2013
ANNUAL REPORT

Woods Hole Oceanographic Institution

Contents

President's Letter

WHOI President and Director Susan Avery testifying before the U.S. Senate Committee on Commerce, Science, and Transportation Subcommittee on Ocean, Atmosphere, Fisheries, and U.S. Coast Guard.

Filmaker and explorer James Cameron (left) presented an amazing gift to WHOI in March: the 24-foot vehicle that a little over a year ago he used to reach the deepest place on Earth. In June WHOI President and Director Susan Avery (center) met with Cameron and his wife, Suzy Amis Cameron as the vehicle departed from the California Science Center in Los Angeles on its way to Woods Hole. "Moving the DEEPSEA CHALLENGER cross-country to its new home at Woods Hole Oceanographic Institution provides an opportunity to make the sub available to students and the general public, so they can see it, touch it, and ask questions," James Cameron said.

The year 2013 revealed a stark contrast between public and private support for oceanography. Early in the year, WHOI was fortunate and heartened to reinforce ties with three philanthropists of enormous accomplishment. At the end of the year, however, we responded to a survey request from the National Science Foundation, our principal federal funding agency, to help identify ocean science priorities for the next decade with an eye to "investments achievable *at the current funding level*"—a disheartening caveat in light of the downward slide in federal support for R&D over the past decade.

Four visionaries who gave a huge boost to WHOI research in 2013 were investor Ray Dalio, Google executive chairman Eric Schmidt and his wife, president of the Schmidt Family Foundation, Wendy Schmidt, and explorer and film producer and director James Cameron.

Ray Dalio purchased the ship *Alucia* after WHOI leased it to conduct our successful search for Air France 447 in the southern Atlantic in 2010 - 2011. With advisory help from WHOI, Ray had *Alucia* completely renovated and outfitted for science, and then generously made the ship available to our researchers, for projects supported from a dedicated Access to the Sea Fund that he established at the Institution. Several groups of WHOI scientists, engineers, students and postdocs sailed on *Alucia* in 2013.

In 2009, Eric and Wendy Schmidt formed the Schmidt Ocean Institute (SOI) and purchased and repurposed another large ship exclusively for ocean science. The 272-foot long R/V *Falkor* offers yet another option for researchers who often wait years to schedule an expedition aboard an academic fleet ship. In 2013, a WHOI-led team used *Falkor* for an exploration of hydrothermal vents on the Mid-Cayman Rise with our hybrid remotely operated vehicle *Nereus*, the same vehicle that dove to the bottom of the Mariana Trench in 2009. SOI has now committed to funding the design of a successor vehicle to *Nereus*, one that will be used on *Falkor* for exploration of the deepest parts of the global ocean.

Someone who has visited the Mariana Trench in person is Jim Cameron, who accomplished that feat in 2012 during a solo dive aboard *DEEPSEA CHALLENGER* (DSC), a vehicle whose design and construction he led and financed himself. In 2013, Jim gave DSC to WHOI to facilitate the cataloging, publication and transition to other vehicles of the many technological advances integral to DSC. In addition to this unprecedented gift, and as part of his commitment to WHOI and desire to stimulate advances in ocean science and exploration, Jim agreed to help the Institution with public outreach. His first demonstration of that commitment was a joint appearance with me in June before a subcommittee of the Senate Committee on Commerce, Science and Transportation. While DSC was on public display on the U.S. Capitol grounds, Jim lent a strong, passionate voice to our effort to highlight the need for federal investment in research.

All of us at WHOI continue to stress that need. Many of our scientists responded individually to the year-end NSF survey about ocean science priorities for the next decade. Responding on behalf of the Institution as a whole, I stressed that ocean science is now at a transformative stage in terms of tools and technologies like those just mentioned. It is counterproductive for budget restraint to stifle scientific opportunity just as new and valuable assets are being deployed in both coastal and deep water. I believe fervently that our nation cannot afford to slacken its traditional investment in R&D. There are countless examples of the high return on that investment in terms of innovation, economic growth, and prosperity.

My gratitude for the vision and commitment of private individuals like Ray, Eric, Wendy, and Jim is unbounded. But their willingness to dedicate their own resources in support of science should inspire, not be expected to replace, the need for public support. My determination to press that point is equally boundless.

Letter from Laurence P. Madin

DIRECTOR OF RESEARCH

WHOI Director of Research Laurence P. Madin

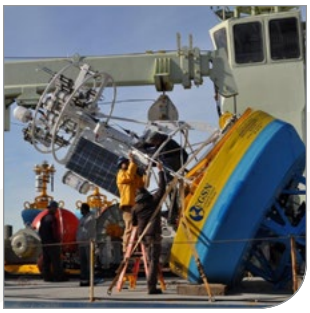
We often say that one of WHOI's special qualities is our close integration of science and engineering. Science questions stimulate innovative engineering solutions for finding the answers, and new technical capabilities can open unexpected research opportunities. This world-class synergy pervades our research activity and has created a long history of innovation and leadership in understanding the ocean. There are examples all around us in the ocean science world—instruments, moorings, underwater robots and our iconic submersible *Alvin*—and we believe that WHOI's future will depend on this successful combination of the scientist and the engineer. But how, exactly, do the ideas become reality?

There is another critical link in the chain connecting science needs to technological innovations and eventually new discoveries—the actual fabrication of the novel and complex instruments, vehicles, and other devices that do the work. Great concepts and clever designs don't actually do anything in the ocean until they take shape in real metal, glass and plastic. That is the task of the skilled machinists, mechanics, welders, electricians, carpenters and painters that work in the WHOI shops. Just like WHOI scientists and engineers, these fabricators are a world-class group— dedicated to excellence, justly proud of their skills, and the envy of most other institutions. During 2013 our shop staff completed many significant projects. Certainly the most consuming and complex was the overhaul and upgrade of *Alvin*, completed in May.

Engineer Casey Machado from WHOI's Deep Submergence Laboratory guides the group's newest vehicle, *Nereid Under Ice* (NUI) into a test pool in the Coastal Research Lab recently. The remotely operated vehicle is designed to travel long distances underwater, including under sea ice.

By far the biggest renovation of the iconic submersible in its 50-year history, the effort required meticulous integration of many new components, including the new and larger personnel sphere, into a modified titanium frame, and being sure everything fit and worked. There is no room for "approximately" in a sub carrying people to the bottom of the ocean. The work by our machinists and mechanics to put *Alvin* together for another 50 years has been highlighted in a recent issue of *Oceanus* magazine, but that wasn't the only one major project to come out of the WHOI shops in 2013. Other underwater vehicles took shape. Two of the new Nereid-class vehicles, built on concepts pioneered with the *Nereus* program, were completed or begun.

The Nereid-UI (for "Under-Ice") is intended for both autonomous and remote-controlled operation under ice sheets, and will see its first field trials in 2014. Its cousin, Nereid-HT (for "Hybrid Tethering") got underway in 2013, for completion in 2014. Another big customer in 2013 was the Ocean Observatory Initiative (OOI) program. WHOI is the main contractor for the Coastal and Global Scale Nodes (CGSN), which are made up of moored instruments and buoys combined with mobile AUVs (Autonomous Underwater Vehicles) and gliders. With responsibility for the fabrication of the many parts needed for these observing arrays, the WHOI shops built more than15 buoys and instrument systems for deployment in 2014 and 2015.



A coastal surface mooring buoy was fastened to the main deck of R/V *Knorr* in November, 2013 in preparation for deployment. The buoy and other instruments on deck are the first elements of the Pioneer Array, one of two Coastal Scale Nodes in the NSF-funded Ocean Observatories Initiative (OOI).

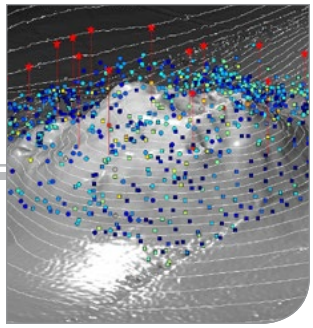
The aluminum, titanium, stainless steel, glass and plastic components of these moorings all require special skills to fabricate with the quality and integrity needed for long-term operation in the ocean. This critical work can't be simply outsourced to commercial shops that lack the experience that our own shop people have. *Alvin*, the Nereids, OOI moorings were some of the big jobs, but altogether the WHOI shops set a record in 2013 by producing more than 100,000 parts for these and other projects—each one of them the product of skilled eyes and hands.

And the shops don't only produce things that go into the ocean. Our buildings, labs and offices are maintained, modified and upgraded to meet changing needs of science by the carpenters, electricians, and painters, craftsmen with long careers here who know the buildings and the people that work in them. In 2013, 10 renovation projects were done on scientists' labs, the dive operations center, and other buildings and spaces at WHOI.

There are many elements that make a world-leading ocean research organization, but where the rubber hits the road—or the titanium hits the water—we rely on the 'blue-collar' guys in our shops. They make our stuff, and it works.

Laurence P. Madin

Applied Ocean Physics & Engineering Department



Results of Richard Camilli's research on autonomous identification of ocean ecosystems at a seafloor 'pingo' (a conical hill or mound) at a depth of 850 m in the Pacific Ocean. Red stars indicate autonomously identified areas of chemosynthetic ecosystems (Camilli et al., EOS, 2010).

The Department of Applied Ocean Physics & Engineering pursues excellence in science and technology across multiple disciplines. Following are research descriptions for six AOPE staff who achieved career milestones in 2013.

Richard Camilli's research focuses on developing and applying robotic technologies for in-situ sensing. He often couples chemical sensing with autonomy to enable real-time situational awareness in regions that are too dangerous or costly to observe using conventional oceanographic methods. His work has demonstrated utility in a variety of contexts, including assessment of environmental pollution from the Deepwater Horizon, as well as discovering extreme life forms in the deep ocean. Rich is now investigating principles of resiliency and cognition to expand real-time marine observation. His goal is to transition these concepts into low-cost sensing that uses cooperative autonomy to efficiently transition between fully autonomous and human supervisory control in complex environments. Rich was promoted to Associate Scientist with Tenure on October 9, 2013.

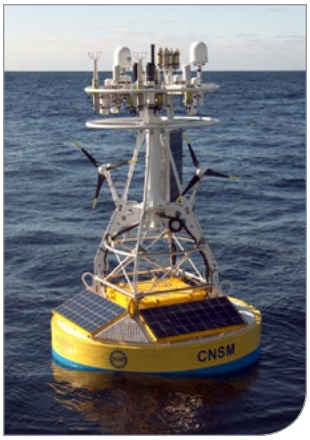
Pushing the boundaries of instrumentation in strong currents and breaking waves, **David Clark** studies the processes by which pollutants, nutrients, and suspended materials are transported within and across the surfzone. David collaborated with WHOI scientists Steve Elgar and Britt Raubenheimer to develop and deploy a new vorticity sensor, the "Ring of Doom," which measures how breaking waves generate the powerful eddies that are primarily responsible for the rapid transport and dispersion that occurs within the surfzone. A month-long deployment off Duck, North Carolina encountered waves ranging from lake-like to four-meter monsters during nor'easters. This broad range of forcing will allow David to document, quantify and analyze the eddy response to the size and shape of the breaking waves. David was appointed as an Assistant Scientist on August 26, 2013.

The "Ring of Doom" vorticity meter, developed by David Clark and colleagues, is lowered into the surfzone by helicopter, while swimmers wait offshore to secure the ring after it is released. (Photo by MIT-WHOI Joint Program student Anna Wargula)

In September 2013, **Lee Freitag** participated in a cruise aboard the Norwegian Coast Guard Ice Breaker KV *Svalbard,* transiting to 82° N, east of the northern tip of Greenland. There, in collaboration with colleagues from the Nansen Centre in Norway, Lee tested a new ice-based acoustic navigation system, which must, unlike conventional systems, transmit position in addition to other information because it moves with the ice. Lee heads the acoustic communications group in AOPE and led the development of the low-frequency (900 Hz) system through several years of engineering and testing. The first demonstration will be during spring and summer of 2014, when eight of the acoustic transmitters will be deployed on the ice in the Beaufort Sea. Lee was promoted to Principal Engineer on October 9, 2013.

James Kinsey's research focuses on new robotics methods for investigating the ocean, especially navigation, control, autonomy, and sensor development. He has recently reported new methods for incorporating vehicle dynamics into navigation and shown that these methods improve our ability to obtain underway gravity measurements with autonomous underwater vehicles (AUVs). A recent project is coordinated navigation and communication between an AUV and an autonomous surface vessel (ASV), which will enable AUVs to remain submerged for extended periods, thereby providing a persistent presence. Recent experiments showed that the ASV could externally aid AUV navigation and serve as a communication relay between the AUV and remotely located human operators. James was promoted to Associate Scientist on October 9, 2013.

Paul Matthias is the Ocean Observatories Initiative (OOI) Coastal Global Scale Nodes (CGSN) Program Manager at WHOI. The OOI, a billion-dollar 25-year project funded by the National Science Foundation, is planned as a network of science-driven sensor systems to measure the physical, chemical, geological and biological variables in the ocean, atmosphere and seafloor. CGSN is responsible for the coastal Pioneer Array off New England and for deep-water arrays in the Northeast Pacific, Irminger Sea, Southern Ocean, and Argentine Basin. The first Northeast Pacific and Pioneer deployments occurred in 2013. Paul brings industrial experience in engineering and management that is essential for success in this complex program. Paul was appointed as a Program Engineer Manager on January 22, 2013.



The Pioneer Central Coastal Surface Mooring, deployed on the Pioneer I cruise in November, 2013.

The focus of **Malcolm Scully's** research is circulation and turbulent mixing in coastal and estuarine environments. Much of Malcolm's recent work has been on water mixing in Chesapeake Bay, to provide a more comprehensive understanding of the processes that control the variability of low dissolved oxygen water (hypoxia). Through a combination of numerical simulations and direct field observations, Malcolm demonstrated an important previously unrecognized mechanism by which wind forcing mediates the inter-annual severity of hypoxia in Chesapeake Bay. Using data collected on a series of recent research cruises, Malcolm has documented and quantified the importance of mixing by internal waves and Langmuir circulation. Malcolm was appointed as an Associate Scientist on January 2, 2013.

—*John Trowbridge, Department Chair*

On June 14, the submersible DEEPSEA CHALLENGER completed a cross-country trip from California to Cape Cod, arriving just as the sun broke through the clouds in Woods Hole (shown here). Explorer and director James Cameron designed the sub to dive to the deepest parts of the ocean and in 2012 used it to reach Challenger Deep, 35,787 feet beneath the surface of the Pacific. In March, he donated the sub and associated technology to WHOI in an effort to help foster development of new manned and robotic vehicles. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

Biology

Members of the Biology Department study the diversity of life in the oceans and the interactions of marine organisms with their physical and geochemical environments. Research in the department ranges from molecules and cells to communities and ecosystems and occurs all over the world as well as in the laboratory. The department in 2013 included 31 scientific staff and 42 highly skilled research and technical staff, supported by a vital administrative team. Approximately 16 postdoctoral researchers and 25 students in the MIT/WHOI Joint Graduate Program in Oceanography/Applied Ocean Science and Engineering participated in the research, as did dozens of visiting researchers who collaborated with members of the department.

In 2013, WHOI biologists reported their findings in more than 130 published papers. The papers included review articles on topics such as cetacean hearing, ocean ecogeochemistry (using stable isotopes to trace nutrient movement in ocean food webs), hydrothermal vents, impacts of climate change on Antarctic seabirds, and methods for studying whales, zooplankton, or marine invertebrate populations. Others reported on the sequencing of genomes from the ecologically important marine phytoplankton species *Emiliania huxleyi*, an enigmatic lobe-finned fish, the African coelacanth *Latimeria chalumnae*, and "microbial dark matter"(poorly understood marine microbes). Yet others reported important advances in real-time monitoring of whale distributions, effects of climate change on Arctic plankton, and the evolution of a key family of genes involved in physiology and adaptation.

The research of several WHOI Biologists was featured in *Oceanus* magazine and in news releases. Members of the department also reached out to share their expertise and make their research more accessible to students, the public, and government officials, through talks, testimony, and other kinds of outreach activities. For example, **Judith McDowell** chaired a committee of the National Research Council that prepared a report on *Assessing Risks to Endangered and Threatened Species from Pesticides*. The report contained policy recommendations for how the various U.S. government agencies should use a common scientific approach to assess the risk posed by pesticides. **Stefan Sievert**'s expedition to study life at deep-sea hydrothermal vents was made publically accessible through WHOI's Dive and Discover web site. **Heidi Sosik** was part of a group of experts who called for establishment of a network to monitor marine biodiversity and how it responds to global environmental change.

Education continued to be a high priority for the Biology Department, involving the MIT/WHOI Joint Graduate program, postdoctoral researchers, and undergraduate summer fellows. Three students defended their Ph.D. theses in 2013 and moved on to pursue postdoctoral research elsewhere. Several of the Biology department postdoctoral researchers completed their WHOI research and obtained faculty or other positions. Biology department student and postdoctoral trainees can be found in academic, research, and other roles around the world.

Biology department personnel received recognition in 2013 through a number of awards and promotions

Jesús Pineda was promoted to Senior Scientist. **Rubao Ji** was promoted to Associate Scientist with Tenure. **Gareth Lawson**, **Sam Laney**, and **Matthew Johnson** were promoted to Associate Scientist. **Drew Brown** was promoted to Administrative Associate. Senior Scientists **Heidi Sosik** and **Carin Ashjian** were recognized with new WHOI Leadership Awards. **Rubao Ji** and **Gareth Lawson** were awarded fellowships in Quantitative Fisheries and Ecosystem Science by the Cooperative Institute for the North Atlantic Region (CINAR). **Diana Franks** received the Linda Morse-Porteous Award to honor her dedication, quality of work, and mentorship over many years in the department. **Dave Kulis** received the Vetlesen Award for his selfless dedication to the WHOI community.

These promotions and awards illustrate the greatest strength of the department: the dedicated and talented people who make this a special place to conduct research on the biology of the oceans.

—*Mark Hahn, Department Chair*

A sperm whale surfaces above the deep Kaikoura Canyon off the East Coast of New Zealand. WHOI biologist Michael Moore, director of the WHOI Marine Mammal Center, and graduate student Julie van der Hoop went on an expedition in March 2013 with colleagues from the University of Otago and elsewhere aboard the research vessel *Alucia* to study these deep-diving whales. The scientists used suction cup digital acoustic tags to measure whales' vocalizations, respiration and movement. (Photo by Maryann Morin, Advanced Imaging and Visualization Lab at Woods Hole Oceanographic Institution)

In Terre Adélie, Antarctica, WHOI biologist Stephanie Jenouvrier holds a five-month-old emperor penguin chick in preparation to tag it. Tagging young birds, coupled with a long-term study of this penguin colony by French scientists, allows Jenouvrier and colleagues to know individual birds' travel and foraging history. Jenouvrier used extensive data from this colony in her research, constructing models that forecast a drastic decline in future emperor penguin numbers due to climate change. (Photo courtesy of Stephanie Jenouvrier, Woods Hole Oceanographic Institution)

Geology & Geophysics

The Department of Geology and Geophysics (G&G) is a diverse and multidisciplinary group of researchers and technical staff who carry out research on a spectrum of topics: plate tectonics and earthquakes; the composition and dynamics of the solid earth; hydrothermal vents and seafloor volcanism; climate history and the oceans' role in climate; ice sheet dynamics and their response to climate change; coastal geology and climate history of coasts; microbial life in extreme environments; and the impacts of rising atmospheric carbon dioxide on ocean chemistry and biology.

We were delighted to add a new member to the G&G scientific staff in 2013 – Assistant Scientist Vernonique LeRoux. Veronique is a petrologist whose research focuses on understanding the composition and physical properties of the earth's mantle. We also note the retirement of Senior Scientist Nobu Shimizu; we are delighted that Nobu has stayed with us as an Emeritus Scientist. We are also happy and proud to recognize four G&G graduate students in the MIT/WHOI Joint Program who received degrees in 2013: Sara Bosshart received a Masters degree, and Drs. Shane McGary, Claire Pontbriand, and Nathaniel Miller received their Ph.D.s. Congratulations!

—*Daniel C. McCorkle, Department Chair*

WHOI microbiologist Virginia Edgcomb works on the Submersible Incubation Device (SID), a robotic instrument designed to collect, incubate, and preserve samples of microbes in the ocean. Scientist Craig Taylor and engineer Ken Doherty developed SID to study bacteria. Edgcomb worked with them and McLane Research Laboratories to expand its capabilities to include protists, single-celled organisms such as amoeba, ciliates, and foraminifera. Edgcomb has used this SID in the Mediterranean and other sites around the world. In 2012, she won the Seymour Hutner Award, a prize given annually by the International Society of Protistologists to an outstanding young scientist whose work on protists is internationally recognized. (Photo by Cherie Winner, Woods Hole Oceanographic Institution)

Lush, diverse, healthy coral reefs in Palau are living where they shouldn't be—under lower-than-normal pH levels that are equal to what the ocean is projected to have by the end of this century if fossil fuel emissions continue at their present rate. WHOI scientist Anne Cohen and graduate student Hannah Barkley, partnering with scientists at the Palau International Coral Reef Center and The Nature Conservancy and with funding from The Tiffany & Co. Foundation, are studying these corals, in an effort to understand how they acquire resilience to ocean acidification. The information will be used to identify and protect coral reefs that have the best chance of surviving 21st-century climate change. (Photo by Hannah Barkley, Woods Hole Oceanographic Institution)

Marine Chemistry & Geochemistry

Research activities in the Marine Chemistry and Geochemistry (MC&G) Department are focused on exploring the broad spectrum of processes that influence chemical cycling in the oceans and their interactions with the atmosphere, land, and Earth's interior. Critical to these efforts are considerations of how ocean chemistry influences and responds to biological activity and the impact of anthropogenic activity on the marine environment. We are a diverse group of researchers working at the interface of multiple disciplines using a combination of laboratory, field-based, and computational approaches. Projects range in size from single investigator studies to large collaborative projects involving investigators from multiple institutions. Below are highlights of just a few of the MC&G activities that occurred in 2013.

Completion of a newly fabricated mesocosm lab—a structure built to create and study small-scale ecosystems—on the Quissett campus allowed assistant scientist Amanda Spivak to initiate experiments focused on carbon cycling processes in coastal habitats. One experiment was highlighted in a video produced for WHOI's *Oceanus* magazine. In this experiment, Spivak and colleague John Pohlman (USGS) used stable isotope probing techniques (a way to track elements through food chains) and novel laser-based gas analyzers to examine the fate of carbon recently photosynthesized by the salt marsh grass *Spartinaalterniflora*. Understanding carbon dynamics in salt marshes is important for evaluating how well these ecosystems sequester carbon over different time scales.

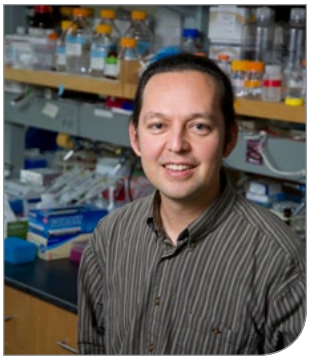
Assistant Scientist Scott Wankel completed field campaigns on the island of Sylt in Germany and Santa Catalina Island off the coast of California for his NSF-funded study investigating the role of intertidal sediments in producing and regulating the release of nitrous oxide, a potent greenhouse gas. This study brings together sophisticated analytical approaches that will improve our understanding of how microorganisms that contribute to the production of greenhouse gases will respond to impending environmental change.

A study published in *Science* by associate scientist Colleen Hansel's research group (postdocs Julia Diaz, Peter Andeer, and Tong Zhang), in collaboration with a colleague at the Colorado School of Mines, discovered that marine bacteria, encompassing a wide ecological and species diversity, produce high concentrations of superoxide within marine waters. Superoxide is a form of oxygen that impacts many biogeochemical cycles and is essential for life at low concentrations, but at high concentrations is toxic and ultimately fatal. Previously known sources of superoxide to the ocean were limited to reactions with light. Thus, this new source expands our understanding of the relevance of these highly reactive and toxic compounds to the approximately 95 percent of our global habitat untouched by light.

Associate scientist Liz Kujawinski and research specialist Dr. Krista Longnecker led a cruise in the western Atlantic Ocean from Montevideo, Uruguay to Bridgetown, Barbados aboard the R/V *Knorr* to investigate dissolved organic matter composition and microbial metabolism in the context of physical water properties associated with surface currents and deep water flow. The cruise involved a broad interdisciplinary group of researchers who came together to collect complementary chemical, biological and physical samples and measurements. Their results will provide unique insights into carbon cycling in the surface and deep oceans. In addition to Liz and Krista, other participants from MC&G included associate scientist Ben Van Mooy, research assistants Catherine Carmichael and Justin Ossolinski, postdocs Colleen Durkin and Carly Buchwald, and Joint Program students Winn Johnson, Harriet Alexander and Evan Howard.

Several members of MC&G were involved in the East Pacific transect of the US GEOTRACES Program cruise, led by Chris German (G&G Department) and former MC&G scientist Jim Moffett, from Manta, Ecuador to Papeete, Tahiti. Drs. Phoebe Lam, Matt Charette, Ken Buesseler, Carl Lamborg, Mak Saito, Bill Jenkins, and Dan Repeta are all principal investigators in this highly coordinated effort to simultaneously measure a broad spectrum of trace metals and isotopes in the Eastern Pacific. Their results will allow a far richer and deeper interpretation of the data and help identify the processes and quantify the fluxes that control distributions of trace elements in the ocean. Even with limited berths available on the ship, MC&G was also represented on the cruise by Joint Program students Erin Black, Nick Hawco, postdoc Daniel Ohnemus, Research Associate Steve Pike, and Research Assistant Gretchen Swarr.

WHOI's Redfield Auditorium overflowed with those who came to hear a panel of American and Japanese scientists discussing Japan's Triple Disaster, the March 2011 earthquake, tsunami, and nuclear accident that sent an unprecedented amount of radioactive contaminants into the ocean. WHOI marine chemist Ken Buesseler has established a Center for Marine and Environmental Radioactivity at WHOI and organized the Morss Colloquium on Fukushima and the Ocean on May 9, 2013. Two days later, he joined Japanese colleagues on a cruise to collect water, sediment, and biota samples three miles from the reactors at Fukushima. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)



WHOI marine chemist Mak Saito has adapted an approach used in biomedical research to study marine organisms: proteomics. He has developed new techniques to detect and measure the proteins that marine organisms make and use to function in their environment and respond to changing conditions—particularly metalloproteins, which contain iron, zinc, cobalt, and other elements. Recently, he collaborated with biomedical researchers to explore proteins in a terrestrial organism, the bacteria that causes Lyme disease, which requires unusually high levels of manganese, but unlike any other known organisms, can live without iron.

Senior scientist Ken Buesseler established a new Center for Marine and Environmental Radioactivity (CMER) that is focused on increasing scientific and public understanding of the sources, fates and consequences of natural and human-made radioactive elements in the environment, in particular the oceans. In keeping with this theme, Ken organized a Morss Colloquium at WHOI in May, 2013 on Fukashima and the Ocean. The colloquium provided a forum to discuss lessons learned from the Fukashima disaster with policy makers, media, and a broad public audience.

In July 2013 Senior scientist Scott Doney testified before the U.S. Senate Environment and Public Works Committee Hearing on *Climate Change: It's Happening Now*. His testimony addressed ocean climate change, the ocean carbon cycle and ocean acidification, addressing how rising atmospheric carbon dioxide levels alter seawater chemistry, put at risk a wide range of marine life, and affect coastal communities and economies.

Several members of MC&G received recognition for their accomplishments through awards and promotions. Scott Doney received the 2013 A.G. Huntsman Award for Excellence in Marine Science from the Royal Society of Canada for his numerous contributions to chemical oceanography. Ken Buesseler was elected as a foreign member of Royal Netherlands Academy of Arts and Sciences for his pioneering role in detection and interpretation of radioactive plutonium in the oceans resulting from nuclear bomb tests, as well as other contributions to marine chemistry. Ken also received a prestigious fellowship from the Japan Society for the Promotion of Science that will allow him to spend significant time in Japan during 2014 to visit with a variety of groups to discuss mutual scientific interests and future activities related to the Fukashima nuclear power plant disaster. Ben Van Mooy was selected as a Kavli Frontiers of Science Fellow by the Kavli Foundation and also received a Diamond Jubilee International Visiting Fellowship from Southampton University. Research assistant Justin Ossilinski received WHOI's Ryan C. Schrawder Award for 2013.

The list of 2013 promotions includes Liz Kujawinski to Associate Scientist with Tenure, Aleck Wang to Associate Scientist without tenure, Dawn Moran and Kristen Rathjen to Research Associate II, Zoë Sandwith and Gretchen Swarr to Research Assistant III, and Athena Aicher and and Hilary Ranson to Research Assistant II.

2013 saw the addition of two new members to MC&G. Jenny Rheuban joined the Department as a Research Associate II and Kristen Whalen as a Research Associate III.

—*Jeffrey Seewald, Department Chair*

Members of the lab run by WHOI chemist Matt Charette installed equipment on a beach during a recent trip to Northeast Japan. In addition to collecting groundwater samples near the city of Sendai (shown here), the group joined a cruise on the Japanese research vessel *Dai-san Kaiyo Maru* to help collect water, fish, and sediment samples less than one mile from Fukushima Dai-ichi to track the spread and impact of radionuclides from the crippled nuclear power plant. (Photo by Ken Buesseler, Woods Hole Oceanographic Institution)

Physical Oceanography

Our branch of ocean science focuses on the fluid-dynamic processes that control and explain ocean currents, the role of those flows in Earth's climate system, and their interaction with the ocean's biological and geochemical systems. Physical Oceanographers use a mix of approaches to address research questions, including using instruments to make direct observations (devices operated in the field by scientists and technicians or sampling autonomously), designing and carrying out laboratory experiments, and applying analytical and/or numerical methods to solve the relevant governing dynamical equations.

PO Department members were engaged in more than 200 funded research projects this year, and collectively contributed to approximately 120 peer-reviewed papers that carry or will carry a 2013 publication date. At the end of the calendar year, the active PO Scientific Staff numbered 31, plus one individual on a leave of absence. This total was the result one addition (Robert Todd joined the department as an Assistant Scientist) and one loss (Senior Scientist Breck Owens retired and transitioned to Scientist Emeritus). In addition to the scientific staff, approximately 60 additional Department members contributed to the PO research effort in 2013; the Department experienced a net reduction of 3 individuals from those ranks this year. Eleven WHOI retirees from our department held Scientist Emeritus posts along with 5 Oceanographer Emeriti; 7 close colleagues from other Institutions held Adjunct Scientist appointments.

As has been the case in past years, the research conducted by WHOI PO Department members was wide ranging (by phenomena, geography and space/time scale). The following represents a very small subset of staff activities.

Air-sea interaction and upper-ocean variability continued to be a focus for many. The field phase of the first SPURS (Salinity Processes in the Upper Ocean Regional Study) program in the eastern North Atlantic's high-evaporation, salinity-maximum zone wrapped up in 2013. Ray Schmitt, Carol Anne Clayson, Lou St. Laurent and others are now engaged in the data analysis phase of the program, while planning for a complementary study of a high-precipitation, salinity-minimum region (possibly in the eastern North Pacific, below the Intertropical Convergence Zone near the equator). Meanwhile, the Upper Ocean Processes Group led by Bob Weller and Al Plueddemann continued their sustained surface mooring programs in the North Atlantic (NTAS - Northwest Tropical Atlantic Station, now entering its 13th year in operation), the southeastern Pacific (Stratus - beginning its 14th year), and off Hawaii (WHOTS, the WHOI-Hawaii Ocean Time Series, starting its 10th year). Extending these local observations of air-sea exchange to basin scale, Lisan Yu continued to develop her flux climatologies that blend remote sensing and *in situ* observations. One goal of air-sea interaction research is to improve long-term weather forecasting (possible since the ocean provides the longer-term memory for the coupled ocean-atmosphere system). Department member Hyodae Seo made advances in understanding variability at 1-2 month time scale related to the atmospheric Madden-Julian Oscillation while Caroline Ummenhofer continued work on relating seasonal rainfall patterns to sea surface temperature anomalies.

The high latitudes continued to be a "hot" research area in 2013. In a collaborative program with Icelander scientists, Bob Pickart and colleagues studied moored and shipboard observations to elucidate the source waters for the dense outflow from the Arctic to the North Atlantic, and a new current, the North Iceland Jet, was discovered. In 2013, the Beaufort Gyre Observing System led by Andrey Proshutinsky and Rick Krishfield celebrated its 10th anniversary, while the WHOI Ice-Tethered Program will reach that milestone next year. The impact of fiord waters on Greenland glaciers also saw continued research effort by Fiamma Straneo in the field and Claudia Cenedese in the laboratory. Greenland field work in 2013 included a test by Magdalena Andres of an acoustic remote sensing method to infer changes in fiord water heat content. Also on the technical front, Steve Jayne and Breck Owens worked to develop an acoustically-tracked profiling float for use in the Arctic while Postdoctoral Investigator Sylvia Cole analyzed data from a prototype Ice-Tethered Profiler with Velocity. Arrays of these new instruments will be deployed in 2014 to study the seasonally-varying Marginal Ice Zone.

Physical Oceanography department members are involved in documenting and building our understanding of large-scale circulations in the world's major ocean basins. A particular focus this

Postdoctoral investigator Jean-Baptiste Gilet (right) points to a vortex, a small whirlpool that's similar to a tornado in air, that was created in a container of colored water in scientist Claudia Cenedese's laboratory. In May 2013 Cenedese held a week-long laboratory open house and invited students, the public, and WHOI staff to tour the Geophysical Fluid Dynamics Laboratory. Visitors, including WHOI engineer Chris Lumping (far left) and guest investigator Dr. Pedro Vélez-Belchí (Centro Oceanográfico de Canarias, Canary Islands), viewed demonstrations of how water flows and circulates in the lab and in the oceans. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

On the way to the high Arctic to study how the polar ocean circulates, the crew aboard the Norwegian research vessel *Lance* took in this scenic sight—the glacial tongues of Northeast Svalbard. During the September 2013 expedition, WHOI scientist Bob Pickart retrieved moorings and measured warm water flowing into the Arctic. While at sea, the research team posted regular updates and interacted with schools. (Photo by Amy Cooper, Woods Hole Oceanographic Institution)

year was on the ocean's meridional overturning circulation (MOC), in which (most commonly) warm, buoyant waters flow poleward, are made denser by cooling due to air-sea exchange, sink, and return equatorward. Jake Gebbie seeks to quantify, on a global basis, the circulation pathways that connect the ocean surface (where sea waters are modified by air-sea exchanges) to the water masses at intermediate, deep and abyssal depths in the ocean interior—in modern times and during the last glacial maximum period. Alison Macdonald analyzed previously-collected water property data to quantify the MOC in the Indian Ocean (and its associated transport of carbon), while Young-Oh Kwon and associates investigated North Atlantic overturning in global climate models. Jiayan Yang developed a simple wind-driven model of the North Atlantic that appears to explain seasonal MOC variability seen in observations at Latitude 26°N.

Addressing the MOC's equatorward return flow, Amy Bower and Mike Spall are starting to analyze observations and models of the bottom water flow through gaps in the North Atlantic's mid-ocean ridge, while Ruth Curry and Kurt Polzin analyzed observations of abyssal flow along Bermuda's eastern flank. Larry Pratt and Joint Program student Rebecca Dell studied the role of abyssal turbulent mixing in the MOC return circulation. In the planning stage, Bower, Pickart, Straneo and others are gearing up to measure the net overturning circulation in the subpolar North Atlantic (the OSNAP field program - Overturning in the Subpolar North Atlantic Program), which will begin in summer 2014.

The Department's coastal physical oceanographers were equally busy in 2013. Steve Lentz and Jim Churchill investigated the flows over shallow coral reefs and the role of surface wave breaking at the reef edge in driving those currents. Ken Brink studied the dynamics of fronts—boundaries between water masses with different properties—in the coastal ocean generated by spatially-varying water mixing. Glen Gawarkiewicz and Robert Todd investigated the structure of fronts observed at the continental shelf-break. And Anthony Kirincich, Irina Rypina and others prepared for a major field study of the inner-shelf circulation to be fielded south of Martha's Vineyard in 2014.

Bio-physical interactions also interest members of WHOI's PO Department. Karl Helfrich, in collaboration with scientists in the Biology Department, conducted laboratory studies of larval responses to turbulence (including for example, the settling rate of juvenile barnacles). And Amala Mahadevan with postdoc Melissa Omand investigated the influences of instabilities in the surface water layer on phytoplankton growth and on how much carbon sinks to depth.

Staff promotions in 2013 included Amala Mahadevan and Steve Jayne to Senior Scientist, Anthony Kirincich to Associate Scientist without tenure, Larry George to Engineer II and Ben Pietro to Engineering Assistant III. Congratulations to all.

—John Toole, Department Chair

An ethereal, distant iceberg can can extend to more than 500 meters below the surface and can actually batter and destroy moorings. Physical oceanographer Fiamma Straneo and engineer Will Ostrom took a chance when they deployed this yellow float at 350 meters on a subsurface mooring in East Greenland's Sermilik Fjord in August 2013 to investigate the role of the ocean in glacier retreat. The mooring will be in the water for two years collecting information about ocean temperature near a major Greenland glacier. (Photo by Will Ostrom, Woods Hole Oceanographic Institution)

Coastal Ocean Institute

Chris Reddy

The majority of the world's population lives within 50 miles of the ocean; in fact, two-thirds of the world's largest cities are situated along coastlines. It's no wonder why—the world's coastlines harbor rich resources, from food to fuel, and provide us with unparalleled beauty. But humans' impact on coastal ecosystems is not without repercussions; as the population grows, the climate warms and the sea rises, new scientific questions emerge that demand answers.

COI's scientists are tackling these questions and the work is by nature collaborative, as the projects described in this report highlight. For instance, the Global Rivers Observatory, a network started by WHOI geochemist Bernhard Peucker-Ehrenbrink that samples sites along the world's most important rivers, expanded last year to include the Mississippi River and Tulane University. This WHOI-Tulane partnership would not have been possible without the enthusiastic support of Corporation Member Rodney Yanker and his wife, Mary.

WHOI chemical oceanographer Zhaohui 'Aleck' Wang teamed up with researchers from several institutions to study the effects of ocean acidification in the Gulf of Maine. Wang discovered that this body of water may be more susceptible to changes in acidity, impacting commercially valuable species like clams and oysters. His work has generated questions not just for the scientific community, but for fishermen, policy makers and fisheries managers, as well.

These are just two of the projects funded through the Coastal Oceans Institute in 2013; I hope you enjoy reading about the cutting-edge research being done with the help of your support.

Thank you again for your continued support of COI. Please feel free to contact me with any questions or comments.

—Chris Reddy, Director, Coastal Ocean Institute

Coastal Ocean Institute projects funded in 2013

Small Changes Big Impacts: Understanding ocean acidification on the East Coast
Zhaohui 'Aleck' Wang

Global Rivers Observatory: A Growing Network
Bernhard Peucker-Ehrenbrink, Marine Chemistry & Geochemistry

What is the Sound of 130 Wind Turbines: Researchers record undersea sound at offshore wind farm site
Aran Mooney, Biology
Laela Sayigh, Biology

The Response of Mercury Species and Related Genes to Long-term Fertilization in a New England Salt Marsh
Carl Lamborg, Marine Chemistry & Geochemistry
Tracy Mincer, Marine Chemistry & Geochemistry

Coastal Sea Level from the Mid-Atlantic United States to Canada—What Causes the International Variability in this "Hotspot" of Sea Level Rise?
Magdalena Andres, Physical Oceanography

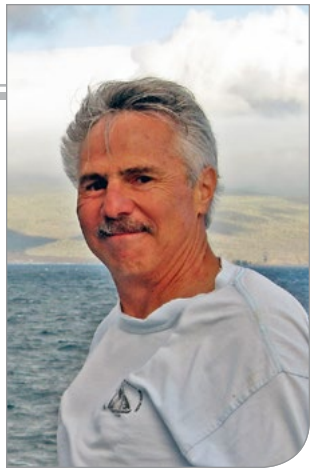
Can Old Plants Learn New Tricks? Testing Adaptation Potential of Crustose Coralline Algae Along a Natural Gradient in Ocean Acidification*
Anne Cohen, Geology & Geophysics

**Also funded by the Institutes' Ocean Acidification Initiative*

Funding Highlights

COI's total spending for 2013 was $420,812. Although the Institute focused the majority of its funding on research grants ($139,858), significant support also went to fellows, graduate education and outreach activities. COI supported one fellow in 2013, Dan McCorkle ($108,152), and postdoctoral scholars Christopher Hein and Roxanne Beinart ($97,939). Discretionary and communications funding was also used for conferences and publications ($46,076).

Deep Ocean Exploration Institute



Dan Fornari

The ocean is truly the world's last frontier. It covers nearly 70 percent of Earth's surface, yet there are vast regions of the ocean, such as the mid-water environment and deep ocean seafloor, that are not well understood. Scientists and engineers supported in part by Deep Ocean Exploration Institute funding are at the forefront of expanding our knowledge of these frontiers, seeking to answer complex questions about the biology, chemistry and geology of the deep ocean seafloor.

I'm pleased to report that the Ocean Ridge Initiative (ORI), a four-year effort focused on the mid- ocean ridge (MOR), Earth's most continuous volcanic and tectonic feature, successfully concluded in 2013. The projects funded during this initiative covered a broad research agenda ranging from microbial and geological/geochemical processes at deep-sea vents to the nature of deep-sea fauna at oceanic spreading centers. It also included research related to understanding deep-sea eruptions and the impacts they have on bio-geochemical processes in these extreme environments of the MOR.

As with all thematic areas supported by DOEI, technology has been an integral part of the research efforts, and ORI work also included engineering advances for autonomous and remotely operated vehicle sensors and systems. Much of the work DOEI supports is inter-disciplinary, and this synergistic collaboration is highlighted by the innovative tools, techniques and equipment co-developed by WHOI engineers and scientists involved in both DOEI-and ORI-funded research.

Part of the work that DOEI and ORI have fostered looks to the future. Certainly WHOI's involvement in the Ocean Observatories Initiative, a major 21st century program funded by NSF to provide real-time observational capability in the oceans and on the seafloor, fits well with DOEI and ORI objectives. DOEI and ORI, along with the generous support of the Burke family, have provided funding to facilitate WHOI scientists and colleagues to monitor changes in the ocean in real-time through the high-definition, web-based imaging and audiovisual infrastructure installed in the newly-named Coleman and Susan Burke Ocean Observing Operations Room in the LOSOS Building. Support for facilities and capabilities such as this one enables the scientific collaboration and innovation that has made WHOI a world-leader in ocean science and technology.

With your support, we will continue to foster the high-risk, cross-disciplinary work that leads to breakthroughs in our understanding of processes in ocean and deep seafloor environments.

—Dan Fornari, Director, Deep Ocean Exploration Institute

Deep Ocean Exploration Institute Projects Funded in 2013

A Closer Look at Underwater Volcanoes
Adam Soule, Geology and Geophysics

Living Rock: A JP student links sub-seafloor hydrology and earthquakes
Claire Pontbriand, Geology and Geophysics

Experimental Investigation: The Influence of Small Amounts of Water on Peridotite Melting in the Oceanic Upper Mantle
Glenn Gaetani, Geology & Geophysics

Establishing a Center for Telepresence & Dive Review
Chris German, Geology & Geophysics

Generation of Subduction—Zone Magmas from Melange Diapirs
Horst Marschall, Geology & Geophysics and Glenn Gaetani, Geology & Geophysics

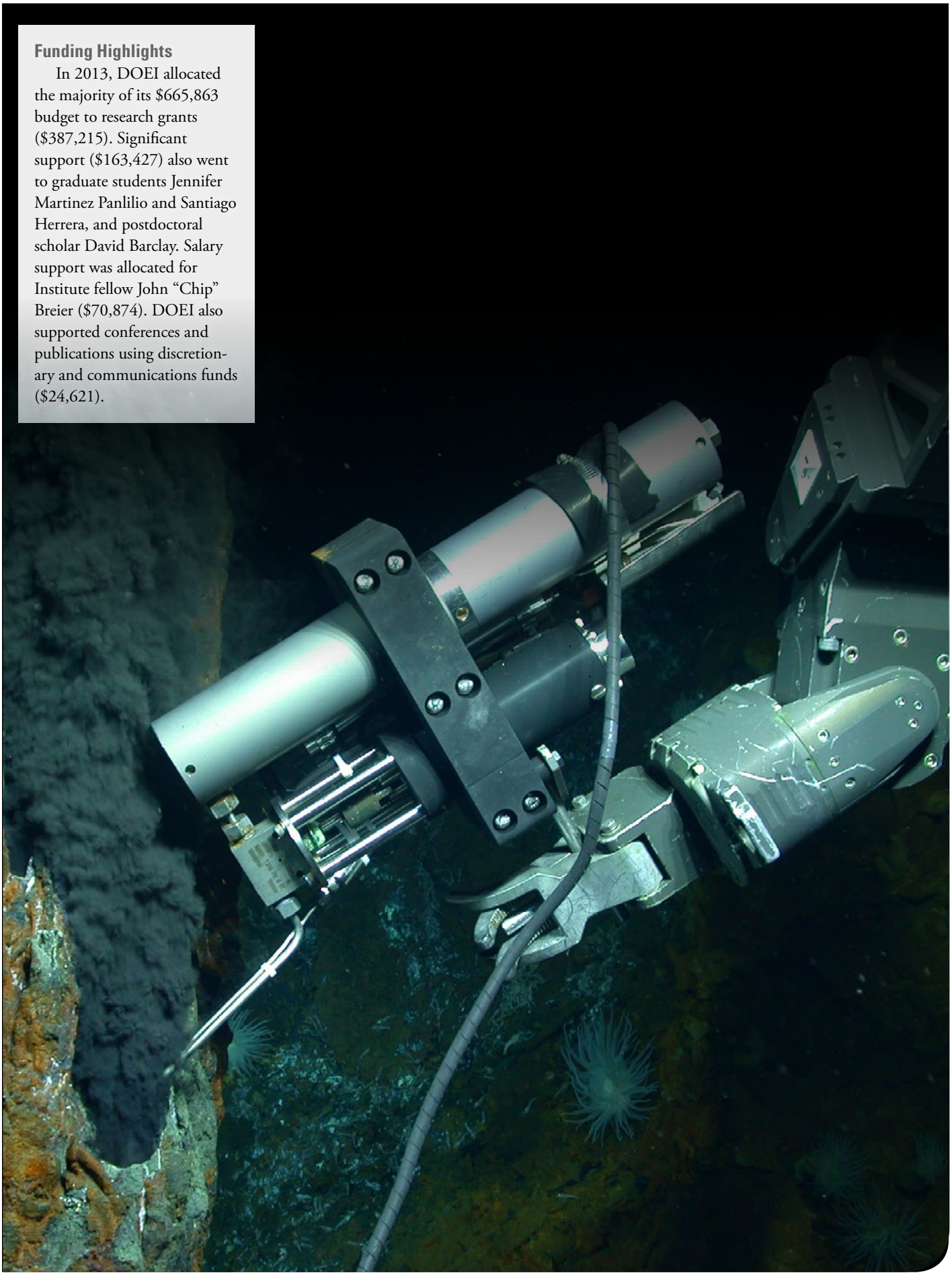
Innovative Tracers for Hydrous Melting in the Earth's Mantle
Veronique Le Roux, Geology & Geophysics
Nobumichi Shimizu, Geology & Geophysics

Development of a Modular Deep Sea In situ Dissolved Gas Extractor System*
Anna Michel, Applied Ocean Physics & Engineering
Scott Wankel, Marine Chemistry & Geochemistry

**2013 Ocean Acidification Initiative Postdoctoral Scholar*

Funding Highlights

In 2013, DOEI allocated the majority of its $665,863 budget to research grants ($387,215). Significant support ($163,427) also went to graduate students Jennifer Martinez Panlilio and Santiago Herrera, and postdoctoral scholar David Barclay. Salary support was allocated for Institute fellow John "Chip" Breier ($70,874). DOEI also supported conferences and publications using discretionary and communications funds ($24,621).



Ocean & Climate Change Institute

Scott Doney

As it has for the past 13 years, the Ocean and Climate Change Institute continues to support the critical research that will help us understand how Earth's climate system works, how climate is changing with time, and what that means for the ocean and people.

Our researchers fanned out across the globe in 2013, funded with seed money to kick-start basic research, grants to continue studies with implications for government policy and society, and support to nurture high- risk projects that meet the goals of OCCI.

In this report you'll read about some of the work OCCI has funded over the past year. WHOI researchers got a glimpse under the ice in the Arctic, discovering a plankton bloom with four times more plankton than in neighboring ice-free waters. Until this discovery, sea ice was thought to block sunlight and limit the growth of microscopic plants living under the thinning ice in the Arctic. Our scientists also looked back in time, probing historical data to understand how wind and sea surface temperature changes in the Indian Ocean can affect farmers in southwest Australia. Other researchers and engineers even deployed to the fjords of Greenland to study the melting of the massive Greenland Ice Sheet. In these and other projects supported by OCCI, scientists tested new technology developed right here at WHOI to help them answer these questions.

I am pleased to introduce you to OCCI's newest fellow, Kristopher Karnauskas (G&G). With funding from the James E. and Barbara V. Moltz Institute Research Fellowship, Kris will also peer into the past to improve our understanding of climate variability over the timespan of centuries. His research focuses on understanding the dynamics of the tropical ocean and atmosphere as a coupled system, its interaction with ecosystems and with higher latitude regions. He'll do this by incorporating global climate model simulations with on-site observations, along with paleoclimate proxies and high-resolution ocean models.

Without your support, this forward-thinking work would be much more difficult, if not impossible, to complete. We are grateful for your continued support of OCCI scientists, engineers and postdoctoral and graduate students.

—*Scott Doney, Director, Ocean and Climate Change Insitute*

Ocean and Climate Change Institute Projects Funded in 2013

Innovation on the ice: WHOI researchers use novel tools to study the melting Greenland Ice Sheet
Sarah Das, Geology & Geophysics
Hanu Singh, Applied Ocean Physics & Engineering
Lee Freitag, Applied Ocean Physics & Engineering
Al Plueddemann, Physical Oceanography
Fiamma Straneo, Physical Oceanography

Cause and Effect: Exploring how changes in the Indian Ocean affect farmers in Australia
Caroline Ummenhofer, Physical Oceanography

Simple Questions, Complicated Answers: Understanding Phytoplankton blooms in the Arctic Ocean
Sam Laney, Biology

Autonomous CTD Profiling at the Edge of Calving Glaciers
Fiamma Straneo, Physical Oceanography
Hanu Singh, Applied Ocean Physics & Engineering
Sarah Das, Geology & Geophysics

Indian Monsoon Variability, Himalayan Climate, and Terrestrial Ecology from Bhutanese Lake Sediments
Jessica Tierney, Geology & Geophysics

Reconstructing Marine Nutrients, Their Utilization, and Role in Past CO2 Sequestration Using Cadmium Isotopes
Tristan Horner, Marine Chemistry & Geochemistry
Phoebe Lam, Marine Chemistry & Geochemistry

An Automated Biogeochemical Observatory on a Ship of Opportunity: Biweekly Assessment of the Carbon Cycle in the Northwest Atlantic
David Nicholson, Marine Chemistry & Geochemistry
Sam Laney, Biology

North Atlantic Deep Water Formation During the Deglacial Rise of Atmospheric C02
David Thornalley, Geology & Geophysics
Lloyd Keigwin, Geology & Geophysics

Abrupt Sea Level Change in the Geologic Record: Reconciling Contradictory Evidence
William Thompson, Geology & Geophysics

Coastal Ocean Acidification and Carbon Cycling Due to Geochemical and Biological Processes: Development of a Novel High-Resolution O2/H+ Eddy Correlation Technique
Matt Long**, Marine Chemistry & Geochemistry
Matt Charette, Marine Chemistry & Geochemistry
Bill Martin, Marine Chemistry & Geochemistry
Dan McCorkle, Geology & Geophysics

**Also funded by the Institutes' Ocean Acidification Initiative *2013 Ocean Acidification Initiative Postdoctoral Scholar*

Funding Highlights

The total budget for OCCI in 2013 was $597,355. While the Institute spent the majority of its budget on research grants ($336,920), OCCI supported other initiatives including education, student support and communications outreach. The Institute supported fellow Kristopher Karnauskas and postdoctoral scholars Peter Kimball and Ben Harden ($143,054). OCCI also funded outreach activities with discretionary and communications funding ($45,138).

Ocean Life Institute

Simon Thorrold

In 2013, OLI funded a wide range of projects through a combination of research grants and fellowships to scientists, postdoctoral investigators and graduate students. The projects supported by OLI are often cross-disciplinary collaborations that foster technological advances. These, in turn, facilitate cutting-edge science.

OLI continues to support initiatives that will enhance ocean conservation science. Since 2011, OLI researchers have been collaborating with the New England Aquarium and Conservation International to deliver a scientific template that will help island nations in the Pacific Ocean develop comprehensive conservation and management strategies in a designated area called the Pacific Oceanscape.

Over the last two years, work has focused on the Phoenix Islands Protected Area (PIPA), part of the island nation of the Republic of Kiribati in the central tropical Pacific Ocean. PIPA remains largely untouched by humans and is therefore a "Rosetta Stone" for understanding how coral reef systems are responding to the changes that have begun to take place rapidly in the 21st century. Our work in PIPA is an excellent example of the potential cross-disciplinary work has for making a profound impact across science, policy and economic disciplines.

Your support of this work has been and continues to be invaluable, and for that, we are grateful.

—Simon Thorrold, Director, Ocean Life Institute

Ocean Life Institute Projects Funded in 2013

New Beginnings: Using larvae to understand how the sea repopulates itself after a destructive event
Lauren Mullineaux, Biology

High-Risk, Yet High-Reward: Mak Saito receives the Gordon and Betty Moore Foundation Marine Microbiology Initiative Investigator Award
Mak Saito, Marine Chemistry and Geochemistry

All in the Family: Could self-fertilizing coral be better equipped to handle ocean acidification?
Ann Tarrant, Biology

Integrating Measures of Animal Movements to Estimate the Winter Distribution of Two Penguin Species
Michael Polito, Biology
Leah Houghton, Biology
Simon Thorrold, Biology

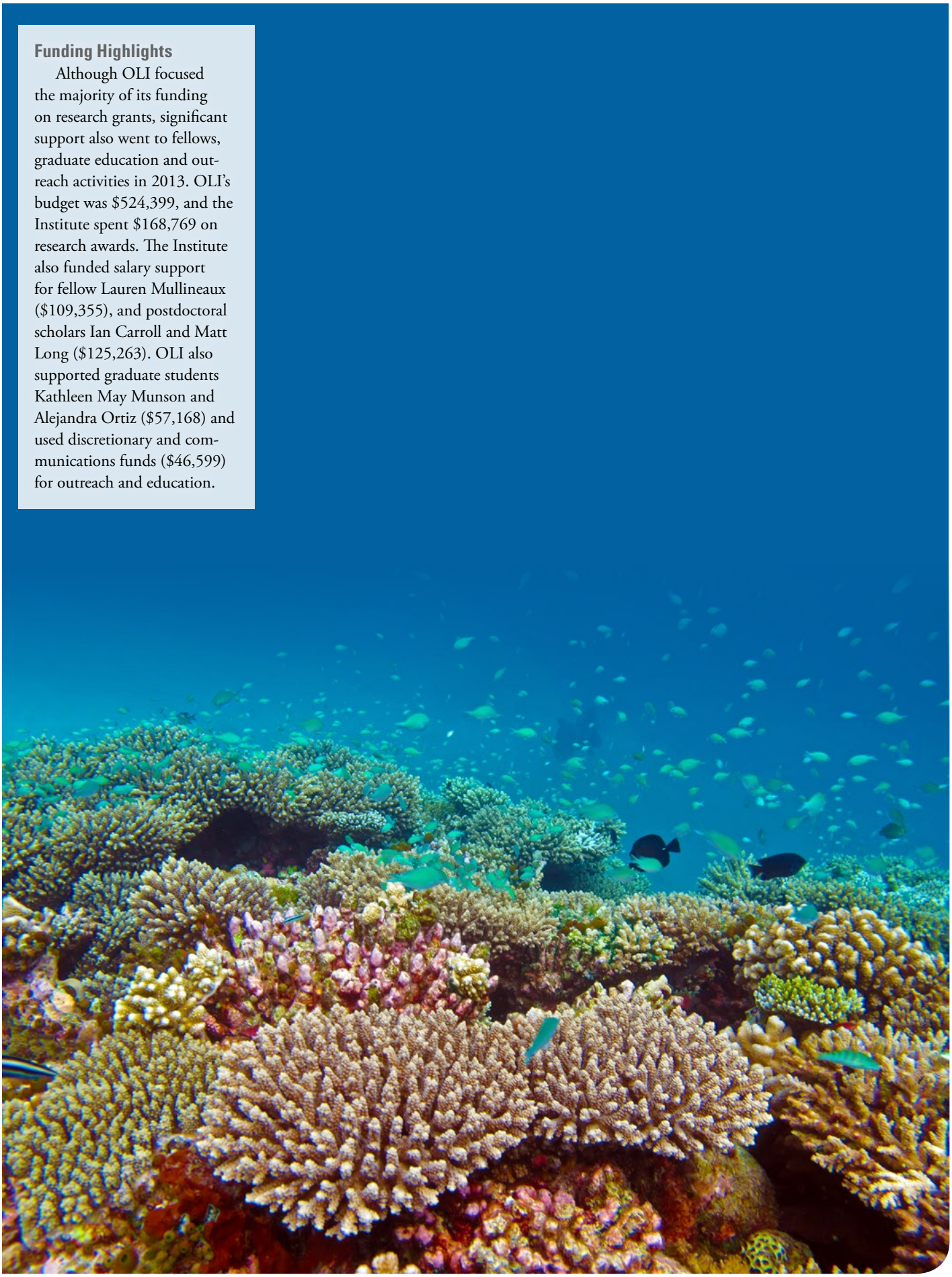
Is Cannibalism Really an Evolved Survival Strategy of Bluefin Tuna Larvae?
Joel Llopiz, Biology

Simulating Coral Calcification in the Lab: Impact of Ocean Acidification and Rising Temperature*
Weifu Guo, Geology & Geophysics
Zhaohui Aleck Wang, Marine Chemistry & Geochemistry

**2013 Ocean Acidification Initiative Postdoctoral Scholar*

Funding Highlights

Although OLI focused the majority of its funding on research grants, significant support also went to fellows, graduate education and outreach activities in 2013. OLI's budget was $524,399, and the Institute spent $168,769 on research awards. The Institute also funded salary support for fellow Lauren Mullineaux ($109,355), and postdoctoral scholars Ian Carroll and Matt Long ($125,263). OLI also supported graduate students Kathleen May Munson and Alejandra Ortiz ($57,168) and used discretionary and communications funds ($46,599) for outreach and education.



Academic Programs

The strength of all the WHOI education programs is the close linkage with the WHOI research mission and projects, and we are very proud of the ways our students and postdocs contribute to WHOI research. For example, our Joint Program (JP) students were authors on 79 scientific papers in 2013. What is most encouraging about our programs is that participating in WHOI education and training programs generally leads to excellent professional opportunities following time spent here. Joint Program graduates and postdoc alums find positions, and most of the summer undergraduates we train continue in science and engineering graduate programs, including some in our joint graduate program with MIT. A recent trend is that more of our PhD alums are finding positions outside of academia than in the past, including biologists who choose to work for biotech firms; engineers for robotic companies and others for firms that analyze risks associated with hazards such as earthquakes, sea level rise and coastal storms.

Our JP students, postdocs and scientists participate in an important National Science Foundation (NSF)-funded climate change education project, led by the New England Aquarium and entitled National Network for Ocean and Climate Change Interpretation (NNOCCI). Students and postdocs participate in Study Circles that include social scientists who specialize in how people learn and retain information, as well as interpreters who engage the public at national science centers, zoos and aquariums. The role of the WHOI participants is to provide accurate information on climate change and its effects on the ocean and its ecosystems. They also receive training as to how to effectively deliver and present climate change and impacts information to public audiences, a skill that should help our scientists' careers and help increase public knowledge of the ocean and its role in climate change.

The ways in which we communicate science are changing, and we are pleased that students in the MIT/WHOI Joint Program are leading the way. Last year, JP students formed the Broader Impacts Group (BIG), a student-run organization that is building networks of connections in the community and using those resources to share science with the public. BIG has convened workshops, hosted outside speakers, and supported a wide variety of outreach projects. They recently initiated a seminar series entitled, "Off the Charts" for graduate students at MIT and WHOI, who learn about professional and personal topics and choices in one lecture from people such as WHOI Director Susan Avery. BIG also sponsored "Ocean Stories: A Synergy of Art and Science", a 4-month running exhibition at the Museum of Science, Boston. The project paired eight Boston and Cape Cod professional artists with ocean scientists from MIT and WHOI to develop novel methods of public engagement with oceanography. Their work was a visual dialogue exploring the broader impacts of science and the multi-faceted nature of research.

WHOI is currently leading a national ocean community diversity initiative (OceanOpportunities and on Facebook) that originated at a WHOI-hosted June, 2012, workshop supported by the Deerbrook Charitable Trust. Minority students, particularly African-, Hispanic-, and Native-Americans, are poorly represented in U.S. ocean science graduate programs and in careers that require an MS or Ph.D. in ocean science. As one of the *OceanOpportunities* activities, WHOI arranged for undergraduate STEM students from minority-serving institutions/programs to visit University of South Florida Department of Marine Science (undergraduate students from Xavier-Louisiana and Dillard), Scripps (students from California State colleges), and WHOI (students from Howard University) in spring and fall, 2013. The students met with faculty, academic administrators and graduate students to learn more about opportunities for summer undergraduate research at ocean science institutions, ocean science graduate programs and ocean science careers. We are learning that even a brief exposure to an ocean science institution stimulates interest in the ocean sciences—interest we hope will translate into more students and postdocs from underrepresented minorities.

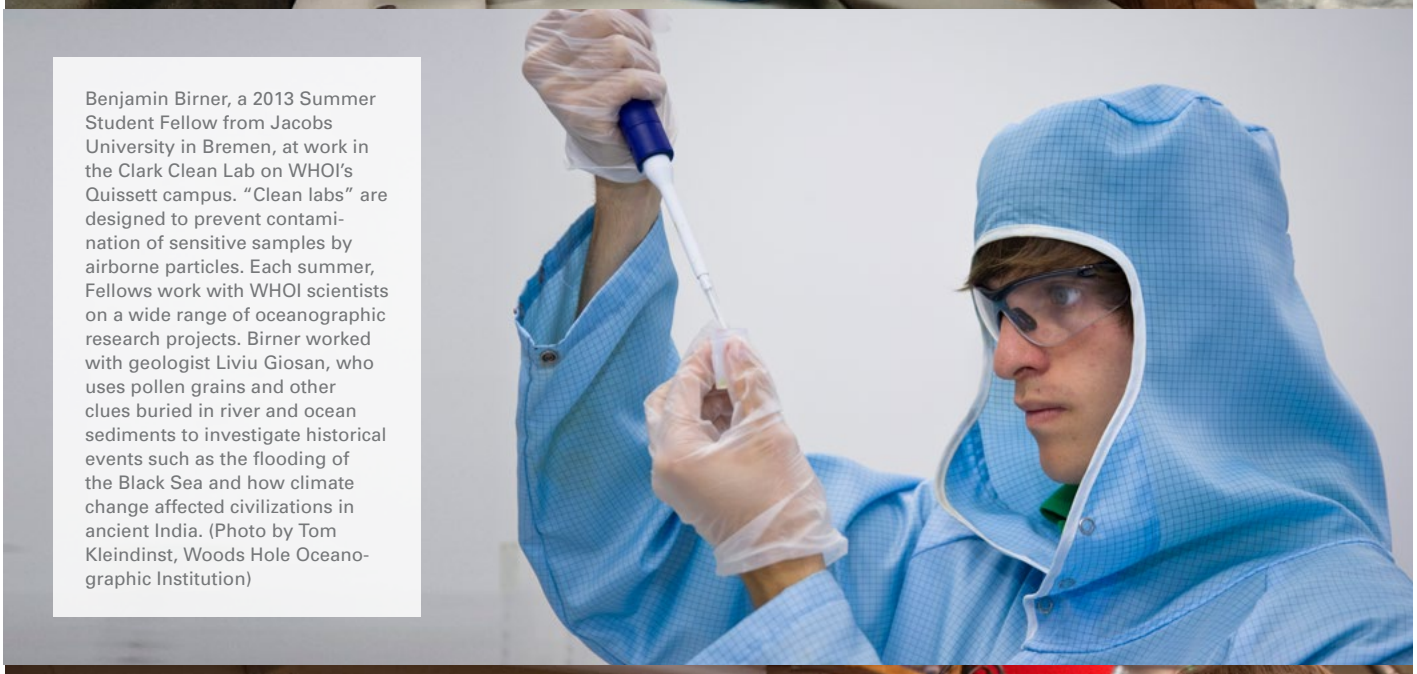
During the 2012-13 academic year, the Massachusetts Institute of Technology-WHOI Joint Program awarded 8 masters' and 25 doctoral degrees in ocean science and engineering. As of fall, 2013 JP enrollment was 125 students split between WHOI and MIT advisers, 56 percent of whom are women. Our Summer Student Fellow program for undergraduates (juniors) trained 31 students during summer 2013, representing 31 U.S. and international colleges and universities. WHOI averaged approximately 85 postdocs in residence during 2013.

—James Yoder, Vice President for Academic Programs & Dean

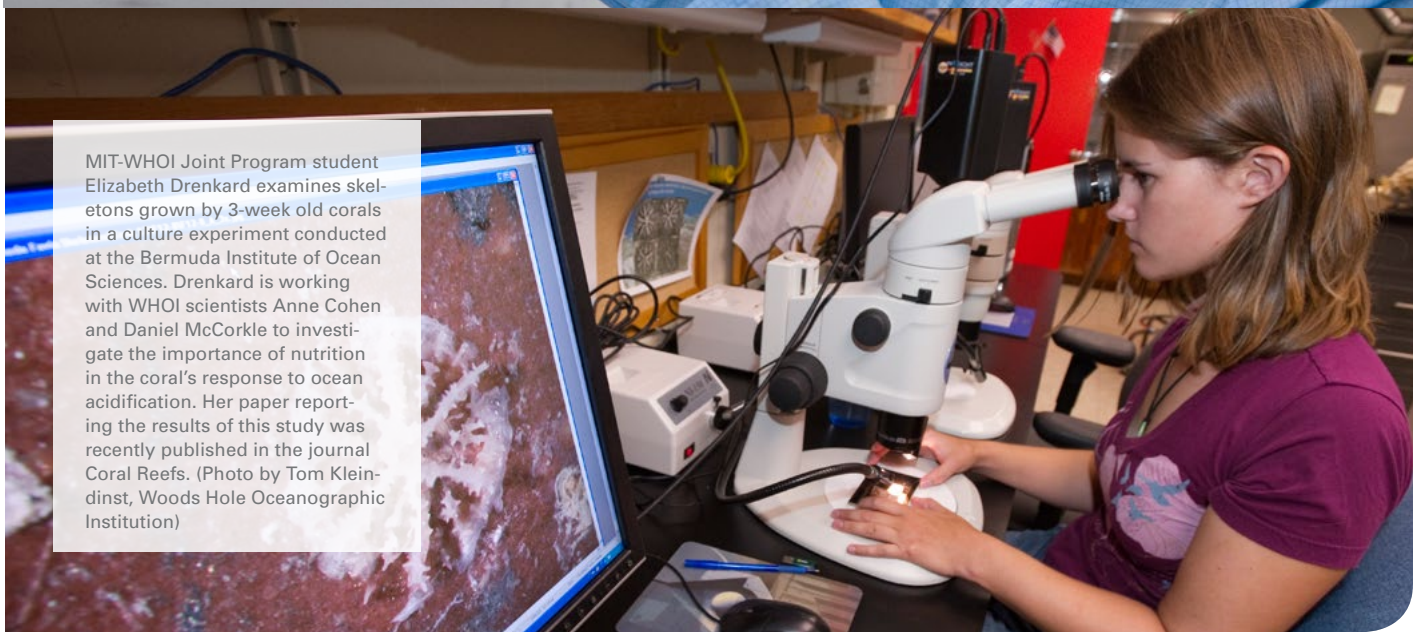
Jim Yoder and past dean John Farrington at the 2013 MIT/WHOI Joint Program Graduation Reception. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

Alterra Sanchez, a 2013 Summer Student Fellow from San Diego State University, readies an optical cell for making pH measurements in a high-precision spectrophotometer. The cell contains a pH indicator and seawater from a local marsh. Each summer, Fellows team with WHOI scientists on a wide range of oceanographic research. Sanchez worked with marine chemists Zhaohui 'Aleck' Wang of WHOI and Kevin Kroeger of USGS on a "blue carbon" project that examined the marsh's ability to export carbon dioxide to coastal waters. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

In a refrigerated room, MIT-WHOI Joint Program graduate student Alison Criscitiello saws ice cores from the Pine Island Shelf, where the Pine Island Glacier extends from West Antarctica into the Southern Ocean. The shelf is vulnerable to melting from the summer sun and from warming ocean waters. With her advisor, WHOI glaciologist Sarah Das, Criscitiello studied whether climate change is affecting sea ice formation around the continent and speeding the flow of glacial ice to the ocean (see video). She defended her thesis successfully handed in her Ph.D. thesis December 20, and is now Dr. Criscitiello. (Photo by Luke Trusel, Clark University)

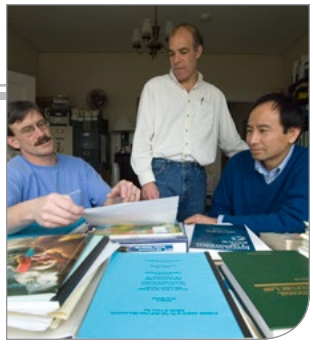


Benjamin Birner, a 2013 Summer Student Fellow from Jacobs University in Bremen, at work in the Clark Clean Lab on WHOI's Quissett campus. "Clean labs" are designed to prevent contamination of sensitive samples by airborne particles. Each summer, Fellows work with WHOI scientists on a wide range of oceanographic research projects. Birner worked with geologist Liviu Giosan, who uses pollen grains and other clues buried in river and ocean sediments to investigate historical events such as the flooding of the Black Sea and how climate change affected civilizations in ancient India. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)



MIT-WHOI Joint Program student Elizabeth Drenkard examines skeletons grown by 3-week old corals in a culture experiment conducted at the Bermuda Institute of Ocean Sciences. Drenkard is working with WHOI scientists Anne Cohen and Daniel McCorkle to investigate the importance of nutrition in the coral's response to ocean acidification. Her paper reporting the results of this study was recently published in the journal Coral Reefs. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

Marine Policy Center



Left to right, Porter Hoagland, Andy Solow, and Di Jin of the Marine Policy Center. (Photo by Tom Kleindinst, Woods Hole Oceanographic Institution)

Hauke Kite-Powell

One of the most common causes of shellfish poisoning in humans is a naturally occurring group of bacteria called vibrio. The number of confirmed cases of vibrio-related illness – due mainly to the consumption of raw oysters – has been increasing in Massachusetts, reaching 58 in 2013. As with many gastrointestinal illnesses, the unreported number of cases is believed to be many times higher. It is unknown how much of this increase is due to improved disease diagnosis and reporting, increased consumption of oysters, or an increase in the concentration of vibrio in coastal waters, possibly connected to climate change.

Until recently, the main regulatory tool for controlling vibrio poisoning has been to identify and close shellfish beds to which confirmed cases of illness can be traced. A notable local example was the closure in August 2013 of oyster farming operations in the towns of Duxbury, Kingston, Plymouth, and Marshfield. This single closure is estimated to have caused a financial loss of nearly $1 million.

The substantial financial impact of closures has not gone unnoticed and, as a result, the Massachusetts Department of Public Health collaborated with the Massachusetts Department of Marine Fisheries to develop a vibrio control plan aimed primarily at harvesting and distribution practices. As warmer temperatures promote vibrio growth, the new regulations involve limiting exposure of oysters to direct sunlight during harvesting and keeping their temperature down after harvest through icing or refrigeration techniques.

Improved harvesting and post-harvest handling practices are one approach to reducing the risk of vibrio infection from oysters. Two others are improved growing practices and monitoring. For these, we need a better understanding of the factors controlling the concentration and pathogenicity of vibrio in oysters in the ocean. The situation is complicated because there are several potentially pathogenic species of vibrio in oysters (including *V. vulnificus* and *V. parahaemoliticus*), each of which can respond to environmental factors in different ways. These factors are thought to include water temperature, duration of exposure of oysters to elevated temperature during low tides on sunny days, and the proximity of oysters to reservoirs of vibrio, such as organic matter on the seabed. The relationship between these factors and vibrio concentrations and pathogenicity are not well understood, making it difficult to design effective growing practices and monitoring strategies that reduce or eliminate risks to public health.

Led by Research Specialist Hauke Kite-Powell, a team from WHOI's Marine Policy Center, including Senior Scientist Andy Solow and Guest Student Katie Sperry (Carleton College), is working with colleagues from Roger Williams University and Saquish Scientific and oyster growers in Duxbury and Wellfleet to study these relationships and determine which growing practices—such as moving oysters to deeper, colder water or keeping them off the seafloor—may reduce vibrio concentrations and pathogenicity. This project is a good example of how scientific understanding can promote economic activities that are protective of the public interest.

—Andy Solow, Center Director

Marine Operations

Rob Munier holding the etched viewport celebrating Alvin's 50th. (Photo by Jayne Doucette, Woods Hole Oceanographic Institution)

R/V *Neil Armstrong*

Woods Hole Oceanographic Institution's (WHOI's) Marine Facilities and Operations Department had a very active year in 2013 which included fascinating science cruises, the certification of upgraded HOV *Alvin* and the continued construction of R/V *Neil Armstrong*.

R/V *Atlantis* began its year in Woods Hole and ended the year working in the Pacific Ocean conducting several science cruises with the aid of ROV *Jason* and AUV *Sentry*. The upgraded *Alvin* certification cruises and sea trials were conducted successfully from *Atlantis* while in the Pacific Ocean. While *Atlantis* spent its time on the West Coast, ending the year in Costa Rica, R/V *Knorr* travelled the world beginning in Cape Town, South Africa and ending its year in Woods Hole. In between, *Knorr* assisted with many science cruises, some of which also included the use of AUV *Sentry*. The final cruise of the year represented the initial infrastructure deployment for the Pioneer Array of the National Science Foundation's Ocean Observatories Initiative (OOI), which was carried out successfully.

HOV *Alvin*'s upgrade was completed this year; both the certification and sea trials were successfully conducted leading the way for *Alvin* science cruises in 2014. Upgrades included installation of a new, larger personnel sphere with an ergonomic interior; five viewports to improve visibility and provide overlapping fields of view; new lighting and high-definition imaging systems; new syntactic foam providing buoyancy; and an improved command-and-control system. For further information on Alvin, please look here.

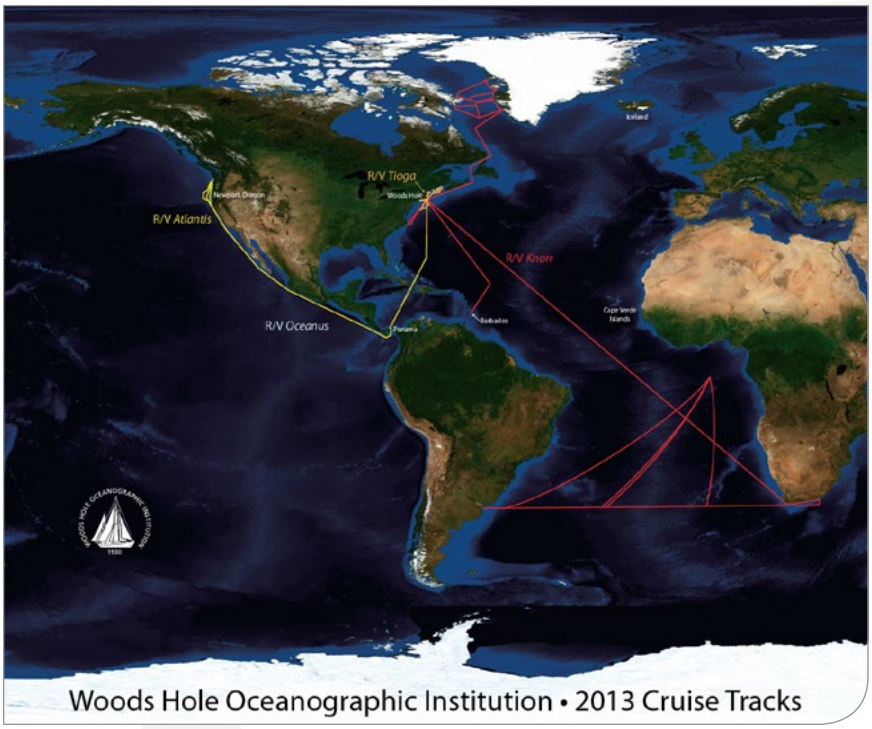
R/V *Neil Armstrong* construction continued vigorously at Dakota Creek Industries in Anacortes, WA throughout 2013. In December the ship was being readied for Synchro-lift, launch and christening, all to take place early 2014. More information regarding R/V *Neil Armstrong* may be found here.

The goals of WHOI's *Access to the Sea* endowment are to provide the resources to maintain state-of-the-art seagoing platforms, develop new technology to observe and sample the ocean, and provide the freedom and flexibility needed to utilize this technology to develop new approaches to study the oceans. The 2013 call for proposals attracted 15 submissions, with seven being funded for a total of $298,000. Studies will include climate change, coral reef health, measuring biodiversity and the monitoring of phytoplankton blooms over an annual cycle.

WHOI operates a fleet of deep sea vehicles in the National Deep Submergence Facility for the national oceanographic community. During the HOV *Alvin* upgrade, both ROV *Jason* and AUV *Sentry* assisted scientists with their important work.

Again in 2013, WHOI was the recipient of generous funding from The Dalio Family Foundation and Ray Dalio. Projects included sperm whale physiology off Kaikoura, New Zealand and development and testing of a prototype ROV. The Dalio Explore Fund was established and several new projects were funded, including studies of the Hannibal Seamount off Panama, the geology of the Galápagos, the coral reefs of Cuba and Adélie penguin population studies in Antarctica. The field programs for these projects will be performed in 2015. WHOI continues to provide support to the operation of the M/V *Alucia*.

—Robert Munier, Vice President for Marine Facilities and Operations



Woods Hole Oceanographic Institution • 2013 Cruise Tracks

Financials

Jeffrey Fernandez (left) and WHOI Trustee Bob James (right) at the with R/V *Neil Armstrong* christening ceremony in Anacortes, Washington. (Photo by Dick Pittenger, Woods Hole Oceanographic Institution)

Letter from Jeffrey Fernandez, Vice President for Finance and CFO

Woods Hole Oceanographic Institution (WHOI) faced several challenges in 2013. These ranged from managing cost increases in our unrestricted budget, reduced federal funding and cost containment pressures to keep the Institution competitive with others in their field. We successfully identified and implemented several operational efficiencies this year, and we will continue to evaluate costs and cost distribution methods, in order to offer scientists and their sponsoring agencies the most cost-effective research. Once again the Institution received an AA- rating with a stable outlook from Standard & Poor's. This favorable rating will enable the Institution to continue and further relationships with business partners, both federal and non-federal. We also continue to succeed in building stronger controls, processes, and systems to support our science and an evolving organization.

Statement of Financial Position

WHOI continues to have a strong balance sheet. At December 31, 2013 WHOI's total assets were $562.5 million, total liabilities were $231.9 million and total net assets were $330.6 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 $57.6 million.

The endowment, $396.3 million, represents 70% of the total assets at December 31, 2013.

Statement of Activities

WHOI's total operating revenues increased by $2.9 million; from $213.5 million in CY 2012 to $216.4 million in CY 2012; and the Institution's change in net assets from operating activities was ($1.3) million.

$16.5 million of endowment income and appreciation was distributed to operations as follows:

- Education $6.9 million
- Research $5.7 million
- Unrestricted $3.9 million

The Institution had overhead costs of $87.5 million, and approximately 66% of that amount, $57.8 million, was recovered from the government and non-government research. The remainder was institutional expenses.

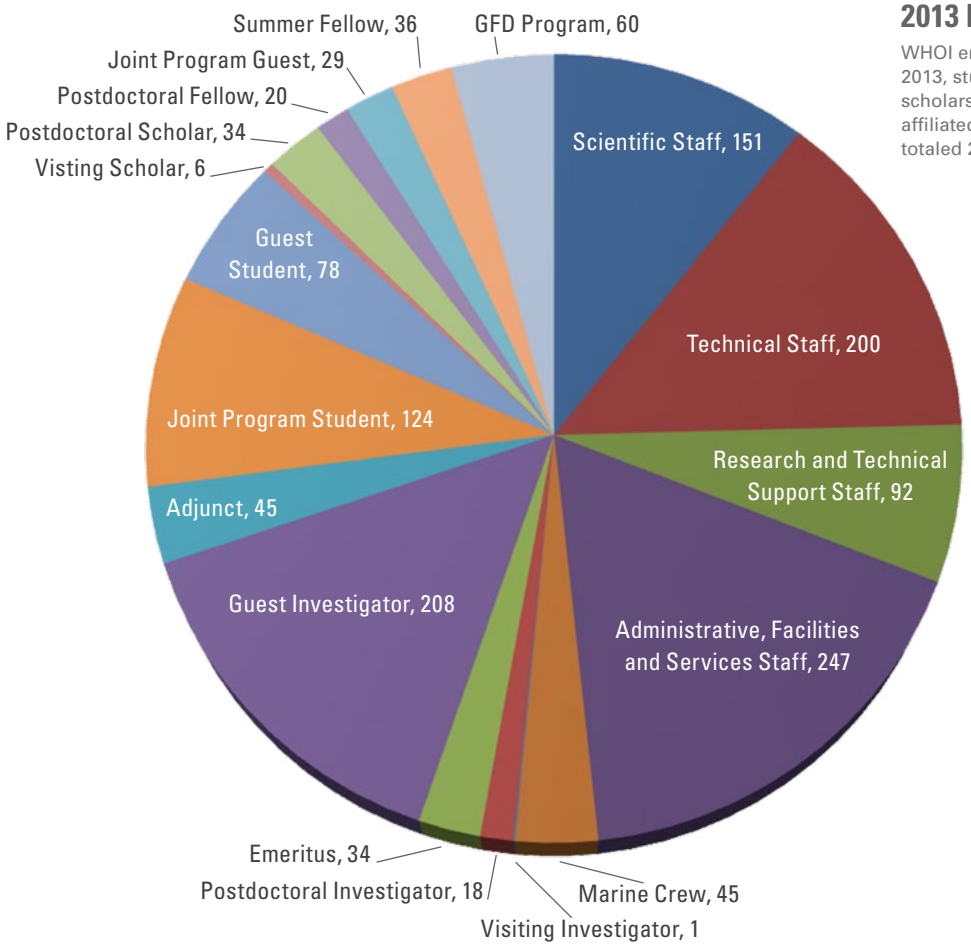
WHOI paid $4.8 million in interest during CY 2013 and $1.6 million in principal payments on the $57.6 million outstanding debt in CY 2013. The Federal government allows interest and depreciation for real property and equipment in the Institution's overhead rates for reimbursement.

Summary

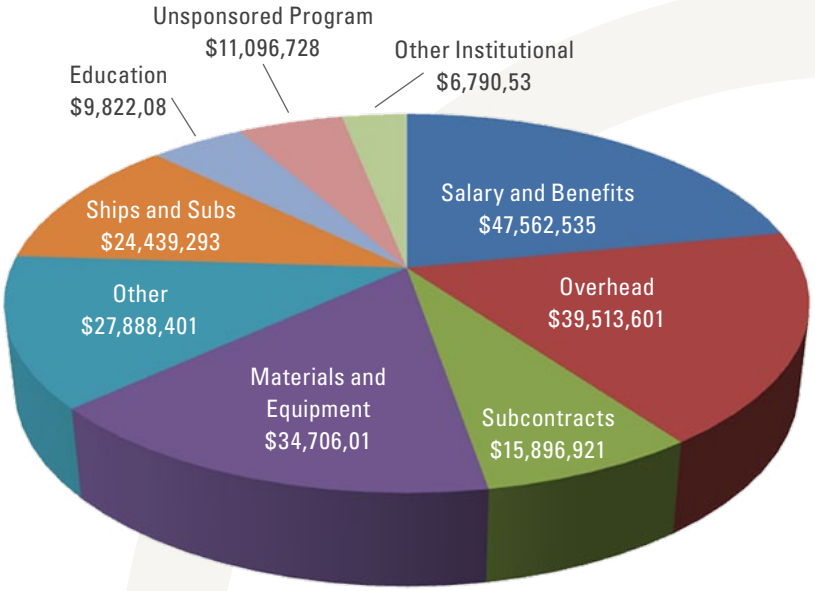
The Institution's commitment to understanding the ocean is unchanged; however, the federal funding environment continues to provide a challenge. WHOI is looking to expand its sources of revenue by leveraging its industry recognized core skills in both the federal and industry marketplaces. We have begun an Institution-wide initiative to examine WHOI's blueprint for success in future years.

2013 People

WHOI employees totaled 788 in 2013, students, postdocs, and scholars totaled 387, and others affiliated with the Institution totaled 253.



2013 Operating Expenses



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