

## 2010 Annual Report: Letter from Susan K. Avery, President and Director

To know the value of our mission to understand the world ocean, we need only review a partial list of natural events in 2010.

January brought a 7.0 magnitude earthquake in Haiti that took 230,000 lives. It resulted from movement along a slip fault running along the seafloor at both ends of the island and lengthwise through its middle.

February saw a magnitude 8.8 earthquake caused by release of friction between oceanic and continental tectonic plates just offshore of Chile.

In March, a volcanic eruption in Iceland effectively paralyzed air travel in Europe and caused hundreds of flight cancellations worldwide. That volcano is part of a global mid-ocean mountain chain, 50,000 miles long and 99% unexplored. Among the few facts we know is that most of its towering tips can only be touched by diving below 8,000 feet.

Then, beginning in April, the Deepwater Horizon oil well blowout in the Gulf of Mexico gave us the worst environmental catastrophe in U.S. history. It will take years of research to fully understand the extent of ecosystem impacts, both at sea and ashore.

Throughout these events, WHOI researchers shared knowledge with frontline responders. Soon after the Haiti earthquake, senior scientist Jian Lin advised the Jamaican government about the island's vulnerability to the same fault line that destroyed Port au Prince. WHOI scientists Chris German, Tim Shank, and Dana Yoerger were working off the coast of Chile at the time of that country's magnitude 8.8 earthquake, and redirected their cruise to gather valuable data at the seafloor fault site.

And many WHOI scientists and engineers played a key role in our nation's response to the oil spill in the Gulf. Using WHOI funds, they travelled quickly to Baton Rouge and provided immediate assistance to BP, the Coast Guard, and the National Oceanic and Atmospheric Administration (NOAA). Several of them soon provided Congressional testimony, but carefully avoided undue publicity in the overheated media environment in order to preserve scientific credibility. That quiet determination to remain objective enabled them to get closer to the blowout site than any other researchers. It was our scientists, with cooperation from BP and assistance from the Coast Guard, who were able to collect fluid samples directly from the damaged wellhead, using specialized WHOI sampling techniques and tools.

We also assisted Air France, deploying two REMUS vehicles owned by the Waitt Institute for Discovery to search a vast area of the southern Atlantic for the black box of the flight that went down in 2009. That search will continue in 2011 in the hope of solving a vexing aviation mystery and bringing closure to the many families still grieving.

This renowned ability to work in the deep ocean is central to WHOI's contributions to oceanography and society. With proficiency extending from inland estuaries to the deepest abyssal regions of the planet, our eagerness to know everything between carries us ever forward in the optimism of discovery.

Emblematic of that ability and spirit is the human-occupied submersible, *Alvin*, which ended the year with the final dives in its current incarnation. Appropriately, its last mission was in the Gulf of Mexico, carrying scientists to deep sea corals to examine potential effects of the oil spill. *Alvin* is now home in Woods Hole, beginning its transformation to a 6,500-meter vehicle capable of exploring more of the ocean than ever before.

The new vehicle will be one more tool WHOI researchers use to not only respond in times of emergency, but anticipate and lead in new directions. 2010 may have been a long and difficult year, with slow economic recovery and that tragic sequence of natural catastrophes, but how wonderfully hopeful it is that we can look forward to decades more of discovery and new knowledge each time *Alvin* rises to the surface from a voyage to inner space!



WHOI President and Director Susan Avery

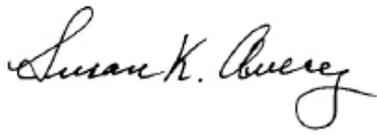


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WHOI President and Director Susan Avery introduces the *Alvin* public event. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

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## **The Oceans and Us**

Understanding the Secret World  
Beneath the Sea

Presentation by Susan Avery at TEDxBoston in the summer of 2010.

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## 2010 Annual Report: Letter from Laurence P. Madin, Director of Research

Events in the Gulf of Mexico made 2010 a spotlight year for WHOI. Our research tools and experience found valuable applications enabling WHOI staff to make significant contributions to understanding the extent of the oil spill. Later in the year our autonomous vehicles were on another applied mission, mapping the wreck site of HMS *Titanic* for future study and a public exhibit. Tools and techniques developed for ocean research carried out a well-publicized mission to the world's most famous shipwreck.

While activities like these were getting the public attention, back in Woods Hole our basic research operations were 'operating normally'. That means that our 140 Scientific Staff and many of our Senior Technical staff were, in addition to doing research, writing 921 research proposals for submission a hundred different government, private, foreign or WHOI internal funding sources. Normally also means that Administrative Professionals in the science departments were preparing budgets according to the various agency requirements, that Department Administrators and Chairs were assembling and reviewing the proposals for scientific and technical accuracy, and the Grants and Contracts office was making final checks, clarifying confusion, negotiating terms and when all was in order, 'pushing the button' that electronically submitted the full proposal to the soliciting agency. There are major peaks of activity in February and August for the main NSF deadlines, but the proposal machinery hums along all year long. It's important for this machinery to work well because the grants and contracts that result from over 60% of the proposal submissions are the lifeblood of the Institution, and the investigators who write them are important fund raisers for WHOI.

All those grants and contracts supported some of the hundreds of projects that were underway at WHOI during 2010. Most of them didn't get the publicity of the oil spill, but, like every year, there were many important discoveries and advances made across the Institution. Here are three examples.

Sound waves are a powerful means of detecting, measuring and communicating in the ocean, and WHOI has a long history of research in ocean acoustics. In 2010 Tim Stanton and Andone Lavery of the AOPE Department demonstrated the value of a new broadband acoustic systems that emits and analyzes a broad range of acoustic frequencies. The resulting resolution allows much more accurate identification of fish, zooplankton and even turbulence in the water. The improvement is described by Stanton as like "the difference between black and white TV and High Definition".

WHOI is famous for the discovery of hydrothermal vents in 1977, and for much of the research that has gone on around them since then. Even 30 years later there are new discoveries. Lauren Mullineaux and her colleagues completed a study of re-colonization after a vent community was 'paved over' by volcanic eruption. They expected that new colonists would be similar species to those wiped out, arriving as larvae from the nearest and most similar sites. But the pioneers turned out to be from hundreds of kilometers away and of very different species. What's perplexing is how the larvae could travel so far – they are slow swimmers and don't live long before settling. One possible answer is that they ride rapid bottom currents, or jets, that provide a highway for long distance transport and colonization in the deep sea.

In another region known for underwater volcanic activity, the Gulf of California, WHOI Geologists Dan Lizzaralde and Adam Soule used seismic methods to discover a previously unsuspected mode of ocean crust formation. Usually new ocean floor forms when lava erupts along a mid ocean ridge, pushing tectonic plates apart. Instead, the WHOI group found that magma was pushing up into the thick sediment layers away from the ridge center, forming sills that remained buried in the sediment. One effect of this seems to be the release of nutrients from the sediments that nourish deep sea life, and of far more CO<sub>2</sub> and methane than would come from normal volcanic activity. The importance of this for the global carbon cycle, and climate change, are just beginning to be examined.

These are only three of many projects underway in 2010 that led to new discoveries or new capabilities to observe and understand the ocean. Supported by some of those 921 proposals submitted in 2010, or the 4,472 submitted since 2006, WHOI researchers worked in all corners of the world ocean, and every year there is something new, astonishing and important to report. All part of 'operating normally' at the Woods Hole Oceanographic Institution.



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From the deck of the research vessel *Endeavor*, WHOI chemist Ben Van Mooy (right) and others survey the scene near the burning Deepwater Horizon oil rig in the Gulf of Mexico in June, 2010. Van Mooy was a member of a team of WHOI scientists who went to the Gulf to study aspects of the oil spill. He used a classic analytical technique for measuring oxygen levels in the water to determine whether microbes were eating oil in the surface slick and in the deep plume of hydrocarbons. (Photo by Dan Torres, Woods Hole Oceanographic Institution)



[A multimedia presentation](#) featuring scientists and engineers who continued the Woods Hole Oceanographic Institution legacy of oil spill research by providing an objective insight into the immediate and potential impacts of the Deepwater Horizon spill in the Gulf of Mexico.

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Larry Madin

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## 2010 Annual Report

### Research Departments



#### [Applied Ocean Physics & Engineering](#)

The Applied Ocean Physics and Engineering (AOPE) Department is a unique collection of scientists, engineers, technical support personnel and students conducting research into ocean processes from the turbulent surf zone to the abyssal depths.

#### [Biology](#)



The overall goal of research in the Biology Department is to gain a better understanding of the ecology and evolutionary biology of living organisms in the sea.

#### [Geology & Geophysics](#)



Research in the Department of Geology and Geophysics (G&G) encompasses earth and ocean processes: from the formation of ocean crust and ocean basins, to the underlying dynamics of plate tectonics and deep earth mantle geochemistry, to climate change and its relation to present and past ocean circulation and coastal environments.

#### [Marine Chemistry & Geochemistry](#)



Scientists within the Marine Chemistry and Geochemistry (MC&G) Department seek to understand the processes that drive chemical cycling in the ocean, and to learn how ocean chemistry influences and responds to biological activity and climate on Earth, both today and in the past

#### [Physical Oceanography](#)



Researchers in the Physical Oceanography (PO) Department seek to describe and understand the physical structure and variability of the ocean and the processes that determine that structure and variability.

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## 2010 Annual Report: Applied Ocean Physics & Engineering

During 2010, Applied Ocean Physics & Engineering (AOPE) scientists, engineers, and research staff investigated ocean processes from the deepest depths to the ocean surface, from the turbulent surf zone to calmer inlets and rivers, and from the Arctic to the Southern Ocean. Ongoing projects examine the mechanics of deep-sea larvae dispersal, sediment distribution, ocean acoustics, and the mixing that occurs between distinct ocean water masses.

Mathematical models are continually developed and refined to predict and explain ocean processes. During the past year, Scientist Tim Duda and Research Associate Ilya Udovydchenkov created a model to describe the effects that increased ocean acidification will have on sound propagation. WHOI/MIT Joint Program graduate student Wu-Jung Lee analyzed sonar echoes reflected from squid to determine how dolphins use sonar to distinguish squid from other animals.

Instruments and analysis methodologies are also developed to generate novel and improved measurements of oceanic processes. Scientists Tim Stanton and Andone Lavery developed two advanced broadband acoustic systems that could mean a major upgrade in the ability to count and classify fish and pinpoint tiny zooplankton in turbulent waters. Collectively, the systems span 1.5 kHz to 600 kHz and are used to study fish, zooplankton, and turbulence.

AOPE investigators responded to the *Deepwater Horizon* oil spill by conducting on-site analysis of flow rates and studying plume movement. Scientists Rich Camilli and Dana Yoerger deployed the autonomous underwater vehicle (AUV) *Sentry* and equipped it with an underwater mass spectrometer to identify and map the plume. Software was added to analyze chemicals in naturally occurring oil, gas, and other hydrocarbons leaking from the seafloor. Camilli and Yoerger also gave *Sentry* the ability to change its course and operating mode based on the chemicals detected, allowing it to act more like a human investigator as it sees and analyzes its environment.

The remotely operated vehicle (ROV) *Jason* also took part in a cruise that helped researchers identify oil-damaged corals seven miles from the *Deepwater Horizon* oil spill. Extensive portions of coral colonies were found to be either recently dead or dying, and samples and data were collected for further testing and analysis. *Jason* completed six cruises in 2010 in areas such as the Mariana Arc, the Juan de Fuca Ridge, and the Gulf of Mexico; and had 64 deployments, the longest lasting 86 hours.

The Autonomous Benthic Explorer (ABE) was lost at sea on a research expedition off the coast of Chile while searching for hydrothermal vents and cold seeps. ABE had reached the seafloor during its 222<sup>nd</sup> dive when all contact with research vessel *Melville* ceased. ABE was one of the first successful unoccupied and untethered submersible vehicles. While ABE will be missed, its functionality will be replaced by that of newer vehicles.

Research Associate Brendan Foley, along with Greek and Swedish colleagues, conducted an ancient DNA and quantitative imaging project in Greece. As the first foreign scientists ever granted access to the Ministry of Culture artifact collection, they collected non-destructive DNA samples from several 5th century B.C. amphorae and performed three-dimensional stereo-imaging and photogrammetry (making measurements from photographs) experiments. Foley and engineers Greg Packard and Robin Littlefield also used REMUS 100 AUVs to survey eight square kilometers of sea floor, while dive teams visually searched the near-shore underwater slopes for shipwrecks. They discovered one 1,000-year-old wreck, recovered an amphora for DNA contents analysis, and surveyed three other ancient wrecks.



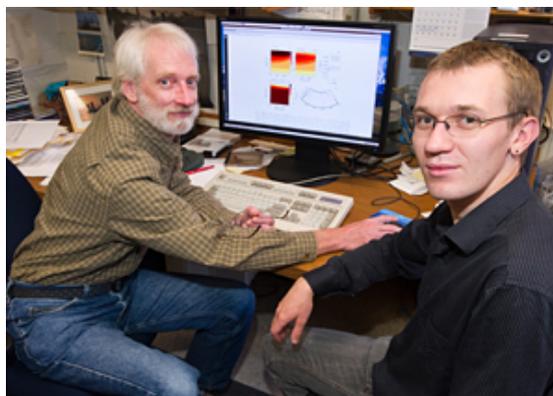
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Aboard the R/V *Tioga*, WHOI engineer Craig Marquette (middle) and physical oceanographers Glen Gawarkiewicz (left) and Anthony Kirincich work to recover a Remote Environmental Monitoring Unit (REMUS) vehicle during a September 2010 cruise to study coastal currents in waters off the Outer Cape. (Photo by Jayne Doucette, Woods Hole Oceanographic Institution)



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WHOI/MIT Joint Program graduate student Wu-Jung Lee adjusts the experimental apparatus that allows her to record sonar echoes from a squid at different orientations. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)



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Tim Duda, left, and Ilya Udovydchenkov developed a mathematical model to test whether the oceans will become noisier as they become more acidic. Their conclusion: ocean acidification will affect how far sound travels in the ocean, but the effect will be tiny. (Photo by Tom Kleindinst,

The Ocean Observatories Initiative (OOI) team deployed its first East Coast test mooring. The team installed the Electro-Optical-Mechanical (EOM) test mooring at the OOI Pioneer Array site on the shelf break about 100 miles south of Woods Hole. The mooring, which is in 150 meters of water, is intended to determine the longevity of optical fibers built into high-stretch mooring hoses. The deployment will also test the first WHOI use of a Fleet Broadband 250 satellite telemetry unit on a surface buoy.

The “Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean” (DIMES) investigation led by senior scientist Jim Ledwell involved a 50-day cruise and a successful survey of a patch of tracer compound that was released west of Chile at 1500 m depth in the Antarctic Circumpolar Current. Research associate Cindy Sellers and senior engineering assistant Brian Guest participated in the cruise, with colleagues from the Physical Oceanography and Biology departments. Shore support was provided by scientist Dennis McGillicuddy and research associates Valery Kosnyrev and Larry Anderson with satellite remote sensing data of sea surface elevation.

Scientists Steve Elgar and Britt Raubenheimer assembled a team of researchers, including WHOI/MIT Joint Program Student Melissa Moulton and research assistants Levi Gorrell, Evan Williams, Dana Giffen, Regina Yopak, Seth Zippel, and Sean Kilgallin, to determine the “impulse response” of the surfzone to disturbances in the form of artificially created deep holes in nearshore sands. The team deployed and maintained a dense array of sensors and collected data under a variety of conditions ranging from flat calm to hurricanes.

Researchers in the Digital Recording Tags lab tagged pilot whales, beaked whales and Risso's dolphins in the Alboran Sea near Spain for behavioral and acoustic studies. The team also studied the ecology and feeding behavior of right and humpback whales in the Gulf of Maine and interactions of pilot whales with the pelagic longline fishery offshore of Cape Hatteras, NC.

—[John Trowbridge](#), Department Chair and [Sheila Hurst](#), Administrative Professional



[Enlarge Image](#)

WHOI scientists Rich Camilli (left) and Dana Yoerger have spearheaded efforts to give more autonomy to the autonomous underwater vehicle *Sentry*. Yoerger, who helped lead the development of the deep-sea robot, has been working closely with Camilli to integrate his TETHYS underwater mass spectrometer into *Sentry* as a payload sensor, enabling chemical measurements to be used as a guidance system for the vehicle. (Photo by Chris Reddy, Woods Hole Oceanographic Institution)



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DTAGs deployed on pilot whales. (Photo by Leigh Hickmott, Woods Hole Oceanographic Institution)

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The Icebot

A team of scientists field-tests an autonomous underwater vehicle, sending it into a hole in an ice floe off the coast of Alaska ...

and hoping they can get it back.

[» From \*Oceanus\* magazine](#)

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## 2010 Annual Report: Biology

Staff members in the Biology Department contribute extensively to the broader scientific community nationally and internationally. The staff provides leadership and other service to federal agencies, scientific journals, universities, the National Research Council and other national and international committees. Staff members also fill lead roles in the WHOI Ocean Institutes, the Woods Hole Center for Oceans and Human Health, the NOAA Cooperative Institute for the North Atlantic Region, and the vital fleet committee of the University-National Oceanographic Laboratory System. Particularly noteworthy during 2010 was the celebration of a decade of research on the Census of Marine Life, held at the Royal Society of London. Staff members Nancy Copley, Tim Shank and Peter Wiebe, in addition to guest investigators Ann Bucklin, Paul Snelgrove and Michele DuRand, attended the celebration that culminated a 10-year exploration involving 2,700 scientists from 80 countries, a truly international effort.

In its research endeavors, the Biology Department strives to improve its understanding of the ecology and evolutionary biology of living organisms in the sea. Our scientists use a variety of tools to observe, experiment and model interactions among species and between species and their environments. In 2010, members of the WHOI Biology Department continued their worldwide investigations of life in bodies of water from oceans to lagoons. Their subjects ranged in size from microscopic to massive marine mammals; their interests from genes to entire ecosystems. Among the expeditions undertaken by Biology staff in 2010 were research cruises to the Bering Sea for the multi-disciplinary Bering Ecosystem Study; to the South East Pacific on a transect from Easter Island to Arica, Chile, examining nutrient gradients as part of the C-MORE (Center for Microbial Ecology: Research and Education) Program; to Indonesia as part of the INDEX program characterizing the marine biodiversity of Indonesian waters; and to the Gulf of Mexico to examine the effects of the *Deepwater Horizon* Oil Spill. In studies of the *Deepwater Horizon* Oil Spill Cabell Davis and MIT-WHOI Joint Program graduate student Nick Loomis deployed a holographic plankton camera on a remotely operated vehicle (ROV) from the *M/V Jack Fritz* in the water column near the site of the spill to characterize the distribution and size of oil droplets in the water column. Tim Shank and colleagues have examined the effects of the oil spill on the deep coral communities of the Gulf of Mexico, specifically addressing whether or not the oil has impacted the viability of deep coral communities. Because the group has surveyed the area before and after the spill they may be able to characterize subtle impacts on the coral community.

Two new Assistant Scientists joined the staff of the Biology Department in 2010, adding new expertise in a variety of sub-disciplines and contributing to the intellectual energy of the department.

T. Aran Mooney is a sensory physiologist with expertise in hearing in marine mammals and cephalopods. He is engaged in important and emerging areas of research, combining expertise in sensory biology and acoustics, and will strengthen not only the marine mammal group, but also the study of other large pelagic organisms.

Stéphanie Jenouvrier is a sea bird ecologist with expertise in field ecology of Antarctic populations and mathematical ecology. She combines interests in demographic models, population ecology and climate science and will contribute not only to the study of seabird ecology, but also conservation biology and the effects of climate change on living systems.

Biology staff received numerous honors and awards during the past year, including the U.S. Coast Guard Meritorious Public Service Award to Carin Ashjian, the NASA New Investigator Program Award to Sam Laney, the Alfred-Krupp Kolleg Greifswald Fellowship in Germany to Stefan Sievert, the Alexander von Humboldt Foundation Research Award in Germany to Hal Caswell, and the Sir Allan Sewell Visiting Fellowship<sup>®</sup> from Griffith University in Australia to Sonya Dyhrman.

—[Judy Mcdowell](#), Department Chair



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WHOI researchers Peter Wiebe, Nancy Copley, and Larry Madin joined the effort to find, identify, and analyze indicator genes of the world's animal plankton, known as the Census of Marine Zooplankton (CMarZ). CMarZ is one of more than 17 research projects within the Census of Marine Life, a ten-year project to catalog all life in the sea. (Woods Hole Oceanographic Institution)

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Life in the Coral Triangle

WHOI researcher Timothy Shank describes his first look at new species on the seafloor of the Coral Triangle.

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## 2010 Annual Report: Geology & Geophysics

The Scientific and Technical staff in the Department of Geology and Geophysics (G&G) carry out research on a diverse range of topics, from earthquakes and volcanoes, to paleoclimate as clues to future climate change, to the response of coastlines to sea-level rise and increased storminess.

Devastating earthquakes marked the beginning of 2010 with major temblors in both Haiti and Chile, occurring within weeks of one another. G&G Senior Scientist Jian Lin was called to comment on and assess the extent of the impact of these earthquakes, finding, for example, that the Haiti earthquake fractured a previously unknown fault.

Closer to home, Jeff McGuire and John Collins and the WHOI Ocean Bottom Seismometer (OBS) group are part of a major west coast experiment to image the earthquake-generating seismogenic zone of the Cascadia subduction zone margin (where one tectonic plate slides under another) along the Washington and Oregon Coast. They are in the planning stage for deployment of OBSs and other instruments over the next year and a half. The Cascadia margin has itself seen major earthquakes in the past, and this timely experiment will begin to build a realistic assessment of the hazard posed by a subduction zone so close to the US mainland.

In late spring, 2010, a major volcanic eruption on Iceland severely impacted trans-Atlantic air travel, grounding aircraft across Europe for days and weeks. The eruption brought into focus how important it is to understand Earth's geologic processes—even on questions as basic as how volcanoes work. One example of basic research in the department is the work of G&G scientists Adam Soule and Dan Lizarralde and Marine Chemistry and Geochemistry department colleague Jeff Seewald. They documented the presence of widely distributed magma under the seafloor, surprisingly far from the known axis of volcanic activity in the heavily sedimented Guaymas Basin in the Gulf of California. Based on their previous geophysical work, they discovered communities of organisms living off chemical energy in these distributed warm seep areas on the seafloor as far as 50 km away from the mid-ocean ridge spreading center.

In the Atlantic, Chris German used the newly commissioned and outfitted autonomous underwater vehicle *Sentry* in a science survey of the Haakon Mosby mud volcano in the Barents Sea. The sensor suite of multi-beam, sub-bottom sonar and chemical sniffers was utilized a few months later to document the extent of underwater oil contamination at the Gulf of Mexico BP *Deepwater Horizon* oil spill site.

In other science operational news, the R/V *Knorr* long core system, under the guidance of Chief technician Jim Broda, proved its worth in an extensive 4 cruise program this past year, bringing back 59 seafloor cores with an average length of 30 meters. Finally, among the new projects on tap for 2011 is a major multi-million dollar NSF Continental Dynamics collaborative project to study the Okavango and Malawi African rift systems with G&G scientists, Rob Evans, Mark Behn, Dan Lizarralde, Pablo Canales and Alison Shaw.

Other news from the department for 2010 includes appointments and promotions, departures and arrivals. Joan Bernhard was promoted to Senior Scientist, Dan Lizarralde was promoted to Associate Scientist with Tenure, and Jurek Blusztajn was promoted to Research Specialist. Senior Scientist Debbie Smith returned to the department after 3 years at NSF as a rotator in the Ocean Sciences (OCE) division. Senior Scientist Bob Detrick continues as NSF Division Director for Earth Science (EAR) for another year. Departures included the retirement of Senior Scientist Hans Schouten after 35 years at the Institution and Research Assistant II Skye Moret-Ferguson who left the coastal group to join a polar research ship as the science research technician.

Three new Assistant Scientists joined the G&G staff in 2010 in the general area of geochemistry:

- Sune Nielsen is an isotope geochemist who has pioneered geochemical tracer work on the “non-traditional” stable isotopes of the elements Thallium (Tl) and Vanadium (V). Sune has broad and diverse research interests that span early Earth and mantle processes related to element cycling, the chemistry of the oceans, the impact of hydrothermal systems on that chemistry and the potential use of Thallium as a paleoceanographic tracer.



[Enlarge Image](#)

WHOI geophysics guest student Tingting Wang and senior scientist Jian Lin (right) study Haiti earthquake data on charts. Lin has studied Haiti and other tectonic areas of the Caribbean and has served as a science source for newspaper, radio and television coverage of that quake, as well as subsequent earthquakes in Chile and China. He cautions that future quakes in Haiti could strike a segment of the Enriquillo Fault very close to the capital city and urges rebuilding of emergency government structures in safer areas outside of Port-au-Prince. He is also working on a major seismic study of fault zones in Algeria. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

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- Horst Marschall is a metamorphic petrologist with an interest in the dynamics of Earth's crust and mantle—using classical metamorphic petrology and field geology, but also applying modern isotope geochemistry and numerical modeling. His work to date has focused on the processes associated with subduction at convergent tectonic plate margins.
- Weifu Guo is a rather unique blend of isotope geochemist who is a top-notch experimentalist and analyst but also extremely strong in the theoretical and modeling aspects of isotope geochemistry. He is one of a new wave of leading practitioners of “clumped isotope geochemistry,” investigating carbon and oxygen isotope ratios in carbonates to estimate ancient sea temperatures.

As always, members of the G&G Department traveled to all corners of the world over the course of the year to carry out their research. Staff participated in research cruises in the Pacific and Atlantic Oceans with ports of call in Australia, Azores, Bahamas, Barbados, Bermuda, Chile, Fiji, Galapagos, Greece, Guam, Hawaii, New Zealand, Philippines, Saudi Arabia, South Africa, Tahiti, US Virgin Islands, and fieldwork around the US and in Alaska, Costa Rica, Ghana, Greenland, Gulf of Mexico, Mexico, Antarctica, Spain, Romania, Oman, and Panama.

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## 2010 Annual Report: Marine Chemistry & Geochemistry

During 2010, the MC&G Department continued to build and extend its historic mission to study processes that regulate the chemistry of the oceans. As our knowledge of the marine environment evolves, so too does the nature of the research undertaken by scientists and staff in our department. The scope of these efforts is necessarily broad and involves exploration of chemical cycling not only within the oceans, but also on land, in the atmosphere, and beneath the seafloor. A recurring theme through much of this research is the relationship between ocean chemistry and climate and the anthropogenic influence on the marine environment.

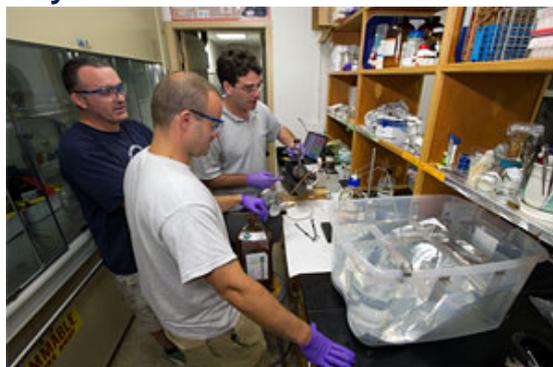
MC&G has a long tradition of developing state-of-the-art analytical techniques along with innovative approaches to field and lab based experimental studies and computer modeling. During the past year, many of these techniques found new and exciting applications.

The *Deep Water Horizon* oil spill reminded us of the enormous impact that human activity may have on marine ecosystems. Members of MC&G, along with several other WHOI researchers, played an integral role in the mobilization of the scientific community to study the fate and environmental impact of oil released into the Gulf and Mexico. MC&G scientists Chris Reddy and Ben Van Mooy, along with research associate Sean Sylva and APOE Department colleagues, rapidly coordinated and mobilized a research cruise during the oil spill to map the spatial extent of the hydrocarbon plume within the water column and determine the composition and abundance of plume hydrocarbons. One of the challenges facing researchers studying the oil spill was the ability to obtain a pristine sample of the extremely gas-rich petroleum released at the sea floor. Using a gas-tight sampling device developed by MC&G scientist Jeff Seewald and Engineers in APOE for collection of hydrothermal vent fluids at mid-ocean ridges, the WHOI group was successful in collecting the only samples of pristine hydrocarbons released at the seafloor during the entire oil spill. Chris Reddy also provided effective leadership for the scientific community at a national level, giving testimony to the National Commission on the oil spill and twice to Congress, in addition to serving as the Science Liaison at the Unified Area Command for the oil spill in September.

MC&G Scientist Liz Kujawinski, working with colleagues at UC Santa Barbara and Stanford University, took advantage of the powerful analytical capabilities she developed in establishing the MC&G FT-ICR-MS Facility at WHOI. Using this instrument to analyze seawater samples from the Gulf, Kujawinski and colleagues were able to elucidate the distribution of the ~771,000 gallons of chemical dispersants that were released to the environment during the oil spill in an attempt to enhance the retention of oil within the water column and dispersion at the sea surface. This fundamental information will be used to assess the persistence of the dispersants once released, and their toxicological effects.

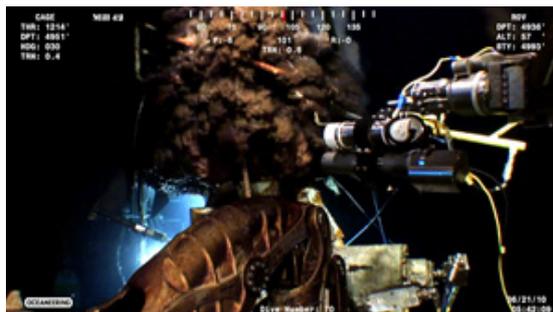
Although the *Deep Water Horizon* oil spill necessarily demanded the attention of many, other MC&G researchers continued to conduct important research in the labs at WHOI. For instance, MC&G Scientist Marco Coolen has initiated a study to investigate the microbial generation of natural gas from the organic-rich Antrim Shale in the Michigan basin. Using carefully designed laboratory experiments, he is exploring whether the addition of organic compounds that represent a source of food for the indigenous microbial communities within the shale can stimulate microbial methane production. A variety of molecular approaches are being applied to identify the microbial organisms responsible for methanogenesis. Results of this work will contribute to our understanding of biogeochemical processes (chemical and physical processes involving organisms organic matter, and minerals) associated with natural gas formation and could lead to enhanced recovery of energy resources from economically viable shale gas reserves.

Other research of note has taken our researchers far afield during 2010.



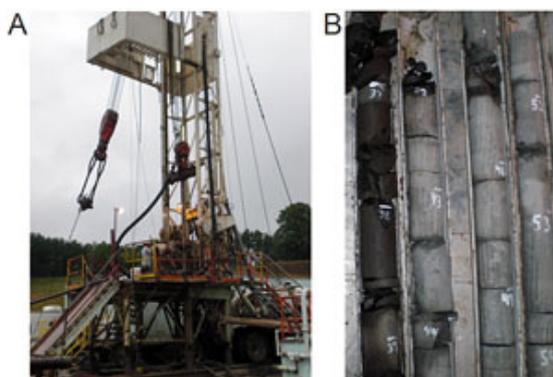
[Enlarge Image](#)

WHOI researchers (l to r) Chris Reddy, Sean Sylva, and Jeff Seewald prepare to tap into the pressurized chamber holding material collected from the damaged wellhead at the Deepwater Horizon oil spill site. A team from WHOI had used a specialized device called an Isobaric Gas-Tight sampler (black object near Seewald) to collect the material, which was the only sample taken directly from the broken wellhead. The sample was analyzed for its gas and oil content, to estimate the amount of each released during the spill. It also served as a reference to determine whether unknown oil samples came from the spill. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)



[Enlarge Image](#)

The manipulator arm of a robotic vehicle (upper right) moves the Isobaric Gas-Tight (IGT) sampler toward the jet of hot oil and gas shooting out of the broken Deepwater Horizon wellhead. The IGT sampler sips fluids jetting into the deep sea through a straw-like snorkel and keeps it at the high pressure of the area where it was collected. (Photo courtesy of Oceaneering)



[Enlarge Image](#)

WHOI researcher Marco Coolen has initiated a study to investigate the microbial generation of natural gas from the organic-rich Antrim Shale in the Michigan basin. The Antrim Devonian Shale drilling site (A) in the Michigan basin where

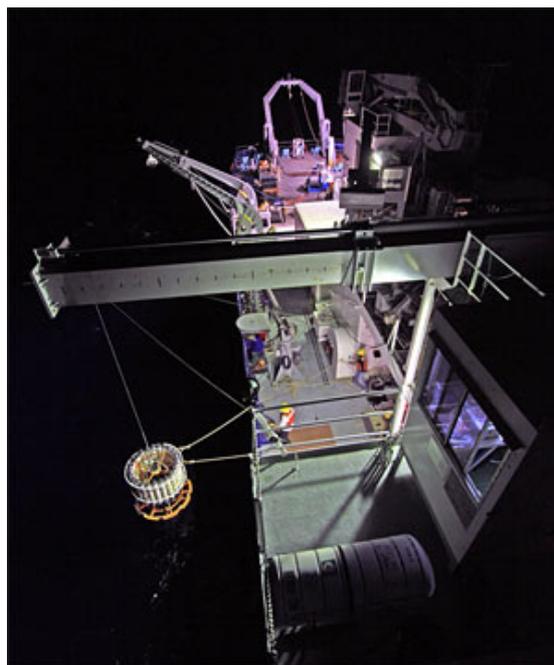
Extensive water sampling occurred at the Mackenzie, Fraser, Ganges-Brahmaputra, and Connecticut Rivers as part of the ongoing multi-institutional World River Project spearheaded by Senior Scientist Bernhard Peucker-Ehrenbrink. This project also involves MC&G colleagues Tim Eglinton, Aleck Wang, Valier Galy, Xiaojuan (Yvonne) Feng, and Joint Program Students Britta Voss and Katie Kirsch. These efforts will document temporal variability in biogeochemical processes that regulate the riverine transport and cycling of chemicals in large rivers around the world. Enlisting international citizen-collaborators living near rivers of interest led to a substantial expansion of this project in the past year and allowed river water samples to be collected at least once a month. In October 2010 WHOI and the Woods Hole Research Center hosted the World River Workshop, to train international participants in sampling techniques and plan for future collaborations. The resulting dataset will provide insights into the variability of river systems, and export of land-derived material from the continents to the coastal ocean, at unprecedented temporal resolution.

MC&G Senior Scientist Dan Repeta led a cruise that traversed the Eastern Subtropical Pacific Ocean from Arica, Chile to Easter Island to investigate how microbes drive transformations and movements of nutrients between seawater and organisms. Meanwhile, Senior Scientist Bill Jenkins led the first U.S. GEOTRACES cruise in the Atlantic. MC&G Scientists Karen Casciotti, Matt Charette, Phoebe Lam, Carl Lamborg, Laura Robison and Mak Saito are also all involved in GEOTRACES, an international program to research the distribution of trace elements and their isotopes in the global ocean. Konrad Hughen led a series of cruises in the Red Sea with funding from King Abdullah University of Science and Technology (KAUST) and conducted a WHOI-funded cruise to Hon Tre Island, Vietnam to sample water and corals, which incorporate high-resolution records of climate and environmental change in their skeletons.

—[Jeffrey Seewald](#), *Department Chair*

*Last updated: June 8, 2011*

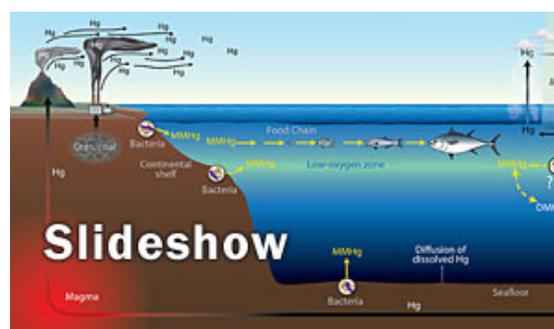
a core section (B) of the ~380 million-year-old gas-rich rock formation recovered from ~400 meter below surface. Most of the biological gas production is expected in the black colored, organic rich core rock intervals.



[Enlarge Image](#)

MC&G Senior Scientist Dan Repeta led a cruise that traversed the Eastern Subtropical Pacific Ocean from Arica, Chile to Easter Island to investigate how microbes drive transformations and movements of nutrients between seawater and organisms. (Woods Hole Oceanographic Institution)

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## 2010 Annual Report: Physical Oceanography

Our branch of ocean science focuses on the physics of ocean currents, the role of those water flows in Earth's climate, and their interaction with the ocean's geochemical- and eco-systems. Physical oceanographic research involves a blend of approaches including direct observation at sea using human-operated or autonomous instruments, laboratory experiments, and analytical approaches to solving equations for a given problem. In December 2010, the Physical Oceanography (PO) Department had a scientific staff of 31, plus 7 scientist emeriti and a combined 8 postdoctoral scholars or investigators, all of whom collaborate with and are supported by a technical staff of 64. Three new Assistant Scientists joined the Department this year: Irina Rypina, Jake Gebbie and Hyodae Seo. There are currently 21 MIT-WHOI Joint Program students enrolled in a physical oceanography curriculum.

Our department's research spans all the major oceans and nearly from pole to pole, from the very near shore regions to the deep. A summary of some of the projects follows, from north to south.

### Arctic regions

- PO Department members carried out research projects in the Arctic Ocean and adjoining subpolar seas in 2010, many of which contribute to the long-term Arctic Observing Network (AON) effort.
- Rick Krishfield supported the WHOI Ice-Tethered Profiler (ITP) program of drifting buoys deployed on Arctic sea ice, and also Andrey Proshutinsky's sustained measurement program, the Beaufort Gyre Observing System (BGOS), in the Canada Basin northeast of Alaska. One focus of this research is the changing amount of low-salinity surface waters that occasionally flood south where they may affect the ocean circulation and climate.
- Closer to the coast, Al Plueddemann led a team that deployed an autonomous underwater vehicle under the sea ice near Barrow, Alaska, and Bob Pickart deployed moorings to measure flows on the continental shelf and did sampling on two cruises, with postdoc Emily Shroyer. These studies are documenting how Pacific Ocean waters enter and flow in the Arctic Ocean.
- In theoretical studies, Andrey Proshutinsky continued to direct the international Arctic Ocean Model Intercomparison Project, whose annual meeting this year had more than 100 participants. Mike Spall used models to investigate overturning circulations (the sinking of dense water) in far northern and southern waters. And Jiang Yang used models to study the flow of that dense water.
- Fiamma Straneo, who is investigating the ocean's influences on Greenland glaciers, led a team to Sermilik Fjord to make the first wintertime observations of the ocean waters touching the base of the glacier, and then returned to Greenland's fjords in August-September to recover moorings deployed in summer 2009. Complementing this field work, Claudia Cenedesi has designed laboratory experiments to investigate how fjord ocean water interacts with a glacier tongue.

### Subpolar and subtropical latitudes

- Amy Bower and German investigators are studying deep waters flowing through the "Charlie Gibbs Fracture Zone", a series of deep passages through the Mid Atlantic Ridge; with moorings to be in place for two years. Mike McCartney's glider program, funded by the WHOI Ocean and Climate Change Institute and the Arctic Research Initiative, is studying the southward-flowing dense waters near the Grand Banks. Dave Fratantoni also contributed to several research efforts using gliders, including using these autonomous instruments to acoustically track whales.
- At subtropical latitudes in the North Atlantic, Ruth Curry and Kurt Polzin started a research program measuring deep currents between Bermuda, Puerto Rico and the Mid Atlantic Ridge, to better understand the deepest water circulation in this region.



[Enlarge Image](#)

WHOI engineers Jim Dunn (left in red jacket) and Kris Newhall (kneeling) prepare to deploy an ice-tethered profiler (ITP) during a cruise on the CCCG *Louis S. St. Laurent* in the Beaufort Sea in October, 2010. The ITP is a package of instruments attached to a weighted line that is anchored to the ice. It will drift with the ice, gathering information on water properties such as salinity and temperature, for up to three years. Scientists from WHOI, the Naval Postgraduate School, and the U.S. Army CRREL (Cold Regions Research and Engineering Laboratory) are studying currents and water masses in the Arctic as part of the [Beaufort Gyre Exploration Project](#). (Photo by Rick Krishfield, Woods Hole Oceanographic Institution)

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Despite significant interruption by Hurricane Igor, their first cruise in September successfully placed moorings on the eastern flank of the Bermuda Rise. Curry is also involved in the “Line W” long-term monitoring program with Terry Joyce, John Toole, McCartney and Lamont-Doherty Earth Observatory scientist Bill Smethie, measuring the equator-ward flow of a deep sea current southeast of Woods Hole. The 6-element Line W moored array was successfully recovered and redeployed in October.

- Joyce, Young-Oh Kwon, Fratantoni, Straneo, J.J. Park, postdoc Xujing Davis, and others continue to analyze wintertime observations of the Gulf Stream, and (with Steve Jayne, Tom Farrar and postdoc Liz Douglass), make comparisons to the Kuroshio current in the North Pacific.
- Anthony Kirincich installed a new multiple-antenna radar system at the Martha’s Vineyard Coastal Observatory (MVCO) that he will use to investigate the near-shore ocean circulation. Meanwhile, Rypina is planning a massive surface drifter experiment within Kirincich’s measurement area. Complementing this fieldwork, Ken Brink and Steve Lentz are doing theoretical studies of water flow along the coastal ocean’s bottom topography.
- In the far western North Pacific, Jayne, Douglass, and Ken Decoteau participated in a cruise studying cold sea surface temperature wakes that develop behind typhoons (and hurricanes)—calling for a careful balance between the need to sample close to a storm—but not too close! In other Pacific Ocean research, Glen Gawarkiewicz, Karl Helfrich and St. Laurent worked to analyze data from the East and South China Seas. Postdoc Magdalena Andres joined a research cruise studying flow through the Ryuku Island arc in Japan.
- Several PO Department members contributed to measurement programs in the Gulf of Mexico after the *Deepwater Horizon* oil platform disaster. Marshall Swartz prepared and mounted instruments aboard ships to sample water properties in the area of the spill; Dan Torres sailed on two of those cruises. Breck Owens and colleagues operated an ocean glider that surveyed the oil spill region autonomously, sending back data in real time via satellite. Jayne assisted the U.S. Coast Guard with their evaluation of proposed oil spill mitigation strategies.
- Bower, Lentz, Farrar, Dick Limeburner and Jim Churchill were again involved in Red Sea research in association with Saudi Arabia’s King Abdullah University of Science and Technology, including an extensive hydrographic survey of the eastern Red Sea, moored instrument deployments and recoveries, and a course Jayne developed and taught to 60 students at KAUST.
- Ray Schmitt continued laying groundwork for a study of sea surface salinity variability to be done in conjunction with the NASA *Aquarius* satellite. Lisan Yu and Bob Weller will also contribute to this study using their ocean evaporation data base.
- The Upper Ocean Processes (UOP) group serviced long-term surface moorings in the North Atlantic, off Hawaii and in the Southeast Pacific.

## South Pacific Ocean

- Weller and Farrar investigated ocean eddies and mixing about the UOP mooring off Chile, to quantify cooling and freshening in the upper ocean under the persistent stratus clouds in this region. Kudos go to Jeff Lord and Ben Pietro for their efforts aboard the vessel *B.I.C Humbolt* to rescue this buoy, that went adrift in July, and to Hazel Salazar for assisting with the logistics of that charter.
- UOP also designed, built, provided to the Australian Government, and helped deploy a surface mooring south of Tasmania as part of the Australian Integrated Marine Observing System.
- Curry and Douglass completed a cruise to study currents at 32°S in January/February (Tahiti to Valparaiso), and were fortunate to return home just before the major earthquake that struck Chile that month.

## The Southern Ocean

- St. Laurent, Toole, Krishfield, Decoteau and Dave Wellwood were aboard the R/V *Thompson*, on a Southern Ocean cruise southwest of Chile at the time of the earthquake—far enough from the epicenter to experience no effects. Tragically, earlier on this cruise, the *Thompson’s* Captain Phil Smith suffered a major heart attack and died. Despite this terrible event, an extensive survey of the anthropogenic tracer that Applied Ocean Physics and Engineering Department (AOPE) scientist Jim Ledwell deployed one year earlier was completed, along with other observations.
- Neutrally-Buoyant Sediment Traps (NBST), developed by Jim Valdes with MC&G scientist Ken Buesseler, collect sinking biological material in the upper ocean. In 2010, Valdes and associates deployed NBST instruments off Bermuda and near the Antarctic Peninsula in the Southern Ocean—including the 100th NBST deployment since the first in 2004. Valdes began testing the next generation of these instruments, which he also helped develop: the “Twilight Zone Explorer”.
- In mid December, Dick Limeburner and Will Ostrom (AOPE) traveled to Antarctica to install velocity, temperature, and salinity sensors below the floating tongue of the Ross Ice Shelf, the largest ice shelf in the world. The sensors transmit data to an electronics package atop the ice and then via satellite to WHOI, the first real-time data from under an Antarctic Ice Shelf. At the same time, Rick Krishfield supported New Zealand investigators deploying an ITP adjacent to the ice shelf. That ITP is sending temperature and salinity profile data from 8-400 meters depth.

## Awards, Anniversaries, Honors, Notes, and Service

- December 2010 marked the 50th anniversary of the first mooring deployment by the WHOI Buoy Group. The descendants of that facility: the WHOI Rigging Shop, Upper Ocean Processes Group, and Subsurface Mooring Operations Group, led by Rick Trask, Jeff Lord and Scott Worriolow respectively, are sustaining the Buoy Group tradition of excellence, now having deployed nearly 1500 deep-ocean moorings.
- Amy Bower received an Unsung Heroine Award from the Massachusetts Commission on the Status of Women, and was elected Fellow of the American Meteorology Society.
- Glen Gawarkiewicz was recognized by the Taiwan National Science Council and U.S. Office of Naval Research for 10 years of effort in support of three research programs.
- Department members continue their service to the community in 2010: Mike Spall serves as Chief Editor of the *Journal of Physical Oceanography* and Ken Brink assumed a lead-editor position this year with the *Journal of Marine Research*. Dave Fratantoni and Andrey Proshutinsky were named editors for the *Journal of Atmospheric and Oceanic Technology* and *Journal of Geophysical Research*, respectively. Ray Schmitt served on two National Academy Panels: "Advancing the Science of Climate Change" for the "America's Climate Choices" study, and "Marine and Hydrokinetic Energy Technology Resource Assessments." Bob Weller was appointed by the Secretary of the Navy to service on the "Ocean Resources and Research Advisory Panel." Spall continued to serve on the Scientific Steering Committee for CLIVAR (Climate Variability and Predictability program).
- Joint Program students Jessica Benthuisen, Beatriz Peña-Molino, Tatiana Rykova and Katherine Silverthorne were awarded Ph. D. degrees, and Rebecca Walsh Dell earned a MS degree and is continuing in the program.
- Lastly we sadly note the unexpected passing of Emeritus Scientist Bruce Warren on September 2.

—[John M. Toole](#), Department Chair

### The Icebot

A team of scientists field-tests an autonomous underwater vehicle, sending it into a hole in an ice floe off the coast of Alaska ... and hoping they can get it back.

» [From Oceanus magazine](#)

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## 2010 Annual Report

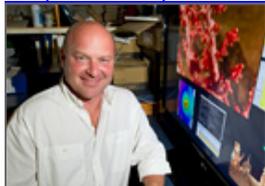
### Ocean Institutes



#### [Coastal Ocean Institute](#)

The Coastal Ocean Institute (COI) promotes scientific inquiry into phenomena that shape our coastal waters and ecosystems. Through research grants, scientific gatherings, and the development of state-of-the-art facilities, COI encourages interdisciplinary research and innovative technology development.

#### [Deep Ocean Exploration Institute](#)



The Deep Ocean Exploration Institute (DOEI) fosters multi-disciplinary study of physical, chemical, geological, and biological processes in all these areas and in the planet's interior, and development of the technology needed to access environments at and below the seafloor.

#### [Ocean & Climate Change Institute](#)



The Ocean and Climate Change Institute (OCCI) uses its energies and resources to advance the knowledge of "How the Ocean works in the Earth's Changing Climate System" by acting across WHOI departmental structures, blending education, research, access to the sea, and outreach to achieve its goals.

#### [Ocean Life Institute](#)



The Ocean Life Institute (OLI) supports groundbreaking basic research related to conservation science and biodiversity in marine ecosystems. The Institute supports WHOI scientists through OLI fellowships, postdoctoral and graduate student awards, and research grants.

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## 2010 Annual Report: Coastal Ocean Institute

My second year as Director of the Coastal Ocean Institute (COI) was full of excellent scientific research and challenging times. COI was able to support many scientists, postdoctoral scholars, and graduate students in a broad range of coastal research projects. The Deepwater Horizon oil spill in the Gulf of Mexico presented many challenges and opportunities for me and many other WHOI scientists and engineers. I feel comfortable stating that WHOI has played a key role in the science of this unfortunate coastal event.

Some highlights of 2010 include the presentation of the 15th Bostwick H. Ketchum award in April to Dr. James E. Cloern, United States Geological Society, for his excellence in estuarine ecology especially his conceptual models of important estuarine processes, collaborations within the US and abroad, and ability to translate his results to policymakers. When Dr. Cloern was present at WHOI, he gave two talks, one on his long-term monitoring work in San Francisco Bay and another on how to write scientific papers. Both of the presentations were well attended and received.

Our efforts to improve our web content included the translation of the COI-sponsored tsunami website into Delhevi, which is the official language of the Maldives. The content and design is well underway for a beach water-quality website with an anticipated launch in May/June 2011.

COI supported five research grants from our annual call for proposals:

- Associate Scientist, Liz Kujawinski, and WHOI/MIT Joint Program student, Dave Griffith, (Marine Chemistry & Geochemistry) are studying the concentrations and fate of sewage-derived estrogens in Massachusetts Bay.
- Postdoctoral Scholar, Gordon Zhang, and Senior Scientist, Dennis McGillicuddy (Applied Ocean Physics & Engineering) along with Senior Scientist, Glen Gawarkiewicz (Physical Oceanography) are working on an interdisciplinary modeling of the New England Shelf Break, where the continental shelf gives way to a steep downward slope to the abyssal seafloor
- Associate Scientists, Ann Mulligan (WHOI Marine Policy Center) and Matt Charette (Marine Chemistry & Geochemistry) are studying the element radium to understand how groundwater flows into the coastal ocean.
- Postdoctoral Investigator Andrea Hawkes and Associate Scientist, Jeff Donnelly (Geology & Geophysics) are developing a microfossil-based approach to estimate past intensities of hurricanes.
- Assistant Scientist, Irina Rypina (Marine Chemistry & Geochemistry) is investigating the stirring of waters on the Martha's Vineyard inner-shelf using a combination of surface drifters, high-resolution high-frequency radar systems, and techniques from advanced theory.

—[Christopher Reddy](#), Institute Director

Last updated: June 8, 2011



[Enlarge Image](#)

After a six-month dry season in coastal Panama, the first rains bring masses of bright red land crabs boiling out of their burrows in the forest and scrambling across the shore to the water, where the females lay fertilized eggs in the sea. The brilliantly colored crabs, *Gecarcinus quadratus*, are abundant near the Liquid Jungle Lab in Panama, but little was known about them before MIT-WHOI Joint Program student Joanna Gyory—funded by the Coastal Ocean Institute, discovered how the species completes its life cycle, from eggs, through several stages of marine larvae, to juveniles that migrate back to land, to the land-dwelling adults. (Photo courtesy of Joanna Gyory, Woods Hole Oceanographic Institution)



The 15th Bostwick H. Ketchum was awarded in April to Dr. James E. Cloern, United States Geological Society, for his excellence in estuarine ecology especially his conceptual models of important estuarine processes, collaborations within the US and abroad, and ability to translate his results to policymakers. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

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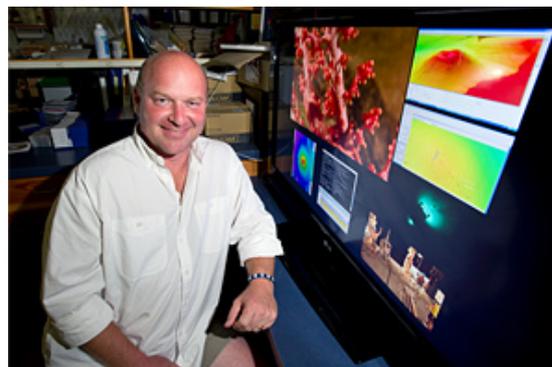
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## 2010 Annual Report: Deep Ocean Exploration Institute

The history of our planet is best revealed by studying the global ocean seafloor. Understanding the geological, chemical and biological processes that form and alter the ocean crust, all of which influence the chemical composition of the ocean, are crucial goals of 21<sup>st</sup> century oceanographic science. The technological and scientific challenges involved in unraveling these processes and their linkages in space and time are significant. The Deep Ocean Exploration Institute (DOEI) at WHOI plays a key role in supporting scientists, engineers and students working on these topics, fostering innovative cross-disciplinary research and developing unique technologies to explore, map and sample in the deep ocean and beneath the seafloor in earth's crust and mantle.



[Enlarge Image](#)

In 2010, DOEI continued to support WHOI staff and students through Institute themes and the Ocean Ridge Initiative (ORI), which encompasses a broad agenda of research focused on Earth's most continuous volcanic and tectonic lineament—the global mid-ocean ridge, the 50,000 mile-long undersea mountain chain where oceanic crust is generated.

Initially the ORI has funded research on microbial and dynamic geological/geochemical processes and the nature of deep-sea fauna at oceanic spreading centers. Technology and instrument development that facilitates such studies are an integral part of the ORI.

DOEI's research themes expand the breadth of the ORI by providing opportunities for high-risk/high-reward science that can lead to breakthroughs in our understanding of coupled dynamic processes in deep seafloor environments, from trenches to mid-ocean ridges to continental slopes. DOEI funding has focused on detailed geochemical studies pertaining to the role of the deep earth and ocean in global elemental cycles—especially the role of volatile elements in magmatic and volcanic systems, carbon sequestration in ocean floor strata and investigating what is perhaps the largest unknown ecosystem on this planet, the deep biosphere within the oceanic crust and the deep ocean.

Nine proposals were funded in 2010 covering various DOEI themes and ORI topics:

### DOEI

*Nobu Shimizu (Geology and Geophysics Department, G&G)* will establish a comprehensive dataset for sulfur isotopic variations in rocks associated with subduction of altered oceanic crust and sediment by determining sulfur isotopic compositions *in situ* in sulfides, apatite minerals and high-pressure metamorphic rocks. The resulting data are essential to developing a quantitative understanding of fluid fluxes across subduction zones and will provide a major step forward in understanding the global sulfur cycle and processes of deep geochemical cycling of elements.

*Virginia Edgcomb (G&G)* will study the long-term consequences of contamination of the marine food web. Ginny's research will use protists—single-celled organisms—that play key roles in microbial food webs, and in global biogeochemical cycles involved in transporting hydrocarbons to higher food chain levels when the protists are consumed. This project aims to determine if the presence of protists enhances degradation of hydrocarbons in deep marine sediments under varying oxygen and nutrient (phosphorus and nitrogen) concentrations, what impact hydrocarbon contamination has on seafloor microbe communities, and whether protists' presence leads to species changes in the *in situ* microbial community.

*John 'Chip' Breier (Applied Ocean Physics & Engineering Department, AOPE)* will develop a new, multifaceted sampling tool for Autonomous Underwater Vehicles (AUVs). This is the next technical evolution of sampling technology Chip and his colleagues developed using DOEI seed money. Migrating the new sampler to WHOI's Sentry AUV will enable autonomous, sensor-triggered sample collection during multi-depth, vent field-scale surveys. This new tool will give us unique scientific capabilities for hydrothermal vent research and for multidisciplinary Ocean Observing Initiative (OOI) studies that WHOI is implementing.

*Tim Shank (Biology Department, BIO), DOEI Fellow.* In summer 2010 Tim participated as a “virtual” chief scientist, with an international team led by U.S. and Indonesian scientists, on cruises exploring deep Indonesian waters in the Coral Triangle—a region where more than 65 percent of the world's shallow-water reef-forming coral species live. Tim helped plan the expedition and collected high-definition video imagery during dives by the “*Little Hercules*” ROV from the NOAA ship *Okeanos Explorer*. Researchers discovered a diversity and abundance of deep corals that they believe is the highest in the world, in more than 25 habitats on varied terrains at depths from 250 meters to more than 3,600 meters in the Sulawesi Sea. Tim and his colleagues video-imaged 40 potentially new deep-sea species and found dramatically different assemblages of coral species on different seamounts and depths. This expedition provides baseline data to let us better understand these ecosystems and identify future changes, information important in Indonesian seas and around the world.

In the summer 2010 DOEI fellow Tim Shank participated as a “virtual” chief scientist, with an international team led by U.S. and Indonesian scientists, on cruises exploring deep Indonesian waters in the Coral Triangle—a region where more than 65 percent of the world's shallow-water reef-forming coral species live. Tim helped plan the expedition and collected high-definition video imagery during dives by the “*Little Hercules*” ROV from the NOAA ship *Okeanos Explorer*. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

### Related Links

» [Deep Ocean Exploration Institute](#)

James Kinsey (AOPE) is engineering the application of a new class of accelerometers to develop an innovative gravimeter for use on AUVs. Gravity measurements can provide valuable information about the density and porosity of the sub-seafloor structure. Gravity anomalies (differences between expected and measured values) are measured from ships and satellites—both too far above the seafloor to resolve small-scale density differences. James and AOPE colleagues will determine the sensitivity of a new class of accelerometer and test it alongside a standard ship gravimeter, allowing them to investigate the potential of AUV gravimetry for solving geophysical problems in the deep ocean and work towards integrating the sensor into WHOI's *Sentry* AUV. The new sensing capability will augment *Sentry*'s geophysical instrumentation and motivate future research using this new class of accelerometers to develop low-cost, high-precision inertial navigation systems—technology with applications to ocean, land, and aerial robotics.

### Ocean Ridge Initiative

Henry Dick and Frieder Klein (G&G) will conduct a systematic study of carbonate-altered serpentinite minerals—minerals that take up carbon dioxide—from several types of hydrothermal vent systems. They will analyze the composition and associations of secondary minerals in these rocks using classic and new methods to unravel reaction pathways during CO<sub>2</sub> uptake. Their results will provide valuable new insights into the process of carbonate alteration in serpentinites and the consequences for CO<sub>2</sub> exchange between the abyssal mantle and the ocean.

Susan Humphris (G&G) and MIT/WHOI Joint Program student Evelyn Mervine will determine the natural rate of carbonation of mantle rocks (or *peridotite*) in an *ophiolite*—a section of oceanic crust and mantle exposed to the atmosphere by tectonic uplifting. Considerable attention has focused on carbon capture and storage as a way to mitigate CO<sub>2</sub> input to the atmosphere from human activities. One proposed option is to increase the conversion of CO<sub>2</sub> gas to stable, solid carbonate minerals, which happens when mantle rock is exposed to the atmosphere. Susan and Evy will study the Samail Ophiolite in Oman—one of the world's largest and best-exposed ophiolites—and measure the volume, ages and weathering rates in ophiolite layers, which will let them quantify the residence time of carbon in three kinds of carbonate-altered rocks within the ophiolite, some of them 350,000 years old. Studying carbonate formation in an ophiolite will provide a case study for seafloor rocks' potential for carbon sequestration, a potentially important 'sink' in the global carbon cycle.

Lauren Mullineaux and Susan Mills (BIO) will study how submarine eruptions along a mid-ocean ridge, the East Pacific Rise (EPR) near 9° 50' N, affect the supply of larvae and the recolonization of fauna specific to hydrothermal vents. They had been monitoring larvae and colonization at the site before a volcanic eruption there in 2005-2006, and were able to mobilize quickly afterward to resume sampling. A striking change in the assortment of species colonizing the site after the eruption, driven in part by the supply of larvae, led Lauren and Susan to ask if these new pioneer species will persist and lead to a different stable community at the vent—or if the vent community will transition back to the pre-eruption assemblage of species? They will address this question by long-term monitoring of species at the eruption site. An invitation to participate in a French cruise to the EPR gave them an opportunity to start this effort in collaboration with a colleague who will provide associated measurements of biologically important environmental components, pH (acidity) and sulfide. Biological and chemical monitoring will let them evaluate the roles of larval supply and environmental change in the recovery of EPR vent communities post-eruption, and to pursue further funding and collaborations to study them.

Jared Goldstone, Tim Shank, and John Stegeman (BIO) will identify genetic (DNA) sequences that can be used as markers of organic chemical (hydrocarbon) exposure in deep-sea mussels, *Bathymodiolus thermophilus* and related species. When exposed to such toxins, animals employ (express) specific genes to produce the enzymes that detoxify those compounds, but how animals in vent or seep environments accomplish this task is not known. It's hard to obtain samples for genetic analysis from the deep sea, so little information is available on the mussels' gene sequences or genes expressed. But they are closely related to a shallow-water species, the blue mussel, for which researchers do have gene sequences. By analyzing evolutionary relationships between mussel species, the team will identify *Bathymodiolus* gene sequences expressed when the mussels are exposed to organic chemicals, which in turn will help define the chemical environment that animals experience at deep-sea vents and hydrocarbon seeps.

### 2010 DOEI Fellows, Postdocs, Graduate students, and the Geodynamics Program

- DOEI continues to support two Fellows, Jeff McGuire (G&G) and newly appointed Fellow Mark Behn (G&G). Jeff uses recordings of the seismic waves and permanent ground deformation produced by earthquakes to improve our understanding of the rupture process and fault structure, and is working to develop a real-time earthquake early warning system for the Pacific Northwest. Mark uses geodynamic models to quantify aspects of tectonic and magmatic systems in marine and terrestrial environments. As a DOEI fellow, he plans to study Earth's deep water cycle. While we typically think the oceans are the largest water reservoir on Earth, hydrous minerals (minerals incorporating water in their structure) may store far more water in the deep mantle. Mark will work with an interdisciplinary group of scientists to develop models for the flux of water into and out of the Earth's mantle at mid-ocean ridges and subduction zones.
- In 2010 DOEI continued to support Postdoctoral Scholars Tetsuo Matsuno and Frieder Klein. Newly joining us in October was postdoctoral scholar Dorsey Wanless. Her research interests lie in understanding magmatic plumbing systems beneath mid-ocean ridges, from mantle melting to the eruption of lavas on the seafloor.
- DOEI also supported three MIT-WHOI Joint Program students: Emily Roland's research focuses on understanding how earthquakes occur along oceanic transform faults; Min Zhu focuses on the seismic structure of oceanic crust created at fast and slow-spreading mid-ocean ridges; and Evelyn Mervine is studying natural carbon dioxide sequestration in carbonate minerals with

Susan Humphris (see above).

- DOEI continues to fund the annual Marine Geodynamics Program. The multi-disciplinary topic for the 2010 course program was "Crust: Planetary, Continental and Oceanic".

--[Daniel Fornari](#), *Institute Director*

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## 2010 Annual Report: Ocean & Climate Change Institute

In 2010, the Arctic Research Initiative (ARI) of the Ocean and Climate Change Institute (OCCI) entered its fourth year. The ARI is our five-year, \$10 million focused effort to study the changes in Arctic climate, ocean chemistry and ecosystems resulting from increased atmospheric CO<sub>2</sub> and a warming Arctic ocean and atmosphere. Many of the OCCI research activities in 2010 focused on the study of ice in the Arctic. Fiamma Straneo (in WHOI's Physical Oceanography Department) used ARI funds to observe and measure the interactions between warm Atlantic Ocean waters and glaciers in several fjords along the eastern coast of Greenland. Al Plueddemann (also in Physical Oceanography) made our first attempts to deploy and navigate an autonomous underwater vehicle (AUV) beneath the ice in the Arctic Ocean. OCCI funded several studies of the fate of organic carbon as the surrounding permafrost begins to melt. These carbon-rich soils have been frozen for thousands of years, and rapid warming of the Arctic region is allowing the carbon to be eroded (through rainfall and melting) and transported through river systems into the Arctic Ocean. Aleck Wang (WHOI Marine Chemistry and Geochemistry Department) received an award to develop autonomous sensors to measure CO<sub>2</sub> in Arctic rivers. Ann McNichol (Geology and Geophysics Department) began a project to measure the radiocarbon content of organic material arriving in the Canadian Basin of the Arctic —measuring this radioactive isotope of carbon allows her to determine how much of the carbon arriving there is “old” and therefore likely to have come from the melting permafrost. In 2010, the ARI distributed about \$1.8 million for research awards and postdoctoral support.

The OCCI also supported research on climate variability in tropical locations. Delia Oppo and Pat Lohmann (both in Geology and Geophysics) mounted a field program to the Bahamas to take cores of skeletons of long-lived corals for records of past tropical climate. The chemistry of these corals is affected by the temperature and salinity conditions in which they live, so by measuring the changes in chemistry of old coral skeletons, records of climate can be developed. Kris Karnauskas (Geology and Geophysics) used models of ocean circulation to study the linkages between changes in the tropical Atlantic and the tropical Pacific Oceans.

Sarah Das (Geology and Geophysics) and Young-Oh Kwan (Physical Oceanography) are in the second year of their three-year terms as OCCI Fellows (having begun in May 2009). In 2010, two new postdoctoral scholars joined us: Sean Bryan, a graduate of the University of Colorado and Donglai Gong, a graduate of Rutgers University. Katie Silverthorne, a graduate student in Physical Oceanography supported by OCCI, successfully defended her Ph.D. thesis in 2010. She is now working as a postdoc at Queen's University Belfast, Northern Ireland. MIT-WHOI Joint Program students Maya Bhatia (Marine Chemistry and Geochemistry) and Camillo Ponton (Geology and Geophysics) are now supported by OCCI for their graduate studies. Maya is working on the biogeochemistry of the Greenland ice sheet and Camillo is studying the long-term history of the south Asian monsoon.

OCCI also hosted the Climate Summer Internship Program again this year, providing local high school students with a summer research experience. Delia Oppo and Joanne Muller (Falmouth Academy science teacher and former WHOI Postdoctoral Fellow) provided six Falmouth Academy students and four Falmouth High School students with hands-on experience using deep-sea sediments to understand Earth's climate history. Following the success of the pilot program in 2009 and again this year, OCCI views this as an important annual contribution to education and outreach activities in the Falmouth area.

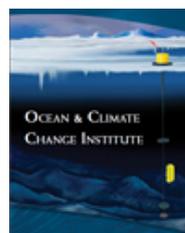
—[William Curry](#), *Institute Director*



[Enlarge Image](#)

MIT/WHOI graduate student and OCCI graduate fellow Maya Bhatia sets up an incubation experiment to measure carbon in the meltwaters that stream and pool across the surface of the Greenland ice sheet. (Photo by Sarah Das, Woods Hole Oceanographic Institution)

### Related Files



» [Ocean & Climate Change Institute 2010 Annual Report](#)  
(pdf format)

### Related Links

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## A Rising Tide

Linking Ocean and Ice

WHOI physical oceanographer Fiamma Straneo examines the connection between ocean conditions and climate-driven changes to Greenland glaciers and describes some of the challenges to doing scientific research in the far north.

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## 2010 Annual Report: Ocean Life Institute

The Ocean Life Institute (OLI) supports groundbreaking basic research related to conservation science and biodiversity in marine ecosystems. We support WHOI scientists through OLI fellowships, postdoctoral and graduate student awards, and research grants. OLI-sponsored research during 2010 was aligned with targeted themes of biodiversity in the ocean, the health of marine ecosystems, and new tools for ocean biology.

Research initiated with OLI funding over the past year include the use of high throughput DNA sequencing techniques to examine biodiversity and phylogenetics of fungi from Delaware Bay, a new laser-based method for visualizing movements of microscopic zooplankton, the influence of the Gulf Stream on silver hake distributions, and the effect of unique temperature and salinity “staircases” on zooplankton distributions in the tropical northwest Atlantic Ocean. New research on marine mammals was also supported by OLI to examine acoustic prey recognition by toothed whales and to refine passive listening devices for remotely monitoring marine mammals.

Research fellows Marco Coolen and Mak Saito continued their cutting-edge research on ancient DNA in marine sediments and ocean carbon and nitrogen cycling, respectively. An OLI-sponsored WHOI postdoctoral fellow, Amy Apprill, identified unique microbial communities associated with the skin of healthy and stressed humpback whales. Finally, OLI support to MIT/WHOI Joint Program students Joanna Gyory and Maya Yamato assisted with studies of planktonic larvae of coastal invertebrates and the morphology of auditory systems in baleen whales.

In addition to supporting individual-based research, OLI has worked on two new initiatives:

- Ecosystem-based management (EBM) of the ocean: OLI's efforts to stimulate research in the area of EBM and modeling observing systems helped to establish a new multi-institutional NOAA-funded Cooperative Institute for the North Atlantic Region, for which WHOI is the lead institution.
- Coral reef research: Research on coral reefs supported by OLI is being conducted throughout the world's tropical oceans. We are developing a new collaborative research initiative focusing on the Phoenix Island Protected Area (PIPA), the world's second largest marine protected area located in central tropical Pacific Ocean. The Liquid Jungle Laboratory on the Pacific coast of Panama continues, with OLI support, to provide WHOI researchers access to a number of tropical coastal habitats including coral reefs.

Finally, I would like to extend my sincere thanks to all who have supported the mission of the Ocean Life Institute so generously during the past year. I will work to ensure that OLI continues to help forge collaborations between WHOI scientists conducting cutting-edge science and those agencies and institutions charged with the conservation and sustainable management of life throughout the world's oceans.

—[Simon Thorrold](#), *Institute Director*

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[Enlarge Image](#)

Fish swim around a reef in the Phoenix Islands, a remote archipelago of coral islands in the equatorial Pacific. The islands, their coral reefs and surrounding water are part of the Phoenix Islands Protected Area, the largest marine reserve in the world. Coral reef research is a new initiative of the Ocean Life Institute. (Photo by Larry Madin, Woods Hole Oceanographic Institution)

### Related Files



» [Ocean Life Institute 2010 Annual Report](#)  
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### Related Links

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## 2010 Annual Report

### Centers & Programs



#### [Marine Policy Center](#)

Research at the Institution's Marine Policy Center (MPC) involves the application of economics and other social sciences to public policy issues connected to the world's oceans and coastal areas.

#### [Center for Ocean, Seafloor, and Marine Observing Systems](#)



The goal of COSMOS is to establish, off the Northeast US, an ocean observing system capable of achieving WHOI's scientific objectives in the region.

#### [Cooperative Institute for Climate and Ocean Research](#)



For over a decade, the Cooperative Institute for Climate and Ocean Research (CICOR) at the Woods Hole Oceanographic Institution has been instrumental in harnessing the depth of leadership and research excellence at WHOI in service of NOAA's mission and goals

#### [Cooperative Institute for the North Atlantic Region](#)



The overall goal of CINAR is to engage NOAA and academic scientists in cutting-edge research that enables NOAA to make informed decisions about sustainable and beneficial management of the U.S. northeast continental shelf ecosystem.

#### [Marine Mammal Center](#)



The mission of the WHOI Marine Mammal Center (MMC) is to develop strength in basic research and technology, concentrating on conservation applications through strategic partnerships and interdisciplinary approaches.

#### [Woods Hole Sea Grant Program](#)



The Woods Hole Sea Grant Program is part of the National Oceanic and Atmospheric Administration's national Sea Grant network of 32 programs. Collectively, Sea Grant promotes cooperation between government, academia, industry, scientists, and the private sector to foster science-based decisions leading to better understanding, conservation, and use of coastal resources.

#### [Woods Hole Center for Oceans and Human Health](#)



The mission of the Woods Hole Center for Oceans and Human Health (WHCOHH) is to improve the public health through enhancing our understanding of how oceanic processes affect the distribution and persistence of human pathogens and toxin-producing organisms in marine and coastal environments.

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## 2010 Annual Report: Marine Policy Center

Methods developed at WHOI to address questions in the ocean sometimes make it ashore and are used to address similar questions on land. Over the past 20 years, Senior Scientist Andy Solow has been working on statistical methods for inferring the extinction of a species from the historical record of its sightings.

This work was originally motivated by a lingering question about the fate of the Caribbean monk seal (*Monachus tropicalis*). The earliest record of the Caribbean monk seal dates to the second voyage of Christopher Columbus in 1494. The species was last seen in 1952. The basic question in inferring extinction from a sighting record is: How long must a species go unsighted before it can be confidently declared extinct? In 1993, Solow developed a method for answering this question, applied it to the modern sighting record of the Caribbean monk seal, and concluded that this species can with high confidence be declared extinct.

Last year, Solow received a call from a government scientist asking about the application of this method to the sighting record of the Ivory-billed Woodpecker (*Campephilus principalis*). The Ivory-billed Woodpecker was once common in the southeastern US, but its numbers dwindled as a result of forest clearing and hunting. The last sighting of the Ivory-billed Woodpecker that is widely viewed as real was in 1944, although there have been a number of questionable sightings since then. Then in 2005, a paper in the journal *Science* reported that a brief video recording of a male Ivory-billed Woodpecker had been made at an undisclosed location in Arkansas in April 2004. This claim was immediately questioned, with a number of experts identifying the bird in the video as a Pileated Woodpecker (*Dryocopus pileatus*). The argument raged.

The question, incidentally, is not purely academic. In response to the 2004 sighting, the US Fish and Wildlife Service developed a multi-million dollar recovery plan for this species. The expenditure of millions of dollars of taxpayer money and the promulgation of regulations to protect a species that most experts believe is extinct is controversial to say the least. At a minimum, there is a need for a more rigorous assessment of the sighting record of this species. In response, Solow worked out a method that accounts for uncertain sightings – including the one in 2004 – and applied it to the record of the Ivory-billed Woodpecker. The results provide substantial, but not overwhelming, support for the extinction of this species.

Interestingly, despite considerable effort – and a large cash reward – no convincing sightings of the Ivory-billed Woodpecker have been made since 2004. On the other hand, in 1998 a paper appeared in the journal *Oryx* entitled “Circumstantial evidence for the presence of monk seals in the West Indies.”

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Engraving of the Ivory-billed Woodpecker. (Prints and Photographs Division, Library of Congress)

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» [Marine Policy Center](#)

## 2010 Annual Report: Center for Ocean, Seafloor, and Marine Observing Systems (COSMOS)

The Center for Coastal Ocean, Seafloor and Marine Observing Systems (COSMOS) works to further research at WHOI relating to ocean observatories and observing systems.

This year COSMOS oversaw the second year of the Massachusetts Technological Collaborative John Adams Innovation Institute (MTCJAI) grant with three components. First, this grant has enabled enhancements to the Martha's Vineyard Coastal Observatory (MVCO) including a new landing at the offshore tower and upgrades to the communications and power capabilities. These upgrades made it possible to install a new radar system for remote sensing of waves and currents, and a more capable CO<sub>2</sub> measurement system at the tower. The MTCJAI grant also supports activities to integrate acoustic communications systems with remote sensors and data couriers. This is significant because MVCO is the testbed for evaluating the reliability and range of the acoustic signals sent through the water between "nodes"—geographically separate installations of ocean-monitoring instruments, part of the Ocean Observatories Initiative (OOI) funded by the National Science Foundation. The third MTCJAI component has led to upgrades to National Data buoy Center buoys at various sites in state waters; these standard national weather buoys now also carry a WHOI-developed system for long wave and short wave radiation measurements that will help provide improved weather forecasts and other important data-related products for a variety of users.

The MVCO has hosted several projects this year. In one of these, Jim Edson (at the University of Connecticut) and colleagues in the Upper Ocean Processes Group at WHOI conducted an experiment on the offshore tower. They added a meteorological mast to hold a suite of sensors that measure wind, temperature, humidity and more, near the ocean surface—and put the same sensor suite on a buoy deployed southwest of the tower. The objective of the experiment was to improve the motion correction algorithms, computational procedures used to compute heat, mass, and momentum fluxes from measurements taken at the buoy, through direct comparison with fluxes computed at the tower. The new algorithms will be used to improve the flux estimates in studies of the North Atlantic and for climate models.

Rob Olson and Heidi Sosik (Bio) continued to use MVCO to support their time series research on processes that affect phytoplankton blooms in New England waters. Their work involves a combination of instrument development activities and scientific study of effects of environmental factors that change with seasons and from year to year. 2010 was a notable year because of phytoplankton bloom differences linked to the warmest spring water temperatures in the MVCO record to date. In addition, Olson and Sosik achieved a record long 11-month unattended deployment of their in situ imaging flow cytometer.

With the enhanced power capabilities now available at MVCO, Anthony Kirincich (PO) has installed three high-frequency (HF) radar systems to make continuous measurements of the speed and direction of surface currents over a 15 by 20 km area south of Martha's Vineyard at spatial resolutions of 300 m. The output from this unique system will be used to determine the effects of spatial variability on circulation and exchanges of a host of factors including heat, mass, water, and more, and will be integrated into the existing HF radar system network along the New England and Mid-Atlantic coastlines.

COSMOS has been involved in several regional and national meetings. Director, Heidi Sosik attended meetings for NASA's mission on Geostationary Coastal and Air Pollution Events (GEO-CAPE) to partake in discussions of one of its goals—to understand the short-term dynamics of coastal ecosystems—and to plan for continued remote sensing validation activities at MVCO.

Building on the success of the MTCJAI grant, Heidi Sosik, spearheaded a proposal to the Commonwealth of Massachusetts to further improvements to MVCO, upgrade more NDBC meteorological buoys, advance acoustic and optical underwater communications, enable longer endurance for remote underwater vehicles, and create new moorings that will extend information from the Pioneer Array (an OOI node consisting of instrumented moorings to be installed off the New England coast) to the MVCO. The specified projects would enhance partnerships with industry in the state of Massachusetts and provide broader opportunities for the marine industry sector

In conjunction with this proposal, COSMOS hosted a visit to WHOI by Gregory Bialecki, Secretary of Housing and Economic Development in the Commonwealth of Massachusetts. This visit highlighted business growth of marine sector technologies and new business start-ups resulting from WHOI's implementation of coastal and global ocean observatories, as part of NSF's OOI.



[Enlarge Image](#)

At WHOI's Martha's Vineyard Coastal Observatory (MVCO), Jay Sisson, Hugh Popenoe, and Jared Schwartz (left to right) switch out part of a "node," a device that connects several ocean-monitoring instruments. Regular maintenance like this ensures that MVCO's offshore nodes provide uninterrupted data exchange and power to support increasingly sophisticated coastal ocean research. WHOI's Center for Ocean, Seafloor, and Marine Observing Systems (COSMOS) oversees MVCO and other regional ocean observing efforts at WHOI. (Photo by Jayne Doucette, Woods Hole Oceanographic Institution)

### Related Links

» [Center for Ocean, Seafloor and Marine Observing Systems \(COSMOS\)](#)

Looking to the future, COSMOS will continue to play a role in creating scientific access to the coastal ocean and to observing systems, and to foster creative new ways to study the ocean

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## 2010 Annual Report: Cooperative Institute for Climate and Ocean Research (CICOR)

This is the final contribution to the WHOI Annual Report from CICOR. A 1998 agreement between WHOI and NOAA (the National Oceanographic and Atmospheric Administration) established a unique center at WHOI for climate research: CICOR, the Cooperative Institute for Climate and Ocean Research. For over a decade, CICOR has drawn on the leadership and research excellence at WHOI to serve NOAA's mission and goals.

With its founding agreement, renewed in 2001, CICOR served as a global and national resource for scientists and strengthened the relationship between WHOI and NOAA, enabling long-term research partnerships in key areas of climate observations and analyses, marine policy, seafloor mapping and harmful algal bloom research. CICOR served as a catalyst and incubator of ideas for collaborative climate, coastal and ecosystems research.

In July 2010 CICOR entered its one-year no-cost extension year, so while there was no new funding to CICOR for the current fiscal year, 57 projects with a combined balance of \$2.37 million remained active in 2010. Since its inception CICOR has supported more than 188 research, education, outreach and program development projects totaling more than \$61.76 million.

NOAA in 2008 replaced CICOR with a new multi-institutional, regional cooperative institute. The new WHOI-led institute, the Cooperative Institute for North Atlantic Research (CINAR), began in mid-2009, continuing the WHOI/NOAA collaboration. During the transition phase, funding for some projects continued via CICOR until June 2010 with a no-cost extension through June 2011. This allowed CICOR to maintain its administrative support and oversight of ongoing projects in the process of completing work funded under previous awards.

CICOR is proud of its contribution to NOAA and to WHOI. CICOR principal investigators and WHOI researchers have deepened their familiarity with NOAA strategic goals for the region, and have strengthened collaborative relationships with NOAA officials and colleagues from other institutions to further these goals. CICOR scientists are actively engaged in ocean observing and regional coordination in the Northeastern U.S. and around the globe. CICOR sponsored a special ocean observing issue of *The Earth Scientist*, a journal of the National Earth Science Teachers Association. Six of the fourteen articles featured research or resources funded by NOAA. The journal and the included two-by-six foot ocean observing educational poster were distributed to 7500 teachers in all 50 states and around the globe.

The strong partnerships between WHOI and NOAA are expected to continue well into the future.

### Highlights of CICOR's accomplishments and contributions to NOAA and WHOI science

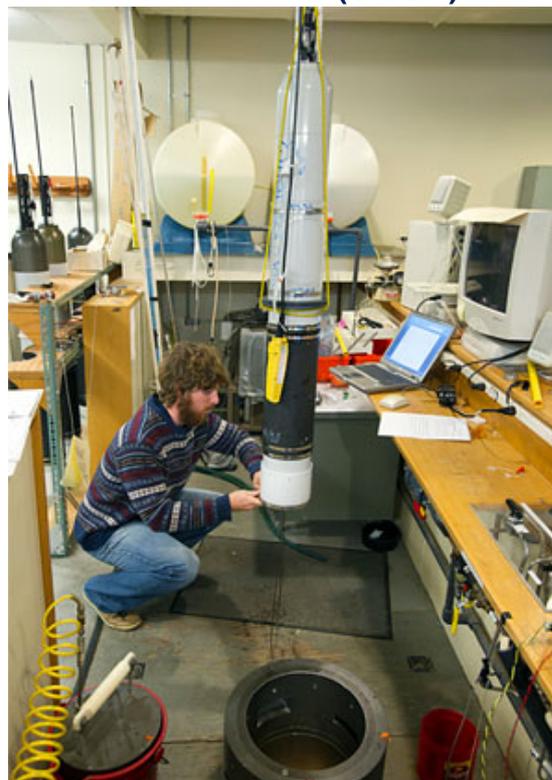
#### GLOBAL OCEAN OBSERVING

##### I. The Argo Float Program

By far the largest single project within CICOR has been the Argo Float Program. Over the last twelve years WHOI's Argo team, lead by WHOI scientist Brechner Owens, has worked in collaboration with partners at Scripps Institution for Oceanography and the University of Washington to meet and advance the program's goal: To build and deploy the 'Argo Armada', a global array of 3,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean. This allows, for the first time, continuous monitoring of the temperature, salinity, and velocity of the upper ocean, with all data being relayed and made publicly available within hours of collection.

##### II. Ocean Reference Stations

Led by Robert Weller and Albert Plueddemann, the Upper Ocean Processes group at WHOI specializes in deep-sea climatological instrumentation and buoys, known as Ocean Reference Stations. These deep-sea stations, three of which are funded by NOAA, collect long time series of accurate global observations of surface meteorology and upper ocean variability in regions of key interest to climate studies. The observations provide a set of high quality calculations of air-sea fluxes of heat, freshwater and momentum which enable scientists 1) to describe the upper ocean variability and the local response to atmospheric forcing; 2) to motivate and guide improvement to atmospheric, oceanic, and coupled models; 3) to calibrate and guide improvement to remote sensing products and capabilities; and 4) to provide anchor points for the development of new, basin scale fields of the air-sea fluxes. These high quality, in-situ time series are the essential data needed to improve our understanding of atmosphere-ocean coupling.



[Enlarge Image](#)

The Argo Float program has been the largest single project within CICOR. Over the last twelve years WHOI's Argo team, lead by WHOI scientist Brechner Owens, has worked in collaboration with partners at Scripps Institution for Oceanography and the University of Washington to meet and advance the program's goal: To build and deploy the 'Argo Armada', a global array of 3,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean. Above, researcher Connor Ahearn ballasts a Argo float in a pressure test tank. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

#### Related Links

» [Cooperative Institute for Climate and Ocean Research \(CICOR\)](#)

### III. Arctic Research

#### *State of the Arctic Report:*

Through CICOR NOAA has funded considerable Arctic research including the annual State of the Arctic Report that is produced by an international team of specialists, including WHOI's Andrey Proshutinsky. The report has been used to create the Arctic Report Card:

<http://www.arctic.noaa.gov/reportcard/>

#### *The Russian-American Long-term Census of the Arctic (RUSALCA)*

WHOI researchers Carin Ashjian and Robert Pickart have both been funded via CICOR for the RUSALCA program, which is a collaborative US-Russian effort to study the Arctic seas regions shared by both countries—the Bering and Chukchi Seas. Climate scientists think that these seas and the life within them are particularly sensitive to global climate change, because they are places where steep thermohaline and nutrient gradients in the ocean coincide with steep thermal gradients in the atmosphere. The Bering Strait, the only Pacific gateway into and out of the Arctic Ocean, is critical for the exchange of heat between the Arctic and the rest of the world. Monitoring the exchanges of fresh and salt water as well as establishing benchmark information about the distribution and migration patterns of the life in these seas are also critical pieces of information needed before placing a climate-monitoring network in this region.

### NATIONAL AND REGIONAL OCEAN OBSERVING

#### IV. The US Office for Harmful Algal Blooms and Related Research

Over the last several decades, the United States has experienced an escalating and worrisome trend in the incidence of problems associated with harmful and toxic algae (commonly called "red tides"). Formerly few regions were affected, but now virtually every coastal state is threatened, in many cases over large geographic areas and by more than one harmful or toxic species. Impacts include mass mortalities of wild and farmed fish and shellfish, human illness and death from contaminated shellfish or fish, death of marine mammals, seabirds and other animals, and alterations of marine habitats or food web structure. These economic, public health, and ecosystems impacts call for coordinated, multidisciplinary research. The US Office for Harmful Algal Blooms led by WHOI Senior Scientist Don Anderson maintains a database of recent HAB activity around the country and around the globe. Through the office and other research initiatives, Dr. Anderson and his team have taken significant steps to link their research with the predictive needs of coastal managers by combining observational analysis with the modeling by WHOI Senior Scientist Dennis McGillicuddy.

#### V. The Integrated Ocean Observing System (IOOS)

##### *Quality Assurance in Real Time Oceanographic Data (QARTOD)*

The Integrated Ocean Observing System (IOOS) is a federal, regional, and private-sector partnership working to collect and deliver information about the ocean. To ensure a solid foundation for developing ocean observing systems, WHOI Information Systems Specialist Janet Fredericks (of the Applied Ocean Physics and Engineering Department and the Martha's Vineyard Coastal Observatory) was funded by the NOAA Coastal Services Center, as part of the Regional IOOS, to implement standards for data quality assurance and control that have been developed as part of the project called QARTOD (Quality Assurance in Real Time Oceanographic Data: <http://qartod.org>), part of an evolving set of methods for tracking, handling, and ensuring the reliability of the volume of data that will result from ongoing ocean observing systems. This innovative and ambitious approach to coordinating the data sharing will be necessary in order to integrate the many planned and existing ocean observing systems.

##### *Northeast Benthic Observatory (NEBO),*

The Northeast Benthic Observatory (NEBO), is a project of the HabCam (Habitat mapping Camera system) group, a collaborative led by WHOI biologist Scott Gallagher that developed and deploys the HabCam seafloor imaging system for monitoring and identifying seafloor life. The objective of NEBO is to produce information for fisheries and marine protected area managers that will foster development of ecosystem approaches to management of fisheries stocks. Their unique approach and the HabCam system allows them to collect and rapidly analyze data with continuous coverage of large areas and high resolution (on millimeter scales). In conjunction with the Northeast Regional Association for Coastal Ocean Observing Systems (NERACOOS), the group identify and quantify key types of organisms and seafloor habitat characteristics, using repeated measurements on time scales of weeks to years. This allows assessment of seafloor species diversity and of organisms that live together and water properties over large spatial and temporal scales. The NEBO data products are of direct utility to fishery and conservation scientists, fishery and sanctuary managers, and environmental policy makers and will be evaluated for their impact on management practices through socio-economic modeling.

#### VI. Post Doctoral and Student Support

CICOR directly funded eleven post docs, five MIT-WHOI joint program students, twelve undergraduate summer student fellows, and also hosted more than six NOAA Hollings Scholars during the last 10 years.

—[Robert Weller](#), Institute Director

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## 2010 Annual Report: Cooperative Institute for the North Atlantic Region (CINAR)

In 2009, The National Oceanic and Atmospheric Administration (NOAA) awarded WHOI the Cooperative Institute for the North Atlantic Region (CINAR). The Institute, which began its operations on July 1, replaced the 10-year-old Cooperative Institute for Climate and Ocean Research (CICOR), which focused predominately on climate observations, with some emphasis on other areas of marine research.

Cooperative institutes are important structures that enable NOAA to fund extramural research. The CINAR award was a result of a competition that WHOI won in partnership with the University of Maryland Center for Environmental Science, Rutgers University, University of Maine and the Gulf of Maine Research Institute (GMRI).

The geographic domain of CINAR is the U.S. northeast continental shelf from Cape Hatteras to Nova Scotia. Because of the importance of large-scale climate and biological connectivity in the North Atlantic, CINAR's geographic scope also includes basin and global-scale processes that affect the shelf ecosystem. The overall goal of CINAR is to engage NOAA and academic scientists in cutting-edge research that enables NOAA to make informed decisions about sustainable and beneficial management of the U.S. northeast continental shelf ecosystem.

A major focus of CINAR is Ecosystem-Based Management. An ecosystem approach to management differs from current strategies that focus on a single species, by considering interconnections within the ecosystem (for example, between feeding levels or species) and among environmental regimes (terrestrial, oceanic, atmospheric), and by integrating social, economic and institutional perspectives as well. CINAR has therefore been formulated with the explicit recognition that effective management of human activities on the northeast shelf requires an understanding of how these activities interact with each other and with other processes, to affect the regional ecosystem and its resources. An understanding of climate variability must also be integrated if the causes of variability are to be identified and understood.

### Research Highlights

- The HabCam optical and acoustic imaging vehicle was integrated into the National Marine Fisheries Service Annual Sea Scallop Survey. A total of 787,832 images were collected with footprints of about 1 m<sup>2</sup> each. Techniques were developed to process all images for lightfield and color correction, image distortion, and conversion to jpeg format for visualization as ground overlays in Google Earth. All image data for the survey cruise HS\_20090623 and associated Google Earth kml files are available through the HabCam website: <http://habcam.whoi.edu>
- GMRI worked with the Northeast Seafood Coalition and their sector (fishing collective) vessels in developing the electronic logbook software, "Fishtrax". GMRI staff also developed a fishermen-friendly training manual for using Fishtrax. The use of electronic trip reports provides an opportunity for fishermen to transmit catch and effort data in a timely manner to the National Marine Fisheries Service (NMFS) and their respective sector managers. This will substantially reduce the time between data receipt, evaluation, and response, thus providing both NMFS and sector managers an improved ability to manage and respond to fishing activity. To date, a total of 39 vessels representing 13 sectors have thus far expressed interest in participating in this project; currently 5 vessels representing 3 sectors are actively participating.
- GMRI convened leading members of the groundfish industry and formed a consensus on how \$1.2 million for dockside monitoring will be divided among the 17 groundfish sectors. The sectors represent the full range of groundfishing activity, from small community-based groups operating from remote, island ports to large, offshore vessels that spend a week on Georges Bank.
- A database was established containing all humpback whale entanglements over the past decade using the categories and definitions given by the New England Aquarium and Provincetown Center for Coastal Studies.
- The Marine Resource Education Program (MREP) of GMRI conducted one full session of the MREP 100 program (one Fisheries Science module and one Management Process module) and one workshop. MREP created an opportunity for fishing industry members to interact directly with the fishery survey scientists and crew, and engage in discussion about a process that has historically been the subject of concern and skepticism. This program increased the industry's understanding of survey methodology, leading to improved relationships between industry and NOAA Fisheries, and increased trust in the fisheries science contributing to management decisions.



[Enlarge Image](#)

CINAR Postdoctoral Scholar Joel Llopiz is working with scientists from WHOI and NOAA to study the trophodynamics—the dynamics of nutrition or metabolism, of larval fish. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

#### Related Links

» [Cooperative Institute for the North Atlantic Region \(CINAR\)](#)

—[Donald Anderson](#), CINAR Director

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## 2010 Annual Report: Marine Mammal Center

Marine mammals have a special hold on our imagination. There is enormous diversity in marine life, but humans are mammals, and we respond to a tension between the familiarity and strangeness of mammals that spend their lives in the sea. Imagine a mammal that can dive a mile below the surface holding its breath for an hour and a half, keeping its body temperature as warm as ours while living in water a few degrees above freezing. Mammals evolved on land, so it is surprising that animals with terrestrial traits such as air-breathing were able to compete with life forms that evolved in the marine environment. Think about it—life originated in the sea. Some organisms managed to evolve adaptations that allowed them to survive on land, but marine organisms continued to adapt to the ocean environment. What could mammals have developed to give them a competitive edge that allowed them to reenter the marine environment, which seems so hostile to mammalian life? In spite of these problems, marine mammals have evolved as top predators of the sea. The main threat they have faced is another top predator—humans. Whalers decimated the populations of whales over the past few centuries, and hundreds of thousands of marine mammals are killed each year in fishing gear. These threats have endangered marine mammal species, which now have a special conservation status in the US and many other countries.

Today the threats to marine mammals are less obvious than when whalers devastated whale populations, but the new threats may be just as dangerous. Fisheries compete with marine mammals for food; chemical and noise pollution threatens them. Our ignorance about the effects of these threats makes it nearly impossible to manage the impacts of human activities on the ocean environment. Protecting marine mammal populations requires the best science and technology for objective assessment of risks and for creative approaches to reduce these risks.

The mission of the WHOI Marine Mammal Center (MMC)—now in its third year—is to develop strength in basic research and technology, concentrating on conservation applications through strategic partnerships and interdisciplinary approaches. The Marine Mammal Center, funded in May 2008 by a generous gift from Pete and Ginny Nicholas and family, builds on WHOI's expertise, capabilities and facilities—including ships, vehicles, and a state-of-the-art laboratory, testing, and imaging facility. To better study marine mammals and improve prospects for their conservation, the MMC promotes the development of interdisciplinary teams and new opportunities, new research initiatives in critical areas, and important outreach activities.

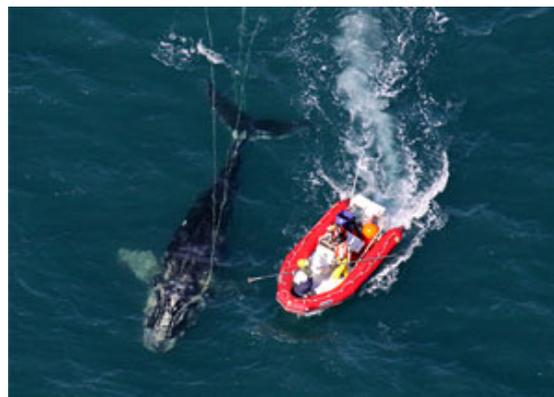
During the past year, WHOI scientists have made bold breakthroughs developing new methods to save marine mammals. Michael Moore, a senior research specialist in the Biology Department, has developed a new way to deliver drugs to large whales at sea. Twice this year, when teams were unable to disentangle endangered right whales from fishing gear, Moore was called in to deliver sedatives and antibiotics to the whales. Within 40 minutes the whales became approachable, and the teams were able to free the whales from life-threatening fishing gear. [\[Publicly available photos\]](#)

The WHOI MMC has partnered with the Nicholas School of the Environment at Duke University to enhance opportunities for graduate education with a competitive fellowship for graduate students at either Duke or WHOI to perform conservation-related research projects with scientists at the other institution. The 2009 call for applications resulted in the funding of six Duke graduate students to work with WHOI advisors from several departments. This fellowship program has created significant opportunities for education, research, conservation, and outreach.

For example, one of the Duke students, Heather Heenehan, was interested in the effects of oil and gas exploration on marine mammals. She arrived just after the blowout of the Deepwater Horizon oil well in the Gulf of Mexico, and she studied the importance of the oil spill site for sperm whales, which are listed as endangered species by the US. Her review of the literature revealed that biologists identified the oil spill site as an important hot spot for sperm whales in the Gulf of Mexico. The importance of this habitat seldom entered public discussions of potential effects of the blowout, and Heather was able to make these points to a large audience in an [op-ed in cnn.com](#).

The WHOI MMC has a commitment to bring scientists together across disciplines to continue to support WHOI's tradition of innovation in studying marine mammals. Here I will highlight two research areas where support from the MMC may help position WHOI for breakthroughs.

The first area involves synergy between ocean engineers and acousticians who are developing sonars that can distinguish different marine organisms based upon echoes, and biologists who study how dolphins use their own biosonar to select prey. Most fish-finders now just use one or two frequencies of sound, but dolphins use broadband clicks to find prey. Engineers at WHOI are using broadband sonars to study the acoustic properties of echoes from marine organisms, using information from more frequencies to improve their ability to discriminate organisms. Dolphins have been working this problem for tens of millions of years. Understanding how they use broadband



[Enlarge Image](#)

Whale avoidance of boats attempting disentanglement is a major obstacle for rescue teams. Michael Moore, a senior research specialist in the Biology Department, has developed a new way to deliver drugs to large whales at sea. This new technique allows disentanglement teams to administer sedation drugs that slow the whale's reaction time, allowing boats to approach the animal and remove the fishing gear. (With permission from EcoHealth Alliance)

### Related Links

» [Marine Mammal Center](#)

signals to find and select their prey may help human engineers improve our own capabilities to use sound to census marine life.

The MMC is also working to improve the ability of scientists to work with stranded marine mammals on Cape Cod. Over the past eight years, an average of 220 marine mammals were stranded dead or alive on Cape Cod each year, a remarkably high number for such a small area. Live stranded animals pose an animal welfare problem while all stranded animals provide unique opportunities for research. The WHOI MMC has strategic partnerships with: the International Fund for Animal Welfare Marine Mammal Rescue and Research Division (formerly the Cape Cod Stranding Network), which finds and cares for animals on the beach, and the National Marine Life Center in Bourne, Mass., which is building a state-of-the-art rehabilitation facility for marine mammals and sea turtles. The WHOI Marine Mammal Center contributes a state-of-the-art necropsy and imaging facility, where researchers can study these animals.

The MMC will be working with our partners and the broader Boston biomedical community to develop research opportunities with stranded marine mammals, consistent with the highest standards of animal welfare and husbandry. These partnerships include an animal welfare organization that decides about the disposition of animals on the beach, a rehab facility responsible for top quality care of captive animals, and the research group at WHOI. The relationship offers a unique opportunity for research on animals that simultaneously meets needs for animal welfare, conservation and research. We believe that this collaboration can create new opportunities for basic research on diving, physiology, cognition and neurobiology of marine mammals. At the same time, the research can help to identify factors contributing to suffering and mortality from strandings, entanglement in fishing gear and other conservation issues.

—[Peter Tyack](#), Center Director

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## 2010 Annual Report: Woods Hole Sea Grant Program

For nearly 40 years, the Woods Hole Sea Grant Program has supported research, education, outreach and extension projects that encourage environmental stewardship, long-term economic development and responsible use of the nation's coastal and ocean resources.

Part of NOAA's national Sea Grant network of 32 programs, the program promotes cooperation between government, academia, industry, scientists, and the private sector to foster science-based decisions leading to better understanding, conservation, and use of coastal resources.

More than half of Woods Hole Sea Grant's annual budget of \$1 million supports multi-year research projects in environmental technology, estuarine and coastal processes, and fisheries and aquaculture, as well as smaller, "new initiative" grants. Sea Grant research addresses local and regional needs, and many projects have national or even global implications.

In 2010, Sea Grant supported 13 projects at WHOI and other institutions that focused on topics ranging from modeling bay scallop populations to the mitigation of the risk to whales from lobster fishing. Andrea Cohen and Dan McCorkle are studying the impacts of ocean acidification on larval shell formation in four shellfish species, while Porter Hoagland, Hauke Kite-Powell and Di Jin of the Marine Policy Center are developing new institutions for managing ocean zoning.

Other studies are focused on the movement patterns and spawning site selection of horseshoe crabs and the integration of experiential field work with a marine ecology curriculum for middle school students.

More than one-third of Woods Hole Sea Grant's budget is dedicated to outreach and education, including the translation and dispersion of research to the general public. Sea Grant reaches its audience through one-on-one advice, training programs, web sites, workshops and lectures.

Collaboration with the Cape Cod Cooperative Extension service brings outreach, demonstration projects and unbiased technical assistance to local communities in fisheries and aquaculture and coastal processes. Successful projects in 2010 included the coordination and distribution of seed oysters to towns across Barnstable County for use in "remote set" programs, the start of an eelgrass restoration program, the mapping of longshore sediment transport and littoral cells on Cape Cod and assisting in surveys of Off-Road Vehicle Corridors.

In the ocean science education field, Woods Hole Sea Grant held workshops for K-12 teachers on topics of concern to the public, such as ocean acidification, and continued to distribute the extremely popular Beachcomber's Companion®, an award-winning publication and Web site highlighting common Atlantic marine invertebrates.

Woods Hole Sea Grant is proud of its track record of creating opportunities to promote effective research—through outreach partnerships with WHOI, as well as initiating efforts to reduce marine debris and plastics in the ocean. In 2010, marine debris efforts included the organization of several beach cleanups with community groups and concerned residents, collecting nearly 300 pounds of trash, and technical support to a major study on plastics in the Atlantic Ocean.

—[Judith E. McDowell](#), Program Director

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[Enlarge Image](#)

Under its partnership with Cape Cod Cooperative Extension, Woods Hole Sea Grant helped coordinate and distribute millions of seed oysters to towns across Barnstable County for use in remote set programs such as this one in Dennis. (Photo by Jeffrey Brodeur, Woods Hole Oceanographic Institution)



[Enlarge Image](#)

Woods Hole Sea Grant extension agents Josh Reitsma (left), Greg Berman (center) and Diane Murphy (right) call it a day after working on a project looking into the coastal processes and aquaculture impact on the Brewster breakwall of hundreds of bags of juvenile oysters they placed around it. (Photo by Jeffrey Brodeur, Woods Hole Oceanographic Institution)

### Related Links

» [Woods Hole Sea Grant Program](#)



## 2010 Annual Report: Woods Hole Center for Oceans and Human Health (WHCOHH)

Centers for Oceans and Human Health (COHH) seek to improve public health through a better understanding of how oceanic processes affect the distribution and persistence of human pathogens and toxin-producing organisms, and the Woods Hole COHH addresses the distribution of such biological agents in the temperate coastal ocean. Research projects focus on harmful algae, bacterial human pathogens and parasitic protists with complementary studies of physical ocean properties, and include methods of advanced genomics, population biology, and coastal hydrodynamics.

### New Findings

New insights into what controls harmful algal blooms

In spring-summer 2010, WH-COHH investigators participated in four NOAA-sponsored cruises studying the toxic dinoflagellate *Alexandrium fundyense* in the Gulf of Maine. Based on the high abundance of resting cysts observed in coastal sediments the preceding fall, the 2010 bloom was expected to be severe. However, observations from research vessels at sea and coastal shellfish monitoring programs documented a below-average "red tide" season.

What factors prevented a large *A. fundyense* bloom from occurring?

Researchers detected significant water mass anomalies indicating regional-scale changes in ocean currents and circulation. These changes had a direct influence on the ecological niche of *A. fundyense*: near-surface waters were warmer, more layered, and contained lower nutrient concentrations than usual. In addition, weaker-than-normal currents lessened *A. fundyense* transport along the coast. Overall, oceanographic conditions in 2010 were outside the envelope of those in the "training set" (from 2003-2009) used to develop the existing computer model that was used to forecast *A. fundyense* blooms. These new findings from 2010 are being utilized to improve forecasting capabilities for future predictions.

### Outreach and Impact

Center Leadership and Investigators participated in the Oceans and Human Health Symposium and Workshop in Washington, D.C. in April 2010. This meeting included presentations for Congressional members and Staff on OHH issues.

Center Director John Stegeman presented a perspective on the U.S. program on Oceans and Human Health at the EuroOCEAN 2010 conference in Ostende, Belgium in October. The talk, [available online](#), was requested by the organizers to help the European marine science community in planning for initiatives to propose to the EU for the next decade.

Center Member Mitch Sogin (MBL) participated in research on microbial populations in the Gulf of Mexico in the aftermath of the Deep Horizon oil blowout. Studies to assess microbial assemblages are important to understanding the fate of hydrocarbons in the Gulf.

Center Investigators also made presentations at OHH sessions at several society meetings, including the Gordon Research Conference on Oceans and Human Health.

### Productivity

The Center investigators have continued to produce publications reporting their findings. As of December 2010, 84 papers from Center research have been published in highly respected journals.

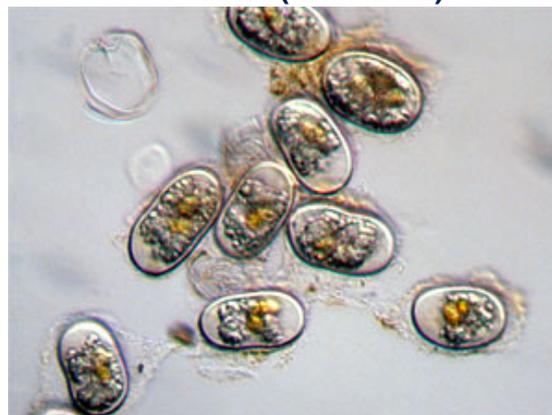
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In spring-summer 2010, WH-COHH investigators participated in four NOAA-sponsored cruises studying the toxic dinoflagellate *Alexandrium fundyense* in the Gulf of Maine. (Photo by Don Anderson, Woods Hole Oceanographic Institution)

#### Related Links

» [Woods Hole Center for Oceans and Human Health](#)

## 2010 Annual Report

### Major Research Collaborations



#### [Ocean Observatories Initiative](#)

In 2010, staff from WHOI's Physical Oceanography and Applied Ocean Physics and Engineering departments expanded and intensified work on the National Science Foundation's (NSF's) Ocean Observatories Initiative (OOI).

#### [WHOI Partnership with King Abdullah University of Science and Technology](#)



At the end of 2010, researchers at WHOI have completed a third year of field work, data and laboratory analysis, and model building as part of the research agreement with King Abdullah University of Research and Technology (KAUST).

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## 2010 Annual Report: Ocean Observatories Initiative

In 2010, staff from WHOI's Physical Oceanography and Applied Ocean Physics and Engineering departments expanded and intensified work on the National Science Foundation's (NSF's) Ocean Observatories Initiative (OOI).

WHOI is the lead contractor on a major component of the OOI, the Coastal and Global Scale Nodes (CGSN—observing platforms to be built both near the U.S. coast to document coastal processes and in deep water in globally significant sites to monitor surface-to-seafloor), assisted by partners at Oregon State University (OSU) and Scripps Institution of Oceanography (SIO) and by Raytheon Integrated Defense Systems.

The successful Final Design Review of WHOI's OOI plan occurred in March 2009. The availability of funds from the American Recovery and Reinvestment Act (ARRA) of 2009 brought the start of the project forward from the planned date of July 2010 to September of 2009. Most of the funding, however, comes from the NSF's Major Research Equipment and Facilities Construction, or MREFC, account. The goal of MREFC investments is to bring a sector of U.S. science to the forefront of its field by investing in the infrastructure needed to advance the science. The NSF calls for 25 years of OOI operations following design and initial installation. Work in 2010, under ARRA and MREFC support, included aspects of design, procurement, and implementation. We began to staff the operations and maintenance teams and to develop procedures and plans for the operations and maintenance phase of OOI.

The team at WHOI has worked with the support of the WHOI administration to build a sound foundation for the OOI effort—hiring staff as WHOI employees and bringing in contractors from Raytheon and Science Applications International Incorporated, obtaining space at a leased facility on Carlson Lane in Falmouth, Mass. beginning in early 2010, and helping plan space for operations and maintenance in the new Laboratory of Ocean Sensors and Observing Systems (LOSOS). WHOI won funding from the National Institute for Standards and Technology of the Department of Commerce for this building. Ground was broken in August 2010 and occupation is expected in 2012. Our partners at OSU and SIO have also worked to set up the teams to support the 66-month period of the MREFC in which the designs are completed, the infrastructure built, and the initial deployments carried out.

Another element of the OOI is the Regional Scale Node (RSN) component, a cabled seafloor and water column observatory being designed and implemented by the University of Washington. Both the CGSN and RSN observatories data will be collected, stored, and made freely available to users by the Cyber Infrastructure (CI) component of the OOI led by the University of California, San Diego. The Consortium for Ocean Leadership is the overall leading organization for the OOI project.

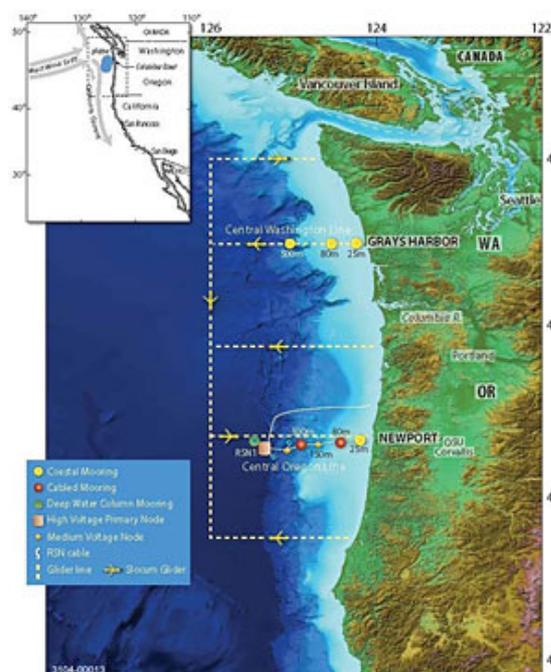
A closer look at the planned Coastal and Global Scale Nodes illustrates the scope, interaction, and promise for continuous ocean observation that they represent.

The CGSN component includes two coastal observatories and four global observatories (Figure 1). The two coastal observatories, the Endurance Array off Oregon and Washington (Figure 2) and the Pioneer Array in the mid-Atlantic Bight (Figure 3), combine instrumented moorings and autonomous vehicles carrying sensors. At the Endurance Array and at the Pioneer Array, ocean gliders, which change their buoyancy and 'glide' forward as they rise and fall through the water column, will sample across their geographic regions and sample in specific patterns in response to different events, such as the passage of an eddy through their ocean regions or a passing surface storm. The Gliders move slowly, at about 1/2 knot, and will be used to sample between moored arrays. At the Pioneer Array, powered autonomous underwater vehicles (AUVs) will also be used to sample between and close by moorings of the moored array.



[Enlarge Image](#)

Overview map of the National Science Foundation's Ocean Observatories Initiative (OOI), showing the four global sites and the two coastal sites of the WHOI-led Coastal and Global Scale Nodes (CGSN) component of OOI. (Image courtesy Center for Environmental Visualization, University of Washington) (Image courtesy Center for Environmental Visualization, University of Washington)



[Enlarge Image](#)

The Endurance Array spans the continental shelf on the west coast off Oregon and Washington, sampling both north and south of the mouth of the Columbia River. A line of moorings at Newport, Oregon and a line of moorings at Gray's Harbor, Washington will be complemented by three ocean gliders. (Illustration courtesy College of Oceanic and Atmospheric Sciences, Oregon State University)

- The Endurance Array has two sets of moorings—one set of 6 aligned east-west off Newport, Oregon, with a pair of moorings at 25 m, 80m, and 500m depth; and a similar set off Gray's Harbor, Washington. Each pair has a surface mooring and a subsurface mooring. The subsurface moorings and benthic packages at the 500m and 80m Newport sites are attached to the fiber and copper cable of the RSN.
- The Pioneer Array has 10 moorings, both surface and profiling moorings. Structures on the seafloor at the base of some Endurance and Pioneer Array moorings will serve as platforms for mounting sensors, and, at the Pioneer Array, provide a place for the AUVs to dock to exchange data and obtain power.
- Two of the four global observatories will be deployed in the northern hemisphere: one in the Irminger Sea southeast of Greenland, and one in the Gulf of Alaska in partnership with NOAA's Pacific Marine Environmental Laboratory (PMEL). The other two will be in the southern hemisphere, off southern Chile and in the Argentine Basin.
- Each global array (Figure 4) combines the use of four moorings and three ocean gliders. The four moorings include a surface mooring, an adjacent mooring with two profiling instrument packages—one that moves from about 200 m depth to the surface and one that moves from 200 m depth to near the sea floor—and two taut subsurface moorings. The moorings will form a four-sided moored array whose sampling will be complemented by sampling done by three ocean gliders. These gliders will also use acoustic modems to collect data from the subsurface moorings and make it available in near-real time, along with data to be telemetered from the surface mooring and the adjacent profiler mooring.

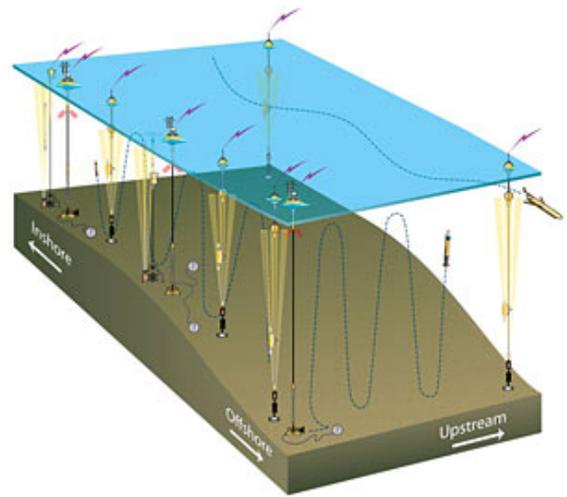
The CGSN observatories will provide data from the full water column, from the sea surface to the sea floor. More than 680 sensors will be used at CGSN sites, making observations of air-sea exchanges and physical, chemical, biological, and geological variability and processes. As much as possible, data will be made available in near-real time.

The OOI is a large undertaking, and work at WHOI in 2010 has laid the foundations for the CGSN observatories:

- The team will soon be fully staffed and operating under updated schedules and plans.
- Tests of prototypical hardware were done off Oregon and off the mid-Atlantic Bight. Plans for two more tests are being finalized.
- Requirements and specifications have been developed, and acquisition of key elements of the hardware and instrumentation is beginning.
- Designs are being finalized and prepared for review.

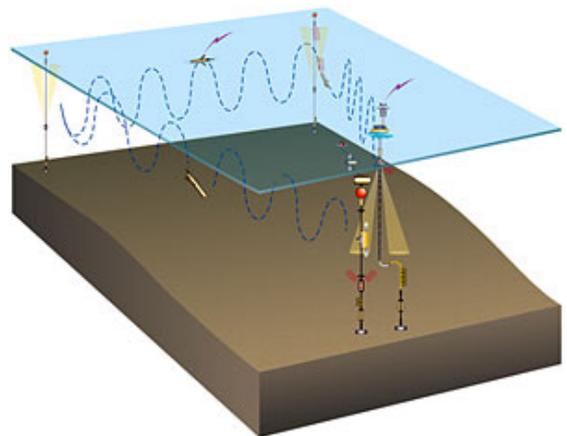
The initial deployments of the CGSN observatories are now scheduled, the times chosen both to provide the best wind and wave conditions for work at sea and to accommodate the planned 12-month turn-around schedules for global arrays and 6-month turn-around schedules for coastal moorings. Coastal gliders will be serviced every three months.

The gliders of the Endurance and Pioneer Arrays will be deployed first, in mid-2012. The Pioneer Array moorings would be added in 2013 to complete that observatory. Additional elements of the Endurance Array to be deployed, in turn, will be the un-cabled moorings of the Newport Oregon line, the Washington mooring line, and finally the cabled elements of the Newport line. The Endurance Array will be completed in 2014; the Argentine Basin observatory will be deployed in the winter of 2012-2013; the Gulf of Alaska and Irminger Sea observatories will be deployed in the summer of 2013; and the observatory off southern Chile will be deployed in the winter of 2013-2014.



[Enlarge Image](#)

The Pioneer Array, to be deployed in the Mid-Atlantic Bight, will combine moorings, ocean gliders and AUVs to sample a region spanning the continental shelf where depth falls off quickly, changing from 100 m to 500 m deep across the array of 10 moorings. Some of the buoys will generate power and provide that power to AUV docking stations on the sea floor. (Illustration by Jack Cook, Woods Hole Oceanographic Institution)



[Enlarge Image](#)

Schematic of the array of four moorings and three gliders to be deployed at the global OOI sites. The surface mooring supports power generation, sampling of surface meteorology and of air-sea exchanges, hardware for data telemetry, and deployment of ocean instruments close to the surface. The profiler mooring will be located about 10 km from the surface mooring and has two profilers: one sampling from below a subsurface float at about 200m to the sea floor, and one that winches itself up to the sea surface from 200 m. The far corners of the moored array, about 50 km away from the surface mooring, have taut subsurface moorings with instruments attached along the mooring lines. The gliders will sample between and around the moorings and will acoustically collect data from the subsurface moorings. (Illustration by Jack Cook, Woods Hole Oceanographic Institution)

#### Related Links

» [Ocean Observatory Initiative \(OOI\)](#)

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## 2010 Annual Report: WHOI Partnership with King Abdullah University of Science and Technology (KAUST)

At the end of 2010, researchers at WHOI have completed a third year of field work, data and laboratory analysis, and model building as part of the research agreement with King Abdullah University of Research and Technology (KAUST). Fieldwork has included a large-scale cruise in the eastern Red Sea; tagging of the world's largest fish, whale sharks; hydrographic measurements of coral reefs; coring and sampling corals; and dialogs with Kingdom of Saudi Arabia Fisheries. In fall 2010 WHOI Director of Research Larry Madin visited KAUST to discuss the research projects and ways to further the research partnership between KAUST and WHOI. The continued success of all the studies has led to two years of extended research under the partnership. The added time will enhance the existing knowledge of the Red Sea and its ecosystems and give WHOI scientists, technicians and students more time to work with KAUST scientists and staff as KAUST continues to grow.



[Enlarge Image](#)

Amy Bower led a successful large-scale hydrographic and current survey in the eastern Red Sea in March 2010, where the air-sea interaction is most intense at this time of year. Participants included scientists and technicians from WHOI, KAUST, American University of Cairo, and King Abdulaziz University. Continuous shipboard measurements gathered data on the vertical and horizontal structure of currents from the sea surface to 600 meters depth, resulting in an unprecedented high-resolution view of boundary currents and eddies. For Richard Limeburner's and Bower's project, near-surface current drifters were deployed during the cruise, and a persistent large eddy centered in the central Red Sea was documented. Analysis of remote sensing data and in situ observation by WHOI MIT Joint Program student Ping Zhai indicates that the Red Sea is dominated by such mesoscale eddies, rather than by a slow overturning circulation.

Assistant scientist Ann Tarrant dissects coral fragments and scans microscopic images for signs of egg development. Tarrant is working with research specialist Anne Cohen and postdoc investigator Neal Cantin to assess coral health in the Red Sea through a project sponsored by King Abdullah University of Science and Technology (KAUST).

(Photo by Neal Cantin, Woods Hole Oceanographic Institution)

### Related Links

» [King Abdullah University of Science & Technology](#)

Nearer to shore, Steve Lentz and Jim Churchill have been measuring currents, temperature, salinity and chlorophyll variability on a reef system and the adjoining shelf to determine the factors that influence across-shelf and shelf-reef exchange of water masses. For the past two years they have collected data from a reef system south of KAUST and have compared exposed and protected reefs relative to offshore waves. Postdoctoral scholar Kristen Davis constructed a heat budget model to describe the temporal and spatial variations in temperature over these reefs due to currents driven by offshore wind conditions. She is investigating wave build-up and passage of waves over reefs. Her analyses incorporate temperature and current data collected by WHOI biologist Jesús Pineda and colleagues on reefs near KAUST.

Tom Farrar has recovered another year of data from the KAUST meteorological tower and the met buoy that were both established in 2008. During this time, the tower and the buoy have been sending hourly-averaged meteorological data to WHOI every four hours. These data and derived quantities such as air-sea heat flux and evaporation have been made available to WHOI and KAUST modelers studying air-sea interactions and researchers describing the variability of wind, waves and temperature over coral reefs near KAUST.

For the past three years Richard Limeburner, Bob Beardsley and colleagues at KAUST have been characterizing regional tidal and lower-frequency variability in the central Red Sea from along-shore pressure temperature and salinity measurements at three coastal sites. These along-shore measurements, along with cross-shore measurements by Steve Lentz, are incorporated into the regional circulation models developed by Larry Pratt and colleagues to understand regional circulation. The data have improved understanding of wind-driven currents in the Red Sea and have been integrated into local and regional numerical tidal models.

The Coastal Ocean and Atmospheric Modeling project, with Larry Pratt, Houshuo Jiang, Dave Ralston, and Changsheng Chen (the University of Massachusetts-Dartmouth) has developed an advance ocean circulation model for the Red Sea and Saudi Arabian coast. As part of this effort, a tidal model has been completed and work continues on the FVCOM model (Finite Volume Coastal Ocean Model) of the Red Sea. Waves appear to be an important force driving flows over coral reefs, and understanding the spatial heterogeneity of the wave field could explain differences among reefs. Dave Ralston is simulating wave height and period in the Red Sea using a wave model that incorporates complex bathymetry. This model is coupled with the high-resolution results of an atmospheric model (known as WRF) developed by Houshuo Jiang. Wave measurements made in Farrar's and Lentz's studies are being used to evaluate the wave model. The WRF model has also been used to analyze wind forcing over the Red Sea due to winds passing through the Tokar Gap Jet, a phenomenon also responsible for generating dust storms.

Corals and coral reefs are being investigated in a number of projects. Coral reef flats are a highly stressed part of the reef, subject to extreme daily temperature variation depending on location on the reef. Biologist Jesús Pineda, researcher Vicke Starczak, and post-

doctoral scholar Kristen Davis are measuring the daily variability of temperature across the reef flat. Temperature fluctuations can depend on location of the reef with respect to offshore waves, and are being investigated in physical models of heat budget over the reef. On a scale of several kilometers, Pineda, post-doc Jonathan Blythe, and Jose da Silva (University of Lisbon) are documenting differences in seasonal temperature variability from inshore to offshore reefs. Pineda and Starczak have conducted a coral transplant experiment of the coral *Stylophora pistillata* to determine whether coral symbionts alter when exposed to different temperature regimes on the reef. Identifying coral symbiotic clades (genetic groups) by molecular sequencing, Biologist Ann Tarrant and post-doc Adam Reitzel have found clade differences with respect to small-scale temperature variation on reef flats.

Surveys and samples of corals taken along the length of the Red Sea by Konrad Huguen and his lab members (Marine Chemistry and Geochemistry Department) show a distinct gradient of coral stress. Organic compounds are being compared between healthy and stressed corals, and microbial assemblages associated with healthy and stressed corals are being characterized using DNA sequencing. WHOI-MIT joint program student Jessie Kneeland is using a new thermal stress index based on lipid compounds to describe the effects of pathogens on coral symbionts. Also, trace metals contained in coral skeletons can be used to infer past changes in the environment of the Red Sea. Cores of coral skeleton taken along the north-south temperature gradient are being analyzed for strontium, which reflects sea surface temperatures, and for barium, a common element in dust and thus a marker of past wind events. Data on elements recorded in coral skeletons from the past 20 years to 250 years can help validate climate models and improve regional forecasts of environmental changes in the Red Sea.

Anne Cohen, post-doc Neal Cantin and Tarrant have finished the fieldwork portion of their project measuring seasonal, spatial and historical skeletal growth and calcification in three species of reef-building corals from the Central Red Sea. Using 3-D computed tomography (CT) scanning and image analysis of coral skeletal cores, they found that *Diploastrea heliopora* skeletal growth and calcification has declined by 30% and 18%, respectively, since 1998, corresponding with rising sea surface temperatures. Their research has also focused on factors that can enhance skeletal growth of corals. Tissue analysis of *Porites lutea* colonies indicates that surplus stored energy in the form of lipid reserves is positively related to calcium carbonate production, suggesting that corals with greater energetic reserves can invest more energy in skeletal growth. Tarrant has also measured coral egg development in *D. heliopora* and *P. lutea* colonies to identify the timing of reproduction and the gender (male/female) of each colony, to help us understand how reproductive development influences seasonal growth rates. To quantify rates of recovery and to assess the resilience of skeletal growth, such factors as symbiont type, calcium carbonate production, and environmental factors (such as temperature, salinity and nutrients) are being correlated with the seasonal variability of coral colony energetic reserves. These results will improve our understanding of coral reef communities and our ability to predict how they will respond to the increasingly frequent stress events of a changing climate.

Marine chemist Dan McCorkle has been working with multiple projects analyzing the water chemistry of the eastern Red Sea. In collaboration with Cohen, Tarrant, and Cantin, he has analyzed near-reef seawater carbonate chemistry, an important factor controlling coral skeletal growth. His group is also measuring nutrient concentrations and carbonate chemistry of samples collected on Amy Bower's Red Sea Hydrography cruises. The basin-scale samples from Bower's cruises give a broad picture of the chemistry in the Red Sea, while the reef sampling documents the immediate chemical environment of corals and the influence of reefs on seawater chemistry. Whitney Bernstein, a WHOI/MIT joint program student taking part in the hydrographic measurements, is analyzing the carbonate chemistry of samples taken in reef surveys made by Konrad Huguen. She is also analyzing nutrients, salinity and carbonate chemistry to estimate reef-scale net calcification rates in the reef system studied by Steve Lentz and Jim Churchill.

Red Sea fish are an important coastal resource that Hauke Kite-Powell, Andy Solow, and Porter Hoagland and Di Jin of the Marine Policy Center and biologist Mike Neubert have been modeling, using data supplied by Saudi Arabia Red Sea fisheries. Their models describe the condition of fish stocks and to characterize the biological and economic value of marine reserves. Initial models considered data from traditional fisheries and found overfishing of stocks. More comprehensive data sets including industrial fishing in the southern Red Sea and fishing in central Red Sea are integrated into models that will support the effective management of fisheries and the design of marine reserves to rebuild and maintain healthy fish stocks and reef ecosystems on the Saudi Red Sea.

Biologist Simon Thorrold and colleagues, in collaboration with Michael Berumen (KAUST), have been studying the movements of fishes in Red Sea habitats. They have successfully tagged 47 whale sharks, the world's largest fish. Movement data from reporting tags suggest that although the whale sharks swim considerable distances, many remain within the southern Red Sea for periods up to 1 year. Kelton McMahon (WHOI-MIT Joint Program) successfully defended his doctoral thesis, which included a detailed study on the movements of juvenile snapper between mangroves, coastal reefs, and oceanic reefs, including those of the Red Sea, using carbon isotope signatures recorded in fish ear bones (otoliths). He found that while adult fish on coastal reefs use mangrove nursery areas, juveniles apparently settle directly into adult habitats on oceanic reefs. This result has important implications for the design of marine reserves to conserve coral reef ecosystems.

With three years of data, results of studies on the climate, hydrography, biology and chemistry of Red Sea are now being published. We anticipate furthering the WHOI-KAUST collaboration and seeing more exciting results come to fruition in 2011. The Red Sea Research Center at KAUST will officially open in spring 2011, and WHOI scientists will be there to welcome it into the scientific community.

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## 2010 Annual Report: Academic Programs

Our big event of 2010 was our on-campus Joint Program graduation in June, which is held on the WHOI campus only every 5 years. The inclement weather did not prevent an outstanding ceremony led by Chairman of the Board, Newt Merrill. Dr. Rita Colwell, WHOI Corporation Member, was the commencement speaker and gave an excellent and meaningful speech to the graduates and their parents. Director Susan Avery also had an upbeat message for the graduates. Rev. Deborah Warner (Church of the Messiah, Woods Hole) presented the Invocation, which contained beautiful words of wisdom for graduates and in fact, for all scientists in the audience. All and all, it was a successful event in spite of the weather.

During the 2009-2010 academic year, the Massachusetts Institute of Technology/WHOI Joint Program awarded 24 masters and doctoral degrees in ocean science and engineering. As of Fall 2010, the Joint Program (JP) has awarded 867 degrees. We had an excellent recruiting year, with 33 new students enrolling in the program in 2010 bringing the total fall enrollment to 131 students.

Thirteen Postdoctoral Scholar awards were made, 6 women and 7 men, with a 10:3 split between U.S. and foreign nationals. At any given time, WHOI averages about 65-70 postdoctoral Scholars, Fellows and Investigators in residence.

The topic for the 2010 GFD summer program was "Swirling and Swimming in Turbulence". Ten fellows attended, 6 men and 4 women. Nine guest students, 56 staff members and one guest lecturer also participated in the program.

Thirty-three Summer Student Fellows (SSF) representing 29 colleges and universities were chosen from 238 applicants. These undergraduates and a few recent graduates spent 10-12 weeks in the summer working on research projects with WHOI scientists, attending lectures and workshops, and enjoying themselves on Cape Cod (time permitting!) The Woods Hole Partnership Education Program (PEP) students joined the Summer Fellows aboard the vessel *Tioga* for a series of day trips where they were introduced to marine sampling techniques and equipment. Both groups were also able to take advantage of a rare opportunity to tour the *Knorr* while the research vessel made a brief stopover in Woods Hole this summer. The SSF program is enthusiastically supported by WHOI scientists, who enjoy working with the undergraduates and appreciate how much they contribute to WHOI research programs. Many later apply for graduate school in the JP and other ocean science graduate programs.

Jim Price retired from WHOI in the spring and thus stepped down as Associate Dean. We appreciated Jim's keen interest in higher education, and his calm and steady hand in the Associate Dean's position, which he held for 4 years. We're fortunate to have Dr. Meg Tivey as his replacement.

Students and postdocs bring energy, enthusiasm and new ideas to WHOI's research portfolio and help us move in new directions. We appreciate the support we receive from individual donors and foundations that support these fine education and training programs.

—[James Yoder](#), Vice President for Academic Programs & Dean

### Sand, Sun, Waves ... and Bacteria?

Elizabeth Halliday spent her summer at the beach, but she wasn't swimming or sunbathing. Instead, the MIT/WHOI Joint Program student traveled to Provincetown three times per week to collect



[Enlarge Image](#)

Anna-Mai Christmas, an undergraduate at the University of the Virgin Islands, worked with WHOI biologist Scott Gallager to study the behavior of week-old lobster larvae exposed to layers of water of different temperatures, in an effort to understand how this may affect wild lobster distribution.

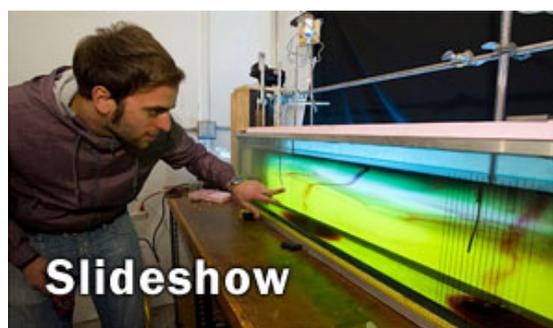
(Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)



[Enlarge Image](#)

Students graduating from the MIT-WHOI Joint Program in Oceanography/Applied Ocean Science and Engineering. In addition to the annual MIT commencement, every five years WHOI hosts an official commencement for all who graduated from the acclaimed program during the previous period. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

#### Related Multimedia



2010 Photo Highlights

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#### Related Links

samples of sand and water in order to study the source of bacteria that can lead to periodic beach closures both on the Cape and around the country.

» [WHOI Academic Programs](#)

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## 2010 Annual Report: Marine Operations

WHOI continued to fulfill its mission of taking science safely to sea with deployments of vessels, vehicles and tools and their operating teams to the Atlantic, Pacific and Indian oceans in a very busy 2010.

The large research vessels we operate - *Knorr*, *Atlantis* and *Oceanus* combined for nearly 800 days at sea. *Knorr* spent most of the year in the Atlantic with operations spanning Brazil to Greenland, plus a cruise into the Indian Ocean to study the Agulhas Current off east Africa. Four of the *Knorr* cruises featured the deployment of the Long Core, a unique tool developed by WHOI engineers and scientists that enable taking 45 m cores in water depths of 7000 m or more. *Atlantis* continued to support the manned submersible *Alvin*, with busy dive programs in the Pacific off Costa Rica, the Galapagos rift and the Juan de Fuca plate. *Atlantis* returned to Woods Hole for the first time in over four years and promptly went back to sea for two cruises in the Atlantic, followed by two cruises in the Gulf of Mexico in response to the *Deepwater Horizon* oil spill. *Oceanus* operated in the western Atlantic between Barbados and the continental shelf off New England, and also had an oil spill-related cruise to the Gulf. Our coastal research vessel *Tioga* had over 100 days of operations, supporting projects for every WHOI science department, in areas from Maine to the Hudson River. We provided shipboard scientific services for all of our vessels' cruises, including oceanographic instrumentation and the technicians to operate and maintain the equipment.

In May WHOI was awarded operation of AGOR 27 (Auxiliary General Purpose Oceanographic Research), a new Ocean Class research vessel to be constructed by the Navy for service in the national fleet. The award calls for WHOI to provide advisory services during the design and construction phase and to operate and maintain the vessel when it is brought into service in 2014. Our advisory role is well underway and construction of the vessel is scheduled to begin in late 2011.

WHOI continued to operate the National Deep Submergence Facility in 2010 on behalf of the oceanographic community. We conducted nearly 200 dives on over 19 cruises with the primary NDSF vehicles HOV *Alvin*, the ROV *Jason* and the newest NDSF entrant, the AUV *Sentry*. *Sentry*, the latest generation of autonomous vehicle, replaced *ABE*, which was lost at sea on its 222nd dive. Ironically, *ABE* was brought out of "retirement" for work at the Chile Triple Junction because *Sentry* was deployed along with *Alvin* at the same time in the Galapagos. The oceanographic user community officially admitted *Sentry* to the NDSF in June. *Sentry* proved its utility that same month as the platform that enabled the detection and mapping of the *Deepwater Horizon* plume. By year's end, *Alvin*, *Jason* and *Sentry* had each made deployments and multiple dives in support of the *Deepwater Horizon* response.

The *Alvin* upgrade project continued in earnest throughout 2010, culminating in a very successful final design review in late September. The National Science Foundation (NSF) panel approved our design and construction plan, which will be implemented in 2011. After sea trials, the vehicle will be ready to go back to work in mid-2012, featuring a new titanium sphere with five viewports, new imaging system, command and control system, interior layout and a host of other improvements.

Ocean observing continues to be a major focus. The Martha's Vineyard Coastal Observatory (MVCO) is an exceptional facility that provides a platform for obtaining continuous, *in situ* data in real time and serves as a test bed for sensors that might become part of our global and coastal observing systems. The MVCO, managed through the Center for Ocean, Seafloor and Marine Observing Systems, required numerous deployments of the *Tioga* to the facility offshore Martha's Vineyard, as well as frequent dive operations. The Coastal and Global Scale Nodes program we are implementing on behalf of the Consortium for Ocean Leadership and NSF as part of the Ocean Observatories Initiative has been in place for just over a year. We have ramped up our technical and project management teams and are well into the system design phase that will enable the first at-sea tests of hardware in late 2011.

Our scientific diving program was very active in 2010, conducting over 1200 dives at sites as varied as Greece, Panama, the Red Sea, the MVCO and the WHOI pier. As of 2010 we have 54 trained and certified divers. The program is sanctioned by the American Academy of Underwater Science, overseen by the Dive Control Board and managed day to day by a full time Dive Safety Officer. The program was significantly enhanced with the donation of the 30-foot dive vessel *Echo*.



[Enlarge Image](#)

Nathan (left) and Patrick McGuire, sons of WHOI associate scientist Jeff McGuire, welcome R/V *Atlantis* home to Woods Hole with the Lego models of the ship they made. Both models include miniature replicas of the deep submergence vehicle *Alvin*. *Atlantis* returned on Sept. 6 after more than four years away. During that time, it sailed more than 104,000 miles and conducted 60 science expeditions, and *Alvin* made 475 dives. Also view [video](#) and a [slideshow](#) of *Atlantis*' return. (Photo by Ken Kostel, Woods Hole Oceanographic Institution)

### Related Multimedia



2010 Photo Highlights

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### Related Links

» [WHOI's Ships & Technology](#)

Our Access to the Sea endowment is funding six new projects initiated in 2010 and continues to be a valuable source of support for high-risk scientific and engineering research. We hope to expand Access to the Sea to enable our support of Ocean Class vessel operations, the MVCO, as well as other research related to taking science to sea.

—[Robert Munier](#), *Vice President for Marine Facilities & Operations*

## **Time Lapse Video from Fantail of R/V *Atlantis***

Taken during Dive and Discover's expedition to the bottom of the Gulf of Mexico. Learn more at [Dive and Discover](#).

*Last updated: June 8, 2011*

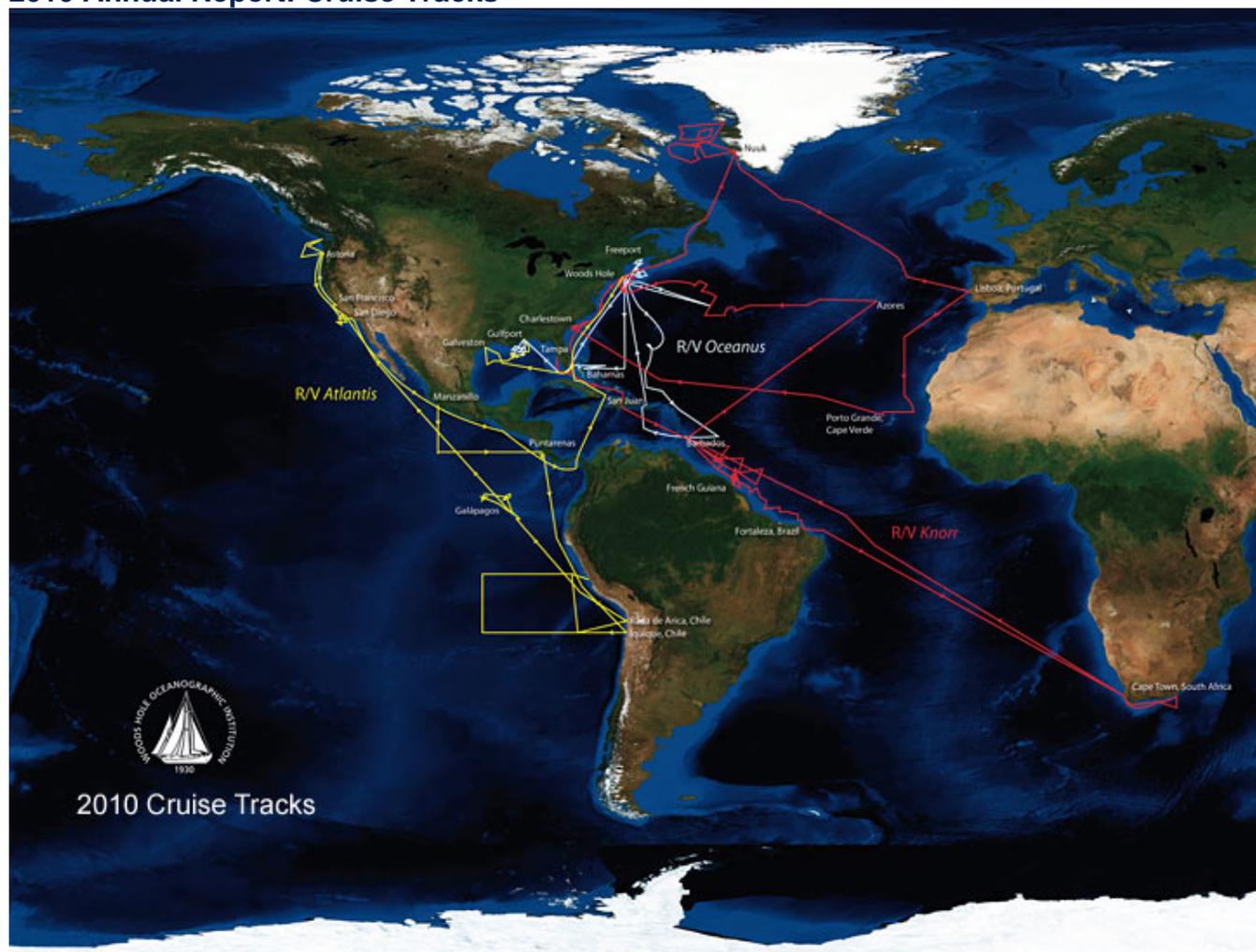
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## 2010 Annual Report: Cruise Tracks



### WHOI's Research Vessels: 2010 Cruise Tracks

#### Related Files

[#0187 Enlarged 2010 Cruise Tracks](#)

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## 2010 Annual Report: Letter from Christopher J. Winslow, CFO and Vice President for Finance and Administration

We are pleased to present the CY 2010 unaudited financial statements of the Woods Hole Oceanographic Institution (WHOI). WHOI completed CY 2010 in good financial condition primarily attributable to strong returns of the endowment, an increase in revenue, and improved operational efficiencies. The Institution is also pleased to announce that S&P issued an investment grade rating of AA- with a Stable Outlook.

### S&P Rating AA- with Stable Outlook

The Institution recently received the results of our Standard & Poor's (S&P) Bond Rating Review, which was conducted on October 13, 2010. The Institution was notified in May 2011. The Institution received a rating of AA- with a Stable Outlook. This favorable rating will enable the Institution to negotiate better banking terms, easily establish partnering relationships for federal government grants, and provide potential donors and foundations with evidence of a stable financial outlook to go along with WHOI's scientific superlatives.

### Statement of Financial Position

WHOI continues to have a strong balance sheet. At December 31, 2010, WHOI's total assets were \$504 million, total liabilities were \$180 million and total net assets were \$324 million.

Net assets represent the accumulated financial strength of a not for profit organization and are an important gauge of its ability to carry out its mission. Included in the liabilities is the Massachusetts Health and Educational Facilities Authority bond debt of \$61.8 million.

The endowment, \$338 million represents 67% of the total assets at December 31, 2010.

### Statement of Activities

WHOI's total operating revenues increased by \$31 million; from \$172 million in CY 2009 to \$203 million in CY 2010; and the Institution recognized a gain of approximately \$2.2 million.

\$16.3 million of endowment income and appreciation was distributed to operations as follows:

- Education \$6.6 million
- Research \$5.9 million
- Unrestricted \$3.8 million

The Institution had overhead costs of \$83.5 million, and approximately 65% of that amount, \$53.7 million, was recovered from the government and non-government research. The remainder was institutional expenses.

WHOI paid \$5.4 million in interest during CY 2010 and \$1.4 million in principal payments on the \$61.8 million outstanding debt in CY 2010. The Federal government allows interest and depreciation for real property and equipment in the Institution's overhead rates for reimbursement.

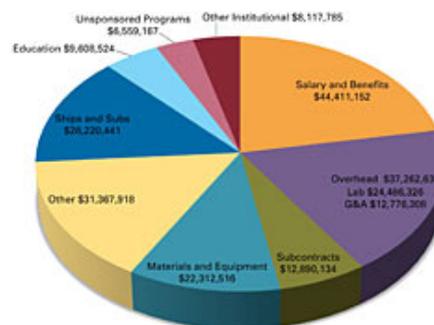
### Summary

The Institution's commitment to understanding the oceans is unchanged; however, the federal funding environment continues to provide a challenge. WHOI is looking to expand its sources of revenue by leveraging its industry recognized core skills in both the federal and industry marketplaces. We are also continuing the process of evaluating our administrative systems and allocating resources to support our science, S&P rating, and an evolving organization.

—[Christopher J. Winslow](#), CFO and Vice President for Finance and Administration

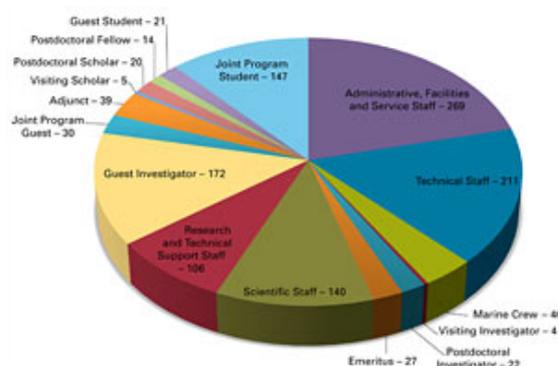
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[Enlarge Image](#)

2010 Operating Expenses



[Enlarge Image](#)

2010 People

WHOI employees totaled 825 in 2010, students and postdocs totaled 202, and others affiliated with the Institution totaled 246.

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