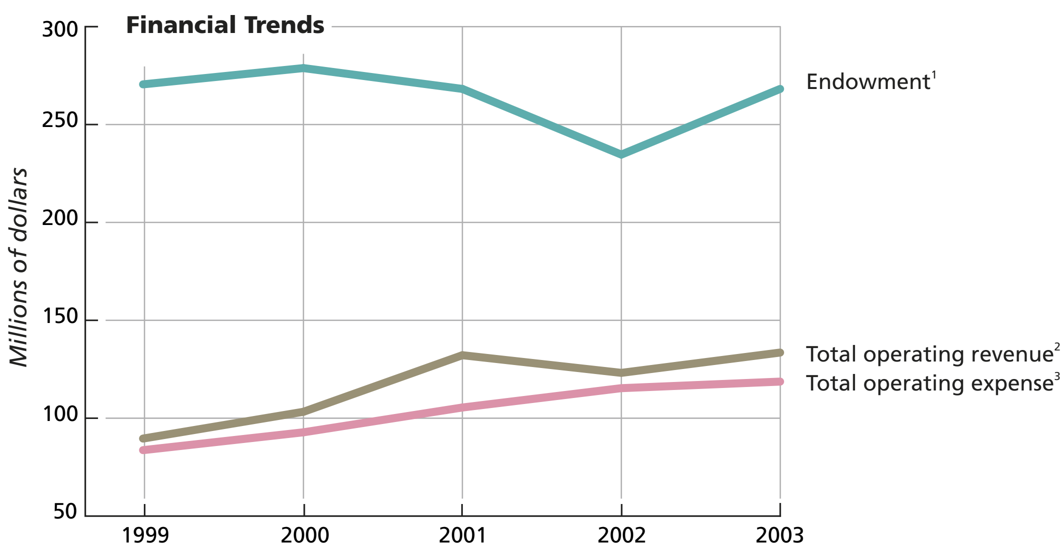
Woods Hole Oceanographic Institution

2003 Annual Report

WHOI at a Glance

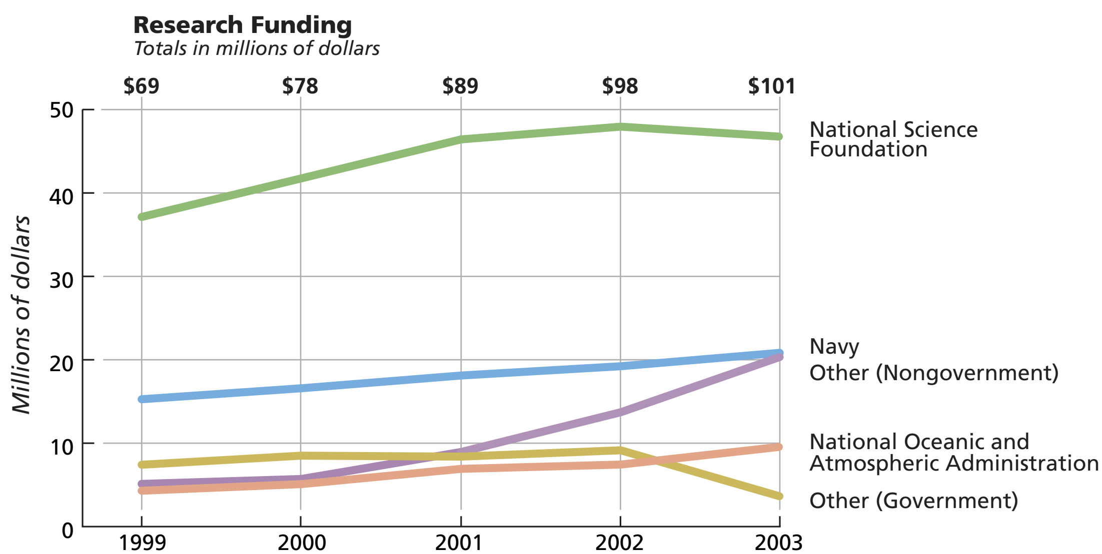


Following a slow rebound of the economy, our endowment returns increased in 2003, and were in line with our benchmarks. Our 2003 endowment total return was 21.8 percent. Revenues and expenses were in line, buoyed by $23.9 million in gifts, grants, and pledges from private sources.

[1] Endowment comprises cash and securities to provide income for maintenance of the organization. Market value is as of December 31.

[2] Total operating revenue is total funding of the Institution's research and education programs, including a component of endowment income appropriated for operations during the financial year ending December 31. See Financial Statements, Note 2, page 48.

[3] Total operating expenses are costs incurred in support of research, education, and operations during the financial year ending December 31. See Financial Statements, Note 2, page 48.



Research funding rose slightly from $98 million in 2002 to $101 million in 2003, driven mainly by growth in Other (Nongovernment) and National Oceanic and Atmospheric Administration funding.

WOODS HOLE OCEANOGRAPHIC INSTITUTION is a private, nonprofit marine research and engineering, and higher education organization. Its mission is to understand the oceans and their interaction with the Earth as a whole, and to communicate a basic understanding of the ocean's role in the changing global environment. Established in 1930 on a recommendation from the National Academy of Sciences, the Institution is organized into five scientific departments, interdisciplinary research institutes and a marine policy center, and conducts a joint graduate education program with the Massachusetts Institute of Technology.


Paul Fucile


Craig N. McLean, NOAA

FRONT COVER: *An autonomous glider during a deep-water field trial in the Bahamas, with Princeton University graduate student Josh Graver. In the summer of 2003, Associate Scientist Dave Fratantoni and Research Associate John Lund used a fleet of 12 such gliders in Monterey Bay, California, to measure the physical and biological response to coastal upwelling with collaborators from Princeton University, Scripps Institution of Oceanography, California Institute of Technology, Harvard University, Monterey Bay Aquarium Research Institute, and the Naval Postgraduate School.*

BACK COVER: *Senior Scientist Susan Humphris, a geochemist in the Geology and Geophysics Department, gets a last glimpse of daylight through a viewport in* Alvin, *as the submersible is lowered to begin an eight-hour dive on the Galápagos Rift.*

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Letter from Robert B. Gagosian, President and Director


Elsa Ruiz

From left, Bob Gagosian with Jim Moltz, Chairman of the Board of Trustees, and Jim Clark, Chairman of the Corporation.

In a year when many universities and research institutions made painful cuts in programs, capital investments and personnel, our strong balance sheet has allowed us to continue to focus on the future.

This future presents some new challenges. Although we continue to secure a significant share of government funds for at-sea science—a testament to the diligence and quality of our investigators, researchers, and students—federal funding itself is increasingly in question. Programs at the National Science Foundation (NSF) that support most at-sea research have not increased significantly above inflation. Budget increases for the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Navy, which together supported about a quarter of our work, have not translated into increased support for at-sea work.

Our endowment, which declined from $268 million in 2001 to $235 million in 2002, rebounded to $269 million. We are pleased with this turnaround and are poised to take advantage of any economic recovery that may be underway.

As the saying goes, the future is not what it used to be. We have entered a period when we need more than just innovation in science, engineering, and education. To secure our future, we need to be innovative in all of our activities.

A Changing Financial Landscape

Like most organizations, we are working to control spiraling pension and health care costs. Meanwhile, we expect government-sponsored research budgets to come under increasing pressure. For a number of years we have not relied on the government as the sole patron of science. Although only 7.4 percent of our sponsored research is from private sources, this is critical seed money for high-risk/high-reward science. This percentage is one of my highest priorities for the near future. We certainly don't expect—or want—government-sponsored research to decrease. But greater diversity in our sources of income will mean better assurance of our security and independence of action. This is our financial objective.

New Infrastructure, New Strategies

For this reason, we are undertaking a major fund-raising effort, to build on the $100 million in private funds we raised over the past four years. In January 2000, we identified initiatives of $247 million, including funds for the four Ocean Institutes, a new coastal research vessel, and campus improvements. New laboratories are needed to alleviate crowding of our investigators and students, better accommodate new technologies, and foster teamwork across disciplines. In short, to remain competitive, our researchers need the best possible facilities. Our effort is focused on two new laboratories totaling 80,000 square feet on the Quissett Campus—one for marine biology research and one for the emerging interdisciplinary field called biogeochemistry.

I want to emphasize that our fund raising efforts are focused on growth in the quality of what we do, not the quantity. I expect the Institution's population to remain stable at about 1,000 people, with about 1,000 science and engineering projects underway at any moment. For the foreseeable future, we will operate three blue-water vessels, a new coastal vessel arriving in April 2004, and a suite of vehicles in the National Deep Submergence Facility at WHOI. It is clear, however, that new technologies in ocean sensors, data telemetry, and data processing make this a time to examine how we will study the ocean in the next 10 years—whether from ships, robotic vehicles, or permanent observatories.

To this end, in 2003 Bob Detrick, chair of the Geology and Geophysics Department, began a major exercise to develop a 10-year plan for what we call Access to the Sea.

While oceanographers will always go to sea in ships, advances in submerged vehicle technology, including human-occupied vehicles (HOVs), remotely operated vehicles (ROVs) and, most recently, autonomous underwater vehicles (AUVs), permit unprecedented access to the oceans and the deep seafloor. Perhaps most significantly, we are on the threshold of the first large-scale deployment of ocean observatories which will allow us to observe natural- and human-induced change in the oceans on the scale of decades or longer. Advances in sensors, battery technology, and data telemetry mean we will soon be able to collect data anytime, anywhere on Earth. The Access to the Sea report, due in June 2004, will provide a road map to guide our seagoing science in the next decade and to identify the resources we will need to get there.

Raising Public Awareness and Private Funds

An immediate need of our federal sponsors and our private funders is for better communication about our work and its value. A catalyst for this communication continues to be our Ocean Institutes.

In 2003, the Ocean Institutes hit their stride in their third year of operation as a means of raising public awareness of WHOI as a scientific leader and are gaining momentum as tools to raise private funds. In 2003, funding support of $2.8 million was awarded to the Institutes to support 60 WHOI investigators and students. In October, an Ocean Life Institute forum on conserving the highly endangered North Atlantic right whale drew more than 90 scientific contributors and participants from 23 institutions. We are now seeking private funding for investigations to determine how this species might be saved from extinction.

Reinforcing Our Leadership

Also in 2003, we developed a communications plan that more tightly aligns our communications efforts with key Institution strategies. In the coming year, we will give greater emphasis to the Web as a major outreach tool, increasing the richness of our Web site's content and functionalities.

Activities in the three themes I have mentioned—the need for greater private funding, a plan for how we will study the sea in the coming decade, and ramping up communication about our work—are taking place against a backdrop of tremendous technical change in science and engineering.

Dr. Rita Colwell, the director of NSF, summed it up when she wrote: "New scientific capabilities, enhanced by molecular biology, genomics, information and communications technologies, and nanoscience and engineering are opening new paths to understanding the dynamics and complexity of ocean systems at all levels—from the nano- to the planetary."

The science features in this report explore our work along the continuum of nano- to planetary—from single-cell organisms to entire ocean basins.

The breadth of our investigations is matched only by the breadth in skills, knowledge, and enterprise of our researchers and students. I am confident that the progress we make in 2004 toward our financial and scientific objectives will reinforce the vigor and originality of our leadership.

Letter from James R. Luyten, Executive Vice President and Director of Research

Elsa Ruiz

Jim Luyten (left) with Honorary Trustee Dick Mintz.

Despite essentially flat federal funding of ocean and earth sciences, the Institution achieved modest growth in federal support in 2003. Our investigators continued to be extremely competitive, writing more than 750 proposals to federal agencies, foundations, and other funding sources.

While the overall picture is positive, pressure on our scientists and engineers to secure adequate support for their work is intense. Growth in federal support for ocean sciences has barely kept pace with inflation, let alone covered the growing cost of increasingly sophisticated instrumentation. As a consequence, funds allocated for the true costs of research have gradually diminished, particularly for the analysis and publication phase of the work. Private funds have helped enormously in supporting the synthesis of diverse sets of observations and in allowing investigators to think broadly about new areas of research. We hope federal support will not be eroded further, and are redoubling our efforts to increase private revenue sources.

As I noted in my letter in 2002, litigation concerning emission of sound in the ocean and its effect on marine mammals continues to have a chilling effect on the very science that aims to understand how sound affects marine mammals. This is a concern for all oceanographic research institutions, since it has already impacted a number of cruises for marine mammal and geophysical studies.

On the larger issue of federal support for basic science, Congress has been outspoken in support of doubling the National Science Foundation (NSF) budget. There has been no complementary support from the Executive Branch, however, and little opportunity to secure the necessary additional funds within the current financial constraints. We expect a small increase in the overall 2004 NSF budget, but little or no increase in 2005. What this will mean for ocean science is unknown. There are several major initiatives for the ocean sciences—the International Ocean Drilling Program, the Ocean Observatories Initiative, and the Oceanographic Fleet Renewal—but each year these get delayed another year as other programs take precedence.

We have been fortunate over the past several years to have consistent and knowledgeable leadership at NSF with Director Rita Colwell, Assistant Director for Geosciences Margaret Leinen, and Director of Ocean Sciences Jim Yoder. All three are recognized ocean scientists, and have been articulate champions for opportunities and exciting developments in the ocean sciences. Both Rita and Jim have announced their intentions to rotate out of NSF in 2004. We are hoping Margaret will stay and that whoever replaces Jim and Rita will share their passion for American leadership in oceanography.

Tools for Seagoing Science

Two major reports were completed in 2003 by the Ocean Studies Board (OSB) of the National Research Council, part of the National Academy of Sciences. Bob Detrick, chair of the Geology and Geophysics Department, chaired the OSB planning study for ocean observatories, a major NSF initiative. Observatories comprise a diverse suite of fixed and floating instruments placed in the oceans to en-

Ellenzweig Associates

Architect's rendering of the Biogeochemistry Laboratory (left) and the Marine Research Facility on the Quissett Campus, which will increase space for science by 30 percent.

able nearly continuous measurement of ocean conditions. (Our Martha's Vineyard Coastal Observatory is a prototype coastal ocean observatory. See page 25). The report strongly affirmed the importance of ocean observatories to the future of scientific objectives and opportunities in ocean sciences, and gave strong scientific and technical support to the NSF Ocean Observatories Initiative.

The OSB also reported on future needs for the nation's deep submergence vehicles and technology. This report acknowledged WHOI's leadership in deep submergence technology and urged the NSF to support replacement of the deep submergence research vehicle *Alvin*.

Launched in 1964, *Alvin* has been the preeminent human-occupied submersible for 40 years. Despite continual upgrades, *Alvin* has reached the end of its useful life and a new submersible will enhance our nation's ability to dive deeper and faster, carry greater payloads, and accommodate more modern research techniques and technologies. This is good news and we are pursuing next steps with the NSF. In addition, the Institution won federal support to design and build the next-generation robotic vehicle capable of going to the deepest depths of the ocean, the Mariana Trench, which, at just under 37,000 feet (11,000 meters), is deeper than Mt. Everest is high. This new vehicle, scheduled for prototype testing in 2005, will be a hybrid of a fully autonomous vehicle, like our Autonomous Benthic Explorer and our tethered, remotely controlled vehicle *Jason II*.

Improvements Ashore

We also made progress this year in improving our shore facilities. Recovery from a fire in a laboratory on the first floor of the Clark Laboratory continues. Most of the laboratories are back in use and replacements for damaged equipment have been installed and are operating. Repair and refurbishment of the instrument most affected by the fire, the ion microprobe, are underway. We expect the equipment to be fully operational in 18 to 24 months.

Plans for a major upgrade in our science facilities on the Quissett Campus are in the final stages, and we expect construction of new facilities (left) to be well underway by the second quarter of 2004. We will build two new laboratory buildings, two additions to the McLean Laboratory, and make associated infrastructure improvements. This 30 percent increase in research laboratory space will provide much-needed relief from overcrowding in the Fye and Redfield laboratories and will represent a significant step in providing state-of-the-art facilities for research in biogeochemistry. New construction will also provide the space to bring together a large and diverse group of investigators interested in marine mammals. We anticipate that the buildings will be completed in late 2005.

We ended 2003 poised to begin ambitious and timely campus improvements and with exciting prospects for renewal of ocean-based facilities. I am cautiously optimistic about the future of our federal support. While we will be diligent in rallying federal support for our work, we will intensify our pursuit of alternative support for exploration and discovery.

Doing the Wave

Surfers and satellites make unlikely oceanographic assistants, but both are helping investigators from the Applied Ocean Physics and Engineering Department study the basic physics of ocean waves on scales varying from centimeters to hundreds of kilometers.

For more than a decade, Associate Scientist Britt Raubenheimer and Senior Scientist Steve Elgar have been working together to decipher the patterns and processes of the shore environment. Most of their work takes place in the breaking waves of the surf and swash zones, from "where the water barely covers your feet to where it just covers your head," as Elgar says.

Along the U.S. coastline, from Truro, Massachusetts to Duck, North Carolina, they have fought the pounding surf to set up current meters, pressure gauges, and other sensors that measure the movement of currents, waves, and sand. Their work could help coastal policymakers and managers understand how the movement of water affects the evolution of coastlines, the safety of beachgoers, and the dispersal of runoff and pollutants.

In the fall of 2003, their work took them to Scripps Canyon near La Jolla, California, for a study of how deep submarine canyons can produce incredible waves, rip currents, and placid lulls all within just a few miles of Pacific shoreline. Working with fellow principal investigator Bob Guza of the Scripps Institution of Oceanography, Elgar and Raubenheimer led a team of 25 scientists, divers, and engineers—plus a few surfers and lifeguards who kept kelp and people off their instruments—in the Nearshore Canyon Experiment (NCEX).

Offshore canyons are thought to focus and channel the energy of ocean waves as they pile up along the continental margins. But until NCEX, very little real-life data had been collected to support the theories and models (most previous work had been done on simpler, smoother shelves).

"As waves pass over the canyons," Raubenheimer said, "the steep topography can act like a magnifying glass and concentrate ocean wave energy in hot spots where waves are large. Alongshore variation of waves and currents can result in rip currents."

Working in arduous conditions—"We've never worked where the circulation is so crazy," Elgar said—the team collected "a spectacular data set." They also showed, in real time, the societal benefits of their research. When 130,000 gallons of sewage spilled from a local water system into the ocean, the NCEX team provided information on how the contaminants were dispersing along the coast.

In the deeper waters of the East China and South China seas, Associate Scientist Tim Duda examines waves up to 100 kilometers long, but so subtle that they are rarely visible at the surface. Duda studies a phenomenon called internal waves, which form along the intersection of waters of different density or temperature in the interior of the ocean (such as saltier water flowing beneath fresher water). These waves can pulse through a sea in cyclic frequencies known as internal tides.

At the extreme, internal waves can grow 150 meters tall, yet the average boater wouldn't notice the passage of an internal wave unless trained to detect the telltale bands or slicks that sometimes

Tom Kleindinst

Associate Scientist Tim Duda demonstrates with a wave tank what it is difficult to see in the ocean: how differences in fluid properties can lead to waves beneath the waves.

form on the surface. Most often, these huge phantoms (and the enormous yet diffuse energies they carry) are detected only by satellites or innovative underwater instruments.

A few years ago, Duda and more than a dozen WHOI colleagues deployed temperature-sensing moorings to examine internal waves and tides as part of the Asian Seas International Acoustics Experiment. Duda and scientists from China and the United States found the internal waves and tides of the South China Sea to be much more potent than expected. The complex seafloor of the region seems unusually efficient at generating internal waves, so the team is now analyzing its new data to figure out where those waves are generated and where their energy goes.

For Duda, understanding the motions and patterns of internal waves could help improve our understanding of how water masses of different densities mix and drive ocean circulation. Energy is radiated throughout the oceans by internal waves, which randomly break down and cause mixing. (By comparison, when atmospheric internal waves mix, you usually spill your coffee as your airplane bounces in the turbulence.)

"If we can demonstrate in a few spots that we can model the tides and waves correctly," Duda said, "then we may improve the fidelity of ocean and climate models by properly accounting for mixing." Understanding internal waves has important implications for understanding acoustic communication in the ocean, sonar performance, and the biological productivity of certain regions. —*Mike Carlowicz*

Related Web Sites

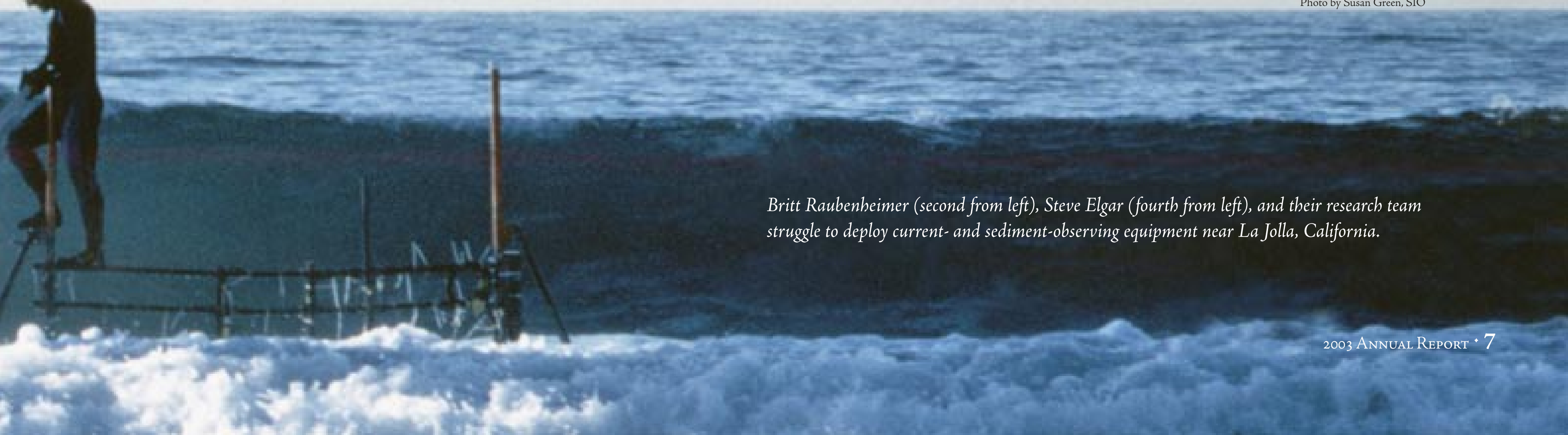
NCEX: science.whoi.edu/PVLAB/NCEX/ncex.html

ASIAEX: www.oal.whoi.edu/ASIAEX01/

Drifting Deep Ocean Shearmeter: www.whoi.edu/science/AOPE/cofdl/tim/smeter.html

Internal Wave Online Atlas: atlas.cms.udel.edu

Photo by Susan Green, SIO



Britt Raubenheimer (second from left), Steve Elgar (fourth from left), and their research team struggle to deploy current- and sediment-observing equipment near La Jolla, California.

The Picoplankton and the Whale

Great fleas have little fleas upon their backs to bite 'em, / And little fleas have lesser fleas, and ad infinitum. / And the great fleas themselves, in turn, have greater fleas to go on; / While these again have greater still, and greater still, and so on.

So wrote the nineteenth century mathematician Augustus de Morgan, noting expanding scales of life and their connections.

Today, biologists at the Oceanographic use miniaturization of technology and clever engineering to illuminate formerly invisible worlds at both ends of the size spectrum, from single-cell photosynthetic plankton to sperm whales.

A dividing Synechococcus *cell, one of the picoplankton that Sosik and Olson are counting in the ocean near Martha's Vineyard. At one micron long, it lies at the base of the ocean food web.*

John Waterbury

At the smallest scale, life on Earth is made possible by humble photosynthetic organisms called phytoplankton, which lie at the base of the ocean food chain and produce most of Earth's oxygen. The smallest among them, called picoplankton, make up in number what they lack in size: picoplankton, including bacteria, photosynthetic, and nonphotosynthetic cells, are the most abundant organisms on Earth. Studying them is a challenge, however, since they are too small to see, like dark matter making up most of the ocean universe.

Microscopic phytoplankton are detectable by proxy. In the laboratory, water samples are exposed to light, and the cells counted and characterized based on fluorescence of their chlorophyll. But no one has been able to study picoplankton in their environment, so their diversity and physiology are poorly understood.

Now biologists Heidi Sosik and Rob Olson have developed the Flow Cytobot (right), an automated submersible flow cytometer that detects small phytoplankton *in situ*. The cytometer (from Greek, *kytos* = hollow vessel, and Latin, *meter* = measure) continuously samples water from its immediate environment, counting cells as they stream through. It can be programmed to operate underwater, unattended for months, transmitting a continuous record of the phytoplankton community to shore.

With this instrument, Sosik and Olson identify cells and measure cycles of growth and division. In 2004, it will be installed at the Martha's Vineyard Coastal Observatory, opening a window into seasonal, annual, and longer-term changes in numbers of phytoplankton of all sizes. Sosik and Olson will monitor ocean productivity on a small spatial scale in relation to changing local conditions. But their results may have implications for the entire ocean food chain.

Tom Kleindinst

Rob Olson (far left), Heidi Sosik (far right), and Research Associate Alexi Shalapyonok (center), all in the Biology Department, load the submersible Flow Cytobot, onto the WHOI vessel Mytilus, *as Marga McElroy, senior research assistant in the Applied Ocean Physics and Engineering Department, looks on.*

"This is the beginning of a long-term effort to look at how phytoplankton communities respond over decades," Sosik said, "and to understand the consequences of human-caused and natural environmental changes at the lowest level of the food chain."

At the other end of the spectrum, Peter Tyack studies the diving behavior of sperm whales, carnivores at the top of the food chain. Like picoplankton sperm whales are hard to study because of their size, and because they are unseen most of the time. They

Two sperm whales dive in tandem.

typically surface for only five minutes, then dive for up to an hour, to depths of 1,000 meters (4,600 feet) or more (above).

New tools, called digital acoustic recording tags, are attached to whales with suction cups and track them throughout dives. Tag measurements are the result of collaboration: Engineer Mark Johnson designed and built the tags; Biologist Michael Moore developed the method of using a cantilevered carbon-fiber pole to touch an instrument to a whale; Johnson and Tyack adapted the pole for attaching tags (below). It's an adventure steering a boat close to an unsuspecting whale and with a 40-foot pole attaching a tag and hoping the whale won't notice. Sperm whales are not noted for friendly behavior toward boats. "Before I started doing this," Tyack said, "I spent a day at the New Bedford Whaling Museum, reading records of sperm whale attacks."

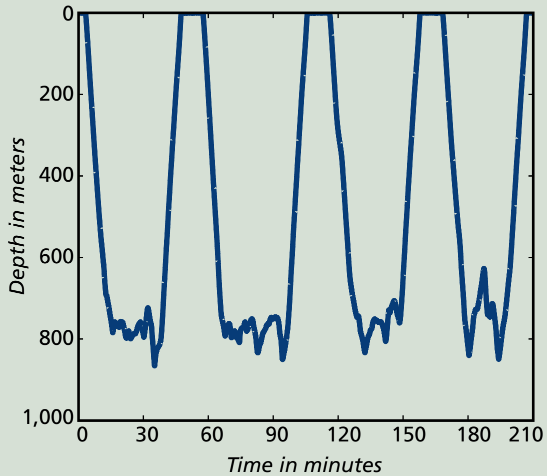
Natacha Aguilar de Soto

Mark Johnson manipulates the long carbon-fiber pole to attach an acoustic tag to a sperm whale.

Luckily, whales don't react to the tags. They are small—like a flea on a Great Dane—but huge in storage capacity. Time, depth, fluke beats, body orientation, sounds the whale makes, and ambient sounds are all stored. After an hour or two, the suction cup releases and the tags, and their data, are retrieved.

Every tagging increases Tyack's understanding of sperm whale diving (right) and individual and population behavior. In 2003, tagging became routine. He followed whales, listened to them, and monitored external sounds, including whale calls, seismic, and sonar sounds. From this he reconstructed normal behavior and behavior in response to sounds. Using the tag as a dosimeter is an important advance in determining the effects of sound on whales. "This will help provide crucial data that decision makers need for the wise regulation of human-induced noise in the oceans," Tyack said.

—Kate Madin



A sperm whale's repeated foraging dives, as recorded by a digital acoustic tag. On each dive the whale descends straight to nearly 900 meters, spends a half hour or more per dive feeding at that depth, and returns to the surface to breathe for a short period before the next dive. When descending, the whale makes regular sounds. At depth, whale sounds change to rapidly accelerating creaks that apparently help it locate prey. On ascent, they change to more regular sounds and social calls.

From Tiny Grains, a Larger Understanding of Earth

Fifty miles below the ocean bottom, where extreme pressure meets temperatures exceeding 2,000 degrees Fahrenheit, rock is squeezed and cooked until it begins to flow like hot syrup. This is the birthplace of magma, the molten rock that rises to erupt from undersea volcanoes or oozes from deep fissures, cooling and solidifying as it hits cold seawater to carpet the seafloor with new crust.

The process has continually paved and repaved two-thirds of Earth's surface, yet it remains a fundamental mystery. For more than 40 years, scientists have been working to learn why magma forms, how it moves through the mantle, and what makes it erupt from the seafloor. Knowing this will help scientists understand the very processes that formed the Earth, and will help them learn about—and perhaps better predict—earthquakes and volcanic eruptions.

The key to understanding this world-shaping dynamic, however, may lie in the interstices between the microscopic mineral grains that make up mantle rock, where all the melting and moving begins.

"People are used to seeing pictures of magma boiling out of volcanoes or the seafloor, but I wonder if they think about it all starting on grains smaller than sand," said Glenn Gaetani, a petrologist and geochemist in the Geology and Geophysics Department.

A new imaging technique called microtomography is giving scientists the previously impossible ability to clearly see the individual mineral grains composing mantle rock. Shaped like circles, squares, and hexagons, the grains resemble a jumble of toy blocks. For Wenlu Zhu, a geophysicist at WHOI, these outwardly simple shapes provide some answers to complex questions about magma.

At the microscopic scale, individual grains of olivine, pyroxene, and other minerals that are the precursors to magma begin to melt along grain surfaces. Small drops of magma form larger puddles along the curved and straight edges between grains. The puddles then channel together into larger pools, gaining momentum and mass as they collect. The pools become rivers of magma that, driven by buoyancy and gas pressure, eventually ascend all the way to the seafloor.

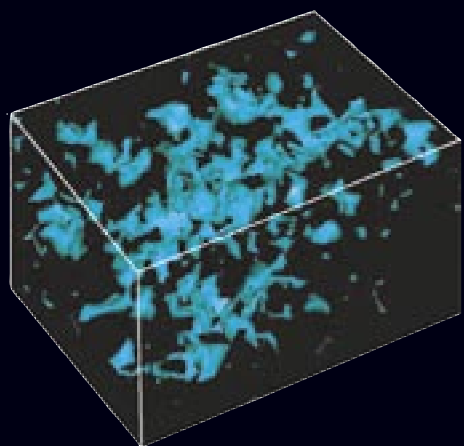
Zhu can't collect magma at its source in the mantle, so in August she began working with Gaetani to make her own magma and simulate conditions 50 miles down. After mixing a chemical recipe, Gaetani squeezes the sample in a hydraulic press and bakes it, creating a substance with the same chemical and physical makeup as the molten magma found in Earth's mantle.

Zhu then examines the samples using microtomography, which takes X-ray images at many angles around the object and reveals the internal structure of the grains that make up mantle rock. More powerful than a computerized axial tomography (CAT) scan, microtomography can capture 3-D images of grains with viewing detail as small as two thousandths of a millimeter, or about twenty times smaller than a strand of human hair.

Zhu's work is part of a larger effort at WHOI to understand Earth processes. Several scientists have overlapping research interests: Greg Hirth, a geophysicist, studies processes that govern the strength of faults and the depth of earthquakes at Earth's plate boundaries; John Collins, a geophysicist, studies the structure of ocean crust and the upper mantle by analyzing seismic waves traveling through Earth; and Stan Hart, a geochemist, focuses on the evolution of hot spots and the formation of Earth's mantle.

"For all of us, it's a chance to learn about how the seafloor is created, and how some of the land we stand on is formed," said Zhu.

—Amy E. Nevala



Scientists can't observe magma moving beneath the seafloor, so Glenn Gaetani (right) makes his own sample of the molten rock by subjecting a tiny capsule of powder that simulates rock in the upper mantle to crushing pressure and intense heat in his laboratory. A 3-D microtomography image of the sample (above) shows the internal structure of the mineral grains, revealing to researchers how the melting magma (blue) has started to pool and flow along the edges and corners of the dark grains. The work is part of a larger effort at WHOI to understand Earth processes, including how magma forms and rises through seafloor cracks to carpet the ocean bottom with new crust.*

Tom Kleindinst

Pumping Iron on the Seafloor

Somewhere on the vast seafloor that covers 70 percent of our planet lies a small rock. On that rock is a microscopic crevice, maybe 10 microns (0.0004 inches) deep and 20 microns wide. And in that crevice is a thriving community of microbes, for whom that nook is as cozy and bountiful as Grandma's house on Thanksgiving.

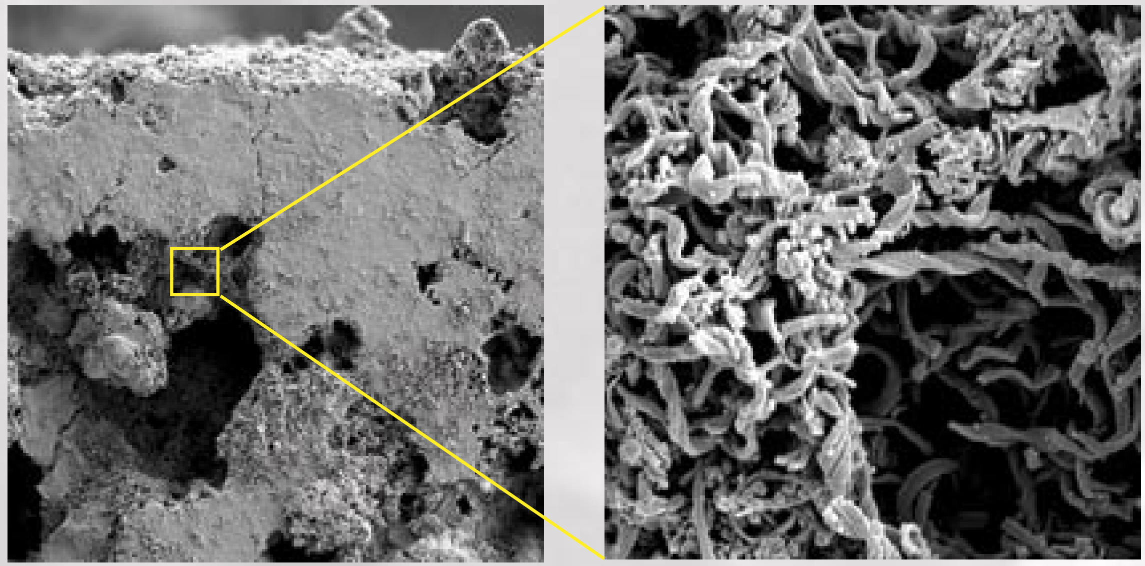
That tiny sheltered cove contains all the ingredients the microbes need. They convert carbon dioxide from seawater into organic matter, and extract a little oxygen or nitrogen to breathe. From the surrounding volcanic rock they extract iron.

The microbes steal electrons from iron atoms—changing them from ferrous (Fe^{+2}) to ferric (Fe^{+3}). They harness the energy produced by this chemical reaction to grow and multiply. In the sunless depths, where photosynthesis isn't an option, these iron-oxidizing microorganisms are making a good living.

Over the past few years, said WHOI geochemist Katrina Edwards "we have found large numbers of previously unidentified, iron-oxidizing microbes, living directly off the minerals in seafloor rocks."

Using the submersible *Alvin*, Edwards and colleagues in the Marine Chemistry and Geochemistry Department placed microbe-free samples of natural iron-rich seafloor rock back on the seafloor. Retrieved several months later, the samples had thick orange coatings of oxidized iron. In tiny pores and pits on the sample surfaces, microbes grew and flourished.

In 2003, near Loihi, an active, submerged volcano off the Big Island of Hawaii, scientists set up an observatory to study iron bacteria at a site where they are unusually prolific. The seafloor at Loihi is carpeted with ocher-red bacterial mats, made by microbial communities living off iron in the rock and in hydrothermal fluids venting from the seafloor. "They are really spectacular," said WHOI geochemist Dan Rogers.



Katrina Edwards

Scientists at WHOI deployed blocks of rock samples containing iron sulfide on the seafloor and retrieved them two months later. The scanning electron micrograph (left) shows a close-up view of pores on the surface of a rock sample. The further magnified image (right) shows huge accumulations of iron oxide material metabolized by iron-oxidizing bacteria that flourish within the pore spaces.

"People have known about the existence of these microbes for decades," said WHOI geochemist Wolfgang Bach. "But no one thought they would be so abundant and ubiquitous."

If the oceans do contain large, widespread populations of these tiny overlooked microbes, it could revolutionize our thinking about colossal mysteries: What regulates the ocean's chemistry and the planet's climate? How did life evolve on Earth and perhaps on other planets?

Rocks on the seafloor and even below it, have potentially infinite niches, where the chemistry is just right for iron-oxidizing microbes. Edwards and Bach analyzed rock samples drilled from the exposed volcanic rock that spreads out on both sides of volcanic seafloor mountains. They found that older rocks were depleted of Fe^{+2} and full of Fe^{+3}—exactly what iron-oxidizing microbes use up and leave behind. The flanks of mid-ocean ridges encircling the globe could represent millions of square miles of fertile territory for innumerable microbial hordes.

Such a massive microbial community would continually extract huge amounts of carbon dioxide, an important greenhouse gas, from seawater, and microscopically mediate large changes in ocean chemistry over geologic time. The drawdown of carbon dioxide into solid rock could revise our understanding of how carbon cycles through the planetary system, giving the microbes an important role in the evolution of Earth's climate.

Plentiful populations of iron-oxidizing microbes might also form the base of a food chain supporting seafloor ecosystems. They might even have been pioneering life forms on early Earth—more than 2.7 billion years ago, when the oceans were rich with volcanic rock, but before plants appeared to supply the planet's atmosphere with oxygen. Similar microbes could have thrived, or may still thrive, in other iron-rich, oxygen-poor locales—such as Mars, for example.

The research "requires you to be a little bit of a biologist, chemist, and geologist," Rogers said. He and others in Edwards' lab are working to identify the microbes, calculate their numbers, and decipher their biochemical machinery and metabolic capabilities. With Mitch Sogin at Marine Biological Laboratory in Woods Hole, Edwards is pursuing genomic studies to help determine these microbes' place in evolutionary history.

Bach, meanwhile, is using new technology, a gallium ion beam, to cut 100-nanometer-thick rock samples and learn how microbes affect the rocks' microscopic texture and composition.

With such knowledge, scientists will be able to distinguish textures caused by microbial activity from those caused by abiotic oxidizing processes such as rusting. With lessons learned from textural, isotopic, molecular, and other studies, Bach said, "we strive to be able to look at a 70-million-year-old rock—or a Martian rock—and say with certainty, 'microbes were here.'"

—*Lonny Lippsett*

Terry Kirby, University of Hawaii

A reddish-orange iron oxide material coats the seafloor on Loihi Seamount, an active underwater volcano off Hawaii. The material, similar to rust, is made by an abundance of microbes oxidizing iron in seafloor rocks to live and grow.

What Goes Down Must Come Up

From space, the ocean may look like a big, calm bathtub. But below its surface lies the ultimate dynamic environment—328 million cubic miles of water flowing, sinking, mixing, and rising.

It's as turbulent as another, more familiar fluid environment—the atmosphere—but the action is hidden from view.

"We can observe the atmosphere because we live in it, rather than just venturing on top of it," said Bernadette Sloyan of the WHOI Physical Oceanography Department.

"But we can't look at ocean dynamics directly to get information about what is happening over space and time," said her colleague, Kurt Polzin. Instead, physical oceanographers work with measurements of thin slices of the ocean at brief moments in time. They piece together snapshots, envisioning the epic movie.

Small wonder, then, that one of the most basic questions about ocean circulation remains a mystery. The world's oceans circulate like a conveyor belt of sinking and rising waters: oceanographers know why cold waters sink to the depths, but what makes them rise back to the surface completing the loop?

It's not an academic question, because the oceans and atmosphere act as equal partners in a planetary heating and ventilation system that transfers equatorial heat to the poles. Together, they regulate Earth's climate and keep the planet habitable.

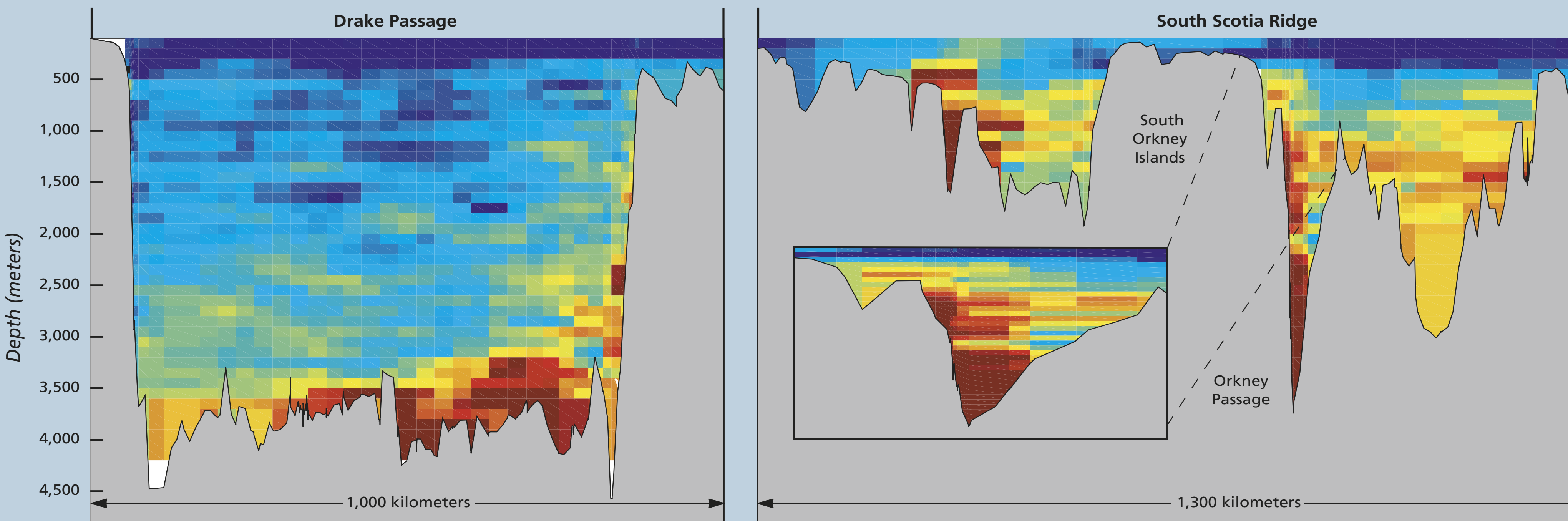
To understand and forecast changes in Earth's climate, scientists construct computer simulations of its complex dynamics, said WHOI physical oceanographer Steven Jayne. But the climate models have a fundamental blank spot: the "up" component of the Ocean Conveyor.

Sinking ocean waters were relatively easy to find and measure, because they are concentrated in a few locations. Only in the North Atlantic and the Southern Ocean around Antarctica do waters become both cold and salty (and therefore dense) enough to plunge swiftly in a pipeline to the deep.

But there's no obvious pipeline coming back up. The cold water spreads through the ocean depths, bounded by overlying layers of lighter waters. It takes energy to break the boundaries between layers, mix waters of different densities, and create a way for denser waters to escape back upward.

"Mixing is dispersed over areas thousands of times larger (than sinking) and happens a thousand times more slowly," Jayne said, which makes mixing tough to locate, and harder still to measure.

Sloyan launched a search to find where mixing might be occurring. She analyzed salinity and temperature data from the World Ocean Circulation Experiment, a multi-institution ambitious effort during the 1990s to collect global ocean measurements. She detected subtle signs of mixing in the Southern Ocean—especially in regions where the seafloor is marked by saw-toothed mountains, steep slopes, and narrow chasms.



The Antarctic Circumpolar Current whips around the continent at great speed and depth, Sloyan said. It may bump into rough topography, like air currents hitting the Rockies, generating waves within the ocean's interior. These internal waves can ripple away, overturning density gradients and causing mixing. Currents surging through a constrained passage, like a river through a narrow gorge, may also force mixing.

Tides may also play a role, providing energy to move water back and forth across seafloor topography. Jayne is exploring models simulating how tides create internal waves that spur mixing (see pages 6 and 7).

Polzin narrows his investigations down to the microscale level, often using a High-Resolution Profiler (HRP), an instrument developed by WHOI scientists John Toole and Ray Schmitt and equipped with sensors developed by former WHOI engineers Sandy Williams, Neil Brown, and Tom Sanford. The HRP accurately measures changes in water temperature, velocity, and conductivity (i.e., salinity) on scales ranging from tens of meters down to centimeters.

"We can reveal turbulence as small as this," Polzin said, holding his thumb and forefinger nearly together. "The HRP gives us an ability to see and understand the ocean in new ways."

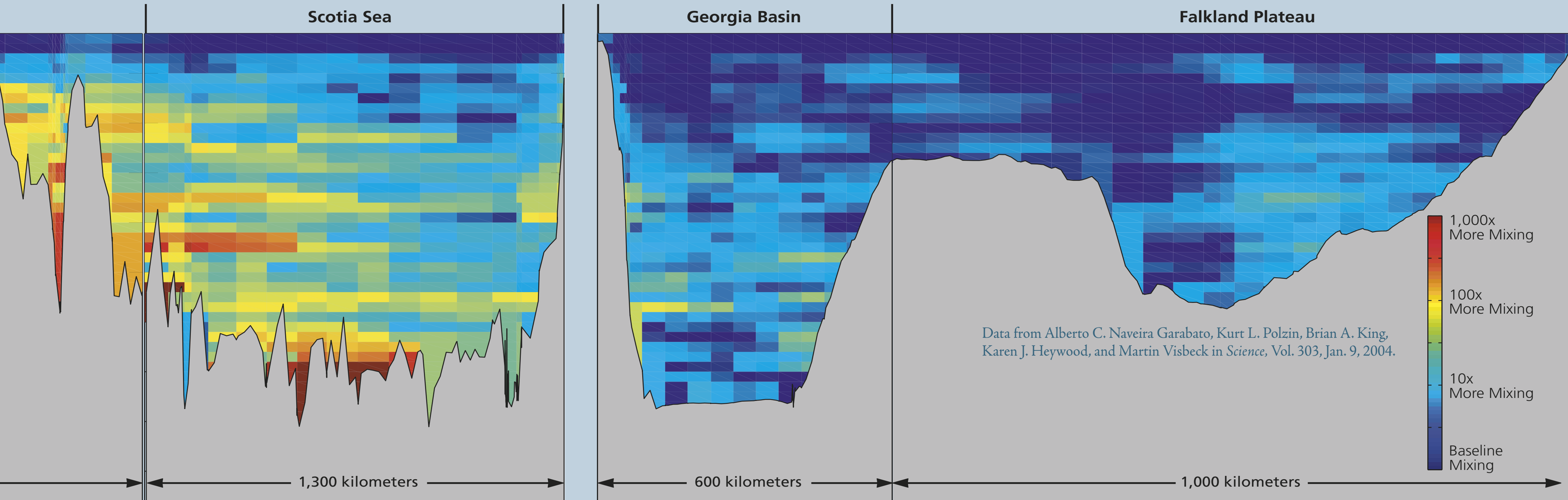
Polzin is trying to find links between flows at disparate spatial scales. "Small changes may not be recognized as important," he said "but they can initiate nonlinear, but coupled, changes that are important."

Today, many scientists see evidence that ocean conditions may be approaching a tipping point that would disrupt the delicately balanced ocean circulation system—a phenomenon that has abruptly rearranged global ocean currents several times in Earth's history and caused rapid, widespread climate changes. Like a tiny cog in a colossal machine, centimeter-scale mixing may prove a small but important piece that helps determine whether the Ocean Conveyor shuts down or keeps running.

—Lonny Lippsett

Jayne Doucette

Data collected on five cruises between 1993 and 1999 (above: yellow, orange, and red tracks) showed evidence of intense turbulent mixing in the Southern Ocean. The mixing helps bring deep, dense waters back toward the surface. Oceanographers now hypothesize that much more mixing (below: red and yellow areas) may occur when the powerful Antarctic Circumpolar Current is disrupted as it flows over rough seafloor topography.



Data from Alberto C. Naveira Garabato, Kurt L. Polzin, Brian A. King, Karen J. Heywood, and Martin Visbeck in *Science*, Vol. 303, Jan. 9, 2004.

Applied Ocean Physics and Engineering Department

The engineers, scientists, and technicians of the Applied Ocean Physics and Engineering Department (AOPE) seek novel ways to observe and model ocean processes, extending the reach of the oceanographic community from the turbulent surf zone to the abyssal depths. Research and development in the department can be divided into five areas: environmental fluid mechanics, ocean acoustics, submersible vehicles, observing systems and sensors, and engineering services.

The department's Deep Submergence Laboratory made strides in 2003 to take science deeper into the abyss. In December, the National Science Foundation, the U.S. Office of Naval Research (ONR), and the National Oceanic and Atmospheric Administration granted Dana Yoerger, Andy Bowen, and Louis Whitcomb $5 million to build a hybrid remotely operated vehicle (HROV) capable of exploring the deepest trenches of the ocean. Part autonomous free-swimming robot, part tethered vehicle, the HROV will combine wide-area survey capabilities with close-up sampling.

www.whoi.edu/science/AOPE/dept

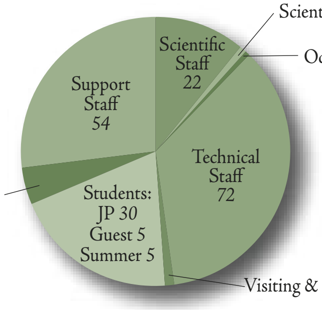
Chris von Alt and Ben Allen of the Oceanographic Systems Laboratory put different versions of their Remote Environmental Monitoring UnitS (REMUS) to work for the U.S. Navy and the City of New York. In the spring, REMUS vehicles were used to detect mines in the Iraqi harbor of Um Qasr. In early summer, the Tunnel Inspection Vehicle, a specially designed REMUS, surveyed the decaying New York City aqueduct system to locate leaks.

Hanumant Singh and colleagues used the SeaBED autonomous vehicle to discover previously unmapped coral communities thriving at intermediate depths off the U.S. Virgin Islands. Using specially outfitted camera systems, the team found corals in regions beyond the reach of divers and most observing systems.

John Trowbridge and Jim Edson led the design, deployment, and instrumentation of an Air-Sea Interaction Tower (ASIT) about three kilometers south of Martha's Vineyard. The tower is connected to shore-based labs via the Martha's Vineyard Coastal Observatory. As part of ONR's Coupled Boundary Layers/Air-Sea Transfer (CBLAST) program, scientists from six institutions used an array of offshore moorings, aircraft and ship-based surveys, as well as the highly instrumented ASIT, to gather data that will improve models of the coupling between the ocean and atmosphere and could improve marine forecasts.

Along the California coast, Senior Scientist Steve Elgar and Associate Scientist Britt Raubenheimer led a team of 25 scientists from 10 institutions in the Nearshore Canyon Experiment (NCEX). From September through December, the NCEX team deployed arrays of instruments to observe how submarine canyons and other seafloor formations affect wave propagation and nearshore currents (see page 6).

—W. Rockwell Geyer, Department Chair



Tom Kleindinst

Rocky Geyer, chair of the AOPE Department (left) discusses the Institution's new coastal research vessel with Port Engineer Dutch Wegman. They were instrumental in the design of Tioga, *which can range from the Gulf of Maine to New York harbor.*

Awards and Recognition

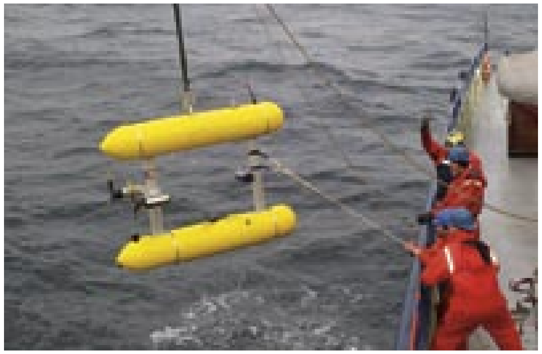
Jim Edson and **Wade McGillis** were part of a team that received a 2003 Outstanding Scientific Paper award from the National Oceanic and Atmospheric Administration for work on air-sea gas transfer.

Rocky Geyer and **Peter Traykovski** received the Donald W. Pritchard Award, presented by the Estuarine Research Federation for best physical oceanography paper published in *Estuaries* in 2003.

Jim Irish received the Al Vine Senior Technical Staff Award for moored instrument technology.

Wade McGillis received a Leverhulme Fellowship to pursue research at the University of East Anglia, U.K.

Britt Raubenheimer received a National Science Foundation Early Career Development Award.



Hanumant Singh

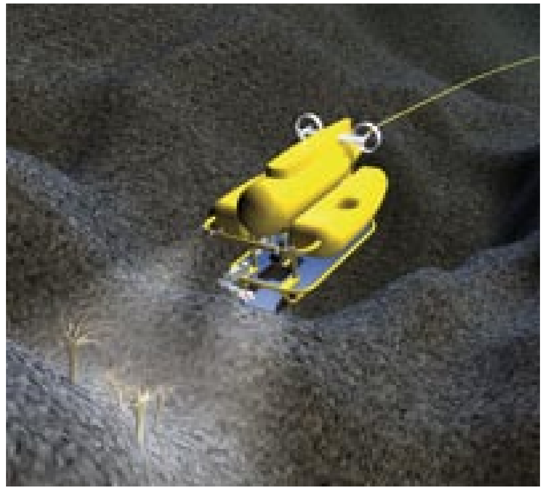
Crew members and scientists on R/V Oceanus deploy the SeaBED autonomous underwater vehicle for habitat characterization studies on Stellwagen Bank off Boston.

Promotions

Bob Brown, Research Associate III
Ken Doherty, Principal Engineer
Matt Grund, Research Engineer
Terry Hammar, Research Associate III
Ed Hobart, Research Engineer
Dennis McGillicuddy, Associate Scientist with Tenure
Britt Raubenheimer, Associate Scientist
Robin Singer, Research Engineer
Sandipa Singh, Research Engineer
Karlen Wannop, Senior Engineering Assistant I
Sarah Webster, Engineer II

Related Web Sites

HROV: www.whoi.edu/media/hrov.html
REMUS:
www.whoi.edu/science/AOPE/dept/OSL/remus.html
SeaBED: www.whoi.edu/DSL/hanu/seabed/index.html
CBLAST:
www.whoi.edu/science/AOPE/dept/CBLASTmain.html



Jack Cook

Researchers in the Deep Submergence Laboratory are developing a part tethered, part autonomous underwater vehicle capable of exploring and mapping the deepest ocean trenches.

Tom Kleindinst

Alan Gardner (sitting) and Matt Gould prepare the marine electromagnetic survey vehicle for engineering tests off the WHOI pier. Rob Evans (left) studies seafloor sediments with the towed vehicle.

Tom Kleindinst

Erik Anderson, a 2003 graduate of the MIT/WHOI Joint Program, uses lasers, robots, and cameras to study how fish overcome the forces of drag.

Biology Department

Biology Department research reflects the breadth of the field: from bacteria to whales, from ocean depths to surface waters, from fossils to newly discovered species, and from molecules to global ecosystems. Collaborating with colleagues here and elsewhere, WHOI biologists also develop and refine instruments and techniques that increase the reach of science and bring new information within our grasp.

In 2003, our biologists traveled more than 'Seven Seas' for answers to scientific questions. They studied material from the Barents, Bering, and Beaufort seas, and visited the Mediterranean, Ross, and Sargasso seas. They sailed the Pacific and Atlantic oceans, the Sea of Japan, and the Sea of Cortez—and spent time in their own backyards: Long Island Sound, Georges Bank, the Gulf of Maine, and Vineyard Sound.

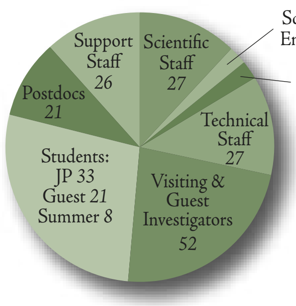
Some biologists concentrated on small scales of research, while others collaborated in large-scale national or international research programs, such as the Southern Ocean GLOBEC (Global Ocean Ecosystem Dynamics), ECOHAB (Ecology of Harmful Algal Blooms), or National Oceanic and Atmospheric Administration (NOAA) Ocean Exploration programs. Their work uses genetic, molecular, or isotopic techniques and ranges from studying disease-causing organisms in lobsters and clams to how whole communities and populations of marine animals—at vents, seamounts, or in shallower environments—are connected over distances. Some studied genetic responses of marine organisms to environmental pollutants, and others investigated the roles of plankton in the cycling of elements in the ocean and atmosphere; models of population change; or the effectiveness of marine protected areas in maintaining populations.

www.whoi.edu/science/B/dept

Instrument development continued on several fronts. Equipment to sample microbial life in the deep biosphere beneath the ocean floor at hydrothermal vents was tested, as was a new suction collector on *Alvin*. Data-archiving tags were used to accumulate information about normal whale diving behavior and responses to controlled sound experiments.

A unique instrument system installed at the Martha's Vineyard Coastal Observatory (MVCO) continuously monitors conditions throughout the water column, collects and identifies images of small animal plankton using imaging technology and artificial intelligence, and transmits data to shore. Also at the MVCO, a continuous automated flow system was deployed to count and identify phytoplankton, producers in the ocean food chain. The long-term data sets these instruments collect will reveal the effects of local climate change on important coastal systems. Another instrument, the Large Area Plankton Imaging System, which produces images of larger plankton, such as jellyfish, was successfully tested at sea.

—John J. Stegeman, Department Chair



John J. Stegeman, chair of the Biology Department (left) with postdoctoral investigators in molecular toxicology Joanna Wilson, a graduate of the MIT/WHOI Joint Program, and Tim Verslycke.

Awards and Recognition

Hal Caswell was awarded a Maclaurin Fellowship by the New Zealand Institute for Mathematics & its Applications for his work on mathematical modeling of population and community ecology.

Lauren Mullineaux received a visiting scholarship at Université Pierre et Marie Curie and CURS, Paris.

John Waterbury was elected a Fellow of the American Academy of Microbiology.

Michael Neubert was elected Vice-Chair, Theoretical Ecology Section, Ecological Society of America.


Tom Kleindinst

The head of a minke whale found on Martha's Vineyard is examined by Darlene Ketten and marine veterinarian C. Rogers Williams of the NOAA National Marine Fisheries Service Aquarium in Woods Hole.


Adam Geiger

Larry Madin, director of the WHOI Ocean Life Institute, diving on a coral reef near the Liquid Jungle Laboratory in Panama.


Fabian Tapia

WHOI scientists and engineers launch a current meter off Baja, Mexico to study larval transport of coastal invertebrates in the area.


Vicke Starczak

In January, Claudio DiBacco, a WHOI postdoctoral fellow, visited a shore in Buzzards Bay to sample rock barnacles that tolerate freezing conditions. Biologists at WHOI study the reproduction, settlement, and survival of barnacles ranging from Rhode Island to Nova Scotia.

Tenure

Jesús Pineda, Associate Scientist
Heidi Sosik, Associate Scientist

Promotions

Stace Beaulieu, Research Specialist
Sibel Karchner, Research Specialist
Sanjay Tiwari, Research Specialist

Related Web Sites

GLOBEC: globec.whoi.edu
ECOHAB: www.whoi.edu/science/B/ecohab
MVCO: mvcodata.whoi.edu/cgi-bin/mvco/mvco.cgi

Geology and Geophysics Department

The scientists and research staff of the Geology and Geophysics Department (G&G) study volcanism, the structure and evolution of the ocean basins and their margins, earthquakes and hydrothermal processes on the seafloor, and the role of the oceans in past climate change.

Staff, students, and postdoctoral investigators in G&G totaled 127 in 2003, and were involved in more than 250 research projects. In July, Associate Scientist Delia Oppo co-led a team of scientists, technicians, and students from the United States and Indonesia as they collected seafloor cores in the Makassar Strait, Indonesia. Oppo and her research team are using these cores to determine whether long-term variations in the behavior of El Niño/Southern Oscillation influence regional climate variations on time scales of hundreds to thousands of years. They want to find out if changes in ocean circulation and temperature in the western Pacific happened at the same time as North Atlantic climate variations during glacial and interglacial periods.

www.whoi.edu/science/GG/dept

In the spring, Associate Scientist Rob Reves-Sohn led the first of four expeditions to study a massive sulfide deposit on the Mid-Atlantic Ridge at the Trans-Atlantic Geotraverse (TAG) site, about 2,000 miles east of Miami. To understand what is driving hydrothermal activity at the site, they deployed a network of seismometers and temperature probes from R/V *Atlantis* to monitor earthquake activity associated with faulting and fluid flow. Statistical correlations between seismic activity and vent fluid temperatures will be used to study fluid circulation patterns beneath the surface and to understand the role of faulting in sustaining hydrothermal flow over tens of thousands of years.

Rob and Juan Pablo Canales, a research associate, returned in the fall for the second research leg to carry out a seismic refraction experiment aimed at delineating the position and size of magma bodies that might be driving hydrothermal activity at this site. Two additional legs are planned for 2004 to recover the seismometers and probes.

In September, Joan Bernhard accepted a tenured associate scientist position in G&G. Bernhard's research lies at the intersection of geology, biology, and chemistry—an emerging interdisciplinary field known as geomicrobiology—as she pursues studies of tiny single-cell creatures that are surprisingly abundant in oxygen-depleted environments, such as deep in the Black Sea and in some seafloor mud sediments.

—Robert S. Detrick, Department Chair

Promotions

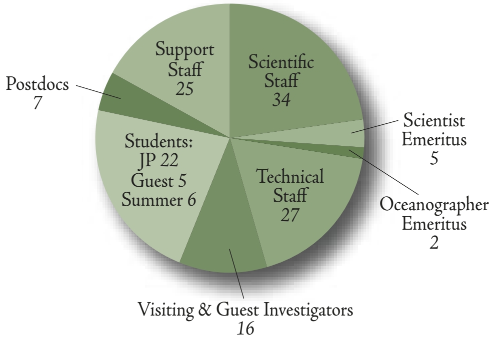
Mary Carman, Research Associate II

Pamela Foster, Senior Administrative Assistant II

Rick Healy, Information Systems Associate III

Rob Reves-Sohn, Associate Scientist

Wenlu Zhu, Associate Scientist



Tom Kleindinst

Bob Detrick, Geology and Geophysics Department chair (right) with research specialists John Collins (left) and Beecher Wooding and the ocean-bottom seismometers they are building as part of a National Science Foundation-funded instrument pool. These instruments detect and record earthquakes and human-made sound sources to learn about the planet's internal structure.

Awards and Recognition

William Berggren, scientist emeritus, received an honorary doctorate degree from the University of Athens for studies on stratigraphy and chronostratigraphy.

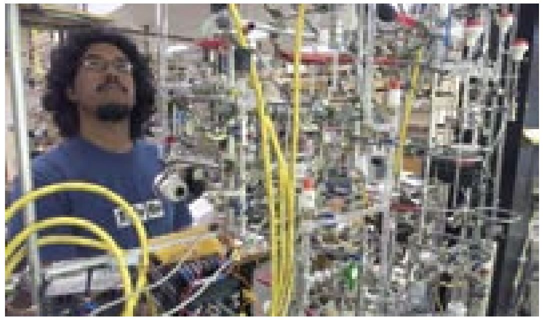
William B. Curry and **Peter B. Kelemen** were elected American Geophysical Union (AGU) Fellows.

John Hayes received the 2003 Medal in Geochemistry from the American Chemical Society.

Jian Lin was recognized, with Geoffrey King and Ross Stein, by the Institute for Scientific Information for the ranking of their paper, "Static Stress Changes and the Triggering of Earthquakes," as the most cited paper on earthquake research in the past decade.

John Hayes

Recovery of the deep submergence vehicle Alvin *after a trip to the "Lost City," a hydrothermal vent field near the Mid-Atlantic Ridge. The dive was one of 18 for* Alvin *during a spring expedition.*



Tom Kleindinst

Fabian Batista, a summer student fellow now studying at Humboldt State University, works in the sample preparation lab in the National Ocean Sciences Accelerator Mass Spectrometry facility at WHOI.

Phil Lobel

Research Associate Anne Cohen studies live coral on the Johnston Atoll in the central Pacific Ocean as part of her studies to interpret the climate record from the growth of coral.

Tom Kleindinst

Mea Cook, a MIT/WHOI Joint Program student in the Geology and Geophysics Department, prepares to take X-rays of a sediment core collected from the Bering Sea. X-rays reveal density changes as well as some 3-D structures—hidden clamshells or snail shells, pebbles, and disturbed sediments. Chemical analyses of these sediments help her to determine what role the Pacific Ocean could have played in rapid climate change events.

Related Web Sites

Video of deep earth convection forces: www.whoi.edu/institutes/doei/videos/video_convection_qt.htm

Model of deep-sea hydrothermal system: www.whoi.edu/home/about/annual02_oceandrill_enlargetop.html

Marine Chemistry and Geochemistry Department

Scientists and staff in the Marine Chemistry and Geochemistry Department (MC&G) assemble pieces of the puzzle that help us understand the ocean and its role in supporting life on Earth. We study chemical exchanges across the boundaries where ocean meets land, seafloor, and atmosphere, seeking insights into ocean processes driven by natural cycles and human-induced changes to our planet.

With evidence from chemical changes in seafloor sediments, for example, Konrad Hughen and colleagues correlated past drought conditions with the collapse of the Mayan civilization. The work was highlighted in *Science* magazine and on a *Nova* television program in 2003.

The oceans directly influence climate by transporting heat via vast ocean currents, and by sustaining marine plankton, which form the base of the ocean food web. As plankton grow, they absorb atmospheric carbon dioxide—a natural, but now increasing, greenhouse gas. When they die, plankton sink, transporting carbon to the deep sea. Through this biological pump, the oceans take up roughly one third of the carbon released to the atmosphere by human activities, such as the burning of fossil fuels.

www.whoi.edu/science/MCG/dept

Many MC&G scientists explore the ocean carbon cycle. Some study complexities of the biological pump (Roger François, Bill Jenkins, Ken Buesseler). Others study the air-sea exchange of greenhouse gases (Nelson Frew, David Glover). Scott Doney incorporates these data into sophisticated models of the ocean carbon cycle. MC&G also houses the main science and data management offices of the Joint Global Ocean Flux Study (JGOFS), the largest ocean carbon scientific program to date.

Beyond sunlight and nutrients, growing plankton also need trace quantities of metals. Research in this field by Jim Moffett has been expanded with the addition of Mak Saito as a new assistant scientist in 2003. Mak uses molecular techniques to fill an important gap in our understanding of how trace metals control plankton growth and influence ocean productivity.

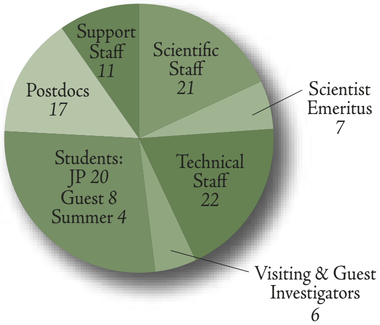
In the sunless depths, where photosynthesis is not an option, chemosynthesis reigns. Studying deep ocean cores, Wolfgang Bach, Katrina Edwards, and colleagues are examining how chemosynthetic microbes, living deep below the seafloor, chemically alter the ocean crust.

MC&G's expertise in oil and natural gas sources and sinks was called into action when a barge spilled up to 98,000 gallons of fuel oil in nearby Buzzards Bay on April 27, 2003. The broad knowledge and rapid response of Chris Reddy and colleagues provided invaluable understanding of the extent of the contamination and longer-term fate of the spilled oil.

In 2003, Mark Kurz stepped down as Chair, and Ken Buesseler was appointed to succeed him. During Mark's term, MC&G expanded into exciting new research areas, including marine microbiology and biogeochemistry, while simultaneously preserving its strengths in classic marine geochemistry, the cycling of dissolved organic matter, hydrothermal systems, sedimentary diagenesis, applications of stable isotopes and radionuclides as tracers, paleoceanography, and chemical alterations in the "subterranean estuary," where groundwater and ocean water meet at the seashore.

—*Ken Buesseler, Department Chair*

Ken Buesseler, chair of the Marine Chemistry and Geochemistry Department (left) and Postdoctoral Scholar Carl Lamborg are members of Café Thorium, the nickname for the MC&G Radiochemistry Group, which measures trace radioactive elements for a wide range of studies.



Tom Kleindinst

Geochemist Matt Charette (left) and technician Matt Allen collect samples of groundwater near Pamet Harbor in Truro, Massachusetts. They are examining how nitrogen and other nutrients in groundwater (mostly from septic systems) enter the coastal ocean.

Awards and Recognition

Chris Reddy received a 2003 Office of Naval Research Young Investigator Award for research on how microbes degrade petroleum hydrocarbons.

Meg Tivey was appointed co-chair of the Ocean Research Interactive Observatory Networks (ORION) steering committee, which oversees a National Science Foundation initiative to establish and operate long-term ocean observatories to collect continuous measurements of ocean phenomena.

Promotions

Wolfgang Bach, Associate Scientist

Katrina Edwards, Associate Scientist

Related Web Sites

Buzzards Bay oil spill: www.whoi.edu/media/oilspill

Katrina Edwards' work on chemosynthesis: www.whoi.edu/science/MCG/dept/highlights/project_ventmicrobes.html

Biogeochemistry: www.whoi.edu/science/MCG/doneylab/index.html

Joint Global Ocean Flux Study: usjgofs.whoi.edu

Konrad Hughen on *Nova*: www.pbs.org/wgbh/nova/laventa/ (see "*Nova* News Minute")

Tom Kleindinst

Senior Research Assistant Joanne Goudreau (right) and Joint Program student Linda Kalnejais offload core samples of sediments from Buzzards Bay. They are studying how trace metals oxidize in sediments, to deduce oxygen levels of bottom waters today and in the past.

C.A. Linder

WHOI scientist Chris Reddy collects a sample of fuel oil spilled in Buzzards Bay, Massachusetts, when a barge ran aground in April 2003. Reddy investigates the molecular degradation of oil and the persistence of contamination in the coastal environment.

Physical Oceanography Department

The Physical Oceanography Department focuses on processes that govern the properties and state of the ocean, and the ocean's interactions with the solid Earth and atmosphere. The Department has traditionally centered on making observations of the ocean, but vigorous activities also include data interpretation, theory development, numerical modeling, laboratory simulation, and the development of new observational tools. This past year has seen advances on all these fronts.

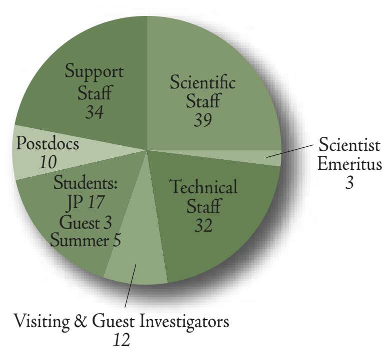
The Arctic Ocean is becoming a new focus for the Department. In 2003 Bob Pickart returned to the Beaufort Sea to recover and redeploy an array of seven moorings containing a newly developed coastal profiler. It is a close cousin of the moored profiler (right) developed at WHOI, which travels up and down a steel cable anchored to the seafloor, continuously measuring physical properties throughout the water column. Bob's instruments performed exceptionally well, and he now feels he understands the mechanism that generates the active eddy field within the Beaufort Sea: a periodically unstable current flowing along the sea's southern boundary. Andrey Proshutinsky set moorings in the center of the Beaufort Sea in 2003. He is testing his theory that the Beaufort Sea acts as a flywheel that alternately stores and discharges fresh water into the rest of the Arctic Ocean and, eventually, into the North Atlantic, where the influx may affect ocean circulation and climate.

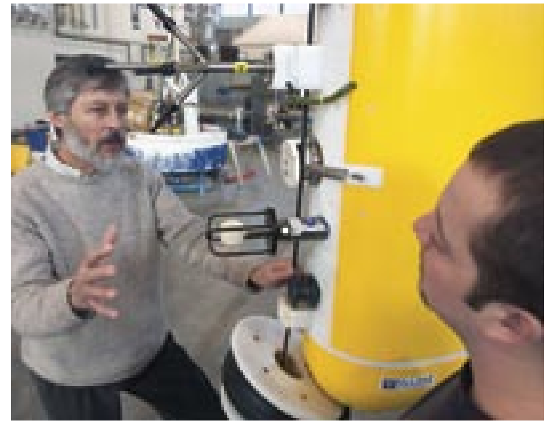
www.whoi.edu/science/PO/dept

Other scientists worked in the Antarctic (Bob Beardsley and Breck Owens), off northwest Australia (Kip Shearman and Ken Brink), and in the tropical Pacific (Bob Weller) and Atlantic (Al Plueddemann). Both Al and Bob also participated in CBLAST (Coupled Boundary Layers/Air-Sea Transfer), the large air-sea interaction program off Martha's Vineyard sponsored by the Office of Naval Research (ONR). Using WHOI's newly launched remotely operated vehicle *Jason II*, Mike McCartney and colleagues recovered six moorings that had been stranded in the tropical Atlantic for more than a year because of defective releases. Dave Fratantoni and his fleet of underwater gliders successfully participated in ONR's month-long Autonomous Ocean Sampling Network project in Monterey Bay, California.

Two new members joined the scientific staff: Jason Goodman and Jim Lerczak. Jason's interests include global ocean-atmosphere coupling, dynamics of the frozen seas of Europa (a moon of Jupiter), and possible causes of Snowball Earth, a period 600 to 700 million years ago when Earth was globally ice-covered. Jim works in coastal and estuarine regions, investigating the physics of tides and river outflow, and couplings between biology and physics that affect larvae dispersal.

Bruce Warren retired in 2003 after a long and productive career. He came to WHOI as an undergraduate during the summer of 1955 and was appointed to the scientific staff in 1963. For his many contributions to physical oceanography, he will be awarded the 2004 Ewing Medal from the American Geophysical Union.





Nelson Hogg, chair of the Physical Oceanography Department (left) and Engineering Assistant Ryan Schrawder with a moored profiler that Schrawder helped build. The moored profiler moves up and down a mooring line to take continuous measurements of water properties throughout the water column.

We were saddened by the death late in 2003 of Nick Fofonoff, Scientist Emeritus, whose career also spanned many decades at the Institution. Nick led efforts to develop and understand current and water property measurements, both for the Department and the field as a whole. Until shortly before his death, he remained at work on a new idea for how thermodynamics might determine the sharpness of the thermocline, the boundary layer between lighter and denser water masses in the ocean.

—*Nelson Hogg, Department Chair*

Awards and Recognition

Amy Bower received the Thomas J. Carroll Blind Employee of the Year Award for 2003, recognizing outstanding achievement by individuals who are blind or visually impaired.

Stephen Jayne received the Office of Naval Research Young Investigator Program Award for his work on the statistics of ocean circulation.

Kurt Polzin received the Fridtjof Nansen Medal of the European Geophysical Society for his pioneering contributions to the measurement of mixing in the deep ocean.

Bernadette Sloyan received the American Meteorological Society Editor's Award for a referee's report of outstanding merit on a manuscript submitted for AMS publication.

Robert Weller received the American Meteorological Society's Sverdrup Gold Medal for his research on ocean-atmosphere interactions.

Promotions

Brian Hogue, Engineering Assistant I

Jeff Lord, Senior Engineering Assistant II

Alison Macdonald, Research Specialist

Theresa McKee, Senior Information Systems Assistant II

Robert Pickart, Senior Scientist

Lisan Yu, Associate Scientist

Appointments

Bruce Warren, Scientist Emeritus

Robert Millard, Oceanographer Emeritus

Related Web Sites

Project overviews: www.whoi.edu/science/PO/dept/projects/research_project.htm

Edge of the Arctic Shelf project: www.whoi.edu/arcticedge

CBLAST project: uop.whoi.edu/cblast

Rick Krishfield

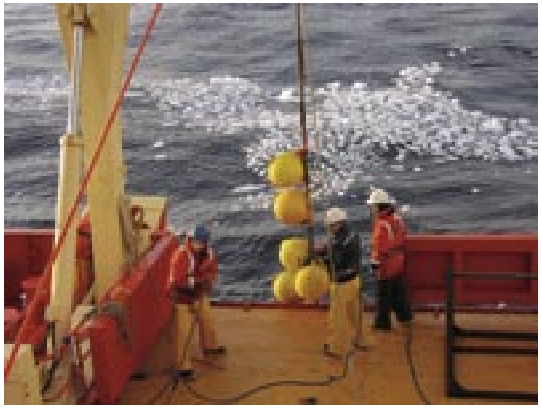
Disembarked from the Canadian icebreaker Louis S. St. Laurent, *scientist Andrey Proshutinsky (left) and technician William Ostrom drill through a two-meter-thick ice floe in the Arctic Ocean in August 2003. They deployed a buoy that drifts with the floe, measuring currents beneath the ice that may affect global ocean circulation and climate.*

C.A. Linder

Physical oceanographer Rui Xin Huang (left) and technician Theresa McKee set up a software program to collect data on water properties in the Irminger Sea aboard R/V Oceanus *in September 2003.*

Jayne Doucette

Physical oceanographers Al Plueddemann and Bob Weller were among many WHOI scientists who used an instrument tower built in 2003 off Martha's Vineyard to study air-sea interactions in the coastal ocean.



Bob Beardsley

In the Southern Ocean aboard the U.S. Coast Guard icebreaker Laurence M. Gould, *WHOI technicians Scott Worrilow (center) and Brian Hogue (left) measure environmental factors that affect the Antarctic food web.*

Academic Programs

The interweaving of research, teaching, advising, and mentoring has been at the heart of the Institution's learning environment since its founding in 1930. This culture and practice was carried forward formally with the inauguration of a graduate education program in 1968. By 2003, the 35th year of the MIT/WHOI Joint Program in Oceanography and Applied Ocean Science and Engineering, more than 600 degrees had been granted through this unique joint degree program. Our alumni and alumnae continue to rise to leadership positions in ocean science and ocean engineering worldwide, advancing knowledge of the oceans and applications of that knowledge in the academic, government, business, and nonprofit sectors. The 134 students enrolled in 2003 are following in the excellent tradition of their predecessors.

Our postdoctoral program has continued to attract the highest caliber recent doctoral degree recipients. We have reorganized our postdoctoral advising and support structure to provide the high-quality WHOI postdoctoral experience for nearly three times the number of postdocs in residence at WHOI, compared to the mid-1990s, due to increased internal and external fellowship support. The postdoctoral program continues to be an important recruiting mechanism for WHOI scientific and technical staff. Four of the five new assistant scientists who took up their appointments this year came from the postdoctoral ranks of WHOI.

www.whoi.edu/education

Our undergraduate offering, a summer program of research experience and introduction to ocean science and ocean engineering, continues to attract a high number of competitive applications nationwide. Thirty undergraduate summer student fellows and minority fellows took part in the program this year, representing 29 educational institutions (see pages 56–57). We are cooperating with our neighbor institutions in Woods Hole—the Marine Biological Laboratory, the National Marine Fisheries Service, the United States Geological Survey, and the Sea Education Association—to recruit and retain greater numbers of students from underrepresented groups into ocean science and ocean engineering.

Our fall and spring workshops for K-12 teachers are enthusiastically received and provide an effective forum for connecting K-12 educators with the latest research. These workshops complement our efforts in various areas of distance learning on the Web. In 2003, we completed the first full year of a five-year grant from the National Science Foundation to establish the New England Center of Ocean Science Education Excellence (NE-COSEE), a partnership of WHOI, the New England Aquarium, and the University of Massachusetts. The COSEE is finding and evaluating ways to link ocean researchers with educators, students, and the public across the region, and assisting researchers with tools, techniques, and opportunities for outreach.

While our primary focus is on higher education, the Institution's education efforts appropriately span the life-long learning experience—sometimes referred to as "K to gray." As one of the "gray" folks, I enjoy immensely my continuing education—learning from the students, postdocs, and colleagues of our WHOI Academic Programs.

—John Farrington, Vice President for Academic Programs and Dean

Tom Kleindinst

Payal Parekh, left (with her mother Meena Parekh), received the George P. "Gera" Panteleyev Award, which recognizes the graduating student who exemplifies a commitment to improving the graduate educational experience and student life at WHOI. The award honors the memory of Gera Panteleyev, a Joint Program student who died during a research expedition in Russia in 1995. The recipient is selected by the Joint Program students. Payal received a doctoral degree in chemical oceanography in 2003.

Coastal Ocean Institute

The Coastal Ocean Institute (COI) carries on the tradition of the Rinehart Coastal Research Center by fostering interdisciplinary coastal ocean research and education and by communicating findings to the world beyond Woods Hole. The coastal ocean—which stretches from the inner reaches of bays and rivers to the edge of the continental shelf—is an incredibly diverse environment. Natural processes in this region affect, and are deeply affected by, human activity. The Coastal Ocean Institute has narrowed its focus to two themes of societal importance: the causes and consequences of our shifting coastlines, and understanding why the coastal ocean is so biologically productive.

In addition to sponsoring six new research projects and several guest lecturers in 2003, COI joined the Marine Policy Center in sponsoring a symposium on offshore wind power (see page 32). Eighteen specialists from six countries were invited to Woods Hole to share knowledge and define the lines of research required to make intelligent decisions about this resource. The symposium attracted more than 50 scientists and decision-makers who are already translating what they learned into policy.

www.whoi.edu/institutes/coi

In November 2003, COI presented the 13th Bostwick H. "Buck" Ketchum Award, which recognizes scientists for excellence in coastal research and in bridging the gap between scientists and society. Ketchum served WHOI for more than 40 years, starting as a graduate student and finishing as Associate Director of the Institution, while making a name for himself in coastal biology along the way. This year's medal was awarded to John Farrington, WHOI Vice President for Academic Programs and Dean, for a lifetime of work on the effects of oil spills on the coastal ocean. The presentation marked the first time the award has been given to an Institution scientist.

Two new COI Fellows were chosen in 2003: John Trowbridge, a senior scientist in the Applied Ocean Physics and Engineering Department, and Heidi Sosik, an associate scientist in the Biology Department (joint fellowship with the Ocean Life Institute). Trowbridge and Sosik will work together to understand the physical processes that drive changes in biological activity, as observed from the Martha's Vineyard Coastal Observatory.

—Ken Brink, Institute Director

Tom Kleindinst

Institute Director Ken Brink (left) with new COI Fellow Heidi Sosik, who is studying how physical processes of the ocean affect the productivity of marine organisms.

Deep Ocean Exploration Institute

The Deep Ocean Exploration Institute (DOEI) investigates processes that shape the planet's surface, regulate the chemistry of its oceans, and impact its inhabitants. In the past two decades, interest has escalated in microorganisms that may live in the crust and sediments of the ocean. In fall 2003, national and international experts came to WHOI for a seminar series on the deep biosphere. At the same time, two new DOEI fellows initiated research on an emerging theme in DOEI called Earth's Deep Biosphere.

Wolfgang Bach, a geochemist, is studying the relationship between geochemical and microbiological processes occurring within oceanic rocks to see if organisms are altering the newly generated crust at mid-ocean ridges. Greg Hirth, a geophysicist, is using his understanding of the physical properties of rocks to investigate interactions between cracking in the oceanic crust and biogeochemical processes. In addition, Olivier Rouxel, a new postdoctoral fellow, began research that uses isotopes as tracers of the existence of a deep biosphere in the oceanic crust.

www.whoi.edu/institutes/doei

Five new research projects were funded within DOEI's ongoing theme of Seafloor Observatory Science and Instrumentation and the theme of Fluid Flow in Geologic Systems. Dan Frye, an engineer, along with John Collins, a geophysicist, will develop data capsules that pop up periodically from the ocean floor instrumentation, float to the surface, and send their data via satellite to scientists on shore. Biologists Tim Shank and Stefan Sievert will investigate how the chemical and microbial environment at seafloor hydrothermal vents might act as settlement cues for larvae during their initial colonization. Geophysicist Jeff McGuire will deploy newly developed instruments to measure movement across a transform fault often associated with earthquakes and seafloor spreading.

Other researchers funded by DOEI plan to study larval dispersal of organisms at hydrothermal vents, while others will adapt an instrument that measures concentrations of many elements simultaneously for use at vent sites.

The Institute hosted two workshops in 2003. "The Next Generation of In Situ Biological and Chemical Sensors in the Ocean" was co-sponsored with the WHOI Ocean Life Institute, the National Science Foundation, and the Office of Naval Research, for participants from academia and industry. Engineers and scientists at WHOI also participated in the workshop "Mapping and Visualization Techniques," conducted by the Center for Coastal and Ocean Mapping at the University of New Hampshire.

In May, DOEI joined with the WHOI Ocean and Climate Change Institute, as well as scientists from the California Institute of Technology, to present a special online Dive and Discover expedition dedicated to climate change. Scientists diving in the submersible *Alvin* at the New England Seamounts, a chain of undersea volcanoes about 500 miles from North America, collected deep-sea corals that reveal variations in ocean chemistry over time. These changes may indicate how Earth's climate rapidly cooled or warmed in the past, and provide clues to how climate may change in the future.

—*Susan Humphris, Institute Director*

Tom Kleindinst

Institute Director Susan Humphris (right) with Senior Research Assistant Margaret Sulanowska.

Ocean and Climate Change Institute

Pursuing greater understanding of the ocean's role in climate change, the Ocean and Climate Change Institute (OCCI) launched support for several new research projects, an OCCI fellow, and two postdoctoral scholars, and also sponsored a conference on a key abrupt climate change in the past.

In 2003, the OCCI initiated a rapid response to the loss of a moored profiler at Station W, which was deployed near the Bahamas in 2002 to collect crucial measurements of the Gulf Stream and Deep Western Boundary Current. The Institute funded deployment of a replacement mooring to prevent a gap in measurements until new moorings funded by the National Science Foundation can be deployed in 2004.

New research projects launched by the Institute include an autonomous glider program; development and application of new geochemical paleothermometers; a comparison of deep convection models; initiation of an integrated biogeochemical flux and hydrographic program at Station W; a study of deep-water variability during the Holocene; and an analysis of sedimentary records of millennial-scale hydrological variability in the northeastern United States over the past 15,000 years.

www.whoi.edu/institutes/occi

The OCCI also funded projects to establish or supplement Arctic Ocean and Atlantic Ocean observing systems to enhance understanding of the region's potential impacts on climate change: the Beaufort Gyre Freshwater Observing System, the Davis Strait–Labrador Sea Observing System, and the East Greenland Current Observing System.

The Institute supported four fellows in the third year of their terms and one new fellow, Scott Doney, who pursues research in marine biogeochemistry and ecosystem dynamics, large-scale ocean circulation and tracers, air-sea gas exchange, and the global carbon cycle. New postdoctoral scholarships were awarded to Mahdi Ben Jelloul, who studies low-frequency variability in the oceans, and Dierdre Toole, whose research focuses on climate responses and potential feedbacks from the biogeochemical cycling of sulfur in the upper water column. The Institute also continued to support MIT/WHOI graduate student Rose Came, who studies the recent geological history of intermediate water circulation.

With additional OCCI funding, OCCI Fellow Lloyd Keigwin hosted a successful international conference analyzing the mechanisms that triggered an abrupt climate change 8,200 years ago, a past analogue to potential future climate change.

—William Curry, Institute Director

Tom Kleindinst

Institute Director William Curry with Research Assistant Marti Jeglinski, who loads a sample vial into a stable isotope mass spectrometer. The mass spectrometer analyzes chemical compositions of fossil marine organisms to reveal the temperature and carbon content of ocean waters that existed in the past when the organisms were alive.

Ocean Life Institute

The Ocean Life Institute (OLI) fosters new research on important biological and ecological questions in the ocean. In 2003, the OLI supported a range of new fellows, projects, scientific meetings, and research initiatives under its three broad themes: biodiversity, ecosystem structure and sustainability, and new tools.

Cabell Davis and Heidi Sosik from the Biology Department were appointed new OLI fellows, joining three others continuing from 2001. Davis will work to integrate advanced optical, genetic, and robotic technologies into autonomous instruments that can survey and identify zooplankton in the ocean. Sosik's fellowship, jointly sponsored by OLI and the Coastal Ocean Institute, will allow her to focus on new approaches to understanding the dynamics of phytoplankton populations in coastal waters.

The OLI appointed a new postdoctoral scholar, Tim Verslycke, who will study genetic and molecular aspects of toxicology in marine animals. New OLI grants to WHOI investigators include those for a demographic study of albatross populations; age measurements of deep-sea corals; and finding new ways to retrieve bacterial samples from the bottom of the ocean.

www.whoi.edu/institutes/oli

In July, OLI hosted a workshop, "The Next Generation of In Situ Biological and Chemical Sensors in the Ocean." Cosponsored by the Deep Ocean Exploration Institute, the National Science Foundation, and the Office of Naval Research, this meeting brought together 160 investigators from many fields of science, engineering, government, and industry to brainstorm on new technologies and possibilities for sensors and instruments in the sea.

Research initiatives are an important mechanism to focus OLI's work on pressing problems. The OLI Right Whale Research and Conservation Initiative got its official start with an Ocean Forum in November that brought together an array of experts from several institutions and scientific fields to chart a course for timely and practical research to help save this highly endangered species. A second program, the Coral Reef Connectivity and Conservation Initiative, has begun planning a program that will marry advanced WHOI science and technology to international conservation efforts in the Caribbean. Our developing partnership with the Liquid Jungle Laboratory, a new tropical field station in Panama, blossomed during the year, and the first WHOI scientists will visit the lab in early 2004.

—Laurence Madin, Institute Director

Tom Kleindinst

Institute Director Laurence Madin (left) examines a salp specimen preserved for genetic analysis, with Research Associate Erich Horgan.

Institution Outreach

While the focus of formal education at WHOI is on the university level and higher, the Institution has a history of formal and informal educational outreach to the public, teachers, and students from pre-kindergarten through high school.

For decades, WHOI staff have participated as judges, mentors, and advisors in local science fairs, with prizes to top winners donated by the Academic Programs office, the Cooperative Institute for Climate and Ocean Research (CICOR), and the WHOI Sea Grant program. Our researchers regularly speak to school groups, visit classrooms, give lab tours, and make presentations at museums and conferences. Sea Grant also sponsors a lecture series on ocean topics every spring, and hosts a Web site on marine science careers (www.marinecareers.net), among other efforts.

The WHOI Exhibit Center hosts approximately 50 school groups each year, and WHOI employees are an important part of the regional Ocean Science Bowl competition. The Woods Hole Science Technology Education Partnership, now in its 15th year, involves local schools, research labs such as WHOI, and businesses, with the common purpose of advancing science, math, and technology education in the schools.

Outreach activities in 2003 reached more than 200 K-12 teachers, and ranged from hosting the annual conference of Massachusetts Marine Educators, to workshops in oceanography for middle and high school teachers.

The Web continues to play an important role in outreach. Several hundred educators registered in May and June on the Dive and Discover Web site (www.divediscover.whoi.edu), created by senior scientists Dan Fornari and Susan Humphris to access daily updates from an expedition to the New England Seamounts and provide classroom activities based on them. During the three-week cruise, nearly 50,000 visitors from more than six countries followed an investigation of deep sea corals. To extend the reach of the Web site, WHOI worked with the Boston Museum of Science to create a temporary exhibit featuring the Dive and Discover Seamounts expedition, which included daily live phone connections between museum visitors and researchers aboard the research vessel *Atlantis* and the deep submergence vehicle *Alvin*.

In 2003, the Institution's museum exhibition, "Extreme Deep," traveled to three venues: the St. Louis Science Center, the Nauticus National Maritime Center in Norfolk, and the Great Lakes Science Center in Cleveland. More than 175,000 visitors encountered the full-size replica of the *Alvin* personnel sphere and explored life in the depths—starting with spectacular images of ethereal jellyfish, and culminating in a life-size, 3-D replica of the exotic life that dwells around seafloor hydrothermal vents.

The New England Center for Ocean Sciences Education Excellence (NE-COSEE) completed its first year of operation in 2003. The Center is among seven nationwide funded by the National Science Foundation (NSF) to enhance collaboration and communication between ocean science researchers and educators. The Center is a five-year partnership between WHOI, the New England Aquarium, and the University of Massachusetts. Led

Andrea Thorrold

Jian Lin (left) and Karl von Reden, both of the Geology and Geophysics Department, plan presentations for K-12 students at a workshop sponsored by the New England COSEE at WHOI.

by Deborah Smith, a senior scientist in the Geology and Geophysics Department, the NE-COSEE team at WHOI surveyed the WHOI community to determine which resources and skills researchers need to conduct outreach. Other activities included:

- A visit by NSF Ocean Sciences Division Director Jim Yoder regarding the agency's "broader impact" requirement;
- Developing a definition of "ocean literacy" to help evaluate educational material;
- Developing necosee.whoi.edu to inform and facilitate networking;
- A one-week experimental Ocean Science Education Institute to bring together scientists and teachers.

With the ever-increasing public interest in the oceans, outreach continues to play an important role in communicating the meaning and value of the research and engineering conducted at WHOI.

—*Stephanie Murphy*

Marine Policy Center

The Marine Policy Center (MPC) conducts social scientific research that integrates economics, policy analysis, and law with the Institution's basic research in ocean sciences. Areas of recent research include offshore wind energy, fisheries and aquaculture, and the management of coastal and marine resources.

Offshore wind energy was an important new focus in 2003. Wind energy is the fastest-growing sector of the electric power industry domestically and worldwide, and the United States accounts for about 15 percent of the world's wind energy market. In recent years, about two dozen proposals have been advanced to build wind farms at locations in the U.S. coastal ocean where winds are consistently strong, demand for power is concentrated nearby, and connections to the electric power grid are readily available.

In October, MPC researchers convened a workshop of international specialists to examine issues raised by such proposals, which entail a new use of a public resource that must be balanced against other, potentially conflicting, uses. Research Specialists Porter Hoagland and Hauke Kite-Powell and Research Assistant Mary Schumacher organized the event, with support from the Coastal Ocean Institute.

www.whoi.edu/science/MPC/dept

The workshop focused on the development of a U.S. management approach and policy framework for siting wind energy facilities in the coastal ocean. Offshore wind energy proposals are currently addressed through a rudimentary system based on the Rivers and Harbors Act of 1899, which was not written with this particular ocean use in mind. The system is incapable of handling multiple claims to the same area, nor can it provide a rational framework for minimizing environmental impacts and conflicts between users.

MPC researchers are now drafting a white paper that will summarize the discussions and results of the workshop. In the next phase of its research, the team will identify features of an optimal system of legal access to offshore areas; describe the tradeoffs that must be confronted by the agencies managing the access system; and propose areas where further policy analysis is most likely to contribute to informed public decisions about the location of wind farms.

In other ongoing projects, MPC researchers are assessing the economic impacts of the introduction and spread of non-native aquatic nuisance species, and evaluating a range of management alternatives. Another study is examining the potential for nutrient removal from coastal waters through the cultivation and harvesting of filter-feeding shellfish, such as oysters and clams.

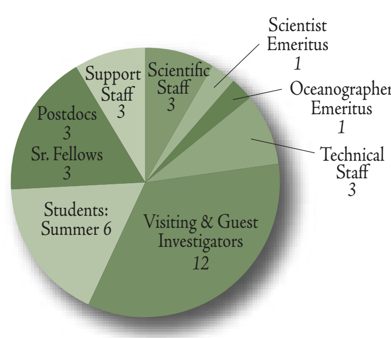
—Andrew Solow, MPC Director

Tom Kleindinst

Marine Policy Center Director Andrew Solow (left) confers with Amit Huppert, a postdoctoral research fellow, on a paper they authored on the use of corals in reconstructing past climate history.

Promotions

Andy Beet, Information Systems Associate II



WHOI Sea Grant Program

The WHOI Sea Grant Program (www.whoi.edu/seagrant) supports research, education, and extension projects that encourage environmental stewardship, long-term economic development, and responsible use of the nation's coastal and ocean resources. It is part of the National Sea Grant College Program of the National Oceanic and Atmospheric Administration, a network of 30 individual programs in each of the coastal and Great Lakes states. Their purpose is to foster cooperation between government, academia, industry, scientists, and the private sector.

With an annual budget of just under $1 million, WHOI Sea Grant supports approximately 10 concurrent research projects in the areas of environmental technology, estuarine and coastal processes, and fisheries and aquaculture. In addition, Sea Grant provides seed money for "new initiative" efforts to take the first steps into promising new areas. Sea Grant research addresses local and regional needs, and many projects have national or even global implications.

www.whoi.edu/seagrant

In 2003, research topics included:

- Possible effects of low-level contamination on key developmental stages of Atlantic salmon;
- Lobster and squid population structures, comparing offshore and near-shore populations, and potential fisheries management impacts;
- Soft-shell clam populations and the role of tidal exchange in larval dispersal and its impact on regional recruitment by using natural tags;
- Chemical pollutants and their effects on marine invertebrates, mammals, and fish;
- Land-derived nitrogen and its effects on commercially important bivalves such as quahogs, soft-shell clams, and bay scallops;
- Groundwater as a transport mechanism for nutrients and contaminants flowing into estuarine systems;
- Tidal marshes as a net sink for nitrogen and a source of nitrogen release within estuarine systems;
- Metal accumulation in sediments as a result of Boston Harbor sewage discharge;
- Aquatic nuisance species and the economic effects associated with their introduction;
- Use of scanning electron microscopy to understand causes and implications of lobster shell disease on the animal and the fishery.

In addition to research, WHOI Sea Grant supports a marine extension program and an outreach/education program. Through those efforts, research is transmitted to a variety of audiences through publications, Web sites, workshops, and lectures. Many Sea Grant outreach programs involve partnerships, such as with the Barnstable County Cooperative Extension Service, to provide technical expertise and demonstration projects on shellfish aquaculture and coastal processes.

A recent partnership with the Waquoit Bay National Estuarine Research Reserve (WBNERR) and the Massachusetts Coastal Zone Management Program is designed to provide research-based training to Massachusetts coastal policymakers (see www.coastaltraining.org). In the ocean science education field, WHOI Sea Grant has partnered with colleagues at New Hampshire Sea Grant to provide marine career information to students

Dann S. Blackwood, USGS

Bill Martin (right), WHOI Marine Chemistry and Geochemistry Department, and Mike Bothner, U.S. Geological Survey, recover push cores from a Sea Grant-supported study of possible links between sewage output and trace metals in surface sediments.

(www.marinecareers.net), and with the WHOI Coastal Ocean Institute and WBNERR to provide teacher workshops using coastal research, technology, and instrumentation. WHOI Sea Grant is also involved with the New England Center for Ocean Science Education Excellence, a partnership between the New England Aquarium, the University of Massachusetts, and WHOI.

—*Judith E. McDowell, Director*

Cooperative Institute for Climate and Ocean Research

The Cooperative Institute for Climate and Ocean Research (CICOR) coordinates and fosters interaction between WHOI and the National Oceanic and Atmospheric Administration (NOAA). CICOR administers NOAA-funded research, builds ties between researchers at WHOI and NOAA, and carries out outreach and education activities. The Institute is one of 13 such joint institutes operating in 12 states.

Research themes at CICOR focus on climate, marine ecosystems, and coastal ocean research. Nineteen new and ongoing projects within these themes were funded in 2003, bringing the total to 45 projects. Funding for all projects in 2003 totaled $5 million.

Funding supported the continuing research of the Global Ocean Ecosystem Dynamics (GLOBEC) project, a group of oceanographers and fisheries specialists addressing global climate change. Multiple efforts by WHOI scientists and their collaborators involved with GLOBEC centered on Georges Bank, a productive North Atlantic fishery stretching from New England to Nova Scotia.

www.whoi.edu/science/cicor

Biologist Peter Wiebe, with others in the Biology and the Applied Ocean Physics and Engineering departments, collaborated with more than a dozen investigators from five universities and the National Marine Fisheries Service in Woods Hole to synthesize data about the distribution and abundance of the larvae and eggs of cod, haddock, and other marine species on Georges Bank. Their goal is to anticipate how these populations might respond to climate change.

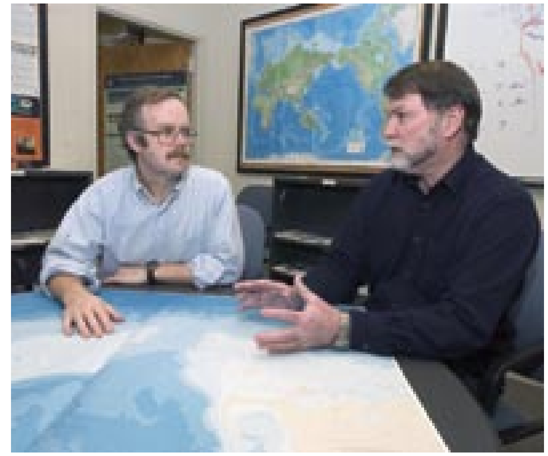
Wiebe also worked with GLOBEC program members on reports and an annual workshop to showcase data sets and modeling efforts at Georges Bank. They presented their results at the American Geophysical Union Ocean Sciences meeting in January 2004.

Robert Beardsley and others in the Physical Oceanography Department worked to describe fluctuations in the currents and stratification on Georges Bank, including the tidal mixing front that develops over the top of the Bank during the summer. Their colleagues in the Marine Policy Center at WHOI, John Steele and Andrew Beet, conducted an analysis of climate impacts on phytoplankton to see how changes in their productivity would affect fish stocks.

Two new postdoctoral scholars joined CICOR in 2003. Ruoying He studies ocean circulation, biophysical interactions, air-sea interactions, numerical modeling, and data assimilation. He is conducting research with Robert Beardsley in the Physical Oceanography Department and Dennis McGillicuddy in the Applied Ocean Physics and Engineering Department.

Nicholas Scott is working on statistical analyses of steep waves in open ocean waters for research with John Trowbridge and Jim Edson, both in the Applied Ocean Physics and Engineering Department.

—Robert Weller, CICOR Director



Tom Kleindinst

CICOR Director Bob Weller (left) and scientist Peter Wiebe of the Biology Department review a chart of Georges Bank, a fishery being studied by oceanographers addressing climate change with the GLOBEC project.

Related Web Site

GLOBEC (Georges Bank): globec.whoi.edu

WHOI in the News

The impact of oil on the marine environment, abrupt climate change, noise and marine mammals, and new undersea exploration vehicles were among the WHOI science and engineering activities attracting international media interest in 2003. Several thousand requests for images and information were received from organizations as diverse as The National Academies, W.W. Norton Publishers, the National Science Foundation, Polish Scientific Publishers, The Exploratorium in San Francisco, and the Museo Tridentino di Scienze Naturali in Italy. A live Web link from R/V *Atlantis* to the Liberty Science Center in New Jersey in August was one of a number of WHOI outreach activities related to the IMAX film *Volcanoes of the Deep Sea*, which featured dives in the submersible *Alvin*. The film was released nationwide in September.

In the United States and abroad, hundreds of articles appeared in print and broadcast media, such as *Newsweek*, *Astrobiology Magazine*, *Marine Scientist*, *Science*, *Harvard Magazine*, and *National Geographic Magazine*, and many programs were broadcast by National Public Radio, NBC, CBS, Discovery Channel, The Science Channel, PBS, The Learning Channel, The History Channel, and The Travel Channel.

www.whoi.edu/media

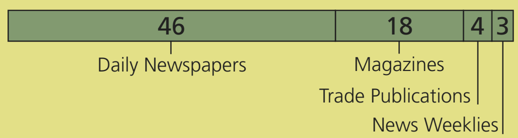
Other highlights for 2003 include:

- The British Broadcasting Corporation (BBC) interviewed Lloyd Keigwin, Terry Joyce, and WHOI President and Director Bob Gagosian for *The Big Chill*, a one-hour program on abrupt climate change.
- WHOI presented its first Ocean Science Journalism Award to Alastair Fothergill of the BBC for the television series *Blue Planet: Seas of Life* and to Robert Kunzig for the book *Mapping the Deep*. The awards ceremony and a press briefing on autonomous underwater vehicles were held in New York City in October.
- Seven journalists from newspapers, magazines, Web sites and television stations nationwide gathered at WHOI in September for an intense week of study during the fourth annual Ocean Science Journalism Fellowship program. Thirty-three journalists have participated in the program since it began in 2000.
- Among the many journalists to visit WHOI during the year were 10 international Knight Science Journalism Fellows from MIT, who came in October.

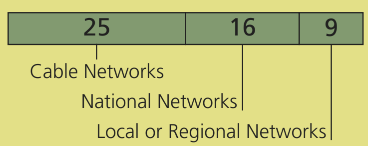
—*Shelley Dawicki*

Print and broadcast stories featuring WHOI science reached a potential audience of 121 million in 2003.

Circulation of print media featuring WHOI
(in millions)



Viewership of television programs featuring WHOI
(in millions)



Dave Gray

Geologist Jeff Donnelly (with cap) with the Ocean Science Journalism Fellows in the marsh at Wood Neck Beach, Falmouth, Massachusetts, explaining how sediment cores are used to study the impact of major hurricanes and storms on coastal marshes.

Jayne Doucette

Marine Meteorologist Jim Edson (top center, with white folder) explains operations at the Martha's Vineyard Coastal Observatory during an August boat trip to the site for federal agency representatives, local officials, and members of the media.

Public Policy

Scientists at WHOI contribute to the discussion of public policy and science policy issues at the national and international levels. A selection of their activities in 2003 is given here.

Don Anderson	Testimony on harmful algal blooms and hypoxia, U.S. House of Representatives Science Subcommittee on Environment, Technology and Standards
	Briefing on harmful algal blooms, U.S. House of Representatives Oceans Caucus and the House Committee on Science
Bob Beardsley	Member, Outfall Monitoring Science Advisory Panel, Environmental Protection Agency (EPA)
Ken Brink	Scientific Advisory Board, U.S. Commission on Ocean Policy*
George Frisk	Chair, Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals, National Academy of Sciences/ National Research Council (NAS/NRC)
Bob Gagosian	Scientific Advisory Board, U.S. Commission on Ocean Policy*
Darlene Ketten	Testimony on military provisions in the Marine Mammal Protection Act, U.S. House of Representatives Resources Committee
	Testimony on impacts of environmental laws on readiness, U.S. Senate Armed Services Subcommittee on Readiness and Management Support
	Testimony on modification of the Marine Mammal Protection Act, U.S. House of Representatives Armed Services Subcommittee on Readiness
	Member, Ambient Noise in the Oceans and Effects on Marine Mammals Panel, Ocean Studies Board**, NAS/NRC

Larry Madin	Member, Advisory Board Science Committee to Review Science Policy and Programs, National Park Service
Judy McDowell	Ocean Management Task Force, Commonwealth of Massachusetts
Andy Solow	Testimony on Bush Administration's plan for global climate change research, U.S. Senate Commerce, Science and Transportation Committee
	Chair, Outfall Monitoring Science Advisory Panel, EPA
	Scientific Advisory Board, U.S. Commission on Ocean Policy*
John Stegeman	Committee to Review Health Effects of Agent Orange in Vietnam Veterans, National Research Council/Institute of Medicine
Peter Tyack	Testimony on Marine Mammal Protection Act Reauthorization, U.S. House of Representatives Resources Subcommittee on Fisheries Conservation, Wildlife and Oceans
	Testimony on modification of the Marine Mammal Protection Act, U.S. House of Representatives Armed Services Subcommittee on Readiness
	Testimony on reauthorization of the Marine Mammal Protection Act, U.S. Senate Commerce, Science and Transportation Subcommittee on Oceans, Fisheries and Coast Guard

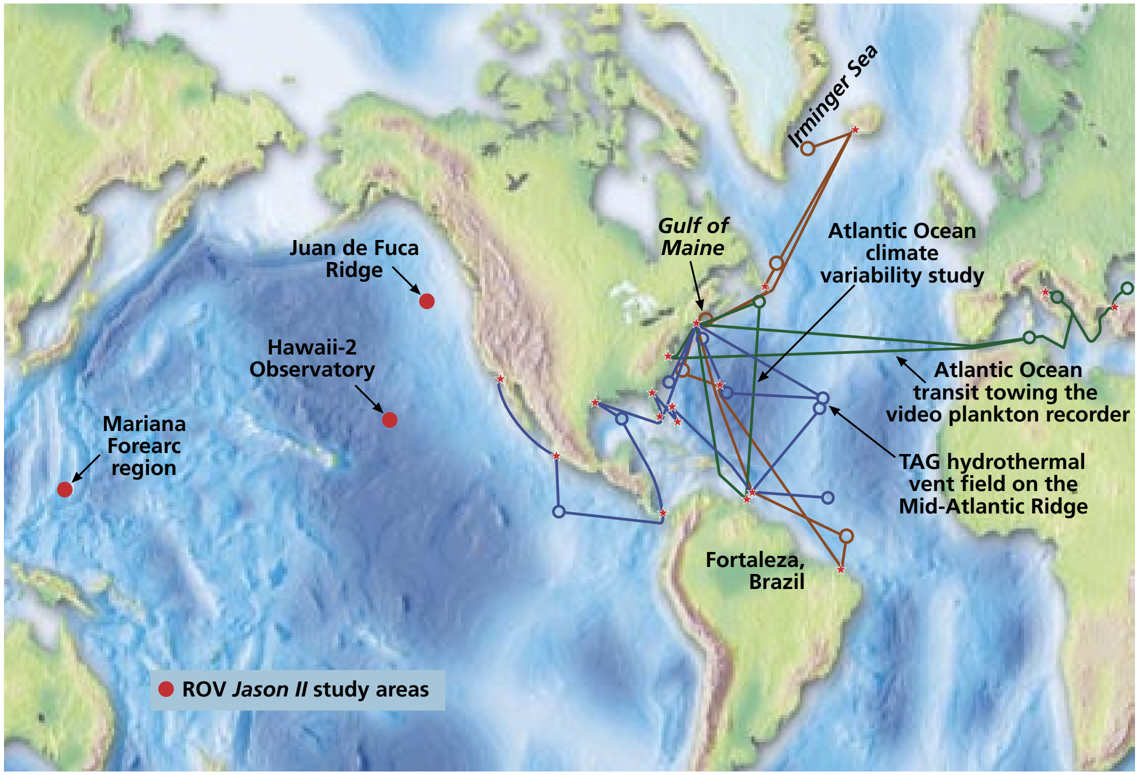
*The U.S. Commission on Ocean Policy is establishing findings and making recommendations to the President and Congress for a coordinated and comprehensive national ocean policy.
**The Ocean Studies Board was established by the National Research Council to advise the U.S. federal government on issues of ocean science, engineering, and policy.

Science Policy

Don Anderson	Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB), Scientific Committee on Oceanic Research, Intergovernmental Oceanographic Commission, United Nations Educational, Scientific and Cultural Organization (UNESCO)
	Director, U.S. National Office for Marine Biotoxins and Harmful Algal Blooms
Bob Beardsley	Member, Atmospheric Sciences and Climate Board, NRC
Bill Curry	Chair, Science Committee, International Marine Past Global Changes Study (IMAGES)
	Member, Earth System History Steering Committee, National Science Foundation (NSF)
Bob Detrick	Chair, Board of Governors, Joint Oceanographic Institutions (JOI)
	Chair, Implementation of a Seafloor Observatory Network of Oceanographic Research Study, NAS/NRC
	Advisory Committee, NSF Geosciences Directorate
	Member, Board of Governors, International Ocean Drilling Program (IODP) Management International
Scott Doney	U.S. Carbon Cycle Science Program Scientific Steering Group, U.S. Global Change Research Program
Bob Gagosian	Member, Science Advisory Board, National Oceanic and Atmospheric Administration (NOAA)
	Member, Board of Governors, Consortium on Oceanographic Research and Education
Rocky Geyer	NAS/NRC Ocean Studies Board**
Stan Hart	NAS/NRC Ocean Studies Board**
Greg Hirth	Member, MARGINS Steering Committee, NSF
Susan Humphris	Member, Science Planning and Policy Oversight Committee, IODP
	U.S. Science Support Program Education Steering Committee, JOI
	Ocean Exploration Committee, NRC

Lloyd Keigwin	Chair, Rapid Climate Change Program Steering Committee, Natural Environmental Research Council, U.K.
Olivier Marchal	Steering Committee Scientific Expert, IMAGES
Judy McDowell	Member, Committee on Oil in the Sea-Update on Inputs, Fate and Effects, NRC
Lauren Mullineaux	Steering Committee, Scientific Committee on Time Series Program, NSF
Dan Repeta	Member, Carbon Sequestration Panel, Department of Energy
Tim Shank	U.S. Deep Submergence Science Committee, University-National Oceanographic Laboratory System
Deborah Smith	Committee Member, Review of NOAA's National Geophysical Data Center, NRC
Andy Solow	Future of Deep Submergence Committee, NRC
John Stegeman	Chair of Advisory Board, Environmental Health Sciences Center, National Institutes of Health
Peter Tyack	Member, Committee of Scientific Advisors on Marine Mammals, Marine Mammal Commission
Bob Weller	Member, Global Ocean Observing System Capacity Building Panel, UNESCO/World Meteorological Organization
	Member, Committee to Review the Climate Change Strategic Plan, NRC
	Member, Senior Research Council, NOAA
	Member, Ocean Observations Panel for Climate, UNESCO/ Intergovernmental Oceanographic Commission
Peter Wiebe	Chair, Executive Committee, U.S. Global Ocean Ecosystem Dynamics Georges Bank Program
	U.S. Representative, Oceanography Committee, International Council for the Exploration of the Sea

Cruise Tracks

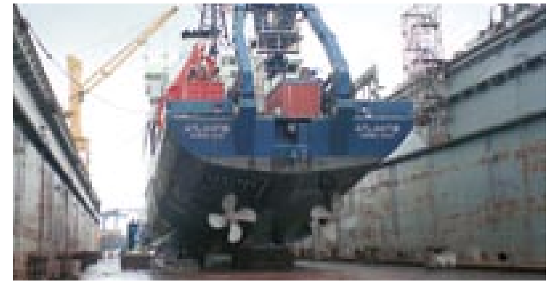


Jayne Doucette

Atlantis
Capacity: 59 people at sea for 60 days
Launched: 1996
Days at sea in 2003: 191
Cruises: 17
Investigators served: 283
Nautical miles: 23,120
Alvin *dives: 100*

Knorr
Capacity: 58 people at sea for 60 days
Launched: 1970, converted in 1991
Days at sea in 2003: 225
Cruises: 20
Investigators served: 444
Nautical miles: 36,215

Oceanus
Capacity: 31 people at sea for 30 days
Launched: 1975, converted in 1994
Days at sea in 2003: 154
Cruises: 21
Investigators served: 240
Nautical miles: 27,876



Bob Elder

A rare look below the water line: R/V Atlantis *during scheduled maintenance in the Bahamas in April.*

R/V *Atlantis* and DSV *Alvin*

Research Vessel (R/V) *Atlantis* spent 2003 sailing regions of the Pacific and Atlantic oceans supporting deep submergence projects. Deep Submergence Vehicle (DSV) *Alvin*, which operates from *Atlantis*, made 100 dives and carried 300 pilots and passengers last year during scientific expeditions to the Mid-Atlantic Ridge, the New England Seamounts, the Gulf of Mexico, and the East Pacific Rise.

Atlantis operates around the clock. *Alvin* typically dives in the morning, spends the day at the bottom of the sea, and is recovered in the late afternoon. At night, while the *Alvin* team prepares the submersible for the next day's dive, the ship performs research operations such as mapping, collection of dredge or water samples, and towing of instruments.

Science operations began in March with a cruise to test Britain's new Remotely Operated Vehicle (ROV) *Isis* (a clone of ROV *Jason II*), capable of diving to 21,325 feet (6,500 meters). In April, researchers on *Atlantis* visited the massive hydrothermal vent field "Lost City" for the second time since scientists discovered the site while diving in *Alvin* in 2000. On May 16, 2003, *Alvin* pilot Pat Hickey marked his 500th dive while sampling there for mussels and carbonates.

In early June the ship sailed to the New England Seamounts, where scientists collected corals that record climate change signals. A cruise in late June to the Mid-Atlantic Ridge focused on the seismicity, structure, and fluid flow of hydrothermal systems. Other summer cruises included an expedition to study species biodiversity at the New England Seamounts and a cruise off the southeastern United States focused on the biology, physics, and chemistry of seafloor methane seeps.

Atlantis returned to Woods Hole in August for scheduled maintenance. In October science operations resumed with a trip to the Gulf of Mexico for the study of chemosynthetic communities. After traveling through the Panama Canal, *Atlantis* sailed to the East Pacific Rise, where scientists using *Alvin* collected biological samples. A second visit to the site in November and December allowed researchers to continue studies of the tubeworms that live on chimneys at hydrothermal vent fields.


Chris Roman

Knorr *arrives in Istanbul, Turkey.*

R/V *Knorr*

The longest ship at WHOI at 279 feet (85 meters), *Knorr* can operate worldwide in any ice-free waters. Like *Oceanus*, *Knorr* is a general-purpose ship.

Knorr is outfitted with thrusters and global positioning system navigation, and in 2003 received a new computer-controlled dynamic positioning system that allows the ship to hold its position to within three feet (one meter). This is an important capability for operations such as drilling core samples and operating tethered vehicles.

In early January, *Knorr* traveled to the Adriatic Sea to support an Office of Naval Research (ONR) cruise to measure seawater mixing, before sailing to the Black Sea for three months of National Science Foundation (NSF) sponsored chemistry, physical oceanography, and marine archaeology research. The ship returned to the Adriatic in late May and June for scientists to complete research on ocean circulation.

Following maintenance in Malta, *Knorr* spent July and August at deep-sea archaeological sites in the Black Sea and the Mediterranean. As *Knorr* traveled back across the Atlantic to Woods Hole, scientists and engineers tested a new underwater video microscope, called a video plankton recorder, that measures the distribution of plankton. In October and November, a cruise supported scientists conducting an extensive hydrographic survey between Woods Hole, Newfoundland, and Trinidad.


Ryan Frazier

Oceanus *in Newfoundland.*

R/V *Oceanus*

At 177 feet (54 meters), *Oceanus* is a mid-size research vessel designed for cruises lasting two to three weeks. The ship is equipped for deploying deep ocean moorings; collecting bottom samples, water samples, and data to depths of 16,404 feet (5,000 meters); and towing oceanographic instruments that measure seawater properties, biological populations, and other physical and chemical variables. Following a mid-life upgrade in 1994, the service life of *Oceanus* was extended to 2009.

Working the Atlantic Ocean from the equator to the Arctic Circle, *Oceanus* supported research projects in nearly every oceanographic discipline in 2003, and even gave some students a first taste of scientific work at sea.

On separate cruises in January and February to the tropical Atlantic, researchers and technicians used *Oceanus* to recover and redeploy moorings that measure meteorological conditions at the sea surface and the flow of deep water from the Antarctic into the

Atlantic circulation system. Between those cruises, the ship tracked the movement of a tracer dye that was released in 2001 in order to measure mixing in the top layers of the tropical ocean.

On a March cruise for the NSF Engineering Research Center, researchers conducted tests of autonomous underwater vehicles. Two cruises for ONR in April and May focused on the acoustic properties of the Atlantic Ocean along the U.S. continental shelf, while a third ONR expedition in November collected data on how fluid dynamics in the sea can affect the propagation of acoustic signals.

A summer cruise in the Gulf of Maine studied the characteristics of *Alexandrium fundyense*, algae known to poison shellfish. Further north, the ship supported cruises in July and August to the Labrador, Irminger, and Greenland Seas to collect data on the flow of water into and out of polar regions.

The ship supported a January oceanographic training cruise from Woods Hole to Brazil for undergraduate students from the University of Maryland.

Dan Fornari

Remotely Operated Vehicle Jason II.

ROV *Jason II*

ROV *Jason II* spent the entire year in the Pacific Ocean working from the R/V Thomas G. *Thompson*. Through five expeditions, *Jason II* was lowered 47 times, logging 752 hours on the seafloor and reaching its diving limit—21,325 feet (6,500 meters)—on several dives.

In the Mariana Forearc region off Southeast Asia, in March *Jason II* conducted a precision mapping campaign of four seamounts and collected samples of mud, rock, and seafloor organisms. In June, the ROV explored the Endeavour hydrothermal vent field on the Juan de Fuca Ridge off Washington state, drilling into basalt and sulfide formations to deploy *in situ* instruments and to take samples of high-temperature fluid flow sites. On a second trip to the Ridge in July, *Jason II* collected wood and organism samples as well as more than 200 gallons of fluid from active hydrothermal vents for a research team investigating the origins of life on the seafloor.

On two other cruises in May and September, the ROV was used to upgrade and install new instruments at the Hawaii-2 Observatory (H2O), which lies on the seafloor halfway between Hawaii and California. Researchers used the vehicle to recover and redeploy the H2O junction box, augmenting and extending the utility of the only U.S. deep-ocean observatory. Among other instruments, the team installed a new seismometer system to monitor earthquakes and submarine landslides, as well as a photographic monitoring system to observe sea creatures that pass through the area.

Tom Kleindinst

Rollover of the new 60-foot coastal research vessel Tioga *in November. The new vessel arrived at WHOI in April 2004, and replaces the 24-year-old* Asterias.

R/V *Tioga*

After 24 years of coastal research, the 46-foot (14-meter) vessel *Asterias* completed its final year of science work in 2003. *Asterias* performed 643 hours of service last year, with cruises supporting the growing demand for coastal research, primarily in the New England region. The vessel will be sold in spring 2004 to be replaced by the new 60-foot (18-meter) *Tioga* (shown under construction above), capable of cruising at 20 knots, twice as fast as the vessel it replaces. *Tioga* will carry twice the weight and feature state-of-the-art laboratories while supporting shallow water diving operations.

—*Richard F. Pittenger*
Vice President for Marine Operations

Trustees and Corporation Members

Report from Carolyn A. Bunker, Vice President for Finance and Administration

The Institution maintained its strong financial position during 2003. Although ocean sciences funding at the federal level was flat, our government-sponsored research revenue increased slightly. This is a tribute to the skill of our researchers, who continue to compete successfully for support despite a difficult funding environment.

Financial Position

Total net assets increased $50.9 million, from $290.8 million in 2002 to $341.6 million in 2003. Net assets are presented in three categories to demonstrate one significant difference between for-profit companies and not-for-profit institutions. The categories represent the restrictions placed on revenue recognized.

Permanently restricted net assets are gifts whose principal can never be spent. They include gifts and pledges to true endowment and assets held in trust, such as life income funds, that will be added to the endowment when they mature or are received.

Temporarily restricted net assets are gifts that, after an event or passage of time, can be used to meet operating or capital initiatives. This category also includes accumulated market gains on permanently restricted endowment funds. The Commonwealth of Massachusetts requires that not-for-profit institutions include accumulated market gains on both permanently and temporarily restricted net assets with temporarily restricted net assets. Most other states allow these gains to be included in unrestricted net assets. If the Institution were to follow the prevalent rule, unrestricted net assets would increase by $30.1 million and temporarily restricted net assets would decrease by a like amount.

Unrestricted net assets include the remaining financial resources available to the Institution.

At year end the Institution had $10.7 million in long-term debt compared with $8 million in 2002. We anticipate that tax-exempt bonds issued by WHOI through the Massachusetts Health and Educational Facilities Authority will finance a substantial portion of the new laboratory space on the Quissett Campus and renovations to existing laboratory space on the Village Campus.

Activities

Sponsored research revenue released to operations increased to $100.7 million in 2003 compared to $97.5 million in 2002, and government-sponsored research, excluding ship and submersible operations, was $63.4 million compared to $59.1 million in 2002. Total revenues increased 9.4 percent from $123.2 million in 2002 to $134.8 million in 2003.

Gifts, grants, and pledges from private sources totaled $23.9 million in 2003, an increase of 73.2 percent over 2002. Outstanding pledges at the end of 2003 were $4.8 million, compared to $4.5 million in 2002.

The market value of investments in the endowment increased from $234.6 million in 2002 to $269.3 million in 2003. The investment policy focuses on total return, a combination of capital appreciation and income from interest and dividends. In 2003 the total return on investments was 21.8 percent compared with an 11 percent decline in 2002. Our endowment spending policy preserves the fund's real purchasing power while providing a predictable stream of income to support annual budgetary needs. During 2003 we distributed $13.6 million of endowment assets: $5.7 million to education, $4.7 million to research, and $3.2 million to other restricted and unrestricted funds.


Tom Kleindinst

Carolyn Bunker (left) with Controller Stacey Medeiros.

Although the financial results of 2003 were positive, we recognize an increasing stress on our scientists and engineers to secure funding for research. Federal funding, while steady, is not growing, and pension and health care costs are increasing faster than our ability to fund them. The major construction projects planned for the next few years, while providing essential additional laboratory space, will add to the cost of research. However, the Institution is launching a major fund-raising effort to provide broad support for science and education. With additional financial support from private sources and the ability and resourcefulness of our scientists, engineers, students, and staff, we believe the challenges, while difficult, will be met.

Carolyn A. Bunker

Financial Statements

Statement of Financial Position

December 31, 2003 (with comparative information as of December 31, 2002)

	2003	2002
Assets		
Cash, unrestricted	$ 18,097,572	$13,973,766
Cash, restricted	1,507,755	2,042,155
Reimbursable costs and fees		
Billed	1,728,635	3,923,078
Unbilled	4,670,629	4,811,138
Receivable for investments sold (Note 3)	22,044,791	-
Interest and dividends receivable	497,941	532,226
Other receivables (Note 12)	8,034,611	14,924,983
Pledges receivable, net	4,846,696	4,463,055
Inventory	1,084,124	1,490,021
Deferred charges and prepaid expenses	775,518	999,204
Deferred fixed rate variance	3,197,693	426,870
Investments, pooled	242,720,582	231,262,026
Investments, nonpooled	5,326,668	6,318,027
Prepaid postretirement benefit cost	788,826	788,826
Supplemental retirement	6,257,039	5,494,326
Intangible pension asset	5,644,240	11,498,524
Other assets	11,983,651	4,177,187
Subtotal	339,206,971	307,125,412
Property, plant and equipment		
Land, buildings and improvements	65,789,103	62,363,781
Vessels and dock facilities	4,365,175	3,474,118
Laboratory and other equipment	15,880,819	14,485,199
Construction in process	7,523,530	3,788,855
	93,558,627	84,111,953
Accumulated depreciation	(49,070,058)	(45,009,763)
Net property, plant and equipment	44,488,569	39,102,190
Remainder trusts	10,532,306	9,395,272
Total assets	$394,227,846	$355,622,874

Liabilities		
Accounts payable and other liabilities (Note 12)	$17,114,484	$24,682,000
Accrued payroll and related liabilities	6,227,950	6,695,441
Payable for investments purchased	-	10,193
Accrued supplemental retirement benefits	6,257,039	5,494,326
Accrued pension liability	6,946,274	12,612,637
Deferred revenue and refundable advances	5,316,136	7,319,338
Loan payable	10,724,206	8,045,162
Total liabilities	52,586,089	64,859,097

Net Assets

	Unrestricted	Temporarily restricted	Permanently restricted		
Undesignated	$ 10,961,721	$ -	$ -	10,961,721	(2,502,046)
Pension	(645,885)	-	-	(645,885)	(801,849)
Designated	2,749,713	8,228,213	-	10,977,926	9,540,569
Pledges and other	-	5,504,283	10,773,064	16,277,347	15,893,707
Plant and facilities	30,068,830	1,351,467	-	31,420,297	30,468,808
Education	-	3,361,005	-	3,361,005	3,524,553
Endowment and similar funds	62,278,784	153,081,679	53,928,883	269,289,346	234,640,035
Total net assets	$105,413,163	$171,526,647	$64,701,947	341,641,757	290,763,777
Total liabilities and net assets				$394,227,846	$355,622,874

The accompanying notes are an integral part of these financial statements.

Statement of Activities

Year Ended December 31, 2003 (with summarized financial information for the year ended December 31, 2002)

	Unrestricted					
	Operating	Sponsored research	Temporarily restricted	Permanently restricted	2003	2002
Operating						
Revenues						
Fees	$ 483,754				$ 483,754	$ 607,986
Sponsored research						
Government		$ 63,389,385			63,389,385	59,124,026
Nongovernment		16,054,625	$ 4,657,347		20,711,972	21,384,225
Ships and subs operations		17,558,382			17,558,382	17,774,506
Sponsored research assets released to operations	100,749,264	(97,002,392)	(3,746,872)		-	-
Education						
Tuition	2,977,535				2,977,535	2,963,417
Endowment income	3,683,100		1,988,455		5,671,555	5,354,459
Gifts			170,620		170,620	239,556
Education funds released from restriction	2,374,247		(2,374,247)		-	-
Investment return designated for current operations	3,453,967				3,453,967	3,682,563
Contributions and gifts	15,070,373		1,462,380	$2,334,192	18,866,945	10,618,986
Contributions in kind	309,153				309,153	237,791
Rental income	718,440				718,440	683,358
Communication and publications	262,004				262,004	283,189
Other	195,644				195,644	210,809
Total revenues	130,277,481	-	2,157,683	2,334,192	134,769,356	123,164,871
Expenses						
Sponsored research						
National Science Foundation	34,097,378				34,097,378	32,456,976
United States Navy	18,379,000				18,379,000	16,903,854
Subcontracts	9,324,911				9,324,911	6,921,702
National Oceanic and Atmospheric Administration	7,412,224				7,412,224	5,513,645
Department of Energy	878,280				878,280	671,558
United States Geological Survey	822,196				822,196	1,150,464
National Aeronautics and Space Administration	753,186				753,186	598,067
Ships Operations	13,001,577				13,001,577	13,920,251

Statement of activities (continued on next page)

Statement of Activities (continued)

	Unrestricted					
	Operating	Sponsored research	Temporarily restricted	Permanently restricted	2003	2002
Submersible and ROV operations	4,556,805				4,556,805	3,854,255
Privately funded grants	3,742,846				3,742,846	3,898,586
Other	7,780,861				7,780,861	11,578,173
Education						
Faculty expense	2,968,490				2,968,490	2,633,267
Student expense	3,840,130				3,840,130	3,591,195
Postdoctoral programs	472,037				472,037	502,313
Other	647,797				647,797	653,290
Rental expenses	535,178				535,178	527,772
Communication, publications and development	2,284,343				2,284,343	1,706,855
Fund raising expenses	2,201,452				2,201,452	1,980,070
Unsponsored programs	3,821,259				3,821,259	4,119,677
Other expenses (Note 12)	980,073				980,073	2,747,399
Total expenses	118,500,023	-	-	-	118,500,023	115,929,369
Change in net assets from operating activities	11,777,458	-	2,157,683	2,334,192	16,269,333	7,235,502
Nonoperating income						
Investment return in excess of (less than) amounts designated for sponsored research, education and current operations	9,012,280		22,170,140		31,182,420	(44,302,970)
Change in split interest agreements	27,968		27,818	1,093,605	1,149,391	(1,252,598)
Net periodic pension cost	(5,819,299)				(5,819,299)	(1,233,787)
Contributions and gifts	-		2,163,286		2,163,286	-
Net assets released from restriction	1,466,753		(1,466,753)		-	-
Nonoperating expenses						
Other nonoperating revenues (expenses)	(81,972)		40,658	(1,100)	(42,414)	(668,567)
Change in net assets from nonoperating activities	4,605,730	-	22,935,149	1,092,505	28,633,384	(47,457,922)
Change in net assets from operating and nonoperating activities	16,383,188	-	25,092,832	3,426,697	44,902,717	(40,222,420)
Change in additional pension minimum liability (Note 8)	5,975,263	-	-	-	5,975,263	(5,975,263)
Total change in net assets	22,358,451	-	25,092,832	3,426,697	50,877,980	(46,197,683)
Net assets at beginning of year	83,054,712	-	146,433,815	61,275,250	290,763,777	336,961,460
Net assets at end of year	$ 105,413,163	$ -	$ 171,526,647	$ 64,701,947	$ 341,641,757	$ 290,763,777

The accompanying notes are an integral part of these financial statements.

Statement of Cash Flows
Year Ended December 31, 2003 (with comparative information for the year ended December 31, 2002)

	2003	2002
Cash flows from operating activities		
Total change in net assets	$ 50,877,980	$(46,197,683)
Adjustments to reconcile increase (decrease) in net assets to net cash used in operating activities		
Depreciation	4,585,752	4,334,922
Change in split interest agreements	(1,149,391)	1,252,598
Allowance for uncollectible pledges	4,708	-
Discount on pledges	(56,202)	64,446
Net realized and unrealized (gain) loss on investments	(41,731,926)	36,276,953
Intangible pension asset	5,854,284	(11,498,524)
Additional minimum pension liability	(5,975,263)	5,975,263
Contributions to be used for long-term investment	(4,926,199)	(3,094,823)
Gift of property	(7,620,000)	-
(Increase) decrease in assets		
Restricted cash	534,400	85,164
Interest and dividends receivable	34,285	215,512
Reimbursable costs and fees		
Billed	2,194,443	(1,653,014)
Unbilled	140,509	(1,018,751)
Other receivables	6,890,372	(14,435,961)
Pledges receivable	(332,147)	(2,690,068)
Inventory	405,897	(151,821)
Deferred charges and prepaid expenses	223,686	(366,405)
Deferred fixed rate variance	(2,770,823)	(426,870)
Other assets	(186,464)	78,272
Prepaid pension cost	-	6,407,201
Supplemental retirement	(762,713)	970,260
Increase (decrease) in liabilities		
Accrued pension liability	308,900	6,637,374
Accounts payable and other liabilities	(7,555,154)	14,754,067
Accrued payroll and related liabilities	(467,491)	859,707
Deferred revenue and refundable advances	(2,003,202)	(164,516)
Accrued supplemental retirement benefits	762,713	(970,260)
Deferred fixed rate variance	-	(2,196,646)
Net cash used in operating activities	(2,719,046)	(6,953,603)
Cash flows from investing activities		
Capital expenditures		
Additions to property and equipment	(9,972,134)	(8,743,124)
Short-term investments:		
Purchase of investments	1,000,000	10,811,667
Endowment		
Receivable for investments sold	(22,044,791)	-
Payable for investments purchased	(10,193)	(271,719)
Proceeds from the sale of investments	51,764,068	252,731,559
Purchase of investments	(21,499,341)	(264,952,755)
Net cash used in investing activities	(762,391)	(10,424,372)
Cash flows from financing activities		
Borrowings under debt agreement	2,679,044	2,977,210
Contributions to be used for long-term investment	4,926,199	3,094,823
Net cash provided by financing activities	7,605,243	6,072,033
Net increase (decrease) in cash and cash equivalents	4,123,806	(11,305,942)
Cash and cash equivalents, beginning of year	13,973,766	25,279,708
Cash and cash equivalents, end of year	$ 18,097,572	$ 13,973,766
Supplemental disclosures		
Cash paid for interest	$ 117,284	$ 109,293
Noncash activity - gift of property	7,620,000	-

The accompanying notes are an integral part of these financial statements.

Financial Statements

Report of Independent Auditors

To the Board of Trustees of
Woods Hole Oceanographic Institution

In our opinion, the accompanying statement of financial position and the related statements of activities and cash flows present fairly, in all material respects, the financial position of Woods Hole Oceanographic Institution (the "Institution") at December 31, 2003 and the changes in its net assets and its cash flows for the year then ended in conformity with accounting principles generally accepted in the United States of America. These financial statements are the responsibility of the Institution's management; our responsibility is to express an opinion on these financial statements based on our audit. The prior year summarized comparative information has been derived from the Institution's 2002 financial statements, and in our report dated March 14, 2003, we expressed an unqualified opinion on those financial statements. We conducted our audit of these statements in accordance with auditing standards generally accepted in the United States of America, which require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements, assessing the accounting principles used and significant estimates made by management, and evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinion.

PricewaterhouseCoopers LLP

March 19, 2004

Notes to Financial Statements

1. Background

Woods Hole Oceanographic Institution (the "Institution") is a private, independent not-for-profit research and educational institution located in Woods Hole, Massachusetts. Founded in 1930, the Institution is dedicated to working and learning at the frontier of ocean science and attaining maximum return on intellectual and material investments in oceanographic research.

The Institution is a qualified tax-exempt organization under Section 501(c)(3) of the Internal Revenue Code as it is organized and operated for education and scientific purposes.

2. Summary of Significant Accounting Policies

Basis of Presentation

The accompanying financial statements have been prepared on the accrual basis and in accordance with the reporting principles of not-for-profit accounting.

The financial statements include certain prior-year summarized comparative information, but do not include sufficient detail to constitute a presentation in conformity with accounting principles generally accepted in the United States of America. Accordingly, such information should be read in conjunction with the Institution's audited financial statements for the year ended December 31, 2002, from which the summarized information was derived.

Net assets, revenues, and realized and unrealized gains and losses are classified based on the existence or absence of donor-imposed restrictions and legal restrictions imposed under Massachusetts State law. Accordingly, net assets and changes therein are classified as follows:

Permanently Restricted Net Assets

Permanently restricted net assets are subject to donor-imposed stipulations that they be maintained permanently by the Institution. Generally the donors of these assets permit the Institution to use all or part of the income earned and capital appreciation, if any, on related investments for general or specific purposes.

Temporarily Restricted Net Assets

Temporarily restricted net assets are subject to donor-imposed stipulations that may or will be met by actions of the Institution and/or the passage of time. Unspent gains on permanent endowment are classified as temporarily restricted until the Institution appropriates and spends such sums in accordance with the terms of the underlying endowment funds at which time they will be released to unrestricted revenues.

Unrestricted Net Assets

Unrestricted net assets are not subject to donor-imposed stipulations. Revenues are reported as increases in unrestricted net assets unless use of the related assets is limited by donor-imposed restrictions. Expenses are reported as decreases in unrestricted net assets. Gains and losses on investments and other assets or liabilities are reported as increases or decreases in unrestricted net assets unless their use is restricted by explicit donor stipulations or law. Expirations of temporary restrictions on net assets, that is, the donor-imposed stipulated purpose has been accomplished and/or the stipulated time period has elapsed, are reported as reclassifications between the applicable classes of net assets. Amounts received for sponsored research (under exchange transactions) are reflected in unrestricted sponsored research and released to operations when spent for the appropriate purpose, or as deferred revenue if expenditures have yet to be incurred.

Contributions

Contributions, including unconditional promises to give, are recognized as revenues in the period received. Contributions subject to donor-imposed stipulations that are met in the same reporting period are reported as unrestricted support. Promises to give that are scheduled to be received after the balance sheet date are shown as increases in temporarily restricted net assets and are reclassified to unrestricted net assets when the purpose or items' restrictions are met. Promises to give, subject to donor-imposed stipulations that the corpus be maintained permanently, are recognized as increases in permanently restricted net assets. Conditional promises to give are not recognized until they become unconditional, that is, when the conditions on which they depend are substantially met. Contributions other than cash are generally recorded at market value on the date of the gift (or an estimate of fair value), although certain noncash gifts, for which a readily determinable market value cannot be established, are recorded at a nominal value until such time as the value becomes known. Contributions to be received after one year are discounted at the appropriate rate commensurate with risk. Amortization of such discount is recorded as additional contribution revenue in accordance with restrictions imposed by the donor on the original contribution, as applicable. Amounts receivable for contributions are reflected net of an applicable reserve for collectibility.

The Institution reports contributions in the form of land, buildings, or equipment as unrestricted operating support at fair market value when received.

Dividends, interest and net gains on investments of endowment and similar funds are reported as follows:

- as increases in permanently restricted net assets if the terms of the gift require that they be added to the principal of a permanent endowment fund;
- as increases in temporarily restricted net assets if the terms of the gift or relevant state law impose restrictions on the current use of the income or net realized and unrealized gains; and
- as increases in unrestricted net assets in all other cases.

Operations

The statement of activities report the Institution's operating and nonoperating activities. Operating revenues and expenses consist of those activities attributable to the Institution's current annual research or educational programs, including a component of endowment income appropriated for operations (Note 3). Unrestricted endowment investment income and gains over the amount appropriated under the Institution's spending plan are reported as nonoperating revenue as investment return in excess of (less than) amounts designated for sponsored research, education and current operations. Nonoperating revenue also includes the change in value of split interest agreements, contributions restricted for property, plant and equipment purposes and the net periodic pension cost (income) on the noncontributory defined benefit pension plan.

Cash and Cash Equivalents

Cash and cash equivalents consist of cash, money market accounts, certificates of deposit and overnight repurchase agreements with initial maturities of three months or less when purchased which are stated at cost, which approximates market value. At times the Institution maintains amounts at a single financial institution in excess of federally insured limits.

Included in restricted cash at December 31, 2003 and 2002 is $1,268,574 and $1,803,162, respectively, representing advances received from the United States Navy and other U.S. Government and state agencies. Such amounts are restricted as to use for research programs. Interest earned on unspent funds is remitted to the federal government.

Also included in restricted cash at December 31, 2003 and 2002 is $239,181 and $238,993, respectively, representing cash restricted by the Massachusetts Department of Public Health. Interest earned on unspent funds is reinvested within the restricted cash account.

In addition, cash and cash equivalents include uninvested amounts from each classification of net assets (e.g., endowment).

Investments

Investment securities are carried at market value determined as follows: securities traded on a national securities exchange are valued at the last reported sales price on the last business day of the year; securities traded in the over-the-counter market and listed securities for which no sales prices were reported on that day are valued at closing bid prices. Investments in closely held, unregistered and nonnegotiable securities, for which market quotations are not readily available, are valued by management at an estimated fair value as approved by the investment committee of the Board of Trustees.

Purchases and sales of investment securities are recorded on a trade date basis. Realized gains and losses are computed on a specific identification method. Investment income, net of investment expenses, is distributed on the unit method.

Investment Income Unitization

The Institution's investments are pooled in an endowment fund and the investments and allocation of income are tracked on a unitized basis. The Institution distributes to operations for each individual fund an amount of investment income earned by each of the fund's proportionate share of investments based on a total return policy.

The Board of Trustees has appropriated all of the income and a specified percentage of the net appreciation (depreciation) to operations as prudent considering the Institution's long and short-term needs, present and anticipated financial requirements, expected total return on its investments, price level trends, and general economic conditions. Under the Institution's current endowment spending policy, which is within the guidelines specified under state law, between 4 percent and 5.5 percent of the average of the market value of qualifying endowment investments at September 30 of each of the previous three years is appropriated. This amounted to $13,509,442 and $12,577,096 for the years ending December 31, 2003 and 2002, respectively, and is classified in operating revenues (research, education, and operations). The Institution has interpreted relevant state law as generally permitting the spending of gains on endowment funds over a stipulated period of time.

Inventories

Inventories are stated at the lower of cost or market. Cost is determined using the first-in, first-out method.

Contracts and Grants

Revenues earned on contracts and grants for research are recognized as related costs are incurred.

The Institution received approximately 90% and 86% of its operating revenues from government agencies including 50% and 49% of its operating revenues from the National Science Foundation and 21% and 20% from the United States Navy in fiscal years 2003 and 2002, respectively. Although applications for research funding to federal agencies historically have been funded, authorizations are subject to annual Congressional appropriations and payment.

Property, Plant and Equipment

Property, plant and equipment are stated at cost. Depreciation is provided on a straight-line basis at annual rates of 12 to 39 years on buildings and improvements, 10 to 15 years on vessels and dock facilities and 5 to 10 years on laboratory and other equipment. Depreciation expense on property, plant, and equipment purchased by the Institution in the amounts of $4,485,774 and $4,234,946 in 2003 and 2002, respectively, has been charged to operating activities. Construction commitments totaled $3,166,754 at December 31, 2003.

Depreciation on certain government-funded facilities (the Laboratory for Marine Science and the dock facility) amounting to $99,978 in 2003 and $99,976 in 2002 has been charged to nonoperating expenses as these assets were gifted by the Government.

Included in construction in process is $4,829,373 and $1,735,010 at December 31, 2003 and 2002, respectively, relating to campus development.

Use of Estimates

The preparation of the financial statements in accordance with accounting principles generally accepted in the United States of America requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and the disclosure of contingent assets and liabilities at the date of the financial statements and the reported amounts of revenues and expenses during the period. Actual results could differ from those estimates.

Reclassification of Amounts

Certain prior year amounts have been reclassified to conform to the December 31, 2003 presentation.

3. Investments

The cost and market value of pooled investments held at December 31 are as follows:

	2003		2002	
	Cost	**Market**	**Cost**	**Market**
Corporate bonds	$ 52,788,223	$ 53,788,201	$ 52,633,479	$ 53,238,160
International bonds	6,993,216	7,124,933	13,286,797	12,726,162
Equity securities and mutual funds	88,645,967	110,400,060	93,437,150	89,751,465
International equities	43,002,089	50,950,411	43,002,089	36,751,352
Hedge fund limited partnerships	2,741,760	3,116,672	23,920,000	23,523,925
Venture Capital and private equity	24,147,061	17,261,882	21,928,173	15,171,834
Other	78,423	78,423	99,128	99,128
Total investments	$218,396,739	$242,720,582	$248,306,816	$231,262,026

Amounts held in venture capital and investment partnerships and other investments are invested in securities or other assets for which there is not necessarily a publicly traded market value or which are restricted as to disposition. The return on such investments was ($128,840) and ($5,372,617) for the years ended December 31, 2003 and 2002, respectively, including dividends, distributions and changes in the estimated value of such investments.

During the year, the Institution terminated certain investment managers. Several of these managers were terminated on December 31, 2003 resulting in a receivable for investments sold of $22,044,791.

The following schedule summarizes the investment return on pooled and nonpooled investments and its classification in the statement of activities:

	Unrestricted	**Temporarily restricted**	**2003 Total**	**2002 Total**
Dividend and interest income	$ 2,566,279	$ 1,988,455	$ 4,554,734	$ 6,355,984
Investment management costs	(1,282,538)	-	(1,282,538)	(1,209,557)
Net realized gains	79,514	275,155	354,669	254,408
Change in unrealized appreciation	14,786,092	26,591,165	41,377,257	(36,531,361)
Total return on investments	16,149,347	28,854,775	45,004,122	(31,130,526)
Investment return designated for				
Sponsored research		(4,696,180)	(4,696,180)	(4,135,422)
Education	(3,683,100)	(1,988,455)	(5,671,555)	(5,354,459)
Current operations	(3,453,967)	-	(3,453,967)	(3,682,563)
Total distributions to operations	(7,137,067)	(6,684,635)	(13,821,702)	(13,172,444)
Investment return in excess of (less than) amounts designated for sponsored research, education and current operations	$9,012,280	$22,170,140	$31,182,420	$(44,302,970)

Investment return distributed to operations includes $312,260 and $595,348 earned on non-endowment investments for the years ended December 31, 2003 and 2002, respectively.

As a result of market declines, the fair value of certain donor restricted endowments is less than the historical cost value of such funds by $1,014,212 at December 31, 2003, and $2,537,533 at December 31, 2002. These unrealized losses have been recorded as reductions in unrestricted net assets. Future market gains will be used to restore this deficiency in unrestricted net assets before any net appreciation above the historical cost value of such fund increases temporarily restricted net assets.

Investment securities are exposed to various risks such as interest rate, market and credit risks. Due to the level of risk associated with certain investments, it is at least reasonably possible that changes in the value of investment securities will occur in the near term and that such changes could materially affect the market values and the amounts reported in the statement of financial position.

Endowment income is allocated to each individual fund based on a per unit valuation. The value of an investment unit at December 31, is as follows:

	2003	2002
Unit value, beginning of year	$ 3.4719	$ 4.0787
Unit value, end of year	3.9177	3.4719
Net change for the year	.4458	(.6068)
Investment income per unit for the year	.0419	.0647
Total return per unit	$ .4877	$ (.5421)

4. Pledges Receivable

Pledges receivable consist of the following at December 31:

	2003	2002
Unconditional promises expected to be collected in:	$1,688,779	$2,101,126
Less than one year	3,428,933	2,684,439
One year to five years	(204,708)	(200,000)
Reserve for uncollectible pledges receivable	(66,308)	(122,510)
Unamortized discount	$4,846,696	$4,463,055

5. Contribution Receivable from Remainder Trusts

The Institution recorded $10,532,306 and $9,395,272 at December 31, 2003 and 2002, respectively, relating to various charitable remainder trusts in its statement of financial position. The receivable and related revenue is measured at the present value of estimated future cash flows to be received and recorded in the appropriate net asset category based on donor stipulation. During the term of these agreements, changes in the value are recognized based on amortization of discounts and changes in actuarial assumptions.

6. Deferred Fixed Rate Variance

The Institution receives funding or reimbursement from federal government agencies for sponsored research under government grants and contracts. Revenue is recognized as related costs are incurred. The Institution has negotiated fixed rates with the federal government for the recovery of certain fringe benefits and indirect costs on these grants and contracts. Such recoveries are subject to carryforward provisions that provide for adjustments to be included in the negotiation of future fixed rates. The deferred fixed rate variance accounts represent the cumulative amount owed to or due from the federal government. The Institution's rates are negotiated with the Office of Naval Research (ONR), the Institution's cognizant agency.

The composition of the deferred fixed rate variance is as follows:

Deferred Fixed Rate Variance (liability), December 31, 2001	$ (2,196,646)
2002 indirect costs	44,079,157
2001 adjustment	(8,664)
Amounts recovered	(41,446,977)
2002 change in receivable	2,623,516
Deferred Fixed Rate Variance asset, December 31, 2002	426,870
2003 indirect costs	50,441,014
2002 adjustment	(7,931)
Amounts recovered	(47,662,260)
2003 change in receivable	2,770,823
Deferred Fixed Rate Variance asset, December 31, 2003	$ 3,197,693

As of December 31, 2003, the Institution has expended a cumulative amount in excess of recovered amounts of $3,197,693 which will be reflected as an addition to future year recoveries. This amount has been reported as an asset of the Institution.

7. Loan Payable

On May 27, 1999, the Institution entered into a $3,000,000 loan agreement with the Massachusetts Health and Educational Facilities Authority (the "Authority") to finance various capital projects. On January 31, 2000, the agreement was amended to increase the maximum loan commitment to $6,000,000. As of December 31, 2003, $5,485,951 had been drawn down on the loan and was outstanding at year-end. The Institution is required to pay interest on the drawdowns at a variable rate established by the Authority, which was 1% at December 31, 2003. The final drawdown has not yet occurred. Once a final drawdown has occurred, a schedule of principal payments will be established by the Authority. The final payment is due on July 1, 2010.

On March 1, 2001, the Institution entered into an $11,000,000 loan agreement with the Authority to finance additional capital projects. As of December 31, 2003, $5,238,255 had been drawn down on the loan and was outstanding at year-end. Drawdowns are expected to occur during an eighteen-month period. During this period, no principal payments are due on the loan, but the Institution is required to pay interest on the drawdowns at a variable rate established by the Authority, which was 1% at December 31, 2003. Once the final drawdown has occurred or the eighteen-month period has lapsed, a schedule of principal payments will be established by the Authority until the final payment due on July 1, 2010. As of December 31, 2003, a schedule of principal payments has not been received from the Authority.

The loan agreements have covenants, the most restrictive of which requires the Institution to maintain unrestricted net assets at a market value equal to at least 1.0x outstanding indebtedness.

The Institution's variable rate debt approximates fair value. Fair value is based on estimates using current interest rates available for debt with equivalent maturities.

On October 16, 2003, the Board of Trustees voted to approve various capital projects to be financed through a tax-exempt obligation with total outstanding debt not to exceed $50,000,000.

8. Retirement Plans

The Institution maintains a noncontributory defined benefit pension plan covering substantially all employees of the Institution, as well as a supplemental benefit plan which covers certain employees. Pension benefits are earned based on years of service and compensation received. The Institution's policy is to fund at least the minimum required by the Employee Retirement Income Security Act of 1974.

The Institution also maintains a restoration plan which covers certain employees. Included in the statement of financial position is a payable of $770,184 and $530,044 and an intangible pension asset of $114,035 and $217,780 related to this plan at December 31, 2003 and 2002, respectively.

	Qualified Plan Pension Benefits	
	2003	2002
Change in benefit obligation		
Benefit obligation at beginning of year	$ 169,123,168	$142,163,706
Service cost	6,118,111	5,024,294
Interest cost	11,068,835	10,340,134
Plan amendments	-	2,628,426
Actuarial loss	4,019,659	16,311,089
Benefits paid	(13,415,396)	(7,344,481)
Benefit obligation at end of year	$ 176,914,377	$169,123,168
Change in plan assets		
Fair value of plan assets at beginning of year	$ 133,980,735	$160,254,856
Employer contributions	-	-
Actual return on plan assets	23,186,048	(18,929,640)
Benefits paid	(13,415,396)	(7,344,481)
Fair value of plan assets at end of year	$ 143,751,387	$133,980,735
Funded status	$(33,162,990)	$(35,142,433)
Unrecognized net actuarial loss	22,579,627	29,035,103
Unrecognized prior service costs	9,937,478	11,280,744
Net amount recognized	$ (645,885)	$ 5,173,414
Amounts recognized in the statement of financial position consist of		
Accrued benefit liability	$ (6,176,090)	$(12,082,593)
Accumulated other minimum liability	-	5,975,263
Intangible asset	5,530,205	11,280,744
Net amount recognized	$(645,885)	$5,173,414
Cumulative (addition) reduction in net assets attributable to change in additional minimum liability recognition	$ (5,975,263)	$ 5,975,263
Weighted average assumptions		
Discount rate as of December 31	6.25%	6.75%
Expected return on plan assets for the year	8.50%	10.00%
Rate of compensation increase as of December 31	3.50%	3.50%
Components of net periodic benefit cost		
Service cost	$ 6,118,111	$ 5,024,294
Interest cost	11,068,835	10,340,134
Expected return on plan assets	(12,710,913)	(15,286,868)
Amortization of prior service cost	1,343,266	1,156,227
Net periodic benefit cost	$ 5,819,299	$ 1,233,787

The Institution has reflected the net periodic benefit cost in nonoperating income. In 2002, the Institution was required to record an additional charge of $5,975,263 to reflect a minimum balance sheet liability equal to the Plan's unfunded accumulated benefit obligation. This minimum was triggered due to investment losses on plan assets during the 2002 fiscal year. In 2003, the additional minimum liability was reversed as the minimum balance sheet liability was no longer necessary.

	Supplemental Plan Pension Benefits	
	2003	2002
Change in benefit obligation		
Benefit obligation at beginning of year	$ 3,282,549	$ 3,243,021
Service cost	78,650	79,154
Interest cost	209,638	216,030
Plan amendments	-	2,261
Actuarial (gain)/loss	53,532	(2,046)
Benefits paid	(193,392)	(255,871)
Benefit obligation at end of year	$ 3,430,977	$ 3,282,549
Change in plan assets		
Fair value of plan assets at beginning of year	$ -	$ -
Employer contribution	193,392	255,871
Benefits paid	(193,392)	(255,871)
Fair value of plan assets at end of year	$ -	$ -
Funded status	$(3,430,977)	$(3,282,549)
Unrecognized actuarial (gain)	(115,013)	(259,057)
Unrecognized prior service costs	1,631	1,946
Net amount recognized	$(3,544,359)	$(3,539,660)
Amounts recognized in the statement of financial position consist of		
Supplemental retirement/accrued supplemental retirement benefits	$(3,544,359)	$(3,539,660)
Weighted average assumptions		
Discount rate as of December 31	6.25%	6.75%
Expected return on plan assets for the year	8.50%	10.00%
Rate of compensation increase as of December 31	3.50%	3.50%
Components of net periodic benefit cost		
Service cost	$ 78,650	$ 79,154
Interest cost	209,638	216,030
Expected return on plan assets	(215,441)	(263,588)
Amortization of prior year service costs	315	315
Actuarial loss/(gain)	-	(26,091)
Net periodic benefit cost	$ 73,162	$ 5,820

The accrued supplemental retirement is matched by a "Rabbi" Trust with $6,257,039 and $5,494,326, respectively, as of December 31, 2003 and 2002. An additional accrual of $2,712,680 and $1,954,666 has been established for the excess of the "Rabbi" Trust assets over the accrued supplemental retirement benefits at December 31, 2003 and 2002, respectively.

9. Other Postretirement Benefits

In addition to providing retirement plan benefits, the Institution provides certain health care benefits for retired employees and their spouses. Substantially all of the Institution's employees may become eligible for the benefits if they reach normal retirement age (as defined) or elect early retirement after having met certain time in service criteria.

	Other Postretirement Benefits	
	2003	2002
Change in benefit obligation		
Benefit obligation at beginning of year	$ 30,459,830	$ 24,305,656
Service cost	669,237	529,739
Interest cost	1,746,394	1,936,615
Actuarial loss	1,407,135	4,803,608
Benefits paid	(1,318,863)	(1,256,870)
Plan participants' contributions	190,142	141,082
Benefit obligation at end of year	$ 33,153,875	$ 30,459,830
Change in plan assets		
Fair value of plan assets at beginning of year	$ 12,619,281	$ 14,532,884
Actual return on plan assets	2,753,110	(2,331,389)
Employer contribution	2,063,679	1,621,939
Benefits paid	(1,318,863)	(1,256,870)
Plan participants' contributions	190,142	141,082
Administrative expenses	(93,679)	(88,365)
Fair value of plan assets at end of year	$ 16,213,670	$ 12,619,281
Funded status	$(16,940,205)	$(17,840,549)
Unrecognized actuarial loss	12,153,392	12,726,764
Unrecognized portion of net obligation/(asset) at transition	7,681,947	8,535,496
Unrecognized prior service cost/(credit)	(2,106,308)	(2,632,885)
Net amount recognized	$ 788,826	$ 788,826
Amounts recognized in the statement of financial position consist of		
Prepaid benefit cost	$ 788,826	$ 788,826
Weighted average assumptions		
Discount rate as of December 31	6.25%	6.75%
Expected return on plan assets for the year	8.50%	10.00%

For measurement purposes, annual rates of increase of 9% and 10% in the per capita cost of covered healthcare benefits was assumed for 2003 and 2002 for both pre-65 and post-65 benefits.

These were assumed to decrease gradually to 5.0% in 2010 and remain at that level thereafter.

	2003	2002
Components of net periodic benefit cost		
Service cost	$ 669,237	$ 529,739
Interest cost	1,746,394	1,936,615
Expected return on plan assets	(1,112,924)	(1,487,375)
Recognized actuarial (gain) loss		
Amortization of transition obligation	853,549	853,549
Amortization of prior service cost	(526,577)	(526,577)
Recognized actuarial loss	434,000	315,988
Net periodic benefit cost	$ 2,063,679	$ 1,621,939

The Institution has reflected the net periodic benefit cost in operating expenses, as the amount is reimbursed through federal awards.

Assumed health care cost trend rates have a significant effect on the amounts reported for the health care plan. A one-percentage-point change in assumed health care cost trend rates would have the following effects:

	December 31, 2003	
	1-Percentage Point Increase	1-Percentage Point Decrease
Effect on total of service cost and interest cost	$ 578,023	$ (446,376)
Effect on the postretirement benefit obligation	$5,633,557	$(4,483,697)

10. Commitments and Contingencies

The Defense Contract Audit Agency (DCAA) is responsible for auditing both direct and indirect charges to grants and contracts on behalf of the ONR. The Institution and the ONR have settled the years through 2002. The current indirect cost recovery rates, which are fixed, include the impact of prior year settlements. The DCAA issued an audit report on the completed audit of direct and indirect costs for the year ended December 31, 2002 on September 11, 2003. The audit resulted in no questioned direct or indirect costs.

The Institution through its endowment fund is committed to invest $53,760,426 in certain venture capital and investment partnerships, of which $29,492,608 has been contributed as of December 31, 2003.

The Institution is a defendant in legal proceedings incidental to the nature of its operations. The Institution believes that the outcome of these proceedings will not materially affect its financial position.

11. Related Party Transactions

In fiscal year 2003, the Institution passed through Federal Awards of approximately $1,227,000 to subgrantee organizations in which an individual at the subgrantee organization is also a member of the Institution's Board of Trustees or Corporation. Additionally, a member of the Board of Trustees is affiliated with a law firm which provides legal services to the Institution. The Institution has purchased insurance services from insurance companies in which officers of the companies are also members of the Board of Trustees. The Institution also has other transactions with organizations where a member of the Board of Trustees or Corporation is affiliated with the organization. Total expenditures for legal, insurance and other transactions were approximately $861,000 for the year ended December 31, 2003.

12. Clark Laboratory Fire

In October 2002, the Institution experienced a fire in the Clark Laboratory Building which resulted in contamination and damage to several laboratories, clean rooms and equipment. Since then, the Institution has coordinated with its insurance carrier and other interested parties to identify and quantify the damage caused by the fire. At December 31, 2002, the Institution had recorded a receivable due from the insurance company of approximately $13,259,000 to reflect the estimated insurance proceeds to cover the cost of renting temporary clean laboratories, repairing the laboratories, and cleaning and repairing or replacing damaged or destroyed equipment. Additionally, the Institution established an accrual of approximately $14,669,000 to estimate the costs to be paid going forward associated with the fire. Included in the accrual but not covered by insurance was approximately $1,500,000 relating to displaced employees' salaries, fringe benefits and general and administrative costs as well as $100,000 associated with renting temporary clean laboratories. The total amount not covered by insurance of $1,600,000 had been reflected as a loss on the fire and included in other expenses in the statement of activities.

In 2003, the Institution has continued to coordinate its fire loss recovery efforts with its insurance carrier and other interested parties. At December 31, 2003, a receivable due from the insurance company of $7,435,000 and an accrual of $8,877,000 are included in the statement of financial position. During 2003, $4,000,000 has been received in cash from the insurance company and approximately $4,150,000 has been paid to various outside parties for fire-related damages. The estimated amounts relating to the fire continue to be subject to revision as more information becomes available. Any resulting gain or loss related to accounting for the fire will be recognized when such amounts can be determined with certainty.

Summer Student Fellowship Program

In 2003, 30 undergraduates from 29 institutions participated in the summer student fellowship program, in which college juniors or seniors studying math, science, or engineering spend 10 to 12 weeks in Woods Hole, working on a project of their choosing with a WHOI advisor. The program is supported by friends of WHOI and by the National Science Foundation Research Experience for Undergraduates program.

1 *Allison Shaw, an applied mathematics/biology major at Brown University, with Mike Neubert of the Biology Department.*

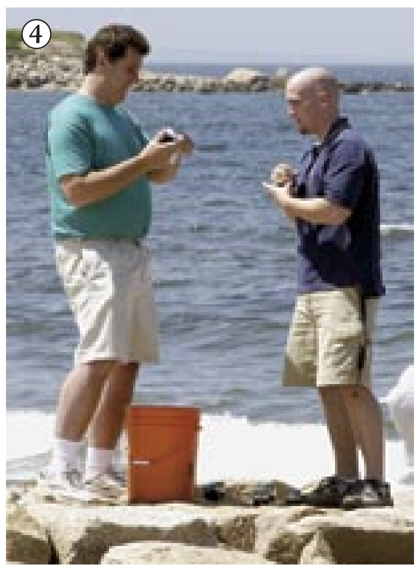
2 *Whitney Krey, a marine biology major at Texas A&M University at Galveston, with Stefan Sievert of the Biology Department.*

3 *Derek Cavatorta, an animal science major at the University of Massachusetts, Amherst, in Michael Moore's lab in the Biology Department.*

4 *Brian Kile (right), a chemistry major at Bates College, with Bob Nelson of the Marine Chemistry and Geochemistry Department.*

5 *Pincelli Hull, a biology/Earth & ocean sciences major at Duke University, in Peter Wiebe's biology lab.*

6 *Suzanne Kern (right), a biochemistry major at Colorado College, with Postdoctoral Fellow Heather Handley Goldstone in John Stegeman's biology lab.*



Photos by Tom Kleindinst

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