like cooked spaghetti. WHOI scientists found this worm, called a terebellid, living at hydrothermal vents on the Galápagos Rift off Ecuador. The researchers conducted experiments to learn why the larvae of deep-sea animals settle in certain places on the seafloor. Read more on page 18.

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