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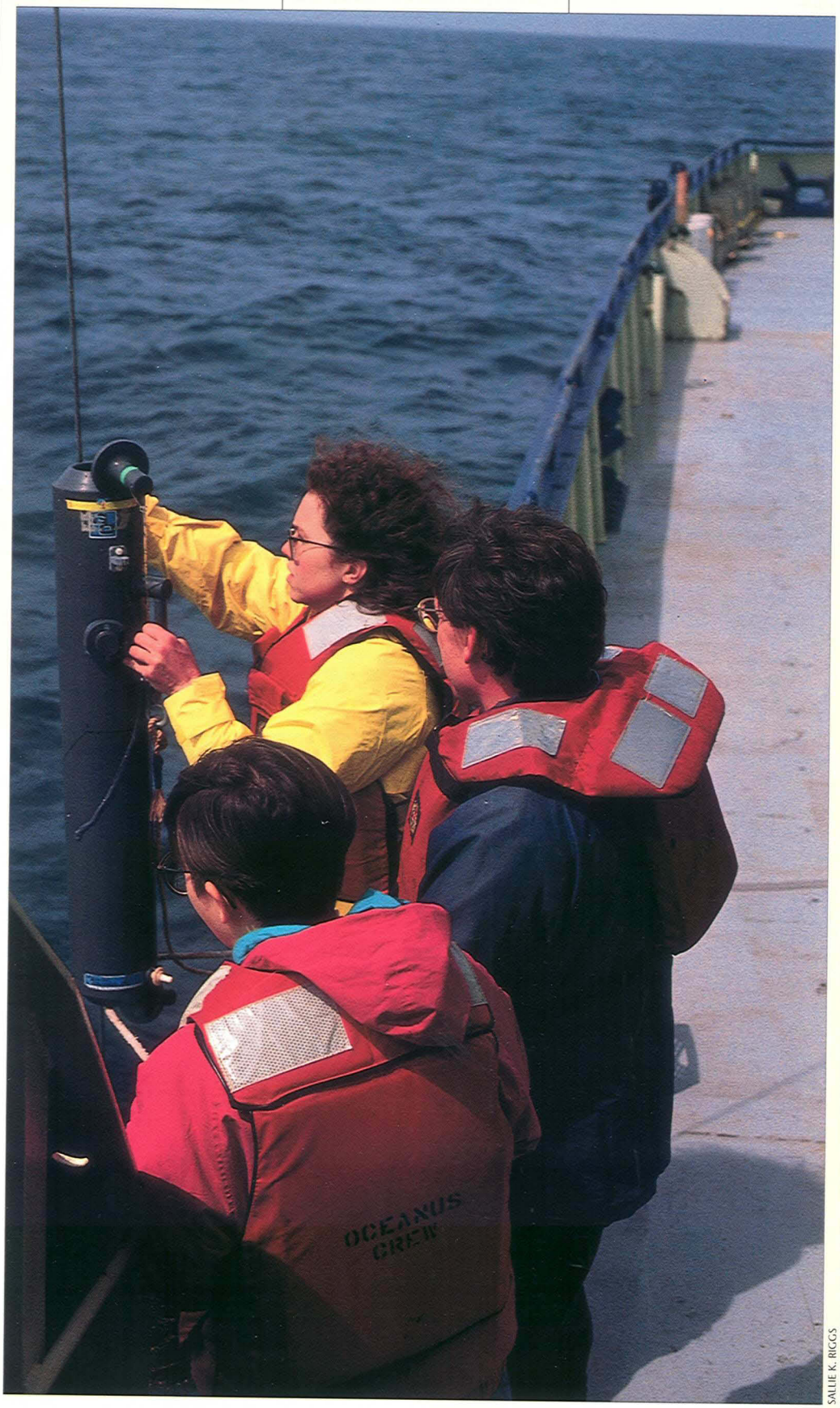


SALLIE K. RIGGS

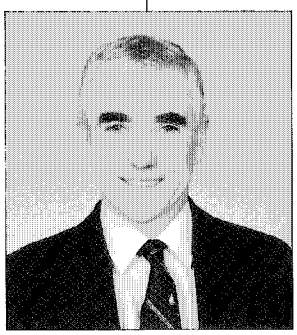
Joyce Irvine (yellow jacket), Dan Repeta, and Lisa Kujawinski set up a water sampling bottle aboard R/V Oceanus.

DIRECTOR'S COMMENTS

TOM KLEINDINST

Russian scientists Mark Slavinsky, left, and Boris Bogolubov provided this sound source for an experiment designed to map climatic temperature changes with sound.

1992 was a year of rising expectations for the Institution and its science. The June United Nations Conference on Environment and Development in Rio de Janeiro and our own Presidential election in November both focused attention on the environment and its interaction with society. A basic science organization like ours—whose work generates the knowledge that underlies and informs environmental policy decisions and educates tomorrow's scientific leadership—faces real challenges from this increased societal attention. We must simultaneously retain our focus on the basic science questions, and forge the links to applied researchers, policy makers, industry, and the public that speed our progress to a healthier world. Locally and globally, we did well at both.



TERRI CORBETT

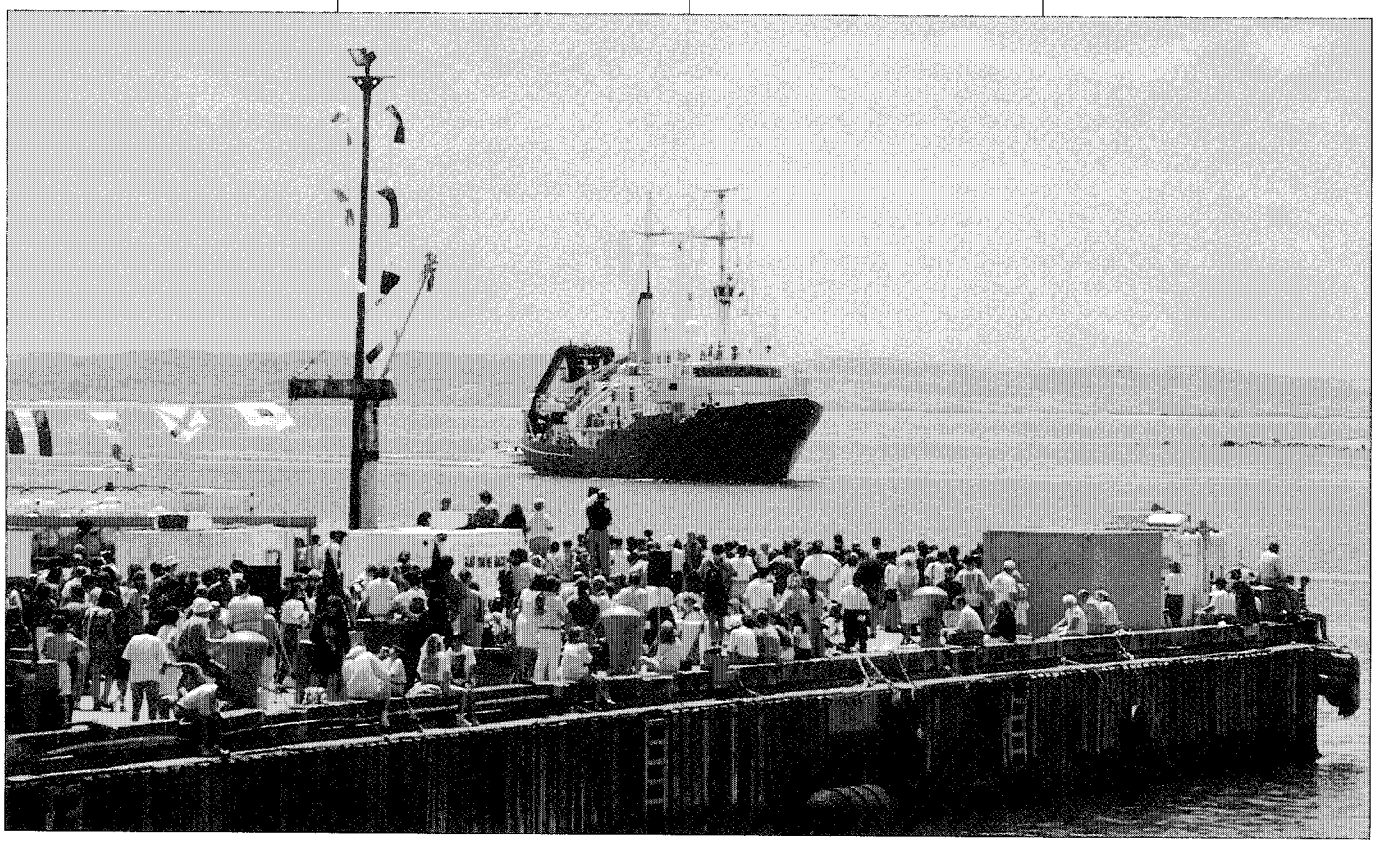
Craig Dorman

Each year we check both our strategy and our strengths. We remain committed to the simple formula that defines us: Our purpose is the acquisition, analysis, and wide dissemination of knowledge of the sea. In 1992, our "health" check took the form of a Visiting Committee—actually six

TERRI CORBETT

Research vessels Oceanus, Atlantis II, Asterias, *and* Eagle Mar *are tied to the WHOI pier in this aerial view of Woods Hole.*

Director's Comments



TERRI CORBETT

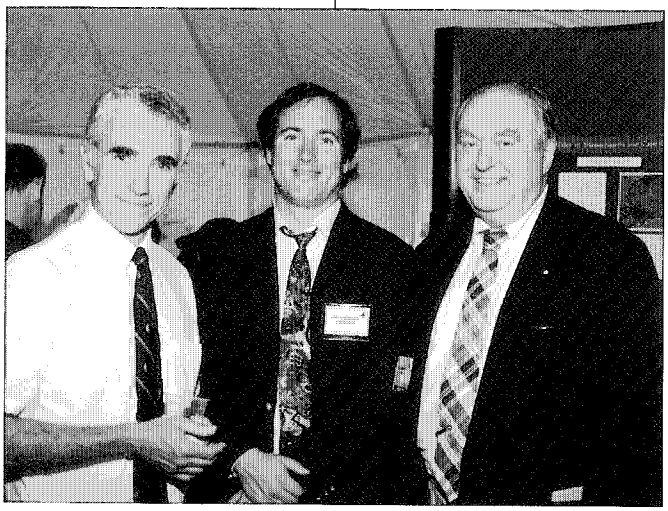
With a welcoming crowd on the pier, Atlantis II *concludes a two-and-one-half-year cruise, the Institution's longest ever, on June 10, 1992.*

groups of renowned scientists and administrators, including our own Trustees and Corporators, that reviewed our five science departments and our management. We went on a Retreat to analyze the findings, and reported at our Annual Meeting that our science was strong, our education program superb, and our management initiatives focused on strengthening administrative skills, professionalism, and fiscal integrity.

In 1992 we welcomed *Atlantis II* and *Alvin* back from an extended tour in the Pacific, sent the newly modified *Knorr* off to that ocean for the flagship cruises of the World Ocean Circulation Experiment, and worked *Oceanus* hard in the eastern Atlantic where we have several major experiments underway. We balanced our Institution operational budget, significantly increased our federal support of research, had a record fund-raising year, established the foundation of a new industrial liaison thrust, welcomed an inspiring class of postdocs and Joint Program students, expanded our scientist-to-scientist and institutional outreach in the states of the former Soviet Union, awarded our coveted Bigelow Medal, saw with pride our own researchers win similar prizes in many fields, and—to renew, update, and clarify commitments by our Trustees—held the first-ever Trustees' Retreat.

One thing stands out in my mind above all. Many of our sister institutions, in looking at the same challenges we see, have decided to change course. They have de-emphasized the oceans, put their resources into weather, or climate, or land-related studies. Many of them also are saddled with crippled state budgets. We've looked deeply at ourselves, and held our course. WHOI remains committed to seagoing science, to the oceans, and to basic research and the education that is intrinsic to the research process. And we're pleased with, and have reason to be proud of, our commitment, our strengths, and our contributions to society.

Craig E. Dorman
Director



DAVE GRAY

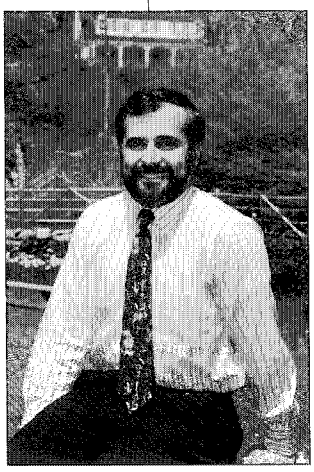
Director Craig Dorman visits with Mike Conner, center, of the Massachusetts Water Resources Authority and Associate Robert Selle at the annual Associates Day of Science.

Senior Associate Director's Comments

Events and developments of 1992 further affirm our prediction that the 1990s will be a decade of extraordinary change and opportunity for the ocean sciences. The development of new sensors and instruments that can be used above, on, and below the sea to collect data year round, and to interrogate, compress, and transmit the data to land-based stations, has completely changed the way we think about our science. New data manipulation, storage, and retrieval mechanisms now allow us to interpret our data in very different ways. These technical advances allow ocean observation on a three-dimensional space scale over varying time scales, a far cry from the traditional single-point measurements that were almost all we had until recently.

The Global Ocean Observing System (GOOS) program being formulated by a number of federal agencies, including the National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF), is an example of this new approach. This program will allow us to observe and predict the nature of ocean dynamics by the end of the decade, much in the same way weather is now predicted for the atmosphere. Institution scientists are playing a major role in these advances. Examples noted in the departmental research summaries include:

- using the acoustic properties of the ocean in global change research and in studies of seafloor and sea-ice morphology;
- employing laser techniques to identify plankton;
- telemetering data collected by new buoys and sensors from harsh environments, such as polar regions, to scientists' laboratories;
- large-scale measurement of carbon dioxide and organic carbon in the ocean; and
- measuring and modeling the role the atmosphere plays in controlling the dynamics of semi-enclosed seas, such as the Mediterranean, and the exchanges through their connecting straits.



TOM KLEINDINST

Robert Gagosian

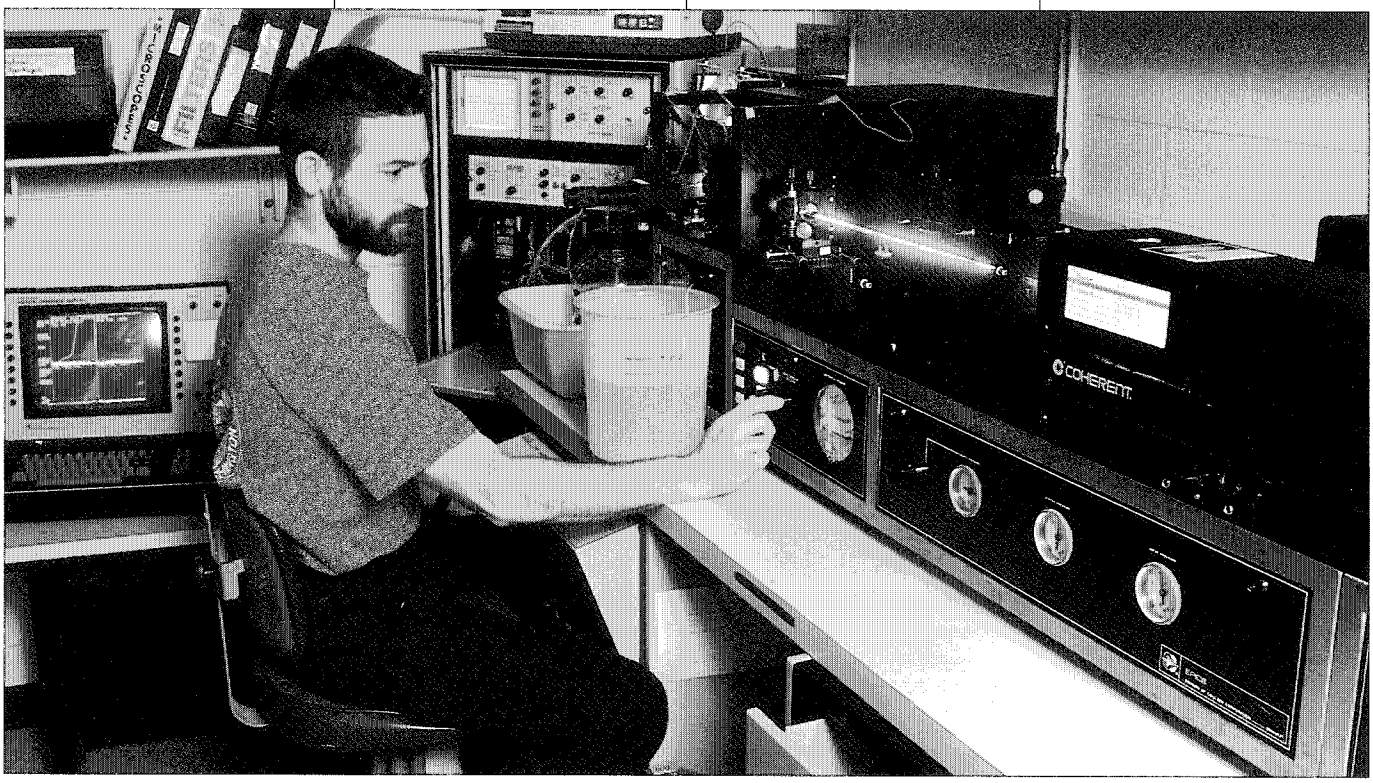
The global nature of many of our research efforts requires us to think about new mechanisms for providing the infrastructure support and opportunities necessary to accomplish the research objectives of many of the climate change programs. The federal agencies understand that these research efforts are larger and more complex than any one agency could manage, so a stronger partnership was formed between the agencies to address the issues needed for success.

The Committee on Earth and Environmental Sciences of the Federal Coordinating Council for Science, Engineering and Technology has been a model for success in coordination among agencies addressing the complexity of the Global Climate Change Programs. This cooperation

SUSUMU HONJO

Rick Krishfield, left, and John Kemp deploy an Ice Ocean Environmental Buoy near the North Pole.

Senior Associate Director's Comments



TOM KLEINDINST

Research Associate Erik Zettler uses the flow cytometer, a laser based optical instrument, in Robert Olson's lab to analyze individual phytoplankton cells that are not detectable using traditional microscope techniques.

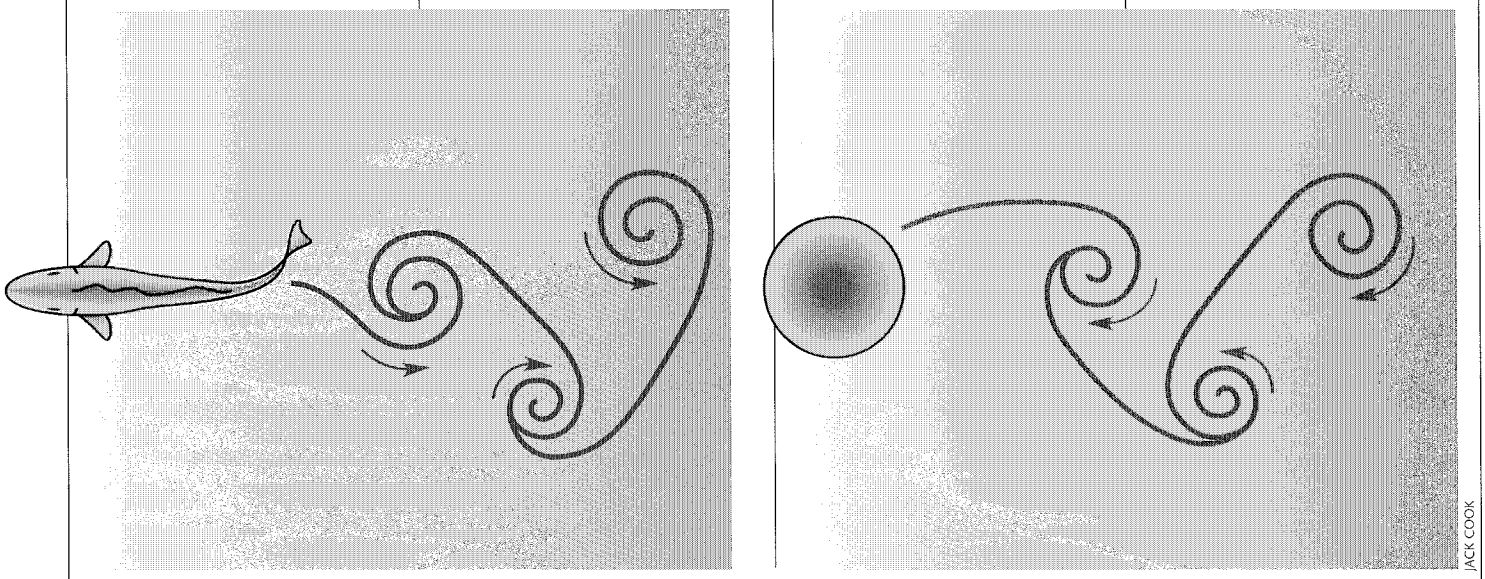
now needs to extend further to the institutions undertaking the research. The Ocean Studies Board of the National Research Council, in a recent report entitled *Oceanography in the Next Decade,* suggested that closer partnerships be formed between the academic research community and the sponsoring federal agencies. This suggestion is broadly supported by the academic community, including this institution. We have a Memorandum of Understanding with the National Ocean Service of NOAA, the lead agency in the GOOS Program, and we are in the process of completing an agreement with the National Marine Fisheries Service to better coordinate our mutual interest in areas such as Georges Bank and the Gulf of Maine. Through these partnerships we can apply efficient and enhanced intellectual and infrastructural capabilities to the complex technical and large-scale scientific challenges facing each organization.

In addition to the need for more cooperation and coordination between federal sponsors and sister institutions, we must monitor federal changes in the direction of the U.S. research enterprises. Most important to WHOI is the current re-evaluation of the National Science Foundation's charge and mission. There is discussion of broadening the Foundation's role to include support of more strategic and possibly more directed research than in the past. In addition, the Office of Naval Research is reorganizing to better serve U.S. defense establishment needs in light of world political change. The agency's shift toward coastally oriented research has been rapid and dramatic.

Institution scientists were very successful during 1992 in obtaining funds from both NSF and ONR, and the WHOI government-sponsored research budget increased 16 percent (9 percent excluding ship support) over the 1991 budget. However, we are quite dependent on these two agencies (NSF supplied 49 percent and ONR 33 percent of our 1992 government-sponsored research). We need to monitor and understand how the changing roles and goals of these two agencies influence our research strategy and plans.

Although the new administration in Washington is very supportive of environmental research, the focus appears to be more on strategic and directed research rather than on basic or curiosity-driven research. This means that the more mission-oriented agencies, such as the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, and the Department of Energy, will probably receive the majority of new funding. We must position ourselves for these changes. Given our world-class research staff and facilities, and the opportunities presented by a changing world, the next several years offer an unparalleled opportunity for major advances in understanding how our ocean works and interacts with other components of Earth's system, the atmosphere, and land masses.

Robert B. Gagosian
Senior Associate Director
and Director of Research



JACK COOK

A fast-swimming fish oscillates its tail to produce a staggered array of vortices. The rotation of these vortices is such that the average flow behind the fish is a jet that produces a thrust and squirts the fish forward. A bluff object moving through fluid also leaves behind a staggered array of vortices. However, these vortices have an opposite rotation to those of a fish, and the mean flow of fluid (and momentum) is directed upstream, resulting in a drag force that opposes the motion of the body.

The Applied Ocean Physics and Engineering (AOP&E) Department conducts a unique blend of activities that includes both fundamental research in applied ocean physics and ocean engineering science and the development of instrumentation for scientists at WHOI and the oceanographic community at large. The department, with 140 staff members and 30 graduate students, is the Institution's single largest unit. The diversity of the AOP&E Department's activities is reflected in the names of its eight laboratories: Coastal and Ocean Fluid Dynamics, Ocean Acoustics, Ocean Systems and Moorings, Advanced Engineering, Instrument Systems Development, Oceanographic Systems, Deep Submergence, and Submersible Engineering and Operations.

In January 1992, Sandy Williams stepped down as Department Chair after more than four years of dedicated service. George Frisk took over as Chair in August following a six-month transition period in which Robert Ballard, James Lynch, and Timothy Stanton served as interim chairs. The transition period served to unify and strengthen the department and triggered the formation of a governing body called the Chair's Council, which consists of Frisk, the laboratory heads, and those who serve as interim chairs.

Robert Ballard received the U.S. Navy's Robert Dexter Conrad Award for Scientific Achievement, and George Frisk received a 1992 Office of Naval Research Ocean Science Educator Award. The latter recognizes contributions to ocean science education and is intended, through the use of postdoctoral fellowships, to support the conversion of scientists outside the field into oceanographers.

AOP&E's research and development activities include laboratory experiments, field programs, and theoretical work. Three projects representative of these efforts are described here.

Research Gives Underwater Vehicles "Something to Flap About"

Nature has created, in fish and cetaceans, a highly efficient propulsion system capable of producing remarkably fast speeds. For example, tuna can maintain speeds of 20 knots for several hours. In bursts, they have been observed traveling at rates up to 40 knots. What makes their performance more remarkable is that it has been accomplished with a muscular structure similar to that of a human being. Biologists estimate that 50 pounds of muscle in a 200-pound tuna can produce 0.5 horsepower, comparable to the power output of a well-trained athlete of the same weight. Yet, tuna can far outdistance not only the best human swimmers, but also existing underwater vehicles equipped with comparable power.

Fast-swimming fish develop thrust by flapping their tails. As they flap, they spin off vortices into the wake alternately from side to side, much the way vortices are shed behind a bluff (non-streamlined) body as it is dragged through the water. However, vortices shed behind a flapping fish tail rotate in the opposite direction from vortices that are shed from a bluff body.

Mark Grosenbaugh, Michael Triantafyllou (Massachusetts Institute of Technology, MIT), and George Triantafyllou (City College of New York) knew from studies of water flow around bluff objects that the wake arising from the spinning vortices produces drag on the body. They reasoned that the opposite-spinning vortices thrown off by a fish tail

must produce thrust through the creation not of a wake but of a jet—a hydrodynamic spurt that pushes the fish through the water. For this theory to be correct, fish would have to flap their tails according to the same hydrodynamic principles that govern wake production by bluff bodies. It has been known that bluff bodies form vortices at a very distinct frequency. But the question remained: Does fish propulsion also have a preferred frequency?

A number called the Strouhal number ties together frequency of tail flapping, amplitude of tail motion, and forward speed of the fish. The researchers calculated, that maximum efficiency would be achieved if the fish flapped its tail with a Strouhal number of 0.3. A check of the biology literature yielded measurements of 13 fast-swimming fish and cetaceans, from goldfish to dolphins, all of whom flapped their tails at Strouhal numbers between 0.25 to 0.35.

The ultimate goal of the research is to implement a flapping-foil propulsor on an underwater vehicle. Such a device would improve efficiency and increase the range and speed of low-power automomous vehicles.

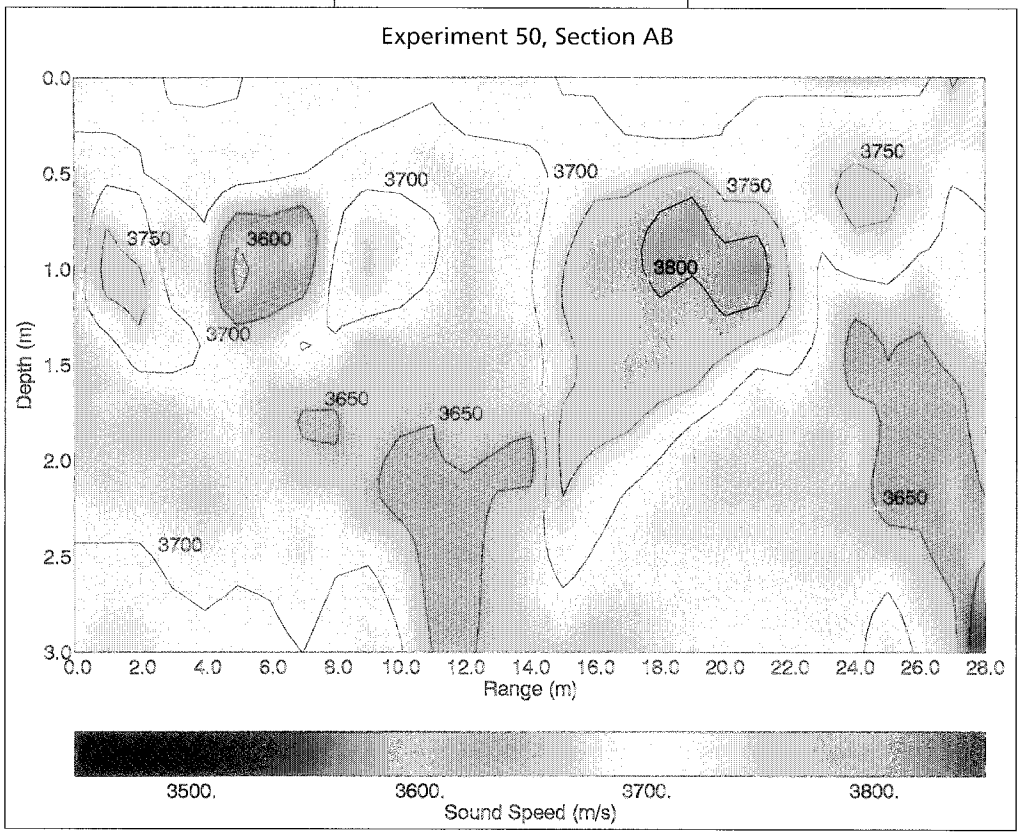
This work has been funded by the Defense Advanced Research Program Agency (DARPA) and the MIT Sea Grant College Program.

Laboratory Works Toward Imaging Acoustic Properties of Ocean Boundaries

Uses of sound in the ocean range from location of objects on the seafloor to measurement of sound-speed structure for global warming studies. Ocean boundaries, whether the ocean floor or a polar ice sheet, play an important role in sound propagation. Their acoustic properties, such as the speed of sound in the medium, the rate at which the sound waves decay as they propagate, and the density of the medium, affect the propagation of sound. The Ocean Acoustics Laboratory (OAL) is developing experimental methods and data-analysis algorithms for estimating the acoustic properties of these boundaries. This is an extremely difficult problem because of the limitations on in situ measurements. Over the years, OAL scientists have developed remote-sensing methods as well as robust analysis tools for obtaining estimates of shallow-water sediment acoustic properties, and they have

SUBRAMANIAM RAJAN

Scientists prepare to deploy remote-sensing equipment for sea-ice tomographic studies in the Arctic.

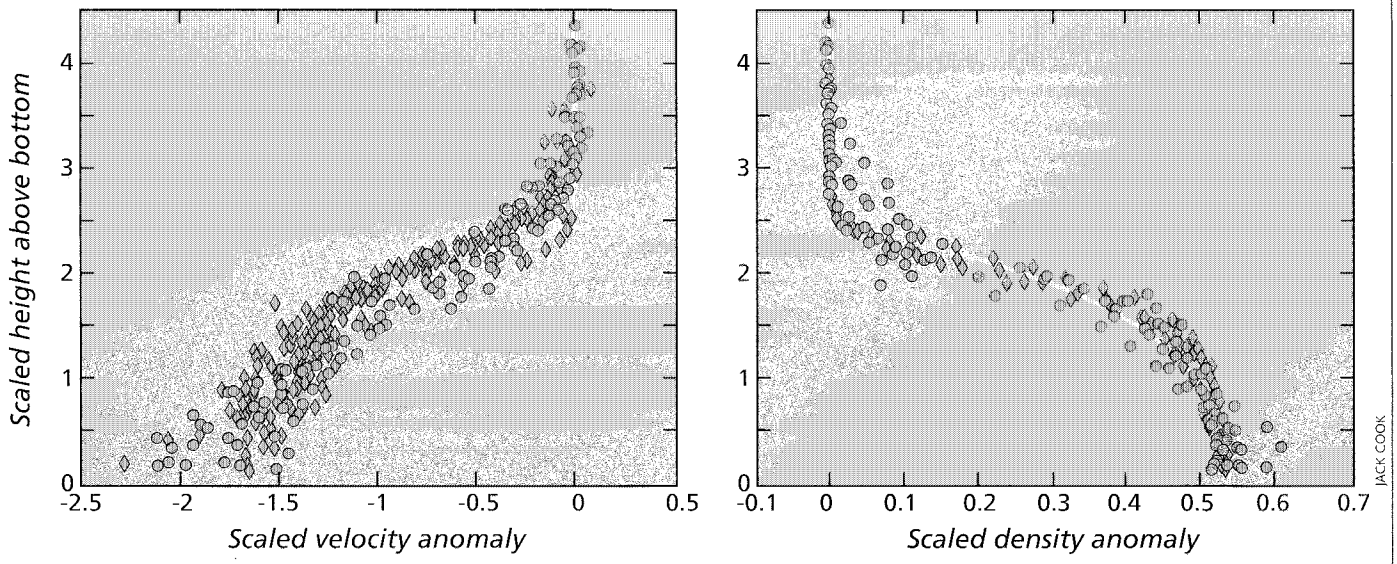


Contour plot of sound-speed structure in multi-year sea ice. The low- and high-speed regions of the complex structure scatter sound that interacts with them.

employed tomographic (similar to medical CAT scan) imaging methods for obtaining high-resolution images of the acoustic properties of sea ice. The laboratory's main goals in these areas are to obtain a three-dimensional image of the boundaries' acoustic properties and to investigate their time variability. An Office of Naval Research-funded tomographic system was deployed in the Arctic in April 1992 for studies of sea-ice acoustic property time variability. This system, which can operate unattended, initiates a new tomography experiment every three days. Data were stored locally for retrieval at the end of the experiment in April 1993. Information transmitted via satellite helps the laboratory monitor the system's operation, which has been successful except for a brief period of failure in May 1992. The team sent to repair the system found that the cables had been tampered with (probably by polar bears). Analysis of the data will help understanding of seasonal variability of the acoustic and mechanical properties (inferred from the acoustic properties) of sea ice.

Model Describes Fluid-Mud Flows On the Amazon Continental Shelf

One of the most dramatic results of AMASSEDS (A Multidisciplinary Amazon Shelf SEDiment Study, funded by the National Science Foundation) was the observation of thick layers of fluid mud over the continental shelf off the mouth of the Amazon River. They were identified in AMASSEDS field work between 1989 and 1991 by Gail Kineke (a University of Washington graduate student during AMASSEDS field work and currently a WHOI post-doctoral investigator) and Richard Sternberg (University of Washington). The fluid-mud layers have thicknesses on the order of a few meters, and they are characterized by large sediment concentrations (tens to hundreds of grams per liter) and large reductions in velocity (several tens of centimeters per second) relative to the overlying flow. John Trowbridge has proposed a dynamical model that explains the structure of these layers under conditions in which the sediment concentration is not too large (tens as opposed to hundreds of grams per liter). The model is based on the idea that the density anomaly associated with the suspended sediment has an effect similar to that of the density anomaly produced by stratification due to heat or salt in more ordinary oceanic and atmospheric flows. The model reproduces the main features of the measurements and also provides two insights: the fluid mud reduces the flow's bottom drag by an order of magnitude, and the dynamics limit the sediment load that may be carried in this mode to a narrow range. These findings are important to understanding the fate of sediments on the Amazon shelf and, in addition, provide a unique perspective on the difficult general problem of understanding the interaction between flows and suspended sediments.



Plots of scaled density anomaly (right panel) and scaled velocity anomaly (left panel) as functions of scaled height above the bottom. The blue circles are measurements over the Amazon shelf in fluid-mud layers with thicknesses on the order of a few meters, the red diamonds are measurements in salt-stratified or heat-stratified laboratory flows with depths on the order of ten centimeters**, and the solid lines are based on John Trowbridge's model. The scaling, suggested by the model, successfully collapses the disparate laboratory and oceanic measurements onto well-defined curves that are reproduced accurately by the model. The agreement between field, laboratory, and model results is striking and indicates that the physics represented by the model do, in fact, control the structure of the fluid-mud flows. (*courtesy of Gail Kineke and Richard Sternberg) (**reported in the literature by C. Kranenburg and by J. F. Piat and E. J. Hopfinger)*

G. RICHARD HARBISON

The ctenophore, Mnemiopsis leidyi, *an apparently harmless inhabitant of the bays and estuaries of the Americas, is having a devastating effect on Black Sea fisheries.*

Research projects of the 24 Biology Department scientific staff members spanned a wide range of interests during 1992, reflecting the tremendous diversity of organisms that inhabit the world's marine ecosystems. Subjects of their studies ranged from very small microbes (viruses, bacteria, and cyanobacteria) to very large mammals (whales and dolphins), and their work led to 66 scientific publications and 127 proposals submitted in 1992.

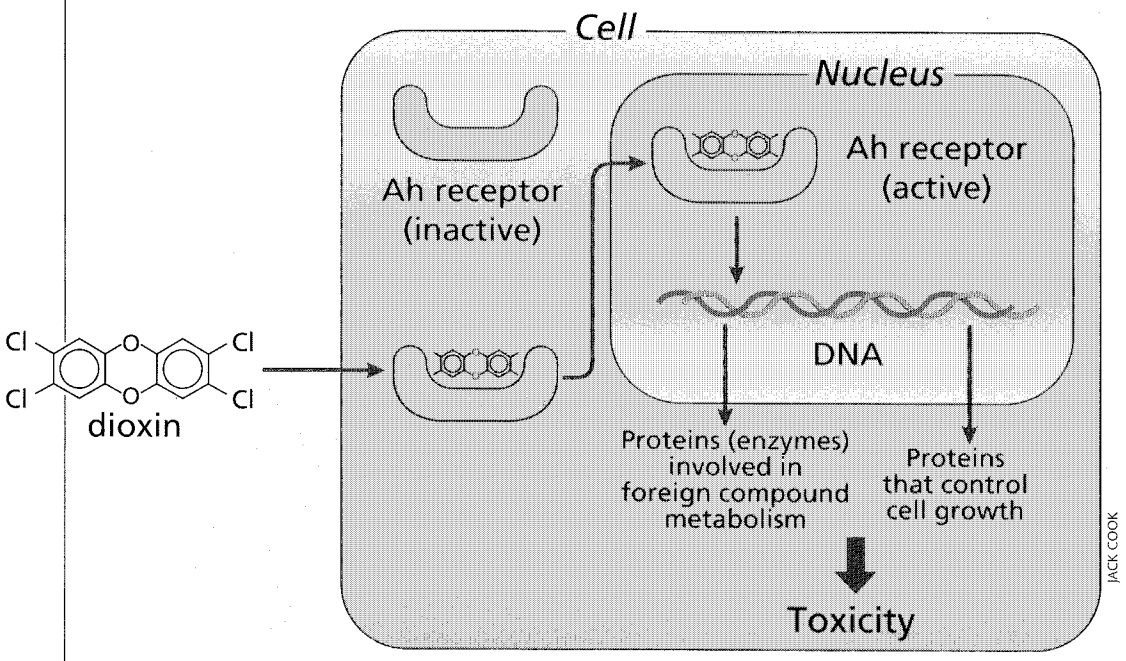
Major personnel changes included Joel Goldman replacing Peter Wiebe in May as Department Chair after Wiebe completed his four-year term, and the addition of two new Assistant Scientists. They are Scott Gallager, who works on both the population ecology and functional morphology and biophysics of locomotion and feeding in marine zooplankton, and Stephen Bollens, whose major interests are in the behavioral ecology and population dynamics of marine zooplankton and nekton.

On the list of notable achievements, Don Anderson received a Special Creativity Extension to a current National Science Foundation award, a paper by Hal Caswell was named the Best Scientific Paper in Biological Sciences by the Venezuelan National Council for Scientific and Technological Investigation, and Judith McDowell was elected a Fellow of the American Association for the Advancement of Science. In addition, several department members played a major role in the preparation of the Global Ocean Ecosystems Northwest Atlantic Implementation Plan for the Georges Bank Study, a global initiative sponsored jointly by the National Science Foundation and the National Oceanic and Atmospheric Administration.

Department staff members continue to integrate molecular biology into their research activities, and they are pursuing ways to increase the number of postdoctoral positions available to people with training in molecular biology in order to bring exciting and innovative new tools to existing research programs.

Solution Sought for "Biological Pollution" Caused By Exotic, Fast-Growing Black Sea Ctenophore Population

In 1982, Soviet scientists working in the Black Sea observed an unfamiliar planktonic animal, a ctenophore called *Mnemiopsis leidyi*. Ctenophores resemble jellyfishes, but they belong to a different phylum, and are not closely related. Since the Black Sea ctenophore was previously known only along the Atlantic coast of the Americas, in a region extending from Woods Hole (about 40° N) to Bahía Blanca, Argentina (about 40° S), it is likely that the animal traveled to the Black Sea in the ballast water of cargo ships. By 1988, Black Sea populations of *M. leidyi* had increased to catastrophic levels, causing a major decline in fisheries by outcompeting fish larvae for food, eating fish eggs and



The molecular mechanism by which marine contaminants such as dioxins and PCBs are thought to cause toxicity involves their interaction with an intracellular protein known as the Ah receptor. Recent studies showing the apparent absence of this receptor in certain marine animals may explain their resistance to these toxic substances.

larvae, and clogging the fishing nets. By 1992, it had spread into the Mediterranean, and there were large populations off the southeastern coast of Turkey.

M. leidyi is ideally adapted for colonizing productive coastal regions, since it can multiply rapidly over a wide range of temperature and salinity. In favorable conditions, it can reach maximum size (about 10 centimeters) in a week, producing thousands of eggs a day. The Black Sea environment is extremely favorable for *M. leidyi* growth and reproduction, and there probably are no indigenous Black Sea animals that can effectively control populations of the ctenophore. The catastrophic effects of introducing *M. leidyi* can be thought of as a form of biological pollution.

One possible way to reduce the numbers of *M. leidyi* in the Black Sea would be to introduce new predators. Importing exotic species has its dangers, because the new species may bring new problems, but it may be the only effective method of control. Richard Harbison is collaborating with Russian and Ukrainian scientists to develop methods that may control this biological pollution.

Since *M. leidyi* is native to the Americas, this is the logical place to seek its predators. While a number of planktonic invertebrates feed heavily on ctenophores, many fishes also eat them. Harbison, with support from the Seaver Institute and the National Science Foundation, is evaluating their potential to solve the *M. leidyi* problem. The ideal candidate for introduction must feed preferentially on *M. leidyi*, must be able to live and reproduce in the specialized conditions of the Black Sea and in the laboratory, and should be commercially valuable. To identify the best species, Harbison is studying the feeding preferences and environmental tolerances of various jelly-eating fish.

This is only the first step, since all of the nations that border the Black Sea must ultimately participate in the program. Because world commerce is increasing, the accidental transport of exotic plants and animals will become more and more common in the future. Close international cooperation will be the only effective way to attack essentially global problems like this one.

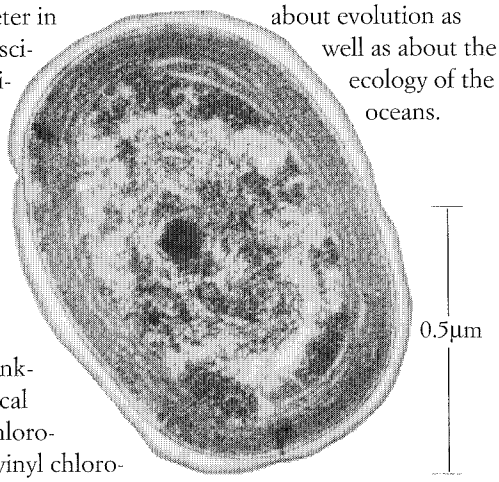
An Intracellular Protein Controls Marine-Animal Sensitivity to Pollutants

Toxicologist Mark Hahn is investigating the molecular mechanisms by which chemical pollutants affect marine-animal health. His approaches include characterization of biological macromolecules that control sensitivity to certain extremely toxic chemicals, such as polychlorinated dioxins and polychlorinated biphenyls (PCBs), which accumulate in tissues of animals at the upper-level of the food chain. These chemicals are found globally, including in polar regions and the deep sea, with highest concentrations in coastal regions near industrial and municipal sources. Rat and mouse studies show that these compounds modulate the action of genes that regulate cell division and maturation, and that this occurs when the chemicals activate a protein known as the Ah (for *A*romatic *h*ydrocarbon) receptor, which is then able to alter the expression of those genes. Hahn, in collaboration with Alan Poland (University of Wisconsin) and John Stegeman (WHOI) looked for the Ah receptor protein in fish and marine invertebrates. The receptor was clearly identifiable in several species of bony and cartilaginous fish, and in

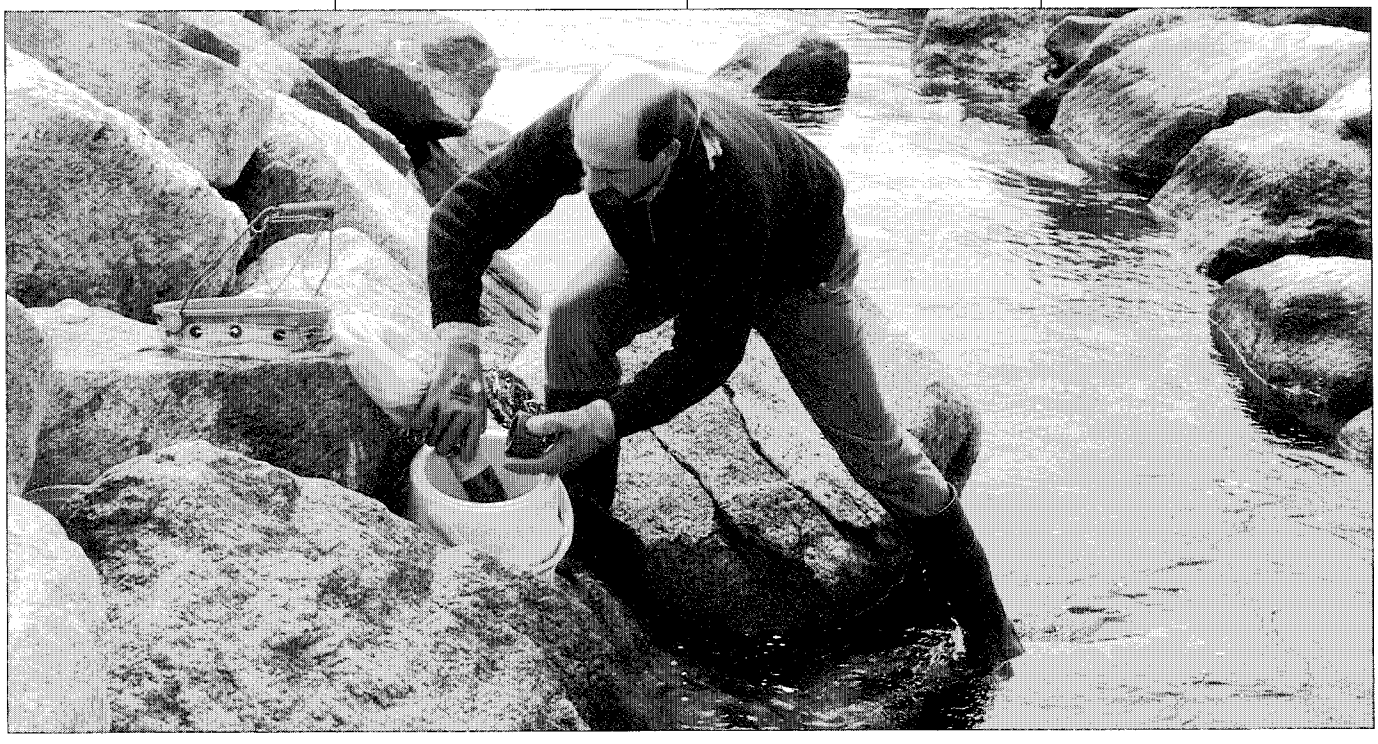
beluga whales. However, it was not found in jawless fish such as hagfish and lamprey, nor was it present in any invertebrate examined, including molluscs (mussel, chiton, squid), crustaceans (lobster, barnacle, horseshoe crab), a polychaete worm, or an echinoderm (sea star). The apparent lack of this receptor may explain why invertebrate animals in general appear to be much less sensitive to the toxic effects of dioxins and PCBs. These initial studies, supported by the National Institutes of Health and the Air Force Office of Scientific Research, are now being expanded. With additional funding from the National Institutes of Health, a Mellon Independent Study Award, and the Richard B. Sellars Fund, Hahn hopes to gain a better understanding of the functioning of the Ah receptor in fish, its evolution, and its role in dioxin and PCB toxicity.

Laser Technique Illuminates The Tiniest Phytoplankton Cells

Robert Olson studies the distribution and physiology of phytoplankton in the oceans, from the perspective of individual cells. In a technique borrowed from biomedical research, measurements of light scattering and fluorescence from cells in natural seawater samples passed through a laser beam provide information about the size and photosynthetic pigments of each cell. Using this technique in a study of phytoplankton distribution across the Atlantic Ocean, Olson and Sallie Chisholm (MIT), with NSF and ONR support, discovered a tiny yet extremely abundant phytoplankter (now named *Prochlorococcus*) that was not detectable using traditional microscope techniques. These cells, which are less than 1 micrometer in diameter, are fascinating for a variety of reasons. They are the smallest known phytosynthetic organisms, and probably numerically the most abundant ocean phytoplankton. The chemical form of their chlorophyll, called divinyl chlorophyll, is unique in the oceans. Chemists had determined this pigment to be an important component of the total chlorophyll in several warm oceans, but its source had been unknown. In addition, morphology and DNA sequence analysis indicate that *Prochlorococcus* is closely related to the cyanobacteria, but its pigments are at least superficially more similar to those in higher plants. The discovery of *Prochlorococcus* thus opens up new questions about evolution as well as about the ecology of the oceans.

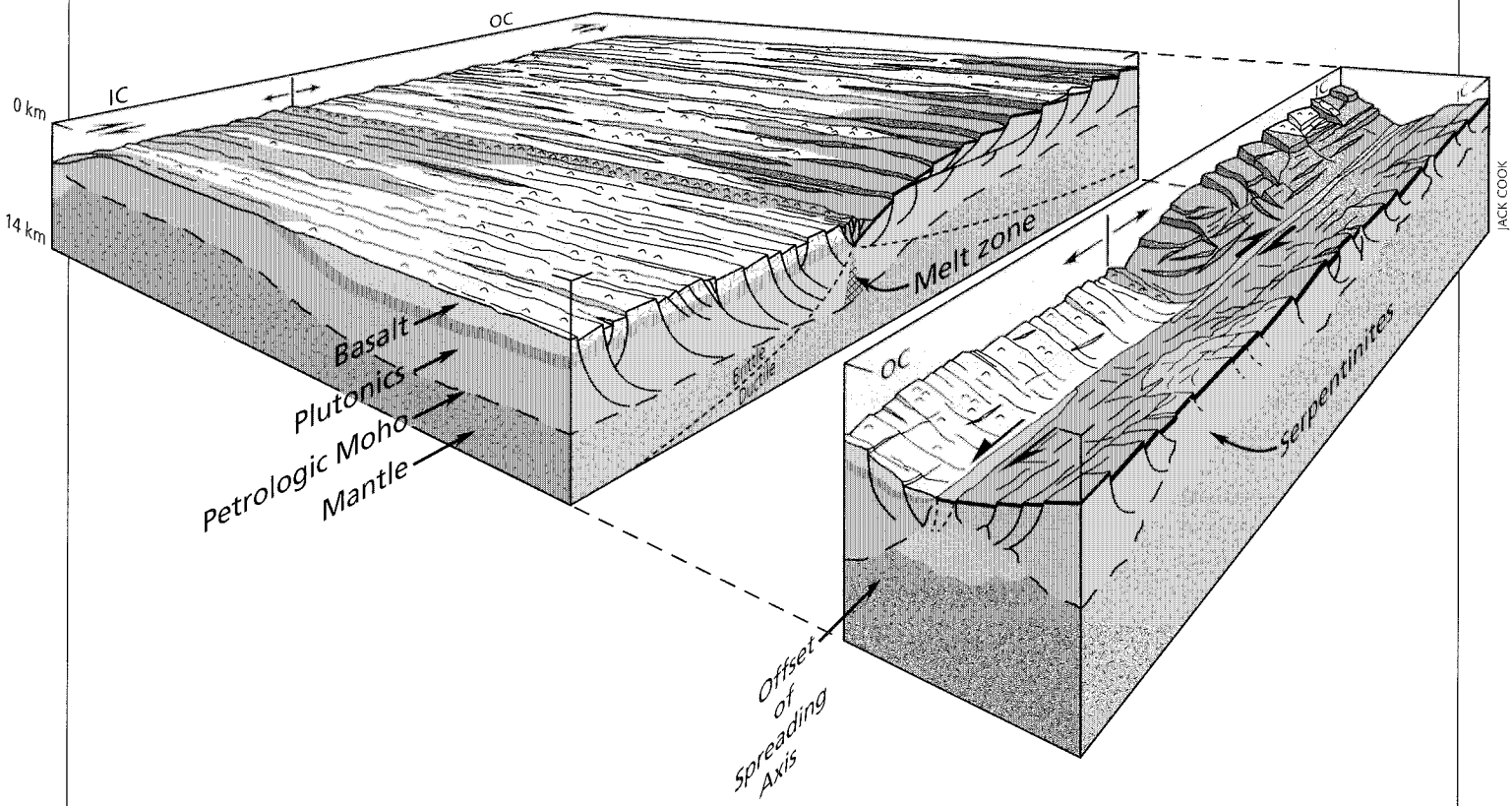


Electron micrograph of a thin section of Prochlorococcus *from a sample collected at 100-meters in the Sargasso Sea. The layers of membranes around the periphery contain chlorophyll pigments whose fluorescence properties allowed identification of the cells by flow cytometry.*



TERRI CORBETT

Phil Alatalo collects zooplankton to feed winter flounder in the laboratory.



This block diagram shows one spreading segment of the Mid-Atlantic Ridge bounded at upper left and lower right by left-lateral offsets; seawater penetrates along faults in these offsets and alters (serpentinizes) upper-mantle peridotites (tan). The spreading axis is marked by a neovolcanic zone (red). The cross section at center shows a detachment-fault surface (bold line and shaded seafloor) that reaches up onto inside-corner crust and extends beneath the neovolcanic zone to a level where rocks deform ductilely (dashed line). Normal ocean crust on outside corners includes basalts, sheeted dikes, and plutonic rocks that are separated from the upper mantle by the Mohorovicic discontinuity or "Moho". The cross section at right side cuts inside-corner crust of an adjacent spreading segment, showing how serpentinized upper-mantle peridotites are episodically exhumed by the detachment fault operating there.

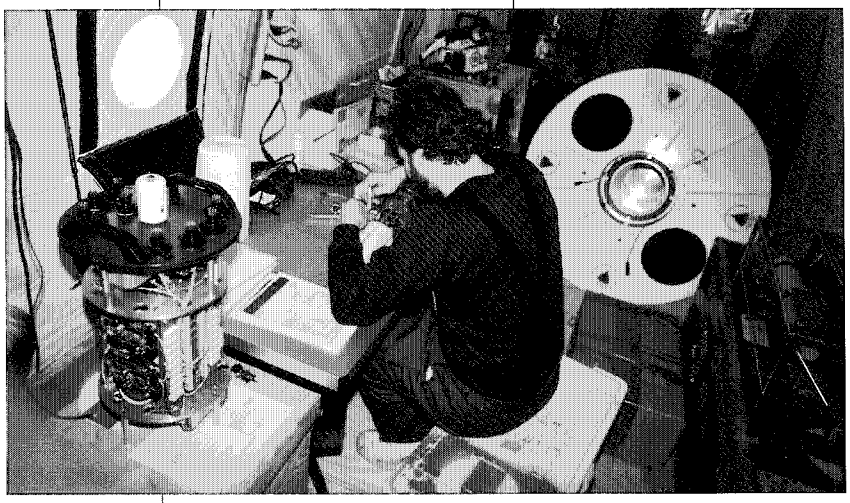
The most effective annual measure of the Department of Geology and Geophysics is the success of its staff in producing significant advances in understanding of the processes that shape and change our Earth. Three short research accounts are included below as typical examples of the high-quality research programs underway at WHOI in geology and geophysics. Overall the scientific staff of 34 led more than 120 research projects in the areas of paleoceanography, marine seismology, tectonics, marine geology, petrology, and geochemistry, and produced more than a hundred research papers. However, the support of these efforts in an ever more competitive federal funding environment required the generation of approximately 160 new research proposals.

The department added three new members to the scientific staff to bring fresh ideas and new research directions to the field. Alan Chave came from Bell Laboratories to begin a new program in marine electromagnetics. Dick Norris, a micropaleontologist interested in evolutionary processes, made the transition from a postdoctoral to an Assistant Scientist appointment working with Senior Scientist Bill Berggren and the paleoceanography group. Greg Ravizza, who had been working as a postdoctoral investigator with Stan Hart, was appointed an Assistant Scientist to continue his research in isotope geochemistry. In addition, the planning office for the U.S. national Ridge Inter-Disciplinary Global Experiments program was established within the department under the leadership of Senior Scientist Bob Detrick.

Senior Scientist John Milliman became the third staff member (along with Ken Emery and Al Uchupi) to be awarded the Francis P. Shepard Medal in Marine Geology by the Society of Economic Paleontologists and Mineralogists, Senior Scientist Stan Hart was recognized for his major achievements in geochemistry with the Geochemical Society's Goldschmidt Medal, and Senior Scientists Brian Tucholke and Carl Bowin were elected Fellows of the American Association for the Advancement of Science in 1992.

Geologists Investigate Spatial Variability and Temporal Cycles of Atlantic Ocean Crust Formation

The great tectonic plates that carry the continents of North America, South America, Europe, and Africa are spreading apart along the axis of the Mid-Atlantic Ridge, a submarine mountain chain that extends from the Arctic south through the middle of the Atlantic Ocean and into the Indian Ocean. New ocean crust forms in the rift valley along the axis of this ridge as molten magma upwells, cools, and is accreted to the edges of the plates. Most studies of the Atlantic rift system have concentrated on this narrow spreading axis. In July and August of 1992, geologist Brian Tucholke lead a team of 22 scientists and engineers, including Martin Kleinrock, Jian Lin, and Ken Stewart of WHOI, on an Office of Naval Research-sponsored cruise to the central North Atlantic to study a much longer geological record of crustal accretion and tectonism. Using acoustic and geophysical sensors, they surveyed a 200-kilometer-wide swath of seafloor that extended from crust of zero age at the spreading axis out to about 30 million-years old 400 kilometers onto the ridge flank. Some of the major fault zones that offset the present spreading axis proved to have persisted over the full 30 million years, but others appeared, vanished, or even reversed their sense of offset in that time. More importantly, the off-axis data show that specific parts of the spreading-ridge segments between these offsets have very characteristic features. Gravity data indicate that "inside-corner" crust, formed at the bight between the spreading axis and a spreading-center offset, appears to average 1 to 3 kilometers thinner than "outside-corner" crust, which accretes on the directly opposite side of the spreading axis. The mechanism for producing this thin inside-corner crust is thought to be detachment faulting. The detachment fault is a low-angle (20° to 30°) fault that dips from the surface of the inside corner to beneath the basalts that form the axial neovolcanic zone. The basaltic upper crust is continuously stripped off the detachment surface and carried to the outside corners. The geophysical data also show that the amount of crustal thinning on inside corners varies significantly over periods of several million years. In fact, dredge samples recovered from comparable inside-corner settings often recover upper-mantle peridotites, indicating that there are zones where no normal ocean crust is present. The ocean floor at the spreading center is always being extended, but the input of magma is episodic. When there are long periods of low magma production, the detachment fault plunges into the upper mantle and brings peridotites to the seafloor at inside corners within a few million years. These processes of detachment faulting and long-period cyclicity of magma production occur only in the slowly spreading crust of the Atlantic Ocean and parts of the Indian Ocean, not in the fast-spreading, magmatically dominated spreading ridges of the Pacific. Thus the Atlantic and Indian Ocean crust is fundamentally more heterogeneous than Pacific crust in the dimensions both of space (along the rift axis) and time (outward from the rift axis).

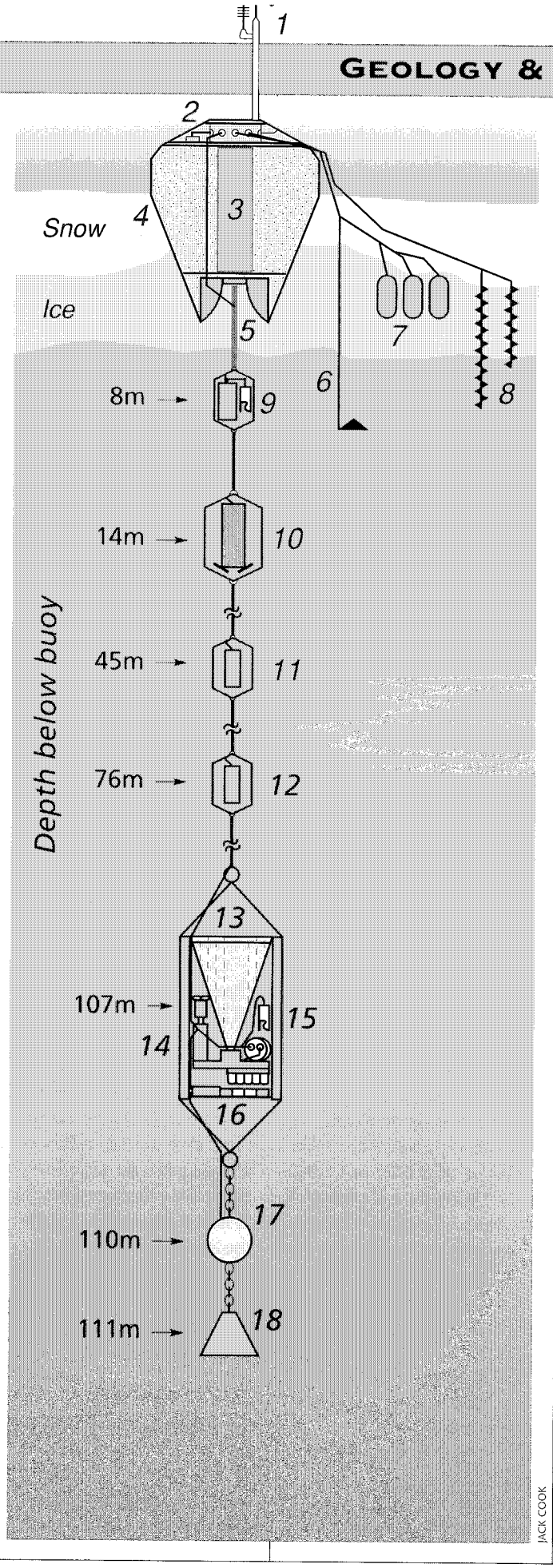


SUSUMU HONJO

Rick Krishfield makes final adjustments to equipment before buoy deployment at Camp Crystal near the North Pole. The satellite communication system and main computer is at left; the black circles on the yellow buoy at right are satellite antennae.

New Buoys Telemeter Extensive Data From Two Locations in the Arctic

On April 12, 1992, an Ice-Ocean Environmental Buoy (IOEB) was deployed on sea ice near the North Pole where ice floes move slowly southward with the Transpolar Drift. About 10 days later, another IOEB was also successfully deployed 2,078 kilometers away on the Beaufort Bay sea ice far off the Alaskan shore. The buoys were designed, assembled, and deployed under the direction of geologist Susumu Honjo with the cooperation of the Japan Marine Science and Technology Center and funded by the Office of Naval Research. WHOI technicians, led by Rick Krishfield and John Kemp, delivered the ap-



JACK COOK

proximately two-ton IOEBs and related equipment to the sea-ice station aboard a small, powerful turbo-prop Twin Otter airplane. Equipment included a small gantry crane and a hot-water jet augur for drilling a one-meter-diameter hole for lowering the IOEBs.

An IOEB carries as many as 200 sensors for coherent measurements of critical parameters of Arctic meteorology, ice physics, and oceanography. The sensors include a weather station and ice-profiling thermistors that provide detailed sea-ice temperature profiles. Along the 120-meter mooring line there are sensors for seawater temperature and conductivity, optical sensors to detect water turbulence, and a fluorometer to record the intensity of under-ice plankton blooms. A time-series sediment trap was installed at the bottom of the mooring to measure the carbon flux in the open Arctic Ocean for the first time. IOEB computers wake up the sensors at 90-minute intervals and then transmit buoy location and sensor data via ARGOS satellites to laboratories worldwide. IOEBs are designed to transmit data from the arctic environment for as long as two years.

Schematic diagram of the Ice-Ocean Environmental Buoy deployed on sea ice near the North Pole

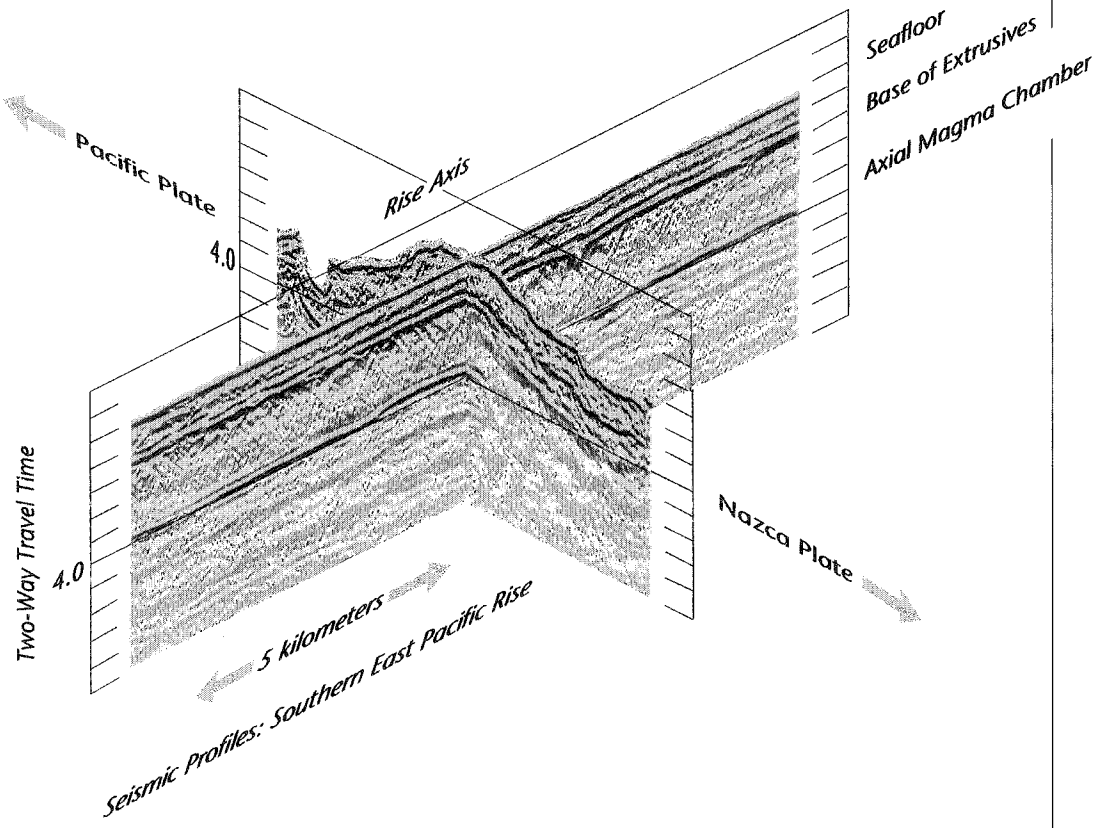
Main sensor/structure

1 *Air sensors*
2 *Top plate and endcaps*
3 *Electronics tube*
4 *Foam shell*
5 *Bell mouth flange*
6 *Reverse echo sounder*
7 *Strain/optical sensors*
8 *Ice thermistors*
9 *Conductivity/temperature (CT) sensor with dissolved oxygen fluorometer*
10 *Acoustic Doppler current profiler*
11 *CT recorder – 2*
12 *CT recorder – 3*
13 *Time series sediment trap*
14 *Water transfer system*
15 *Fluorometer*
16 *Transmissometer*
17 *Current meter with logger*
18 *Anchor*

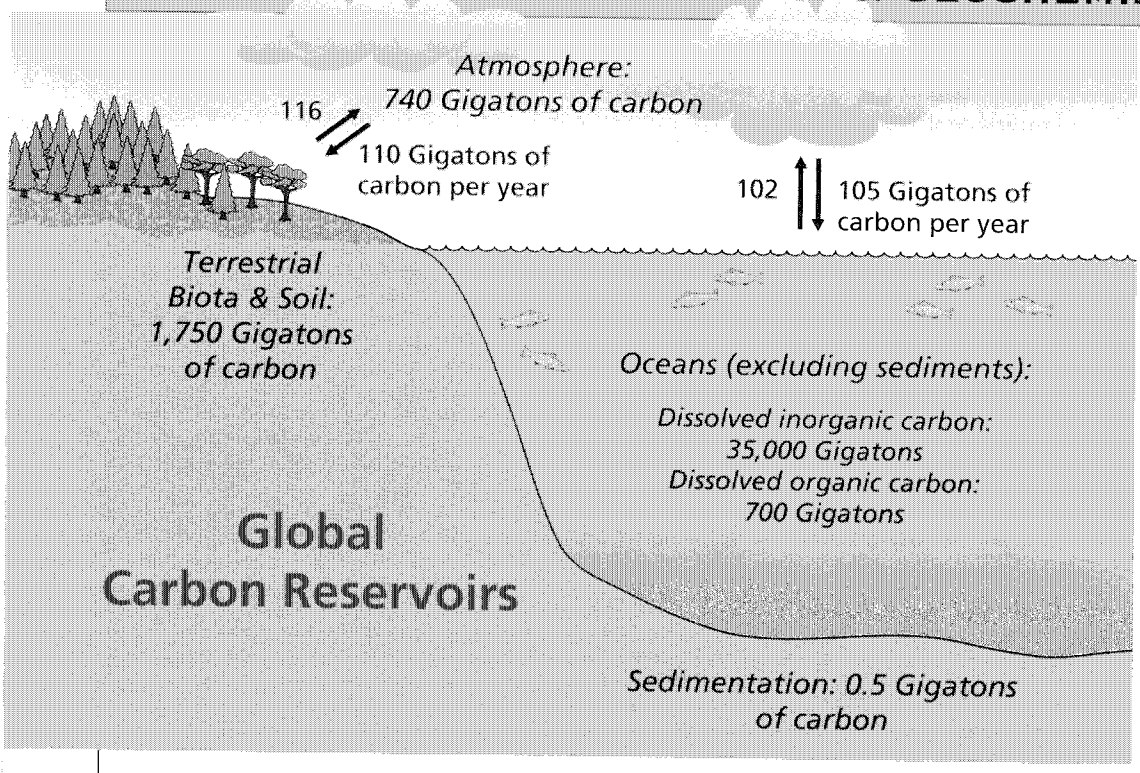
Predictions of global warming make the IOEBs especially timely. Though the arctic region is covered by frigid air—the winter air temperature dips as low as -60°C—seawater temperature is never lower than -2°C. This relatively warm water is constantly supplied to the Arctic Basin from the North Atlantic through the deep strait between Greenland and Norway. A thin (usually 2-to-5-meter), mobile canopy of sea ice insulates the warm seawater from the cold air. Should winter arctic air temperature rise, due to global warming, for example, the sea ice would be less extensive, have more cracks, and become thinner, and heat from the ocean water would warm the arctic air. In addition, should global warming also induce a drier climate over the circum-arctic land masses, particularly Siberia, the shortened supply of river water would result in diminished sea-ice cover, reducing the insulating effect. This unique accelerating mechanism would further increase arctic temperatures once the thermal balance swung toward warming. Thus many scientists believe that such conditions in the Arctic would be the precursor of global warming. IOEB monitoring across all seasons will contribute to a better understanding of global climate both by establishing a baseline of knowledge about the Arctic ocean environment and indicating deviations from the norm.

Seismic Reflection and Refraction Techniques Image Structure of Crust and Mantle

Each year volcanism creates about 20 cubic kilometers of new oceanic crust along the global mid-ocean ridge. Bob Detrick and Graham Kent, together with colleagues from the Lamont-Doherty Earth Observatory and the Scripps Institution of Oceanography, recently carried out a major seismic study of one of the fastest spreading portions of this ridge system located in the remote southeastern Pacific near Easter Island. The goal of this NSF-supported project, part of the Ridge Inter-Disciplinary Global Experiments (RIDGE) program, was to use seismic reflection and refraction techniques to image the structure of the crust and upper mantle at this spreading center and to determine the size and shape of magma bodies lying beneath the rise axis. These "magma chambers" supply the lava that forms the oceanic crust and the heat that drives the spectacular hydrothermal systems found at ridge crests. This area is of particular interest since many ridge-crest thermal models predict that large (up to several kilometers wide), steady-state magma chambers should exist at these very fast spreading centers. The 1991 seismic experiment involved two ships. Using techniques adapted from the oil industry, one ship towed a 4-kilometer-long streamer outfitted with 160 different groups of hydrophones. It fired a powerful array of 20 airguns and recorded reflections (echoes) from as deep as 10 kilometers below the seafloor. The second ship deployed ocean-bottom seismometers (sound recorders) along the reflection profiles and also fired shots recorded by the first ship. These refraction studies (sound waves are bent or refracted as they pass through Earth layers of differing composition) were used to determine the speed of sound in the crustal and upper-mantle rocks. The reflection and refraction data were then combined to yield crustal-structure images both along and across the rise axis. These images show that a thin (less than 200-meter-thick) lava layer lies beneath the axis of the southern East Pacific Rise. Its base is marked by a discontinuous reflector that more than doubles in thickness away from the rise crest, indicating that lavas are implaced over a zone at least two or three kilometers wide. A second, much stronger reflector marks the top of a layer of molten rock about 1,000 to 1,500 meters below the seafloor. This molten body is less than one kilometer wide and only a few tens of meters to a few hundred meters thick, although it can be traced as a relatively continuous feature for considerable distances along the rise axis. The dimensions of this thin, narrow melt lens are comparable to the magma bodies found along slower spreading ridges. However, the melt lens found along the southern East Pacific Rise is unexpectedly shallow, rising in some locations to within 1,000 meters of the seafloor. These new images suggest that magma-chamber depth decreases with increasing spreading rate at intermediate and fast spreading ridges, although the size of the melt lens remains relatively constant. This observation has important implications for thermal models of ridge crests and the relative importance of hydrothermal circulation in cooling the newly formed crust.



Plot of two intersecting seismic reflection profiles that cross the southern East Pacific Rise near 14°S. High-amplitude reflectors (colored red) mark the base of a thin layer of extrusive lava just below the seafloor and the top of a narrow, crustal magma chamber located about one kilometer below the rise axis.



These are current estimates of the major reservoirs (in gigatons of carbon) and fluxes (in gigatons of carbon per year) involved in the global carbon cycle.

The Department of Marine Chemistry and Geochemistry consists of 20 Scientific Staff, 15 Technical Staff, and 30 Graded and Administrative staff, plus 9 postdocs and 8 graduate students in residence at Woods Hole. The department had an extremely interesting and successful year in 1992. Two-thirds of department projects are closely linked to studies of the element carbon (and related nutrient elements such as nitrogen, phosphorus and sulfur, their isotopes, or proxy radionuclides of the uranium-disequilibria series to calculate rates of processes) and its complex geochemical cycle. They range from the transfer of carbon dioxide from atmosphere to ocean, nutrient cycling in the upper ocean, particle delivery to the seafloor, and subsequent remineralization, burial, and diagenesis in the sediment column up to and including oil and gas formation. Other studies include tracing and dating water masses using helium-tritium tracers, remote sensing of surface-ocean chemical properties, photochemical reactions, paleoceanography, metal cycling, hydrothermal venting on the seafloor, crust-seawater reactions, cosmochemistry, and geochemical studies of the earth's mantle. Three of the plethora of WHOI Marine Chemistry and Geochemistry projects are described here.

Carbon-Dioxide Flux Studies Aim Toward Global Monitoring

The total quantity of carbon on Earth remains constant, although its distribution among three reservoirs—land, atmosphere, and ocean—changes. Atmospheric carbon dioxide is a major player in global warming: As the amount of carbon dioxide increases in the atmosphere, the "greenhouse effect" warms the earth. Carbon dioxide continuously crosses the ocean-atmosphere interface in both directions, and thus continuously changes the distribution of carbon between these reservoirs. Atmospheric studies suggest that the ocean absorbs approximately 2.6 gigatons of carbon per year.

Catherine Goyet is involved in national and international oceanic programs to measure carbon dioxide in the surface ocean and to determine how much and where anthropogenic carbon dioxide enters the ocean. It is possible to measure the carbon dioxide content of seawater by determining its "partial pressure." (Partial pressure is the pressure that would be exerted by one component of a mixture of gases if it were present alone in a container.) This gives the fractional amount of carbon dioxide dissolved in a seawater sample compared to all the gases dissolved in the sample. It is difficult to separate the anthropogenic signal (approximately 8 μatm—1 μatm=0.000001 atmosphere) from the large spatial and temporal variations of the natural partial pressure of carbon dioxide in surface seawater (+/-140 μatm). Diurnal variations alone may be nearly 10 μatm. The immensity of the ocean is an additional difficulty. Resources (ship time and personnel) are, and will remain, limited. As a result, the current strategy is to measure temporal variations of carbon dioxide in surface seawater in a few areas as part of the international Joint Global Ocean Flux Study (JGOFS) program and to measure spatial variations over as much of the ocean as possible under cooperative JGOFS/World Ocean Circulation Experiment programs. Goyet and colleagues from WHOI and other institutions, funded by the National

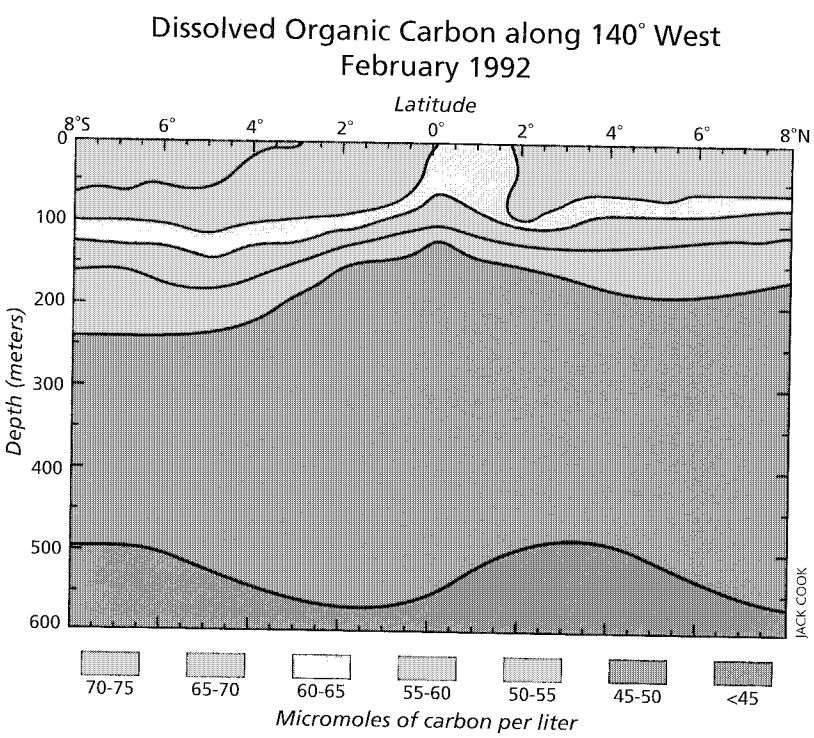
Science Foundation, the Department of Energy, and the National Aeronautics and Space Administration, are working toward using these data to elaborate an algorithm for interpolating surface seawater carbon-dioxide content based on remotely sensed data such as sea-surface temperature or ocean color that might be obtained regularly (perhaps monthly) from satellite images.

Dissolved Organic Carbon Measurements: Resolution of a Controversy

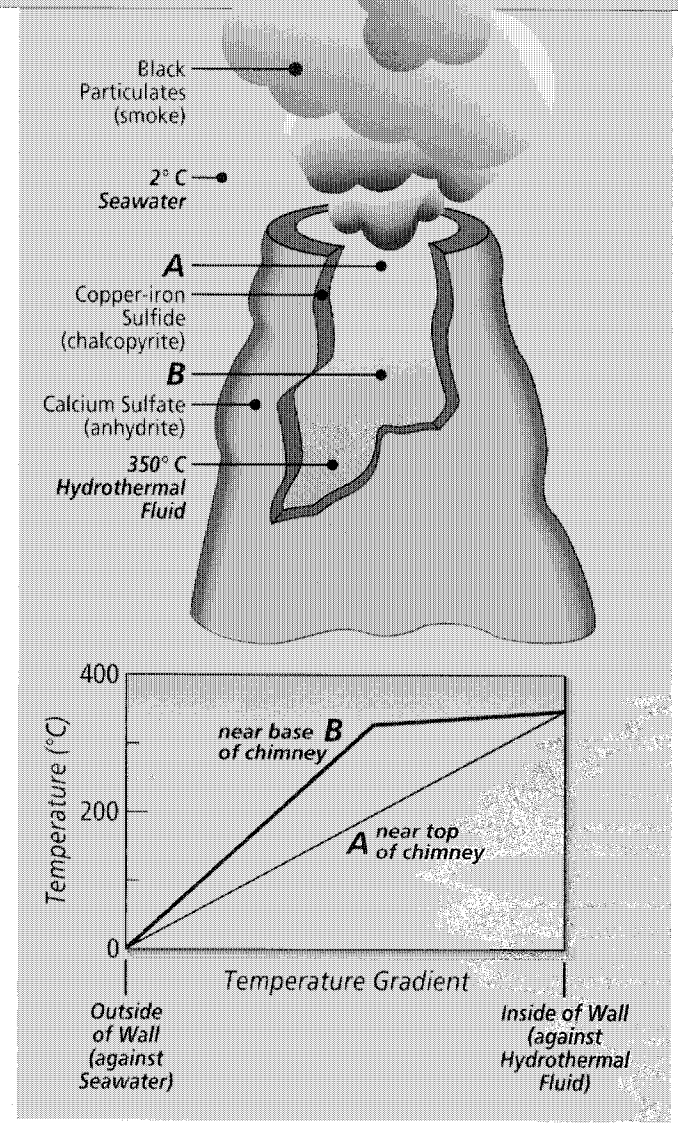
Measurement of dissolved organic carbon (DOC) has long challenged marine chemists. Unlike other substances that can readily be identified as single compounds, DOC is the carbon contained in a pool of thousands of organic compounds that range from simple molecules (such as sugars and amino acids) to complex macromolecules (such as proteins and nucleic acids) or biogeopolymers formed by condensation reactions in natural waters. Traditional methods of DOC measurement lack precision and are very difficult to use at sea. Determining whether any method accurately measures this pool of DOC requires the rather daunting task of demonstrating that the method is capable of oxidizing all of the possible compounds—few investigators have been bold enough to attempt this experiment. Instead, comparisons with other results are usually offered as proof of current results. At present, the DOC pool is thought to represent a mass of carbon equivalent in size to all the carbon dioxide contained in the atmosphere. Since approximately half the annual marine primary productivity passes through this pool, any persistent change in the rate or amount of carbon cycling through this pool could have a profound effect on the global carbon cycle.

In the mid-to-late 1980s, a group of Japanese investigators developed a technique for measuring DOC by directly injecting seawater into a high-temperature furnace. The method not only offered the hope of a simple, rapid technique for use at sea, but appeared to identify a previously overlooked fraction of DOC that would have doubled our estimate of the DOC pool size. However, in 1991, a major international workshop was convened in Seattle to discuss the Japanese investigators' results as well as those of others attempting to verify the discovery. While it now appears that the initial reports of high DOC levels were artifacts of the way the instrument blank was handled, the method itself emerged as a means of rapidly and precisely determining DOC at sea.

After modifying the technique to improve its accuracy, Edward Peltzer used the method extensively during the 1992 U.S. Joint Global Ocean Flux Study equatorial Pacific cruises. When the seawater sample is injected into the furnace the water vaporizes almost instantaneously and the carbon in the sample is burned to carbon dioxide, which is swept out of the furnace by a carrier gas to a detector, where the amount of carbon dioxide is recorded. The high concentrations reported by the Japanese investigators and others were not found. Instead, the measurements revealed a pattern of low DOC concentrations that are largely controlled by physical mixing processes. The upwelling of cold, nutrient-rich waters along the equator is well known, but it is now possible to see this process for the first time in the DOC data. In the figure, a tongue of low DOC water (yellow) can clearly be seen rising to the surface at the equator. Even though DOC is a biological product, its distribution near the equator is now known to be heavily influenced by physical processes. These results are also in fairly good agreement with earlier wet chemical measurements of DOC in the Pacific ocean, suggesting that the long-standing controversy regarding the measurement of DOC is near resolution and an accurate picture of the distribution and cycling of DOC will soon be revealed. This research was funded by the National Science Foundation.



Cross-section of the distribution of dissolved organic carbon in the surface waters of the Equatorial Pacific Ocean along 14°W from 8°N to 8°S during February and March 1992. The different colors represent different concentration zones (see key).



JAYNE DOUCETTE

Geochemical Modeling Used To Quantify Hydrothermal Vent Processes

Meg Tivey has been studying processes of mass and energy transfer and mineral precipitation at seafloor hydrothermal vent sites by combining field studies (using deep-sea submersibles) with geochemical modeling techniques. Vent sites, first discovered in the open ocean in 1977, are found along mid-ocean ridges, at hot spots, and in back-arc basins. At these locations, hot, acidic (low pH) fluid with abundant silica, metals, and hydrogen sulfide exits the seafloor rapidly, forming stacks, or chimneys, of precipitated minerals, and plumes of black particulate-laden smoke. This hydrothermal activity cools young ocean crust, and significantly affects the composition of seawater, acting as a sink for magnesium, and a source for iron, manganese, and other elements.

At vent sites, coexistence of seawater, high temperature fluid, and minerals precipitated from these fluids offers a rare opportunity to examine ore-forming processes. With funding from NSF, Tivey has developed a modeling approach that allows simulation of the fluid/solid interactions and of the chemical reactions that control the formation of black-smoker chimneys. Composed of calcium sulfate and copper, iron, and zinc sulfides, these chimneys have remarkably thin walls, varying in thickness from about 10 centimeters to as little as 1 centimeter. Across this thin layer is a temperature difference of 300° or greater; similar steep elemental gradients also exist. Knowing the composition of the hydrothermal fluid and of the existing chimney wall, and the shape of the central channel of the chimney, model calculations are used to address questions about how seawater and hydrothermal fluid interact as the chimney matures: For example, is seawater drawn in across chimney walls, or is hydrothermal fluid advected out, or does diffusion (transport of matter as a result of random molecular motions) dominate? Model calculations are used to estimate profiles of temperature and fluid composition across the chimney wall. These profiles are controlled by the wall's composition, which changes over time as minerals precipitate and dissolve. For example, the temperature profile across the wall is controlled by the strong contrast in thermal conductivity between the sulfate-dominated outer layer of the wall and its sulfide-dominated inner layer. Sulfide is 4 to 6 times more conductive than sulfate. As layer thicknesses change, owing to precipitation of sulfide against the inner wall and dissolution of sulfate from the outer wall, the temperature profiles also change. Calculation of mineral stabilities in the wall are complicated because temperature and pressure conditions of hydrothermal fluid (about 350°C, 250 bars) are close to those of the critical point of water (374°C, 218 bars). Tivey has used her modeling approach to successfully reproduce the mineralogy and texture of black smoker chimneys from four different vent sites with differing fluid compositions. The calculations also give information on the time scales (months to years) of processes occurring at vent sites, and can be used to delineate areas of vent deposits hospitable to biological activity (such as those at temperatures less than 100°C). The modeling approach is now being expanded to examine and quantify heat and mass transport and chemical reaction in other portions of vent deposits, and in portions of the ocean crust.

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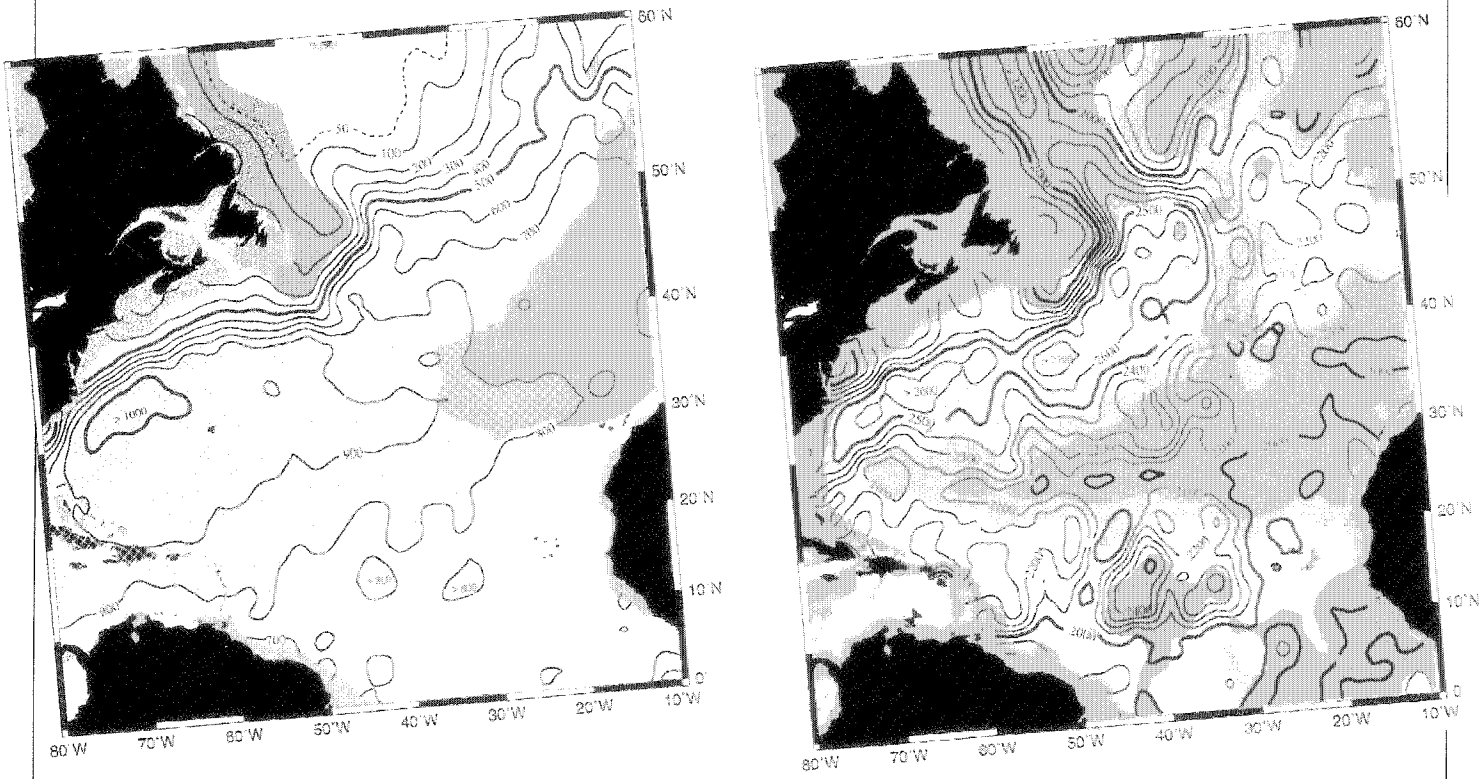
Meg Tivey is modeling fluid/solid interactions at hydrothermal vent sites like this one on the East Pacific Rise.



Density contours show the climatology of the North Atlantic.

The scientific research interests in the Department of Physical Oceanography span a range of scales from the very large-scale general circulation in ocean basins over years and centuries to the mixing and dissipative processes that occur on scales of millimeters and seconds. Department staff members are involved in individual research programs as well as participating in large cooperative inter-institutional and international field programs. Specific research efforts include theoretical and field work, analysis of observations, remote sensing, laboratory experiments, and analytical and numerical modeling programs. Areas of special interest are the structure and dynamics of the deep circulation, air-sea interaction and the role of fresh water through evaporation and precipitation in the formation and modification of water masses, and the role of fronts in coastal circulation.

Significant participation continues in the World Ocean Circulation Experiment, with three major cruises as part of Core I (Global Survey) in the South Pacific, and the continuation of the field work in three elements of Core III (Process Studies): the Subduction Experiment, the North Atlantic Tracer Release Experiment, and the Deep Basin Experiment. Department members also participated in the large scale western Pacific air-sea interaction project called Tropical Ocean-Global Atmosphere Program and Coupled Ocean-Atmosphere Response Experiment.

Roger Samelson, an Assistant Scientist in Physical Oceanography, received the prestigious Office of Naval Research Young Investigator Award in 1992 for his work on small-scale coastal winds and currents.

Perhaps the most significant event of 1992 was the death of Senior Scientist Henry Stommel, who was much loved as a friend and colleague by many at the Institution. Not only was Henry a towering individual figure in the development of physical oceanography as a discipline, but he also had a unique ability to engage his colleagues and bring them together in cooperative research programs. We miss him dearly. More than 60 colleagues and friends contributed to *A Tribute to Henry Stommel*, a special issue of *Oceanus* published in 1992 with Jim Luyten and Nelson Hogg as guest editors.

Analysis of Hydrographic Data Helps Scientists Describe North Atlantic Climatology

Breck Owens, Ruth Curry, and Susan Lozier (now at Duke University) are analyzing hydrographic data in order to produce a description of the climatology of the North Atlantic. Their data set includes over 76,000 National Oceanographic Data Center temperature and salinity profiles that were collected between 1904 and 1990 from the equator to 60°North. The North Atlantic was chosen because it has been the site of more measurements than any other ocean basin. The researchers' objective is to produce the best estimate of the mean (time-averaged) three-dimensional North Atlantic distri-

bution of temperature and salinity. This is a first step toward the World Ocean Circulation Experiment goal of providing a similar description for all the world's oceans. Data for areas outside the Atlantic will be collected over a few years' time to provide a snapshot of present ocean circulation.

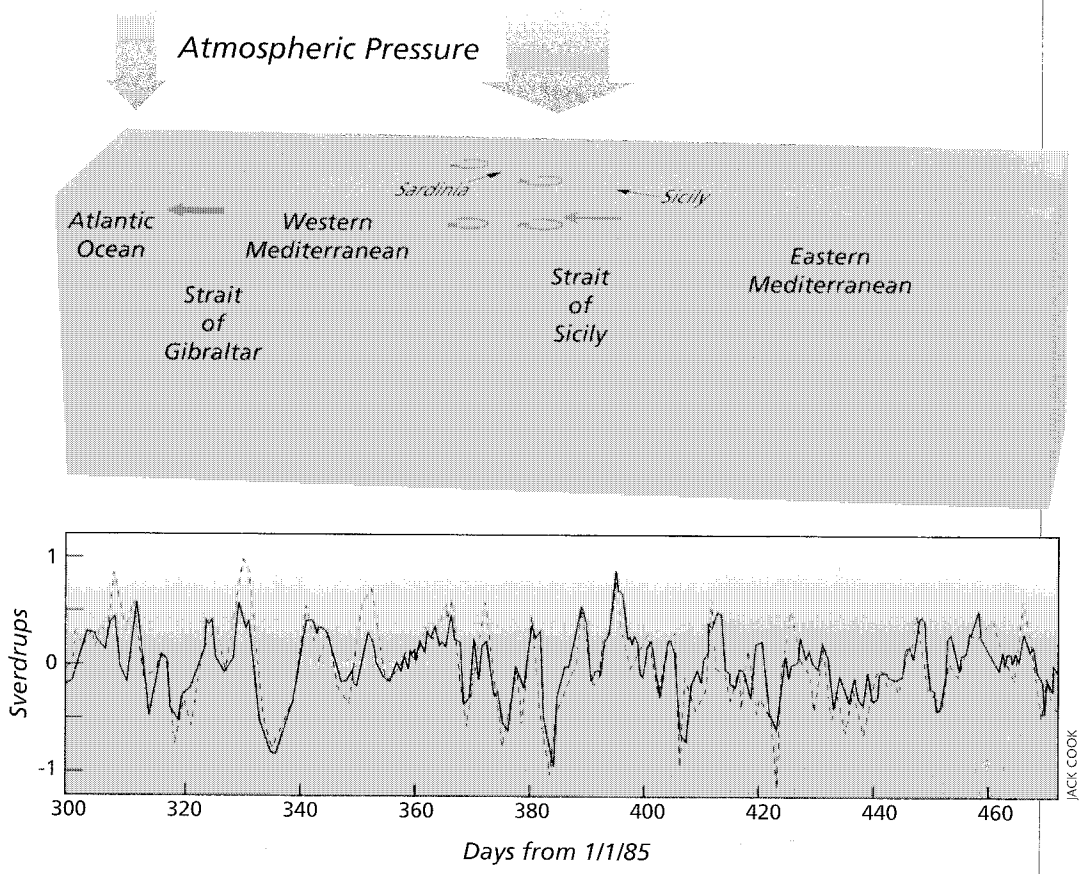
There are two novel aspects of this analysis, which is funded by the National Science Foundation. First, these averages were made over as small a horizontal area as possible. Second, the averaging necessary to produce the mean fields was carried out on "potential density surfaces," the surfaces on which water would move if there were no mixing in the ocean. Potential density is the density of a parcel of water that can move up or down to a prescribed reference pressure from its real pressure without gaining or losing heat.

An example of the results of this procedure for a surface that would have a density of 1.03185 grams per cubic centimeter when moved to 1,000 decibars is shown in the left panel of the figure on page 19. The right panel shows the results for a density of 1.03695 at 2,000 decibars. The contours are the pressure (or depth) of this surface. Blue shading represents cold, fresh water feeding into these layers at high latitudes. Pink shading shows warm, saline water flowing out of the Mediterranean Sea. The sharp shoaling of these surfaces off the east coast of North America is influenced by the Gulf Stream. Yellow shading indicates recirculating gyres. The gyre in the northwestern Atlantic is associated with the Gulf Stream, while the one centered near 15°N, 40'W lies on the eastern flank of the Mid-Atlantic Ridge and has not been observed before.

Ongoing projects will also combine these results with average current velocities at two depths obtained from acoustically tracked, neutrally buoyant floats, using simple mathematical models to produce estimates of the mean circulation of the North Atlantic. These analyses are crucial to advancing understanding of the ocean's role in world climate.

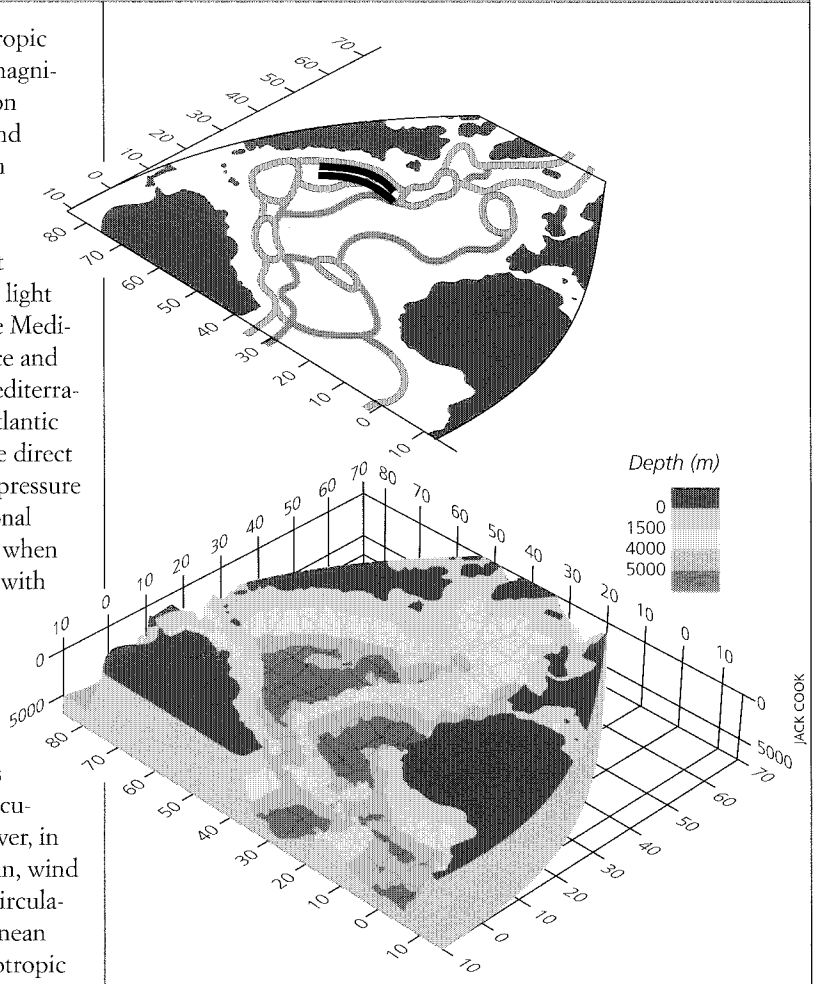
Physicists Study Atmospheric Forcing in Semi-Enclosed Seas and Exchange through Straits

Semi-enclosed seas are dynamic but nearly closed systems that exchange mass, momentum, and vorticity with adjacent water bodies, usually through narrow, shallow straits. The internal dynamics of semi-enclosed seas and the exchanges through their connecting straits are mainly driven by atmospheric forcing—atmospheric pressure, wind stress, and net evaporation-precipitation—and the thermohaline structures resulting from exchanges through straits. The Japan Sea, the Mediterranean Sea, and the Red Sea are examples of semi-enclosed seas. Julio Candela is collaborating with Carlos Lozano (Harvard University) on a systematic study of semi-enclosed-sea response to



Sketch of the Mediterranean Sea showing the physical mechanisms by which atmospheric pressure drives barotropic flows through the Strait of Gibraltar. When the mean atmospheric pressure over the Mediterranean is higher with respect to the ocean outside the strait, water is forced to flow out. The lower plot shows a comparison between directly measured barotropic flow at the strait and that predicted by a simple model driven only by the observed atmospheric pressure over the region. The flow measurements were made during the Office of Naval Research-funded Gibraltar Experiment October 1985 to October 1986.

support from the Office of Naval Research, they are developing a new approach to basin dynamics using a model based on the real geometry and bathymetric configurations of the basins under study, as well as the observed meteorological forcing. The circulation of a sea is represented by both its nonrotating (divergent) and rotating (nondivergent) parts, and the evolution and interaction of these components are investigated as they respond to specific atmospheric forcing fields. So far, the study has concentrated on the barotropic response to atmospheric forcing, that is, the part of the motion that is independent of depth, in two important North Atlantic marginal seas, the Mediterranean and the Gulf of Mexico-Caribbean Sea system. This work has revealed atmospheric pressure's important role in exchange through connecting straits. For example, the barotropic exchange for periods longer than a day between the Mediterranean Sea and the North Atlantic Ocean through the Strait of Gibraltar is principally driven by variation in atmospheric pressure over the Mediterranean. This process is due to a simple physical mechanism sketched in the figure, at left: the difference between the mean atmospheric pressure over the Mediterranean and over the Atlantic is the driving force for barotropic exchange through the strait. A model that considers conservation of mass inside the Mediterranean and flow dynamics in the strait can reproduce a large fraction of observed barotropic transport in the strait. These atmospheric-pressure-driven barotropic transports can reach magnitudes above one million cubic meters per second and are superposed on the classical two-way exchange through the Strait of Gibraltar that moves relatively fresh, light Atlantic water into the Mediterranean at the surface and saltier, more dense Mediterranean water into the Atlantic at depth. Although the direct effect of atmospheric pressure is to induce nonrotational motion inside the sea, when this motion combines with flow over topography, the earth's rotational effect on fluid flow, and bottom frictional stress, the nonrotational motions generate rotational circulation patterns. However, in the interior of the basin, wind stress also drives the circulation. In the Mediterranean Sea, wind-related barotropic circulation is about six times more important than atmospheric pressure. The next step for Candela and Lozano will be to examine the sea's baroclinic motions, those that vary with depth.



Principal pathways of flow for the combined deep and bottom water circulation in the North and tropical Atlantic, with a perspective view of the seafloor bathymetry that contains and shapes the pathways. Red pathways indicate the southward trending flows, and blue the northward. The parallel black strips are the axes of the intense deep recirculating gyres to either side of the Gulf Stream. Additional counter-clockwise recirculating gyres are shown in green. These gyres act to mix the characteristics of the northward and southward flowing waters, and intensify the southward flow along the western boundary.

A Dozen Years of Hydrographic Measurements Bring a New View of Atlantic Deep Circulation

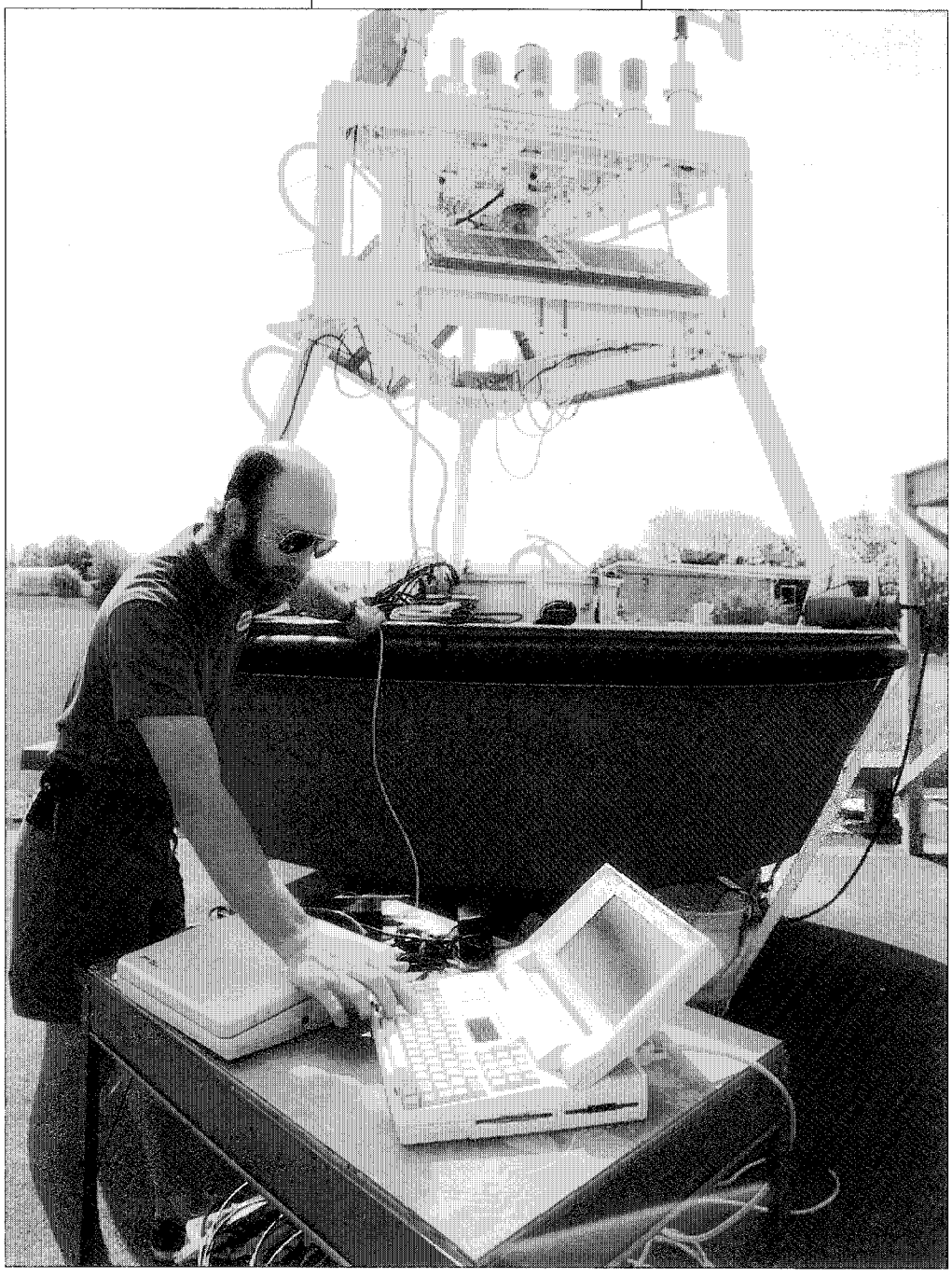
Attempts over the past 20 years to understand the role of the ocean in global climate have focused on the dominance of North Atlantic deep water export and compensating warm water input from the south as key elements of a global conveyor belt. In this scheme, warm water from around the world is drawn into the North Atlantic on the upper part of the belt loop, converted to cold water in the northern North Atlantic and carried back to the rest of the world on the lower part of the conveyor belt loop.

When Mike McCartney first came to WHOI in the early 1970s, Atlantic deep water circulation was visualized as having a vast interior region with essentially imperceptible movement bounded in the north and west by a deep boundary current carrying cold, dense water of Nordic Seas origin. This old image of the deep water circulation has persisted to this day in the conveyor-belt conception. Observations by WHOI colleagues Val Worthington, Bill Schmitz, Nelson Hogg, and Bob Pickart, beginning in the mid-1970's, showed that intense recirculating gyres of

deep water exist to either side of the axis of the Gulf Stream. These observations were the beginning of an exploration that is yielding a far-from-quiescent image of deep circulation in that vast interior region to replace that old image.

With NSF and ONR funding, McCartney began a series of cruises in the early 1980s that has taken him on eight hydrographic transects of the Atlantic as well as on several more concentrated western Atlantic hydrographic surveys. The image of deep circulation emerging from this rich data set differs in several major ways from the image of 20 years ago and from the simple image of a conveyor belt. The magnitude of the deep boundary current was expected to be about the same as the net export of deep water from the North Atlantic. The transects and independent measurements by colleagues in Miami have yielded estimates of deep-boundary-current magnitude as much as three times the expected value. McCartney's long transects show that the net export of deep water from the North Atlantic is not achieved by a unidirectional flowing deep boundary current of the expected magnitude, but rather as the difference in flow between the observed large deep boundary current's southward flow and a partially compensating northward flow farther offshore. These opposing flows represent recirculating deep gyres. These deep gyres also act as abyssal egg-beaters that blend the characteristics of northern originating water with those of water coming into the North Atlantic from the south. A stronger involvement of Antarctic bottom water and South Atlantic deep water in the interior of the North Atlantic is also apparent. The physics of the deep gyres is a subject of active theorizing.

The emerging synthesis of Atlantic deep-circulation observations is replacing the lower part of the conveyor belt with something more resembling the baggage carousel of an airport terminal. Usually a bag gets from an airplane to its owner's hand, but the actual route is rather circuitous, involving one or more localized recirculations. The overall transit time is much larger than the distance from the plane and the mean speed of the bag would suggest, and sometimes its final destination is not the owner's hand! For the deep North Atlantic carousel, the work of the next decade is to complete the mapping of its circulation, the measurement of the intensities of its components, and the determination of its physics.



TOM KLEINDINST

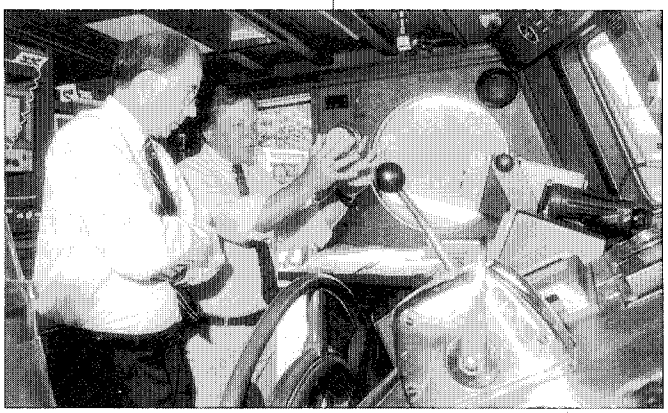
Neil McPhee calibrates a meteorological buoy.

MARINE POLICY CENTER

Scholars at the Marine Policy Center (MPC) are engaged in social scientific research on public policy issues related to coasts and oceans. Their work fosters the integration of economics, statistics, policy analysis, and law with WHOI's basic strengths in the ocean sciences. In 1992, the Center's research made significant advances in the areas of ocean resource conservation and science and technology policy.

Biological conservation is a leading public policy issue. Continuing their path-breaking work on problems of biological diversity, statistician Andrew Solow and economist Steve Polasky developed a simple model that links biological diversity to the potential social benefits of the conserved species. This model has led to a new "measure" of biological diversity—the "effective number" of species—depending upon the "joint dissimilarity" of species in a set.

Land-based marine pollution is the world's most serious marine pollution problem. Economist James Broadus, MPC Director, led an MPC research team in a comparative assessment of regional international programs to control land-based marine pollution in the Baltic, the North Sea, and the Mediterranean. The research resulted in several useful findings: active investment in or strict compliance by the state-parties to these programs cannot be shown to be in each party's own self-interest; with one exception, the programs do not include explicit mechanisms for trade (e.g., emissions quotas, quid pro quos); all of the programs were hindered by inadequate compliance reporting and lack of transparency; and all have benefited from the establishment of high-level political review and oversight structures. These and other project results will enable governments to design more effective international protocols on land-based marine pollution.



TERRI CORBETT

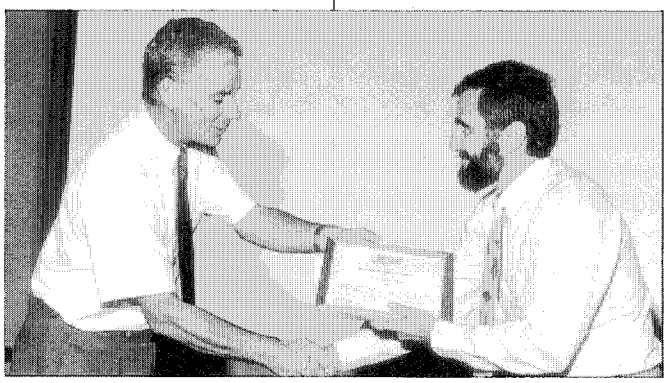
Arthur Gaines, right, and Massachusetts Congressman Gerry Studds are shown aboard R/V Eagle Mar during an August briefing on the Electronic Chart Display and Information System test-bed project being coordinated by the Marine Policy Center.

Arthur Gaines coordinates an advanced technology development and assessment effort aimed at improving the safety of maritime transportation and protecting the marine environment. The project has demonstrated the feasibility of shipboard integrated electronic charts as an alternative to more expensive and ineffective oil spill clean-up remedies and other technologies. MPC scholars have concluded that the proposed performance standards for electronic chart navigation systems, currently under consideration by the International Maritime Organization, are unnecessarily restrictive and may in fact hinder the adoption and improvement of technology best suited for maritime safety. Di Jin, Hauke Kite-Powell, and Broadus also devised and applied a dynamic economic model that indicates the electronic chart technology may be a more cost-effective means of controlling tanker-source marine pollution than existing legal requirements for the construction of double hulls.

Jin, a recently appointed MPC Fellow, received a 1992 National Sea Grant Association student research award honoring meritorious Great Lakes and marine-related research. His research into the cost and impact of environmental regulations on the exploration and production of offshore oil while a doctoral student at the University of Rhode Island led to the award.

In August, Broadus, Porter Hoagland, and Hongye Zhao, along with Robert Ballard of the WHOI Center for Marine Exploration, met in Beijing with Chinese officials at the National Museum of Chinese History and the State Bureau of Cultural Relics to plan a collaborative effort in underwater archaeological investigation and cultural resource management. MPC researchers are currently seeking funding for their portion of the project, which will involve research on comparative law and practice, resource allocation decisions, and international market behavior. This project complements NSF-funded research on the development of advanced marine technologies and the management of historic shipwrecks.

Ocean dumping continues to be an issue of considerable interest to policymakers. Because of the risks of waste disposal on land and into the atmosphere, scientists continue to explore the potential advantages of future ocean disposal options. With support from the Sloan Foundation, MPC



TERRI CORBETT

Scott Nixon, left, of the University of Rhode Island accepts the eighth B.H. Ketchum Award from Senior Associate Director Bob Gagosian.

scholars have undertaken a comparative economic analysis of an abyssal ocean disposal option. This research complements earlier research by WHOI scientists on the technical feasibility and environmental parameters of abyssal ocean disposal. The MPC research findings suggest that existing alternatives limit the economic attractiveness of abyssal ocean disposal. For example, the scarcity of landfill options is not so severe as often supposed. Also, transportation costs can be a dominant factor in the cost of ocean disposal. While nearshore ocean sites might appear to offer low-cost alternatives to land disposal for some waste streams, environmental and legal constraints are typically prohibitive. Substantial gains also still seem available through waste reduction, beneficial uses, and recycling. The factors shaping the long-term potential for abyssal ocean disposal require more careful study, but local factors have a strong influence on the comparative economics.

COASTAL RESEARCH CENTER

The Coastal Research Center (CRC) is a "center-without-walls" within WHOI designed to catalyze multidisciplinary, multi-organizational (industry, government, academic), and multinational research, contributing to an improved understanding of the coastal ocean, its physics, chemistry, biology, and geology. CRC provides research facilities and intellectual forums and stimulates joint ventures.

The Cooperative Marine Science Program for the Black Sea (CoMSBlack) has grown from a loosely knit group of scientists with mutual research interests in the Black Sea into a cohesive, focused program with truly interacting parties. Accomplishments during 1992 included two international research cruises, CoMSBlack '92a and '92b. The first was a five-vessel, five-nation study of Black Sea biology, including fisheries and a recently identified ctenophore predator on fish populations, *Mnemiopsis leidyi* (page 9). The second cruise extended the study of the fish predator and its distribution in the water column ecosystem.

TOM KLEINDINST

Bruce Lancaster, foreground, Dale Leavitt, and Sasha Leland of the Marine Biological Laboratory collect samples from New Bedford Harbor for clam disease studies.

The International Mussel Watch coastal monitoring program is based at CRC. Its initial phase in 1992 focused on field sampling and analysis of collected tissue samples for chlorinated hydrocarbon biocides. A total of 370 samples from 125 stations along the Atlantic and Pacific coastlines of Central and South America are being analyzed by collaborating laboratories. The results will provide a unique overview of coastal contamination in these regions.

CRC provides the WHOI link to the recently created Regional Research Association of the Gulf of Maine, and participated in the development of a regional research plan. Proposals were submitted last year by several WHOI investigators to the NSF-NOAA Global Ocean Ecosystems Northwest Atlantic/Georges Bank program. CRC helped to coordinate the WHOI response to this program and will provide continued support when it begins.

Other CRC regional outreach efforts in 1992 included:

- Co-sponsorship, with the Waquoit Bay National Estuarine Research Reserve, of a two-day symposium on alternative septic-system technologies. One cause of coastal embayment eutrophication is excessive nutrient loading, and residential septic systems are a significant source of these nutrients;
- Co-sponsorship, with WHOI Sea Grant, of a forum on salt marsh loss due to construction of structures to protect coastal properties from erosion. This discussion among experts in coastal processes and regulation will be followed by a broader presentation in 1993.
- Participation through a variety of mechanisms in public discussions of the new Boston ocean sewer outfall.

An annual grant from the Mobil Corporation provides CRC with the unique ability to respond quickly to unpredictable events such as severe coastal storms. In December 1992 the Andrew W. Mellon Foundation announced a grant of $900,000 for WHOI-based coastal research over the next six years. During this time, the Institution intends to raise permanent endowment to support coastal research.

In September, Scott Nixon of the University of Rhode Island received the eighth B.H. Ketchum Award in recognition of his innovative research in coastal ecology and nutrient cycling and his effective synthesis of scientific results for fellow scientists, students, and resource managers. As a part of his award visit, Nixon presented a lecture on "Changing Nutrient Inputs and the History of Primary Productivity in Narragansett Bay" and met with WHOI and MBL students and staff, providing all with a firsthand opportunity to experience his sharp intellect and gracious good humor.

CENTER FOR MARINE EXPLORATION

Center for Marine Exploration activities focused on three major areas in 1993 :

- continued transition of the *Argo/Medea/Jason* technology base from the Deep Submergence Laboratory to the operational side of the Institution,
- planning for the Guaymas Basin expedition and its involvement in the JASON Project, and
- development of a marine archeology program with the People's Republic of China.

Argo/Medea/Jason: In 1982, the Office of Naval Research (ONR) began funding development of the *Argo/Jason* system within WHOI's Deep Submergence Laboratory (DSL). The Institution created the Center for Marine Exploration (CME) in 1987 and charged CME with creating a scientific user base for this new exploration technology. Since 1987, CME has organized and sponsored a number of expeditions utilizing the *Argo/Jason* system including discovery of R.M.S. *Titanic* and the German Battleship *Bismarck*, various scientific expeditions to the Mid-Ocean Ridge, several military programs, and three JASON Projects to the Mediterranean, the Great Lakes, and the Galapagos Islands. Given the success of these efforts and the completion of *Argo/Jason* development, ONR and the Institution decided in 1992 to transfer this new technology base to the operational side of the Institution and combine its operational team with the *Alvin* team. CME has been working with ONR, DSL, and the *Alvin* Group to make this a smooth transition.

Guaymas Expedition: A great deal of 1992 CME activity was devoted to organization of the JASON Project's March 1993 science program, its most comprehensive to date, an investigation of hydrothermal vents in the Guaymas Basin by Mexican scientists and 16 U.S. colleagues representing five institutions. In a 1993 JASON Project innovation, arrangements were made for several participating scientists to conduct their work from a network of North American and European downlink sites, where they could work directly with *Jason* pilots and receive data by satellite. This fourth JASON Project live-broadcast program was aimed at 750,000 students and 10,000 teachers. The JASON Project was honored in 1992 with one of 22 National Education Association Awards for the Advancement of Learning through Broadcasting.

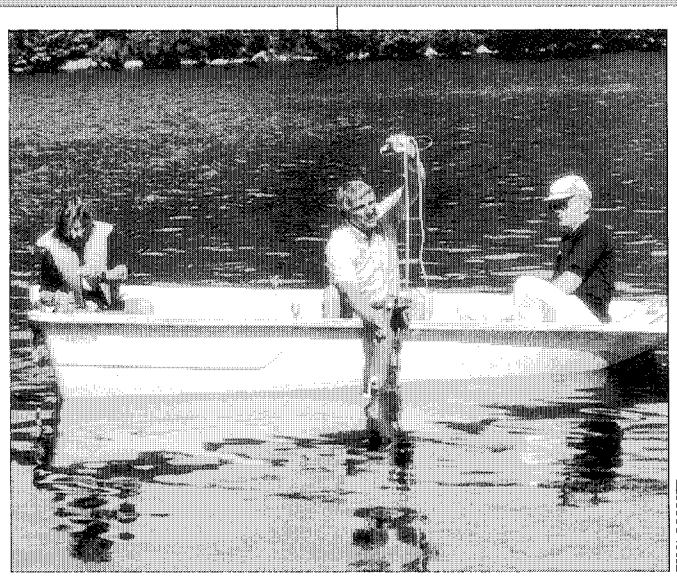
Chinese Marine Archaeology: In August 1992, a series of meetings were held in China to discuss creation of a joint program between CME/WHOI's Marine Policy Center and the People's Republic of China, to help China establish a world-class program in marine archeology utilizing the Institution's advanced technology in deep submergence engineering as well as its past experience in marine archaeology programs.

SEA GRANT PROGRAM

WHOI Sea Grant supports 12 to 15 concurrent research projects and several smaller "new initiative" efforts aimed at taking the first steps into promising new areas. Many of the projects address local and regional needs while others have national or even global implications. Some examples of 1992 Sea Grant-supported research include studies of:

- economic impacts from harmful algal blooms and red tides,
- contamination of edible marine resources,
- continuation of water quality monitoring efforts in Falmouth's coastal ponds using local volunteers, and
- creation of a coastal studies program in which high-school teachers and students monitor coastal feature changes that have a significant impact on their community.

Sea Grant supports three ongoing projects relating to research in Massachusetts and Cape Cod bays and the Boston Harbor Outfall Project. They focus on red-tide bloom dynamics, the effect changing nitrogen inputs or changing sewage treatment strategies will have on nitrogen budgets and trophic status of coastal waters, and the rate of vertical mixing across the thermocline in Massachusetts Bay.



TERRI CORBETT

Sea Grant Pond Watchers Julie Rankin, left, John Dowling, and Barry Norris sample Oyster Pond in Falmouth, Massachusetts.

Communication and outreach activities included the creation of a cable television video series; organizing beach cleanups, storm-drain painting projects, and guided beach and coastal walks; compilation of a database cataloging hundreds of reference materials; and creation of an activity booklet that includes facts and illustrations on various topics in oceanography.

"All-Cape Coastal Science Seminar" topics included changes and trends in Chatham's coastal waters, sulfur metabolism in salt marshes, habitats and population dispersal of the Eastern coyote, vegetation response to fire in coastal oak-pine communities, and Cape Cod's coastal turtles.

The popular "Oceans Alive" lecture series, designed for the general public, featured presentations on Winslow Homer's paintings of the sea, the Ashumet Valley sewage plume, marine science in the Middle East, trends and challenges in ocean science, and *The Central America* shipwreck.

Dean's Comments

As the United Nations Conference on Environment and Development (UNCED) convened in Rio de Janeiro in early June 1992, several thousand miles to the north the Sea Education Association SSV *Corwith Cramer* departed Woods Hole for a 10-day research and education cruise. The ship carried a majority of the 1992-93 incoming MIT-WHOI Joint Program class of graduate students. Its mission was to introduce the students to seagoing oceanography and to each other. I am confident that as these students pursue their careers they will bring the very best of theory, experimentation, field observation, and modeling to help answer many of the important questions raised at UNCED (and at other forums) about the role of the oceans in climate and about the wise use of ocean resources.

The *MIT-WHOI Joint Program in Oceanography and Applied Ocean Sciences and Engineering* and the *WHOI Graduate Program* have always attracted excellent students, but 1992 was an exceptional year! Our applicant pool increased for the third consecutive year. We are proud that over 72 percent of our admission offers were accepted and that more than 50 percent of the 38 students accepting came to us with fellowships earned in national or international competitions. Graduate student enrollment reached a record high of 147 for the fall semester. These students contribute substantially to the intellectual efforts of the Institution by their probing queries of the faculty (scientific and technical staff members of the Eduational Assembly), guests, and visitors, and by their own research efforts in conjunction with faculty and staff.

Thirty graduate degrees were awarded in 1992 bringing the total degrees awarded to 360. Plans are under way for the 1993 celebration of the 25th Aniversary of the founding of the unique and highly successful MIT-WHOI Joint Program.

During the December 1992 American Geophysical Union meeting in San Francisco, 55 alumni/ae were joined by present students and faculty from both WHOI and MIT for an enjoyable reception involving approximately 125 people.

Once again, there was also a strong applicant pool for our *Postdoctoral Scholar Program*. Ten awards brought outstanding postdoctoral scientists and engineers to the Institution for a year of study (see box below). As one measure of their high professional standing, five of them brought competitive national or international awards that will support their second postdoctoral year.

The important contributions of present and past Postdoctoral Scholars to oceanography and ocean engineering worldwide are recognized in many ways. This year we were particularly pleased to receive a challenge grant from the Henry L. and Grace Doherty Foundation, Inc. in support of the Institution's first Postdoctoral Scholar endowment. This grant is a significant step towards our goal of 18- to 24-month appointments for all Postdoctoral Scholars, to provide them vital time to make the transition from graduate studies to full-time professional careers in academic, government, or industry research.

Few places in the world offer the unique blend of intellectual vitality, hard work, and *bonne vie* of summer in Woods Hole. For the past 34 years, undergraduates, mainly between their junior and senior years, have participated in the Institution's *Summer Student*

TOM KLEINDINST

Earthwatch students listen to a presentation by Dale Goebringer.

1992 Postdoctoral Scholars

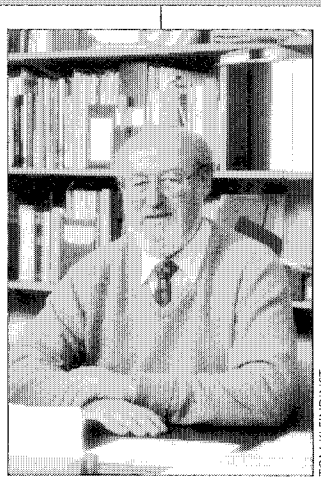
Name	University	Major	Citizenship	Department	Sponsor
Steven Paul Anderson	UCSD/SIO	Physical Oceanography	USA	PO	Weller/Plueddemann
Wei Jun Cai	UCSD/SIO	Chemical Oceanography	PRC	MC&G	Sayles/Martin
Scott France	UCSD/SIO	Marine Ecology	Canada	B	Mullineaux
Lynn D. Gilson	Harvard U	Microbiology & Molecular Genetics	USA	B	Dunlap
Miguel Goni	U Washington	Organic Geochemistry	Spain	MC&G	Repeta/Eglinton
J. Gregory Hirth	Brown U	Geological Sciences – Rock Mechanics	USA	G&G	Dick
Graham M. Kent	UCSD/SIO	Geophysics – Marine Seismology	USA	G&G	Detrick
Heidi Nepf	Stanford U	Civil Engineering – Fluid Mechanics	USA	AOPE	Geyer
Anya Waite	U Brit Columbia	Biological Oceanography	Canada	B/PO	Olson/Price
Louis L. Whitcomb	Yale U	Electrical Engineering – Robotics	USA	AOPE	Yoerger/Ulrich

Fellowship Program. This year 28 students, representing 24 colleges and universities, took part in the program that includes an individual research project, a special student seminar series, and the wide range of other activities that characterize summer in Woods Hole.

The Summer Student Fellows were joined by 11 MIT undergraduates participating in the second year of WHOI involvement in the *MIT Undergraduate Research Opportunity Program.* In addition, eight high school students selected by *Earthwatch* participated in a two-week program that introduced them to coastal environmental quality research.

One measure of the intellectual vitality of a scholarly endeavor is the extent to which new knowledge and ideas are brought into a discipline or field of study from both contiguous and unrelated disciplines. This, among other laudable features, is the hallmark of one of the Institution's oldest formal education efforts, the *Geophysical Fluid Dynamics Summer Study Institute.* During its 34th summer, eight fellows joined faculty and visitors for a series of seminars and discussions concerned with "Dynamics of the Outer Planets."

The Institution's national and worldwide leadership role in ocean sciences, ocean engineering, and marine policy coupled with its longstanding, successful education programs generates many requests for WHOI involvement in other education activities, especially in the undergraduate and K-12 arenas. This year, we completed three agreements for *cooperative ventures in education* with other southeastern Massachusetts institutions in a modest expansion of Institution efforts at these educational levels:



TOM KLEINDINST

John Farrington

- Under a memorandum of understanding, WHOI will cooperate with the Massachusetts Maritime Academy (MMA) on a new MMA program in marine safety and environmental protection.
- Building on more than 20 years of local experience and interaction with the Falmouth Schools (most recently in the Woods Hole Science and Technology Education Partnership), the Institution entered into an agreement to inaugurate the Southeastern New England Science and Engineering Education Society (SENESEES) "to strengthen science, technology, and mathematics education" and to "add richness, excitement and depth to science, technology, and mathematics education." Participating organizations include WHOI, the Marine Biological Laboratory, the University of Massachusetts-Dartmouth, the Massachusetts Maritime Academy, Bridgewater State College, Cape Cod Community College, Bristol Community College, the Lloyd Center, the Manomet Bird Observatory, and the Children's Museum in Dartmouth, Massachusetts.
- Under a memorandum of understanding with Bridgewater State College, WHOI co-sponsored a 1993 JASON Foundation for Education Primary Interactive Network Site. The Institution was one of the founders of the JASON Foundation, which is noted for its pioneering efforts, under the leadership of Robert Ballard, in the use of telepresence and distance learning technologies. Provision of a curriculum supplement and the active involvement of teachers have been key factors in the JASON Foundation's telepresence experience. As an institution known for excellence in teacher education and as a center for research on and implementation of advanced education technologies, Bridgewater State College, less than an hour's drive from Woods Hole, is a natural match with the JASON Foundation mission. The cooperative effort between WHOI and Bridgewater State College brings the strengths of both institutions to the regional implementation of the JASON education program.

We are fortunate in many of our education activities at the local, state, national and international level to have a productive and mutually reinforcing partnership with the Institution's Communications Office. One of many examples this year was the special four-issue volume of *Oceanus* magazine that constitutes a primer on modern oceanography that is especially useful to ocean science educators. In addition, the Institution's Associates Program, through the Development Office, sponsors *Ocean Explorer,* a quarterly publication that brings the excitement of ocean sciences and ocean engineering to the Young Associates.

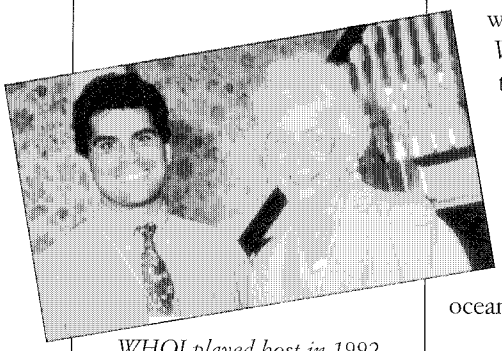
The *Minority Trainee Program* is an important part of the Institution's effort to attract more scientists and engineers from underrepresented groups into ocean sciences and engineering. We are pleased to note that between 1978 and 1992 WHOI supported 38 Minority Trainees: 22 African-

DEGREE STATISTICS

		1992	1968-92
WHOI	Ph.D.	0	3
MIT/WHOI	Ph.D.	14	246
MIT/WHOI	Sc.D.	0	26
MIT/WHOI	Engineer	4	*40
MIT/WHOI	S.M.	12	*45
		30	360
Total Degree Recipients		27	348
Total Graduates		21	**339

*Some receive more than one degree. **Nine with interim degrees.

Dean's Comments



WHOI played host in 1992 to an Office of Naval Research sponsored week-long College Faculty Workshop. The program's objective is to develop a network of knowledgeable advisors for undergraduate students in the fields of oceanography and ocean engineering. The top photo shows all wookshop participants. In the middle photo A. Lawrence Peirson (left), Associate Dean and Registrar, speaks with Lilli Hornig (center), Chair of the Trustees Education Committee, and Professor Reza Hashemi from Howard University. In the bottom photo Isidro Bosch (left), of the University of New York, Geneseo, a former WHOI Minority Trainee, poses with Cecily Selby, a member of the Trustees Education Committee.

Americans, eight Hispanics, three Native Americans, and five Asian/Pacific Islanders. In addition, the fall semester Joint Program class of 46 graduate students included 10 from minority groups. We are proud of our success with the Minority Trainee Program and other efforts to recruit minorities and recognize that success with programs of this type comes only with sustained effort over time.

With funding from the Office of Naval Research, we were host in summer 1992 to the third week-long *College Faculty Workshop*. The goal of this program is to develop a network of knowledgeable advisors to whom undergraduates can turn for guidance in the fields of oceanography and ocean engineering. The workshops provide a broad overview of modern oceanography and ocean engineering and in-depth exposure to research through lectures, seminars, and one-on-one visits with staff and graduate students. This year there was a special emphasis on involving faculty from schools with primarily underrepresented minority group enrollments (see box). The first two workshops, also funded by the Office of Naval Research, were held in cooperation with the University of Washington, Seattle, in 1987 and with Scripps Institution of Oceanography in 1989.

The Institution's commitment to education includes providing opportunities for WHOI employees to continue their education as one of the benefits of employment. The program is administered by the Education Office with advice from the Staff Training and Development Committee. In addition to providing financial assistance for continuing education at area colleges and universities, WHOI began a cooperatiave arrangement in 1991 with the *University of Massachusetts-Lowell Continuing Education Program* to offer evening courses at WHOI. In the program's second year, 47 employees took advantage of 10 classes. The classes are also open to people in the surrounding communities on a regular tuition and fees basis.

As is evident from the preceding report, I am pleased once again to report that the faculty, postdoctoral scholars and investigators, staff, and students have met the high expectations of the Institution's education responsibilities commensurate with a national and international leadership role in ocean sciences and ocean engineering.

John W. Farrington
Assocate Director for Education and Dean of Graduate Studies

1992 College Faculty Workshop Attendees

Name	Department	College/University
Isidro M. Bosch	Biology	University New York, Geneseo
Larry C. Brown	Life Sciences	Virginia State University
Douglas Coe	Chemistry	Montana College
James E. Fox	Geology	South Dakota School Mines & Tech.
Larry L. Funck	Chemistry	Wheaton College
Reza Hashemi	Computer Science	Howard University
Douglas Hileman	Biology	Tuskegee University
Alice L. Hoersch	Geology/Physics	La Salle University
Raymond N. Laoulache	Mech. Engineering	University of Massachusetts, Dartmouth
Carol Mankiewicz	Biology/Geology	Beloit College
Charles H. McGruder	Physics	Fisk University
Vijaya L. Melnick	Biology	Univ. of the District of Columbia
Pinar M. Menguc	Mech. Engineering	University of Kentucky
Marco Pagnotta	Chemistry	Barnard College
John F. Patzer	Engineering	University of Pittsburgh
Solomon Quaynor	Engineering	Morris Brown College
James K. Schooley	Biology	Northeastern State University
Michael E. Smith	Biology	Valdosta State University
Jack W. Travis	Geology	Univ. Wisconsin-Whitewater
George Trevino	Mech. Engineering	Michigan Technological University

Research Vessel *Knorr* departed Woods Hole February 8 on its first scientific cruise in nearly three years, a month-long voyage to the Mid-Atlantic Ridge as part of the Ridge Inter-disciplinary Global Experiment program. The ship had returned to Woods Hole in October 1991 after nearly three years undergoing a mid-life refit and major upgrade that included lengthening the ship by 34 feet and installing a new propulsion system.

After two and one-half years at sea, Research Vessel *Atlantis II* and Deep Submergence Vehicle *Alvin* returned to Woods Hole June 10, completing the longest scientific voyage in Institution history. Several hundred employees, family members, and friends gathered on the pier under sunny skies as Relief Master Paul Howland guided the ship to the dock to a round of applause and *Pomp and Circumstance* performed by Falmouth's Morse Pond School Hot Jazz Band. Voyage 125 began December 29, 1989, when the vessels left Woods Hole to begin the first of 44 cruise legs (37 scientific, 7 transit), mostly in the Pacific Ocean. During the extended voyage *Atlantis II* was at sea 575 days and *Alvin* made 368 dives. The voyage set the WHOI record for most days away from Woods Hole at 894.

DSV *Alvin* set yet another record March 8 when it made Dive 2,500. The dive was made in 2,536 meters of water near 10° North on the East Pacific Rise off the Mexican coast. *Alvin* pilot was Tim Connors and scientific observers were Karen Von Damm of the University of New Hampshire and Debra Colodner of Lamont-Doherty Geological Observatory.

Senior Scientists William J. Schmitz of the Physical Oceanography Department and Henry J.B. Dick of the Geology and Geophysics Department were named the new recipients of the W. Van Alan Clark, Sr. and Jr., Chairs for Excellence in Oceanography. The permanently endowed chairs are awarded for a five-year period to tenured members of the scientific staff "who have distinguished themselves through extraordinary accomplishments in marine scientific research and education." Schmitz was cited for his fundamental contributions to our understanding of ocean circulation and eddies. His efforts to develop and utilize the technology of moored current meters revolutionized descriptive physical oceanography. Dick's work in the early 1980s on the correlations of ridge tectonics and basalt chemistry spawned a whole new approach to studying ridge tectonics.

Scientist Emeritus Mary Sears of the Biology Department received an Alumnae Recognition Award from the Radcliffe College Association in June. The award honors "women whose lives and spirits exemplify the value of a liberal arts education." Sears, a planktonologist, began working at WHOI in 1931 with Henry Bigelow, the first Director, and became a staff member in 1939.

Scientist Emeritus Stanley Watson of the Biology Department was presented the Cecil H. Green Award for outstanding contributions to oceanography at the annual Associates Dinner June 19 on the Iselin Mall. The award was established in 1991 by the WHOI Associates and is named for the philanthropist and Texas Instruments founder, who has had a long association with the Institution. The award, a memento and plaque, was presented to Watson by the 91-year-old Green.

Research Associate George Hampson of the Biology Department was honored by The Coalition for Buzzards Bay with its annual Guardian Award for "outstanding service in the stewardship of this magnificent estuary entrusted to our care." Hampson, one of four recipients, was recognized "for his studies to pinpoint

TOM KLEINDINST

Falmouth's Morse Pond School Hot Jazz Band joined a large WHOI crowd to welcome Atlantis II *home in June.*

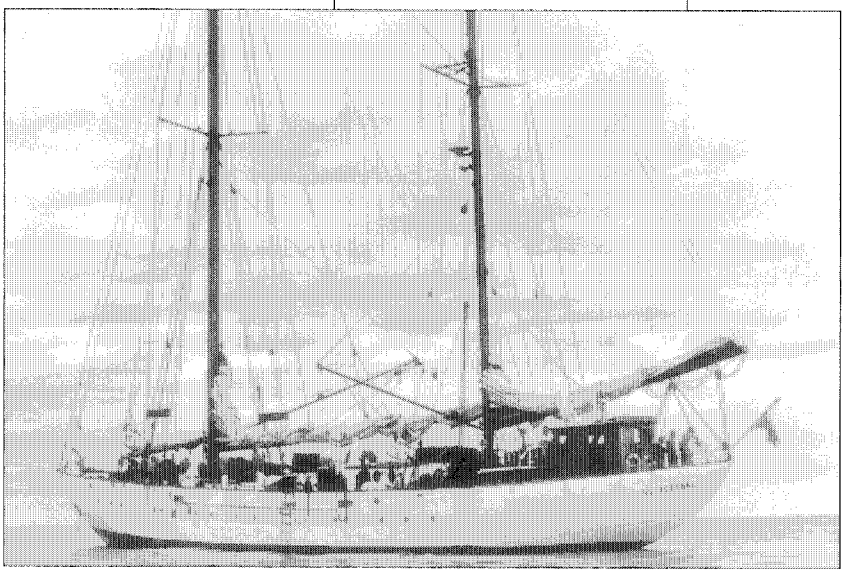
TERRI CORBETT

Stanley Watson displays the Cecil H. Green Award he received at the Associates western barbecue in June. It was presented to him by Cecil Green, second from right. Associates President Charles Dana is at left, and Vice President of the Corporation Charles Hollister is at right.

the Bay's ills, his ongoing efforts to educate the public on its role in the Bay's clean-up, his expertise in damage done by oil spills, and for his early leadership in forming the Coalition."

WHOI awarded its thirteenth college scholarship to Margaret Bothner, the overall winner of the Fourteenth Falmouth Community Science Fair March 14. Bothner, a junior at Falmouth High School, was awarded the $1,500 scholarship for her work on the sources and concentrations of radon in Falmouth homes, particularly in well water. The Institution's Education Office also awarded a $500 college scholarship, a day trip on the Research Vessel *Asterias*, and two two-year subscriptions to *Oceanus* magazine to winners of the Falmouth Academy Science Fair March 6.

Word reached the Institution early in the year that WHOI's former research vessel *Atlantis* was returned to service in Argentina after years of neglect. Rechristened *El Austral* when WHOI sold the 142-foot ketch to Argentina in 1966, the ship was drydocked and neglected between 1986 and 1990. Considerable restoration and repair work was undertaken in 1990 and 1991 and *El Austral* has been returned to good sailing condition. Director of Development Jacqueline Suitor visited Argentina and spoke with Horacio Ezcurra, master of *El Austral*, who provided recent photos and information on the vessel.



HORACIO EZCURRA

El Austral, *formerly* Atlantis, *WHOI's first research vessel, was recently refurbished by the Argentine government and is working again as a research vessel.*

The 305-foot NATO Research Vessel *Alliance* made a port call at WHOI September 13 on its way to Halifax, Nova Scotia. More than 200 Associates and staff members visited the vessel during an afternoon open house.

The increasing flow through WHOI of international employees, students, postdocs and guest students spurred the creation of a Task Force on International Arrivals to consider and recommend a program for meeting the needs of foreign visitors and their WHOI hosts.

Institution administrative changes in 1992 included promotion of Associate Director for Research Robert Gagosian to Senior Associate Director and Director of Research. The new Controller, Karen Lauritzen, arrived September 15 from her previous position as Assistant Vice President for Finance and Assistant Treasurer at California's Santa Clara University. Joseph Agius, who became Manager of Management Information Systems (formerly called Systems & Procedures) in June, came to WHOI from the Bank of Boston, where he was a systems administrator and project manager.

A July planning meeting to discuss radioactivity and environmental security in the oceans attracted representatives from the Department of State, Canadian Centre for Global Security, the Russian Academy of Sciences, the National Academy of Sciences and many others. The scientists issued an urgent plea to step up investigations of radioactivity in northern

oceans. The Institution will host an international conference on this topic in June 1993.

Nearly 300 Associates and guests filled the Clark fifth floor September 11 for the annual Day of Science, which featured "Waste Disposal in Massachusetts and Cape Cod Bays: A Scientific Perspective." Poster exhibits on the topics discussed during the program, including an interactive computer display, were featured in a tent on the Fenno House lawn, where Associates and guests joined staff for further discussion and refreshments.

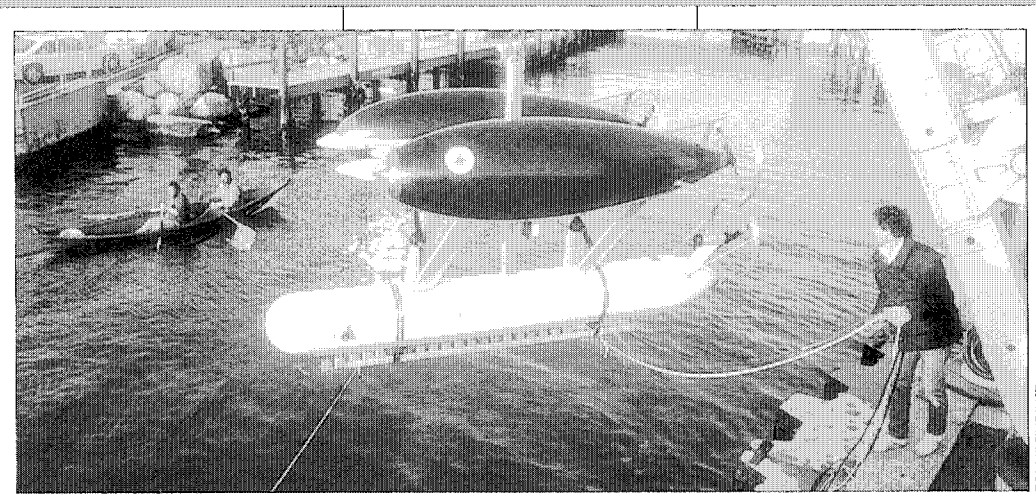
The Autonomous Benthic Explorer (ABE) took its first plunge September 29 for ballast checks in the Eel Pond channel. The new vehicle is designed to perform scientific surveys of the seafloor over an extended period of time without a support vessel, complementing existing manned submersibles and remotely operated vehicles. One of its expected uses will be repeated surveys of hydrothermal vent areas at depths eventually up to 6,000 meters.

The Clark 507 conference room was filled to capacity November 16 for the presentation of the eleventh Henry Bryant Bigelow Award in Oceanography to Alice Louise Alldredge and Mary Wilcox Silver "for their groundbreaking work in understanding the importance of marine snow." Alldredge is a Professor of Biology at the University of California, Santa Barbara, and Silver is a Professor of Marine Sciences at the University of California, Santa Cruz. Each received a gold medal, a certificate, and $5,000.

A three-year, $662,000 grant from the Island Foundation, Inc., of Marion, MA, will support research on alternative sewage and septage treatment technology. Senior Scientist John Teal and Associate Scientist Brian Howes of the Biology Department are co-principal investigators. The award is the largest single grant ever given by the Island Foundation.

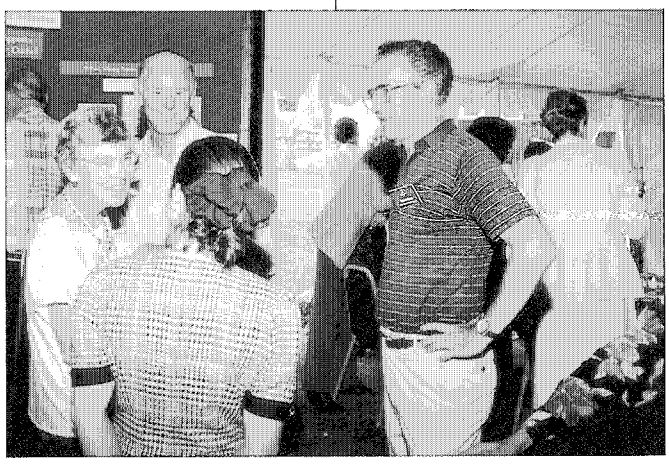
A $500,000 challenge grant from the Palisades Geophysical Institute, Inc., (PGI) will establish the J. Lamar Worzel Assistant Scientist Fund. WHOI has raised an additional $500,000 to match the challenge grant. The entire amount of $1 million will be used to establish the endowment fund, and its income will be used to support young scientists pursuing careers in geophysical oceanography at WHOI. Worzel, president and chairman of PGI, was a research associate in geophysics at WHOI from 1940 to 1946.

Thousands of negatives taken by the late Jan Hahn, the first editor of *Oceanus* magazine, during his 25-year



TOM KLEINDINST

Rod Catanach handles lines during the first pierside tests for a new remote vehicle, the Autonomous Benthic Explorer, in the fall of 1992.



DAVE GRAY

Exhibits, information, and good company abounded at the Associates Day of Science, which featured perspectives from several scientists on waste disposal in Massachusetts and Cape Cod bays.

TERRI CORBETT

The 11th Henry Bryant Bigelow Award went to University of California scientists Alice Alldredge, left, and Mary Silver for their pioneering work on marine snow.

career at WHOI were donated to the Institution Archives in November by Hahn's widow, Dorothy Parshley Hahn. The collection of an estimated 10,000 negatives is considered a significant contribution and the backbone of the Institution's visual history from 1947 to 1972.

After nearly two years of discussion, WHOI adopted a no-smoking policy on September 1, following a six-month notice to smokers. It prohibits smoking in the interiors of WHOI buildings and vehicles and restricts smoking on ships.

TERRI CORBETT

Linda Morse-Porteous award winner Sheila Griffin celebrates with John Porteous at the Employee Recognition Ceremony.

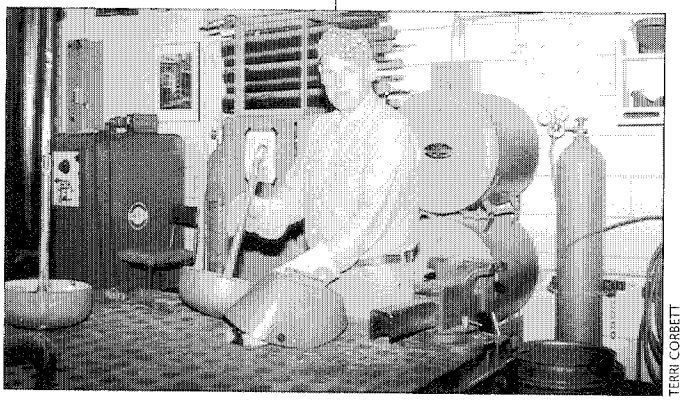
The WHOI Exhibit Center attracted 36,346 visitors in 1992, up from 31,661 visitors in 1991, and was open a record 254 days. Information sessions, sponsored by the Information Office, were held in May and June for prospective and returning volunteers who help staff the Exhibit Center, answer inquiries in the Information Office, serve as Sea Grant "pond watchers," and work in other volunteer positions throughout the Institution.

A concept for an Ocean Science and Technology Discovery Center, discussed in various forms by many people at WHOI during the past decade, was publicly discussed during the fall in order to gain support for a grant proposal to the state's Executive Office of Economic Affairs. The Institution received a $73,000 Tourism Fund grant and matching funds from the Bank of Boston, Branch of Atlantic Marine Geology of the U.S. Geological Survey, and WHOI. The grant funds a feasibility study to determine the financial viability of a science center with the ocean as its theme. A 21-member Steering Committee was appointed by the Director to oversee the feasibility study, whose results are expected in summer 1993.

The largest Institution event of the year, the Employee Recognition ceremony, attracted more than 450 employees, retirees, and guests September 14 to a tent on the Fenno House lawn. Fifty-one individuals were honored, twenty seven with ten-year pins, eighteen with 20-year pins and a Seth Thomas schooner desk clock, and six with 30-year pins and a choice of a Nichols & Stone WHOI armchair or rocker. Since the celebration began three years ago, 383 employees have been honored for long-term service to the Institution. A highlight of the event is presentation of the Penzance, Vetlesen, and Linda Morse-Porteous Awards. The Vetlesen Award (a plaque and $2,500), for "exceptional contributions not merely above and beyond superb performance of their jobs and service on committees, but for true selfless dedication of a major portion of themselves to the entire WHOI community over a long period of time," was presented to welder Charles Clemishaw. The Penzance Award (a plaque and an account for $5,000), presented for "sustained exceptional performance, for outstanding representation of the WHOI spirit, and for major contributions to the personal and professional lives of our staff," was given to the Stockroom crew: Richard Lovering, Sam Lomba, Donna Andrews, Joseph Curran and Glenn Enos. The second Linda Morse-Porteous Award, in memory of the Senior Research Assistant who died in January 1991, was presented to Research Associate Sheila Griffin. The award is given to a female technician on the technical or graded staff who has consistently demonstrated leadership, dedication to and quality of work, service as a role model and/or mentor to junior women, and involvement in the WHOI community.

JOHN PORTEOUS

The Penzance Award for 1992 went to the Stockroom crew (shown here with Senior Associate Director Bob Gagosian at far right), who are, from left, Glenn Enos, Rich Lovering, Joe Curran, Donna Andrews, and Sam Lomba.



TERRI CORBETT

Welder Charlie Clemishaw was the 1992 Vetlesen Award winner.

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TOM KLEINDINST

Dick Pittenger, left, and Craig Dorman survey the WHOI pier from R/V Oceanus.

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As of December 31, 1992

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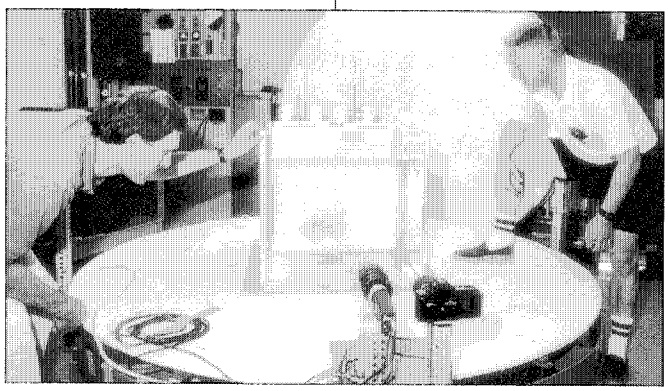

TERRI CORBETT

Karl Helfrich, left, and Jack Whitehead work with an ocean current model in the Geophysical Fluid Dynamics Laboratory.

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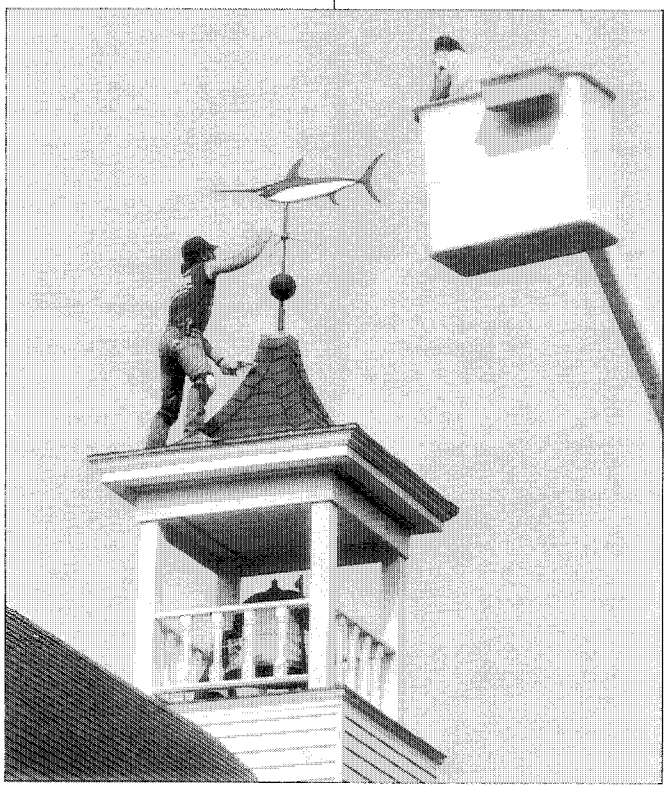

TOM KLEINDINST

Chris Kennedy, on the roof, and Jay Dufur set the refurbished weather vane atop Endeavour House. Pete Marenna supplied a new fish for the vane.

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Carlton W. Grant, Jr.
Thomas P. Hurst
John N. Kemp
Wendy W. Liberatore
Linda E. Lucier
Marguerite K. McElroy
Neil M. McPhee
George A. Meier
Stephen D. Murphy
Susan M. Oliver
Patrick O'Malley
Stanley G. Rosenblad
William J. Sellers
John D. Sisson
Gary N. Stanbrough
Cindy L. Sullivan
Nancy Y. Trowbridge
Karlen A. Wannop
Judith A. White
Martin C. Woodward

Biology Department

Philip Alatalo
Susan Brown-Leger
Catherine M. Cetta
Marjorie K. Clancy
Nancy J. Copley
Mary A. Daher
Linda H. Davis
Diana G. Franks
Linda Hare
Erich F. Horgan
Terrance J. Howald
David M. Kulis
Bruce A. Lancaster
Ethel F. Lefave
Jane E. Marsh
Ann E. Michaels
Susan W. Mills
Zofia J. Mlodzinska
Stephen J. Molyneaux
Karen E. Moore
Jane M. Ridge
Daniel W. Smith
Trevor R. Spradlin
Lisa G. Taylor
Armando F. Tamse
Bonnie L. Woodward

Geology & Geophysics Department

John W. Bailey
Pamela R. Barrows
John Billings
S. Thompson Bolmer
Katherine W. Brown
Peter R. Cadden
Dolores H. Chausse
Karen L. Coluzzi
Diane E. Cook

Regular Support Staff

Tracey I. Crago
Sheri D. Derosa
James W. Dolan
David L. Dubois
Kathryn L. Elder
Pamela V. Foster
C. Eben Franks
Alan R. Gagnon
Robert E. Handy
Daniel Hutton
Janet M. Johnson
Ernest H. Joynt III
Carol A. Kauffman
Richard A. Krishfield
Karen Littlefield
Peter B. Mills
Anita D. Norton
Susan A. O'Connor-Lough
Anita M. Palm
Evelyn J. Price
May A. Reed
Ellen Roosen
Kimberly A. Sapp
Lu Ping Zou

Marine Chemistry & Geochemistry

Robert J. Adams
John E. Andrews III
Rebecca A. Belastock
Scot P. Birdwhistell
Carla J. Bold
Sigalit Caron
Howard M. Chen
William R. Clarke
Joshua M. Curtice
Marcia W. Davis
Joanne C. Donoghue
Anne S. Edwards
Lorraine Eglinton
Joanne E. Goudreau
Mary C. Hartman
Nancy A. Hayward
Marilyn R. Hess
Joyce E. Irvine
Timothy C. Kenna
Peter B. Landry
John J. Lee
Molly M. Lumping
Robert K. Nelson
Julianne Palmieri
Nancy L. Parmentier
Edith H. Ross
Margaret M. Sulanowska
Colm Sweeney
Maren E. Tracy
N. Joye Wirsen
Mary Zawoysky

Physical Oceanography Department

Carol A. Alessi
Karin A. Bohr
Kenton M. Bradshaw
Nancy J. Brink
Maureen E. Carragher
Margaret F. Cook
Lawrence P. Costello
Gennaro H. Crescenti
Jane A. Dunworth
Penny C. Foster
Robert E. Frazel
Marjorie A. Friedrichs
Barbara Gaffron
Helen E. Gordon
Veta M. Green
Brian J. Guest
William H. Horn
George P. Knapp III
Mary Ann Lucas
Theresa K. McKee
Anne Marie Michael
Andrea L. Oien
William M. Ostrom
Julie S. Pallant
John B. Reese
Samuel Simkins
Ralph D. Simoneau
Robert J. Stanley
Susan A. Tarbell
Robert D. Tavares
Deborah A. Taylor
Toshiko T. Turner
Bryan S. Way
W. David Wellwood
Scott E. Worrilow
Jeanne A. Young
Marguerite E. Zemanovic
Sarah L. Zimmerman

Marine Policy Center

Suzanne Demisch
Matthew J. Lamourie
Mary E. Schumacher

Coastal Research Center

Olimpia L. McCall
Stephen P. O'Malley

Information Systems Center

Gail F. Caldeira
Bruce R. Cole
Aganoris Collins
Eric Cunningham
Peter J. Cvitan
Lisa M. Dipalma
Edward F. Dow, Jr.
Annda W. Flynn
Channing N. Hilliard, Jr.
Robert G. Lowe
Deborah K. Shafer

Administrative Staff

Joseph P. Agius
Manager, Management Information Systems
Susan S. Berteaux
Information Systems Associate I
Kendall B. Bohr
Assistant Purchasing Manager
Stella A. Callagee
Assistant Registrar, Education Office Administrator
Lee A. Campbell
Information Officer
Karen E. Carmichael
Information Systems Associate I

TERRI CORBETT

The Personnel group took a short break from propriety and celebrated Halloween with costumes. Back row, from left, they are Marcey Simon, Kathy LaBernz, Elaine Wilcox, Barbara Wickenden, Nancy Barry, Maggie Walden, June Taft, and Mary Jane Tucci. Front row, from left, Tricia Palmer, Nanci Hickey, and Susan Callahan.

Regular Support Staff

Jane A. Caruso
Security Officer

Susan A. Casso
Executive Assistant, Marine Chemistry & Geochemistry

Lisa A. Clark
Assistant Editor, Oceanus

Vicky Cullen
Manager of Publications & Graphic Services, Editor, Oceanus

Amy L. Donner
Development Officer

Patricia J. Duffy
Accounting Operations Manager

William M Dunkle, Jr.
Research Associate, Data Library

Larry D. Flick
Executive Assistant, Applied Ocean Physics & Engineering

Kathy S. Frisbee
Business & Advertising Coordinator, Oceanus

David G. Gallo
Director, Corporate Research & Technology Programs

Ellen M. Gately
Executive Assistant, Marine Policy Center

Sonya Hagopian
News Officer

Carolyn S. Hampton
Information Systems Associate II

Frederic R. Heide
Assistant Manager of Graphic Services

Ann C. Henry
Executive Assistant, Applied Ocean Physics & Engineering

Hartley Hoskins
Research Associate

Colleen D. Hurter
Information Systems Associate II

Charles S. Innis, Jr.
Security Officer

Susan Kadar
JGOFS Field Program Coordinator

Victoria A. Kaharl
Science Writer

Robin Kaiser
Senior Development Officer

Judith L. Kleindinst
Executive Assistant, Biology

Kathleen P. LaBernz
Assistant Personnel Manager

Karen E. Lauritzen
Controller

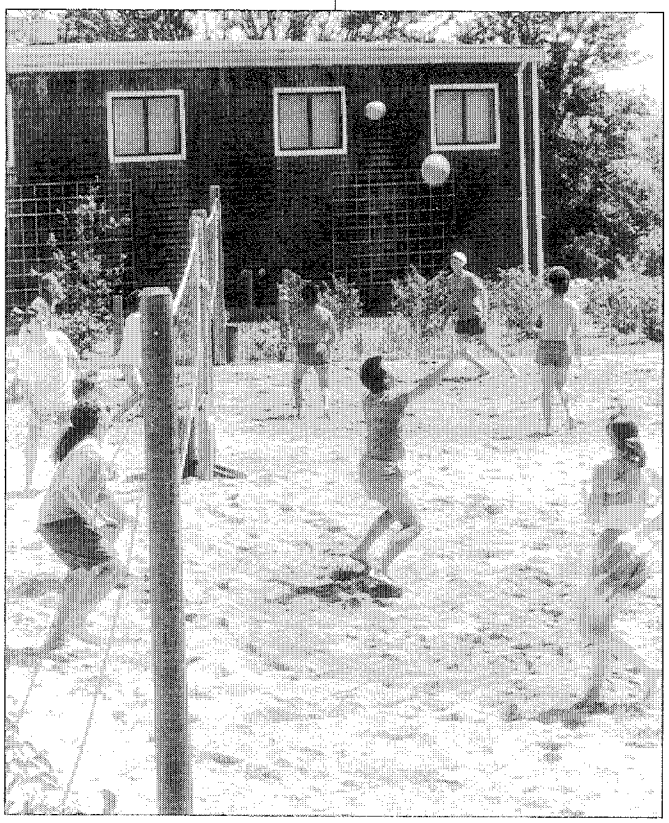
Shelley M. Lauzon
Senior News Officer

Virginia A. Lefavor
General Accounting Administrator

Alexander E. McAra
Financial Analyst

David J. Miller
Assistant Sponsored Programs Administrator

Elizabeth D. Milot
Senior Development Officer



TERRI CORBETT

WHOI volleyball players enjoy the Shepley Athletic Courts on the Quissett Campus.

Mozart P. Moniz
Purchasing Manager

Laura A. Murphy
Payroll Administrator

A. Lawrence Peirson III
Associate Dean and Registrar

Claire L. Reid
Executive Assistant, Physical Oceanography

Lesley M. Reilly
Conference Coordinator

Margaret A. Rioux
Information Systems Associate I

R. David Rudden, Jr.
Assistant Controller

Clarence L. Smith
Executive Assistant, Geology & Geophysics

Peggy A. Stengel
Development Officer

David L. Stonehill
Director, WHOI/MBL Library

Martha E. Tarafa
Executive Assistant to the Senior Associate Director

Maurice J. Tavares
Sponsored Programs Administrator

Mary Jane Tucci
Housing Coordinator

Melissa R. Weidman
Staff Training & Development Administrator

Mary Jo Wheatley
News Officer

Barbara Wickenden
Personnel Manager

Elaine M. Wilcox
Benefits Administrator

Carolyn P. Winn
Research Librarian

Alexandra B. Witten
Development Officer

Dianna M. Zaia
Financial Analyst

Administrative Personnel

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Steven W. Allsopp
Patricia Askew
Nancy E. Barry
Janice R. Battee
Mary E. Berry
Eleanor M. Botelho
Sandra L. Botelho
Marilynn Brooks
Susan F. Callahan
James J. Canavan
Leonard Cartwright
Peggy A. Chandler
Linda L. Church
John E. Cook
Michelle J. Cooke
Terri C. Corbett
Margaret M. Costello
Joseph J. Curran
Cheryl C. Daniels
Dale V. DePonte
Helen M. Desmond
Shawna R. Dipetta
Jayne H. Doucette
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Kathleen M. Eimer
Lynne M. Ellsworth
Glenn R. Enos
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Nancy A. Hickey
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Donna L. Lamonde
Tariesa A. Lemmon
Ellen Levy
Lillian R. Lomba
Samuel J. Lomba
Helene J. Longyear
Richard C. Lovering
Virginia McKinnon
Gretchen McManamin
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Cheryl L. Newton
E. Paul Oberlander
Maureen E. O'Donnell
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Mary E. Parker
Kathleen Patterson
Alora K. Paul
Maryanne F. Pearcey
Doreen M. Perito
Clara Y. Pires
Jeannine M. Pires

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Mildred M. Teal
Judith A. Thrasher
Maeve Thurston
Alice I. Tricca
Margaret M. Walden
Katherine T. Walsh
Leo R. Wells
Susan B. West
Mary Ann White
John A. Wood, Jr.

Facilities, Services, *Alvin*, and Marine Operations Staff

David F. Casiles
Assistant Marine Operations Manager
Richard S. Chandler
Submersible Operations Coordinator
Ernest G. Charette
Assistant Facilities Manager
Gary B. Chiljean
Master, R/V Atlantis II
Joseph L. Coburn, Jr.
Marine Operations Manager
Arthur D. Colburn, Jr.
Boat Operator, R/V Asterias
Timothy J. Connors
DSV Pilot, Alvin
Alysia Cox
Assistant Marine Engineer
Robertson P. Dinsmore
Marine Operations Consultant
Richard S. Edwards
Port Captain
Joel A. Fahnley
Facilities Engineer
Richard E. Galat
Facilities Engineer
Robert J. Grieve
DSV Pilot, Alvin
David L. Hayden
Chief Engineer, R/V Knorr
J. Patrick Hickey
DSV Pilot, Alvin
Paul C. Howland
Master, R/V Oceanus
Roger N. Hughes
Submersible Operations Expedition Leader
Robert L. Joyce
Traffic Manager
Lewis E. Karchner
Safety Officer
Barbara J. Martineau
Marine Operations Administrator
Barrett H. McLaughlin
Chief Engineer, R/V Oceanus
William E. McKeon
Facilities Manager
Joseph M. Milner
Manager of Marine Employment
Donald A. Moller
Marine Operations Coordinator
Richard F. Morris
Chief Engineer, R/V Atlantis II
David I. Olmsted
Boat Operator, R/V Asterias
Terrence M. Rioux
Diving Officer
Carl F. Swanson
Master, R/V Knorr
Ernest C. Wegman
Port Engineer

Facilities, Services, *Alvin*, and Marine Operations Personnel

Nadine N. Athearn
Helen L. Ayres
Ernest E. Baker
Janice M. Baker
Linda Benway
William K. Blanchard
Robert Bossardt
Thomas A. Bouche
Leonard A. Boutin
John R. Bracebridge
Frederick A. Brauneis
Joan Brazier
John L. Broadford
Edmund K. Brown
Frederick V. Brown
Mark Buccheri
Socrates J. Carelo
Richard J. Carter
Edward H. Chute
John P. Clement
Charles Clemishaw
Jeffrey D. Clemishaw
Charles H. Clifford
James E. Coddington
Debra A. Coleman
Alden H. Cook
Arthur Costa
Gregory Cotter
Jane E. Crobar
John A. Crobar
Donald A. Croft
William B. Cruwys
Judith O. Cushman
Pearl R. DeMello
James H. Dufur, Jr.
Daniel B. Dwyer
Kittie E. Elliott
Anthony Ferreira
Catherine H. Ferreira
Michael J. Field
Patricia A. Grace
Robert J. Greene
Barry V. Hamilton
K.I. Faith Hampshire
William H. Handley
Patrick J. Harrington
Joan B. Hulburt
Kathryn T. James
Marie M. Johnson
John A. Keizer
Fred W. Keller
Christopher F. Kennedy
Dennis E. Ladino
William D. Lambert
Donald C. LeBlanc
Donald F. LeBlanc
Paul E. LeBlanc
Lori Mahoney
Peter D. Marenna
Robert A. McCabe
Paul J. McCaffrey
Napoleon McCall, Jr.
David McDonald
Carlos A. Medeiros
Thomas W. Moore
Jose S. Mota
Jay R. Murphy
John R. Murphy, Jr.
Stephen Murphy
Patricia A. Odams
Charles A. Olson
Stephen G. Page
Sheila T. Payne
Isabel M. Penman
Frank R. Perry
Charles J. Peters, Jr.
Arthur Peterson
Steven J. Poore
Maura E. Power
George R. Price
Thomas D. Rennie
John P. Romiza
Lewis J. Saffron
Michael J. Sawyer
Robert W. Schreiter
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Andrew E. Sokolowski
Steven P. Solbo
Robert G. Spenle
Carlotta S. Squire
Mark L. St. Pierre
Harold W. Swanson
William R. Tavares, Jr.
Kevin D. Thompson
Michael Toner
Carlos Velez
Robert Wichterman
John C. Williams
Robert J. Wilson
Ronald E. Woods

TOM KLEINDINST

Coastal Research Center work was highlighted at a spring open house.

Marine Personnel

Wayne A. Bailey
Stewart E. Baker
Courtenay Barber III
Jonathan W. Barros
Mitchell G. Barros
Robert Bastarache
Gunter H. Bauerlein
Harold A. Bean
Richard C. Bean
Lawrence T. Bearse
Douglas M. Bell
James L. Boardman

Regular Support Staff

TOM KLEINDINST

WHOI volunteers, who help with the Exhibit Center and a variety of other activities, were honored at an October party.

Edward R. Brodrick
Frederick E. Bull, Jr.
Paul Carty
Arthur D. Colburn III
Alberto Collasius, Jr.
Janet Costello
Jerome M. Cotter
Steven M. Cross
Hugh B. Dakers
Sallye A. Davis
Mark C. DeRoche
Craig D. Dickson
Derek F. Dineen
Gardiner S. Doughty
William J. Dunn, Jr.
Richard Edwards, Jr.
William A. Eident
Jovinol Fernandes, Jr.
Kevin C. Fisk
Daniel H. Gould
Jerry M. Graham
Edward F. Graham, Jr.
Christopher M. Griner
John F. Gumbleton
Charles F. Hall
William S. Hartnett III
Philip W. Hodgkins
Alan J. Hopkins
Kurt S. Jilson
J. Kevin Kay
Paul A. Kay
Gregory A. LeBlanc
Darcy J. Lever
Jeffrey Little
Thomas J. Lively
Ellis H. Maris, Jr.
J. Douglas Mayer
Joseph L. Mayes
Kevin M. McGrath
David H. Megathlin
Anthony D. Mello
Mirth N. Miller
Patrick S. Mone
John D. Morgan
Paul D. Morrissey
Richard M. Nolan
Michael P. Nolin
David A. Ouellette
Gregory J. Packard
Michael Palmieri, Jr.
Patricia L. Pasanen
Charles G. Perry
Craig S. Peters
Eben W. Plettner
Susan Quigley
William J. Reid III
Jacqua S. Rumery
Richard F. Simpkin
Evan L. Smith
Harry H. Stanton
Jeffrey M. Stolp
John K. Sweet, Jr.
Wayne A. Sylvia
Stacy W. Towne
Robert J. Traverso
Philip M. Treadwell
Herman Wagner
Kelly Walinski
Stephen A. Walsh
Kathleen D. Wilson
Carl O. Wood
Laura C. Yeates

1992 Retirees

Rose Lorraine Barbour
Henri O. Berteaux
Harry F. Clinton
Richard H. Dimmock
John E. Rice
Eric W. Spencer
Robert J. Stanley
Margaret P. Stern

Guest Investigators

John A. Allen
University Marine Biological Station, Millport, Scotland

Fortunato A. Ascioti
WHOI Biology Department

Marie-Pierre Aubry
WHOI Geology & Geophysics Department

Jesse Ausubel
Rockefeller University

Arthur B. Baggeroer
Massachusetts Institute of Technology

Brian J. Binder
Massachusetts Institute of Technology

Mary Blance
University of Massachusetts Medical Center

Donald Bourne
WHOI Biology Department

Solange Brault
Imperial College, England

Changshen Chen
Texas A&M University

Robert F. Chen
WHOI Marine Chemistry & Geochemistry Department

Sallie W. Chisholm
Massachusetts Institute of Technology

John Church
CSIRO Marine Laboratories, Tasmania, Australia

Paul Cloke
University of London, England

Margaret G. Collins
WHOI Coastal Research Center

Richard C. Connor
Harvard University

Thomas J. DiChristina
WHOI Biology Department

Anatol Eberhard
Ithaca College

Carolyn Eberhard
Cornell University

Alan J. Faller
WHOI Physical Oceanography Department

Scott Farrow
Council on Environment Quality

Jean Filloux
WHOI Applied Ocean Physics & Engineering Department

Judith Grassle
Rutgers University

Charles S. Greene
WHOI Biology Department

Makio Honda
WHOI Geology & Geophysics Department

Hsiao-Ming Hsu
Shanghai Acoustics Laboratory, Shanghai, PRC

Guoliang Jin
WHOI Applied Ocean Physics & Engineering Department

Christopher C. Joyner
George Washington University

Andrey Karachintsev
Institute of Biology of the Southern Seas, Sevastopol, Ukraine

Dong Ju Kim
Chonnam National University, Korea

Richard H. Lambertsen
Ecosystems Technology Transfer Inc.

Katherine Madin
WHOI Biology Department

Newton Millham
WHOI Biology Department

Alan Oppenheim
Massachusetts Institute of Technology

Joseph R. Pawlik
University of North Carolina

Barbara Peri
WHOI Biology Department

T.S.S. Rao
WHOI Biology Department

Patricia E. Rosel
Southwest Fisheries Science Center

Priscilla Roslansky
WHOI Biology Department

Laela Sayigh
WHOI Biology Department

Amelie Scheltema
WHOI Biology Department

Johan Schijf
Free University, Amsterdam, Netherlands

Henrik Schmidt
Massachusetts Institute of Technology

Rodman E. Taylor, Jr.
WHOI Biology Department

Andrew Trivett
Dalhousie University, Halifax, Nova Soctia

Maura Tyrrell
Stonehill College

James R. Weinberg
WHOI Biology Department

Randall Wells
Bookfield Zoo

David S. White
WHOI Biology Department

Joanne Willey
Harvard University

William Williams
University of Michigan

Hongye Zhao
WHOI Marine Policy Center

1992 Degree Recipients

Massachusetts Institute of Technology/Woods Hole Oceanographic Institution
Joint Program in Oceanography/Applied Ocean Science and Engineering

Doctor of Philosophy

Chang Sheng Chen
B.S., M.S., Shandong College
Special Field: *Physical Oceanography*
Dissertation: *Variability of Currents in Great South Channel and Georges Bank: Observation and Modeling*

Sarah A. Green
B.A., University of Minnesota
Special Field: *Marine Chemistry and Geochemistry*
Dissertation: *Application of Flourescence Spectroscopy to Environmental Chemistry*

Erik H. Hauri
B.Sc., University of Miami, Florida
Special Field: *Marine Geology and Geophysics*
Dissertation: *Geochemical and Fluid Dynamic Investigations into the Nature of Chemical Heterogeneity in the Earth's Mantle*

Christopher T. Howell
B.S., Texas A&M
S.M., Massachusetts Institute of Technology
Special Field: *Oceanographic Engineering*
Dissertation: *Investigation of the Dynamics of Low-Tension Cables*

Barry A. Klinger
S.B., Massachusetts Institute of Technology
Special Field: *Physical Oceanography*
Dissertation: *Eddy Generation at a Convex Corner by a Coastal Current in a Rotating System*

Zheng Yu Liu
B.S., Nanjing University
M.S., Academia Sinica
Special Field *Physical Oceanography*
Dissertation: *Time-Dependent Ventilated Thermocline*

Mark R. Loewen
B.S., M.S., University of Alberta
Special Field: *Oceanographic Engineering*
Dissertation: *Laboratory Measurements of the Sound Generated by Breaking Waves*

Mark H. Murray
B.S., Massachusetts Institute of Technology
Special Field: *Marine Geology and Geophysics*
Dissertation: *Global Positioning System Measurement of Crustal Deformation in Central California*

Kurt L. Polzin
B.A., Whitman College
Special Field: *Physical Oceanography*
Dissertation: *Observations of Turbulence, Internal Waves and Background Flows: An Inquiry into the Relationships between Scales and Motion*

James C. Preisig
B.S., United States Coast Guard Academy,
S.M., S.M.E.E., Massachusetts Institute of Technology
Special Field: *Oceanographic Engineering*
Dissertation: *Adaptive Matched Field Processing in an Uncertain Propagation*

Laela S. Sayigh
B.A., University of Pennsylvania
Special Field: *Biological Oceanography*
Dissertation: *Development and Functions of Signature Whistles of Free-ranging Bottlenose Dolphins,* Tursiops truncatus

David Walsh
B.A., Earlham College
Special Field: *Physical Oceanography*
Dissertation: *A Model of a Mediterranean Salt Lens in External Shear*

Xiaoming Wang
B.S., Shandong College
M.S., University of Rhode Island
Special Field: *Physical Oceanography*
Dissertation: *Interaction of an Eddy with a Continental Slope*

William S.D. Wilcock
B.A., Cambridge University
M.S., Imperial College
Special Field: *Marine Geology and Geophysics*
Dissertation: *The Seismic Attenuation Structure of the East Pacific Rise*

Master of Science

Jamie M. Anderson
B.S.M.E., University of California, San Diego
Special Field: *Oceanographic Engineering*
Dissertation: *Efficient Control Based on a Verified Model for an Autonomous Underwater Vehicle —A Case Study of the Autonomous Benthic Explorer*

Jonathan N. Betts
B.A., Harvard College
Special Field: *Marine Chemistry and Geochemistry*
Dissertation: *Electronic Automation of a Remotely Deployable Seawater Sampling Device*

Marjorie A. M. Friedrichs
B.A., Middlebury College
Special Field: *Physical Oceanography*
Dissertation: *Meridional Circulation in the Tropical North Atlantic*

Kenneth A. Malmquist
B.S., Drexel University
Special Field: *Oceanographic Engineering*
Dissertation: *Modeling a Forward Scanning Bathymetric Sonar System*

James M. Njeru
B.S., B.S.E.E., Lafayette College
Special Field: *Oceanographic Engineering*
Dissertation: *A Tomographic Ocean Sound Speed Profile from a Long Vertical Acoustic Array*

John R. Nystrom
B.S., University of Idaho
Special Field: *Oceanographic Engineering*
Dissertation: *Study of Basin Scale Acoustic Transmissions*

Mindy L. Roberts
B.Sc., University of California, Berkeley
Special Field: *Oceanographic Engineering*
Dissertation: *An Analytical Two-Layer Coupled Hydrodynamic and Ice Floe Movement Model*

Brian H. Tracey
B.A., Kalamazoo College
Special Field: *Oceanographic Engineering*
Dissertation: *Design and Testing of an Acoustic Ultra-short Baseline Navigation System*

Hui Xia Wu
B.S., Xuzhou Teachers' College
M.A., Academia Sinica
Special Field: *Oceanographic Engineering*
Dissertation: *Ambient Noise Measurements in the 200-300 Hz Band During the Greenland Sea Tomography Experiment*

Master of Science and Ocean Engineer

Gary W. Edwards
B.S., University of Richmond
Special Field: *Oceanographic Engineering*
Dissertation: *Kinematic Evaluation of End Effector Design*

John Van Gurley
B.S., University of Florida
Special Field: *Oceanographic Engineering*
Dissertation: *Experimental Investigation of Scattering from Randomly Rough Elastic Cylinders*

John G. Kusters
B.S., California State Polytechnic University
Special Field: *Oceanographic Engineering*
Dissertation: *Analysis and Application of a High Resolution Underwater Optical Ranging System*

TERRI CORBETT

Steve Murphy paints a buoy base on the WHOI pier.

Fellows, Students & Visitors

MIT/WHOI Joint Graduate Program 1992-1993 Fall Term

Jess F. Adkins
Haverford College

J. Ewann Agenbroad
University of Washington

Einat Aharonov
Tel-Aviv University, Israel

Susan E. Alderman
Mount Holyoke College

Keith D. Alverson
Princeton University

Linda A. Amaral
Brown University

Jamie M. Anderson
University of California, San Diego
MIT/WHOI Joint Program, S.M.

Andrea L. Arenovski
University of North Carolina, Wilmington

Carol Arnosti
Lawrence University

Jay A. Austin
California Polytechnic Institute

Katherine A. Barbeau
Long Island University

John F. Barimo
Virginia Commonwealth University

Molly O. Baringer
Tulane University

Natalia Y. Beliakova
Moscow State University, Russia

Joseph E. Bondaryk
Massachusetts Institute of Technology
Massachusetts Institute of Technology, S.M.

Stephen G. Bowen
United States Naval Academy

Christopher R. Bradley
University of New Mexico
University of Utah, M.S.

Edward J. Brook
Duke University
University of Montana, M.S.

Benjamin A. Brooks
University of California, Santa Cruz

John R. Buck
Massachusetts Institute of Technology
MIT/WHOI Joint Program, S.M., S.M.E.E.

Antonietta Capotondi
University of Pisa, Italy

David B. Chester
Southampton College of Long Island University
MIT/WHOI Joint Program, S.M.

Gail L. Christeson
Texas A&M University

Maureen E. Clayton
Eckerd College

Mary Carla Curran
University of South Carolina at Columbia
Victoria University, Australia

Max Deffenbaugh
Princeton University

Edward P. Dever
Texas A&M University
Texas A&M University, M.S.

Daniel T. Diperna
Lafayette College

Michele D. DuRand
Carleton College

Jeffrey A. Dusenberry
Northwestern University
Massachusetts Institute of Technology, S.M.

Henrietta N. Edmonds
Yale University

Christopher A. Edwards
Haverford College

Thomas Ehrendorfer
University of Vienna, Austria

Ari W. Epstein
Harvard University

Deana L. Erdner
Carnegie Mellon University

Javier G. Escartin
University of Barcelona, Spain
Perpignan University, France, M.S.

Francis Felizardo
University of the Philippines
University of the Philippines, M.S.

Derek A. Fong
Stanford University
Stanford University, S.M.

Carl T. Friedrichs
Amherst College

Elizabeth D. Garland
Florida Institute of Technology

Sarah T. Gille
Yale University

Karina Y. H. Gin
University of Melbourne, Australia

Anand Gnanadesikan
Princeton University

Ramnarayan Golpalkrishnan
India Institute of Technology, India

James R. Gunson
Flinders University of South Australia
University of Technology, Western Australia, M.S.

Orjan M. Gustafsson
Slippery Rock University

Jill K. Hahn
Harvard-Radcliffe College
Boston University, M.S.

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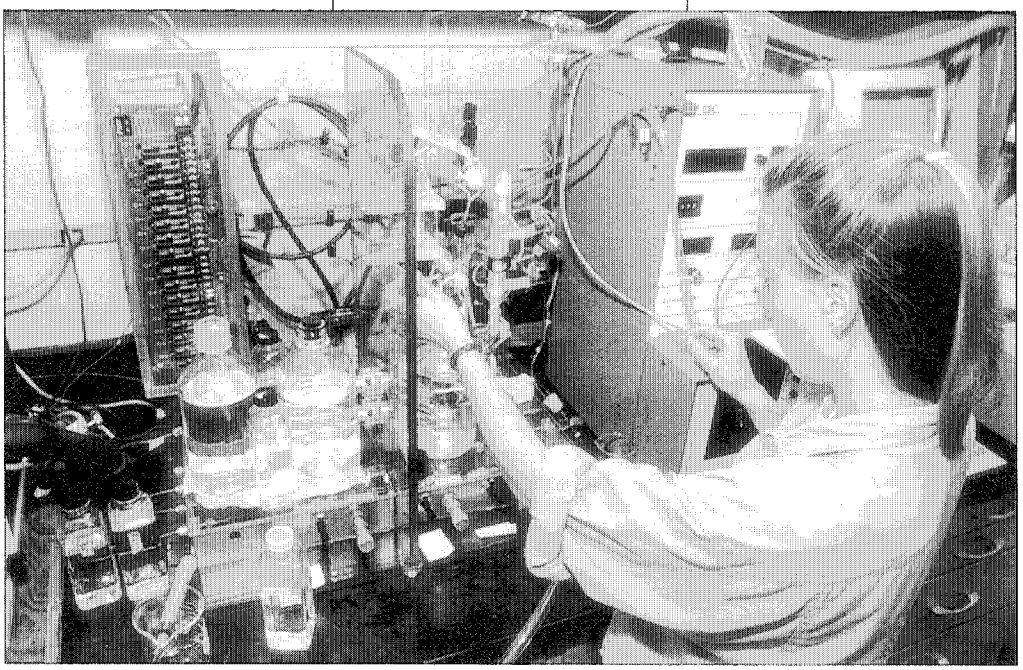

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At work in the laboratory of Cathine Goyet, Summer Student Fellow Amy Snover investigates a new way to measure carbon-dioxide concentration in seawater.

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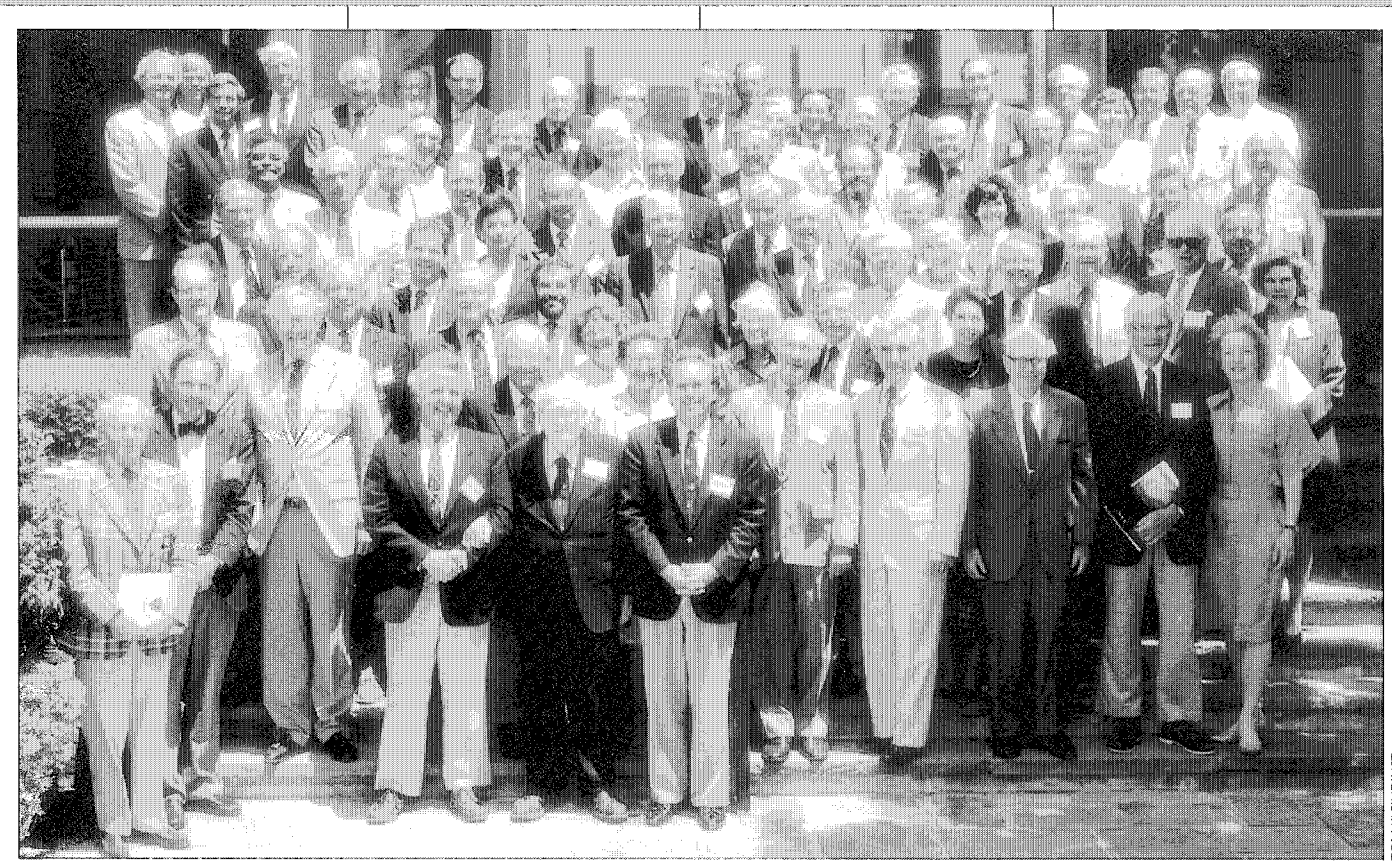

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E. Bright Wilson
Taggart Whipple

and those who passed away in 1993:

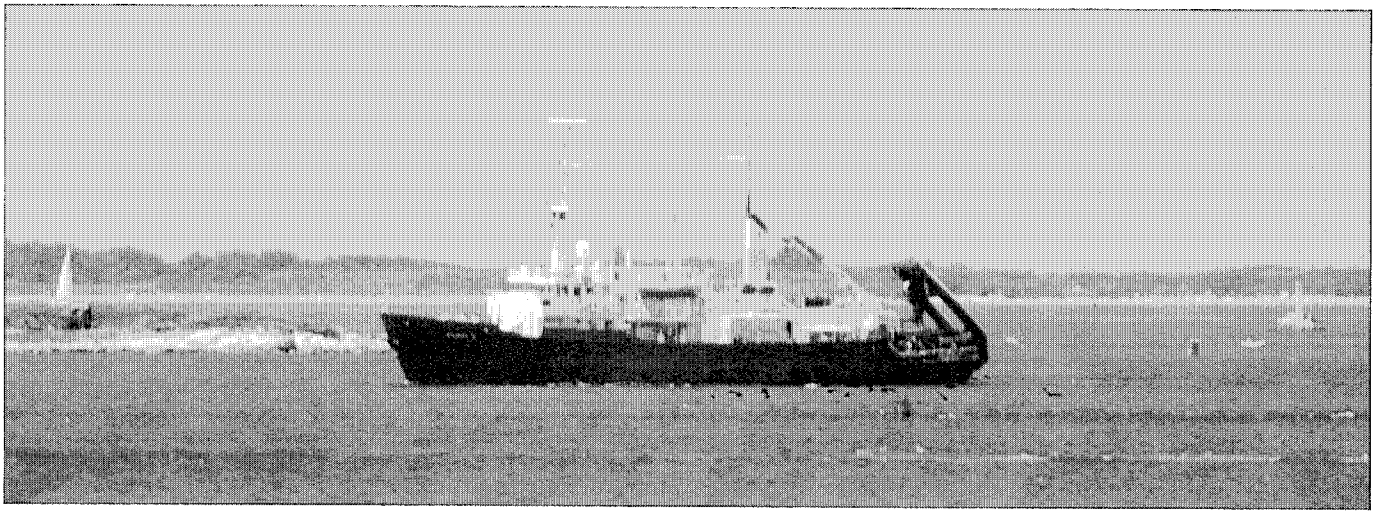
Robert W. Pierce
Arthur J. Santry, Jr.

1992 Voyage Statistics

Atlantis II & DSV *Alvin*

Total Nautical Miles in 1992 – 15,160; Total Alvin Dives – 71; Total Days at Sea – 167

Voyage	*Cruise Period*	*Principal Objective, Area of Operation*	*Ports of Call*	*Chief Scientist*
125-XXXVI	6 Feb - 12 Feb	California coast, 5 engineering dives	San Diego	B. Walden
125-XXXVII	17 Feb - 22 Feb	Transit to Manzanillo	Manzanillo	—
125-XXXVIII	22 Feb - 15 Mar	East Pacific Rise at 10°North, volcanological, geochemical and biological studies at hydrothermal vents in support of Ocean Drilling Program, 18 dives	Manzanillo	R. Haymon (UCSB) D. Fornari (Lamont) M. Perfit (Florida) R. Lutz (Rutgers) K. Macdonald (UCSB)
125-XXXIX	20 Mar - 27 Mar	East Pacific Rise at 21°North, geochemical and chemical studies of hydrothermal vents, 5 dives	Manzanillo	J. Edmond (MIT)
125-XL	1 Apr - 27 Apr	East Pacific Rise at 13°North, long term ecological studies at hydrothermal vents, 22 dives	Acapulco	J. Childress (UCSC) D. Desbruyers (IFREMER)
125-XLI	1 May - 13 May	Transit Panama Canal to Galveston	Galveston	—
125-XLII	19 May - 29 May	Gulf of Mexico, geochemical and biological studies of petroleum-derived seep communities, 9 dives	Pensacola	I. MacDonald (TAMU) R. Carney (LSU)
125-XLIII	31 May - 5 Jun	Gulf of Mexico, collection of invertebrates at cold water seeps on Florida Escarpment, 2 dives	Fort Lauderdale	C. Cavanaugh (Harvard)
125-XLIV	5 Jun - 10 Jun	Transit to Woods Hole and biological studies at Block Canyon, 1 dive	Woods Hole	S. LaRosa (U.Conn)
126-I	6 Aug - 8 Aug	New England coast, 1 engineering dive	Woods Hole	B. Walden
126-II	11 Aug - 20 Aug	New York Bight, biological, chemical and ecological studies at Dump Site #106, 8 dives	Woods Hole	J.F. Grassle (Rutgers)
127-I	29 Aug - 20 Sep	Mid-Atlantic Ridge, geological, geochemical ocean crust, and search for new hydrothermal vent sites, (non-*Alvin*)	Ponta Delgada	C. Langmuir (Lamont) G. Klinkhammer(OSU) H. Bougault (IFREMER)
127-II	25 Sep - 20 Oct	Mid-Atlantic Ridge, continuation of Leg I (non-*Alvin*)	Ponta Delgada	C. Langmuir (Lamont) G. Klinkhammer(OSU) H. Bougault (IFREMER)



TERRI CORBETT

Atlantis II *worked out of Woods Hole during the summer months in 1992.*

1992 VOYAGE STATISTICS

R/V *Knorr*

Total Nautical Miles in 1992 – 35,979; Total Days at Sea – 255

Voyage	*Cruise Period*	*Principal Objective, Area of Operation*	*Ports of Call*	*Chief Scientist*
136-II	19 Jan - 21 Jan	Local waters, sea trials	Woods Hole	J. Coburn
136-III	7 Feb - 7 Feb	Local waters, sea trials	Woods Hole	J. Coburn
137	8 Feb - 10 Mar	Mid-Atlantic Ridge, side-scan surveys of escarpments in the MARK region for RIDGE	Woods Hole	F. Spiess (Scripps)
138-I	21 Mar - 25 Mar	Transit to shipyard in Jacksonville	Jacksonville	—
138-II	13 Apr - 29 Apr	Transit to Valparaiso	Valparaiso	—
138-III	2 May - 26 May	Eastern South Pacific, hydrographic survey for WOCE Hydrographic Program, line P6	Easter Island	H. Bryden
138-IV	30 May - 7 Jul	Central South Pacific, hydrographic survey for WOCE Hydrographic Program, line P6	Auckland	M. McCartney
138-V	13 Jul - 30 Jul	Western South Pacific, hydrographic survey for WOCE Hydrographic Program, line P6	Sydney	J. Toole
138-VI	25 Aug - 30 Aug	Transit to Auckland	Auckland	—
138-VII	1 Sep - 15 Sep	Western South Pacific, hydrographic survey for WOCE Hydrographic Program, line P14C	Suva, Fiji	D. Roemmich (Scripps)
138-VIII	15 Sep - 29 Sep	South Pacific, current meter mooring deployment in the Samoan Passage for WOCE, line PCM11	Papeete	D. Rudnick (U. Wash.)
138-IX	6 Oct - 26 Nov	South Pacific, hydrographic survey for WOCE Hydrographic Program, lines P16S & P17S	Papeete	J. Reid (Scripps)
138-X *	4 Dec - 22 Jan	South Pacific, hydrographic survey for WOCE Hydrographic Program, line P17S	Punta Arenas	J. Swift (Scripps)

*At sea, 31 Dec

TOM KLEINDINST

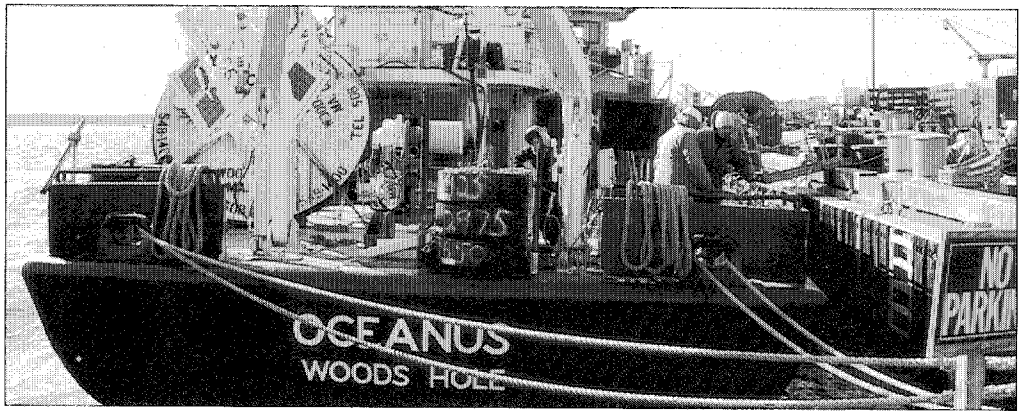
R/V Knorr *steams out of Woods Hole harbor to begin a research voyage.*

1992 Voyage Statistics

R/V *Oceanus*

Total Nautical Miles in 1992 – 39,574; Total Days at Sea – 286

Voyage	*Cruise Period*	*Principal Objective, Area of Operation*	*Ports of Call*	*Chief Scientist*
249-I	1 Jan - 4 Jan	Transit to shipyard at Jacksonville	Jacksonville	—
249-II	17 Jan - 20 Jan	Transit to Woods Hole	Woods Hole	—
250-I	25 Jan - 16 Feb	Eastern North Atlantic, Subduction Experiment - mooring deployment	Funchal	R. Weller R.Davis (Scripps)
250-II	19 Feb - 26 Feb	Eastern North Atlantic, continuation of Leg I	Ponta Delgada	R. Weller R.Davis (Scripps)
250-III	2 Mar - 20 Mar	Eastern North Atlantic, Subduction Experiment - hydrographic surveys and water sampling	Funchal	D. Rudnick (U. Wash.) D.Kadko (U. Miami) J.Luyten
250-IV	25 Mar - 24 Apr	Eastern North Atlantic, hydrographic profiling	Las Palmas	R. Schmitt
250-V	29 Apr - 21 May	Eastern North Atlantic, tracer release and float deployment for WOCE- NATRE experiment	Ponta Delgada	J. Ledwell J.Price A. Williams R. Davis (Scripps)
250-VI	29 May - 27 Jun	Eastern North Atlantic, meteorology for ASTEX/MAGE experiment	Ponta Delgada	B. Blomquist (Drexel) B. Huebert (URI)
250-VII	27 Jun - 5 Jul	Transit to Woods Hole	Woods Hole	—
251	20 Jul - 29 Jul	New York Bight, side-scan surveys at Dump Site #106	Woods Hole	J. Robb (USGS)
252	31 Jul - 4 Aug	New York Bight, side-scan testing at Dump Site #106	Woods Hole	T. O'Brien (USGS)
253	10 Aug - 30 Aug	Mid-Atlantic Ridge, OBS instrument deployment	Woods Hole	G. M.Purdy
254-I	8 Sep - 17 Sep	Transit to the Canary Islands	Las Palmas	—
254-II	21 Sep - 21 Oct	Eastern North Atlantic, tracer and float tracking for WOCE- NATRE experiment	Las Palmas	J. Ledwell
254-III	26 Sep - 19 Nov	Eastern North Atlantic, tracer tracking and hydrography for WOCE- NATRE experiment	Las Palmas	N. Oakey (Bedford) J. Ledwell
254-IV	24 Nov - 16 Dec	Eastern North Atlantic, Subduction Experiment - hydrographic surveys and water sampling	Ponta Delgada	T. Joyce
254-V	21 Dec - 30 Dec	Mid Atlantic Ridge, OBS instrument recovery	Woods Hole	D. Toomey (OSU) G.M. Purdy



TERRI CORBETT

Oceanus *is loaded for a Subduction Experiment cruise in early 1992*

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Compiled by:
Maureen O'Donnell,
Office of the Research Librarian

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Insitution contribution number appears at the the end of each entry.
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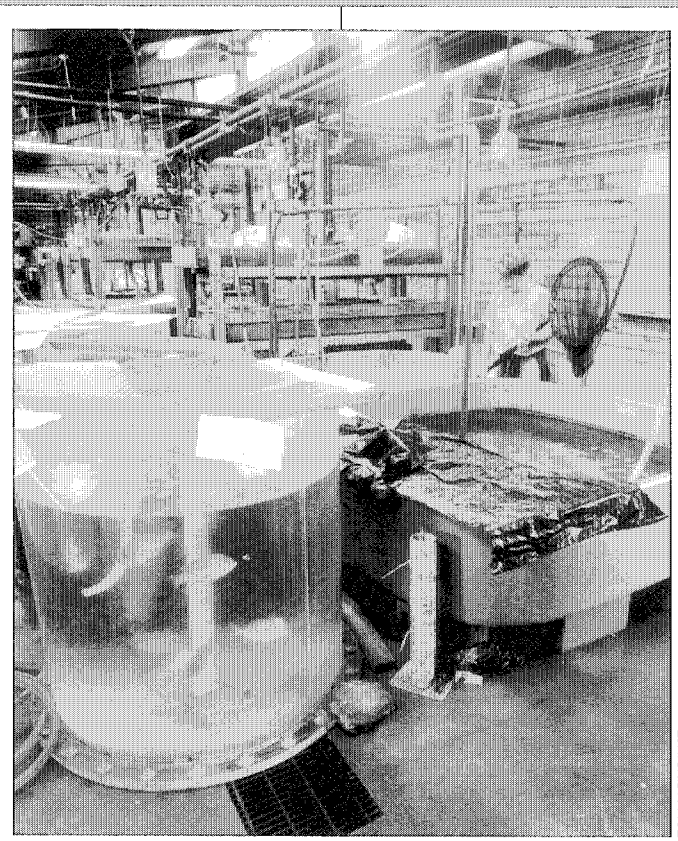

TOM KLEINDINST

Summer Student Fellow Alice Shumate is ready to net a fish at the Environmental Systems Laboratory.

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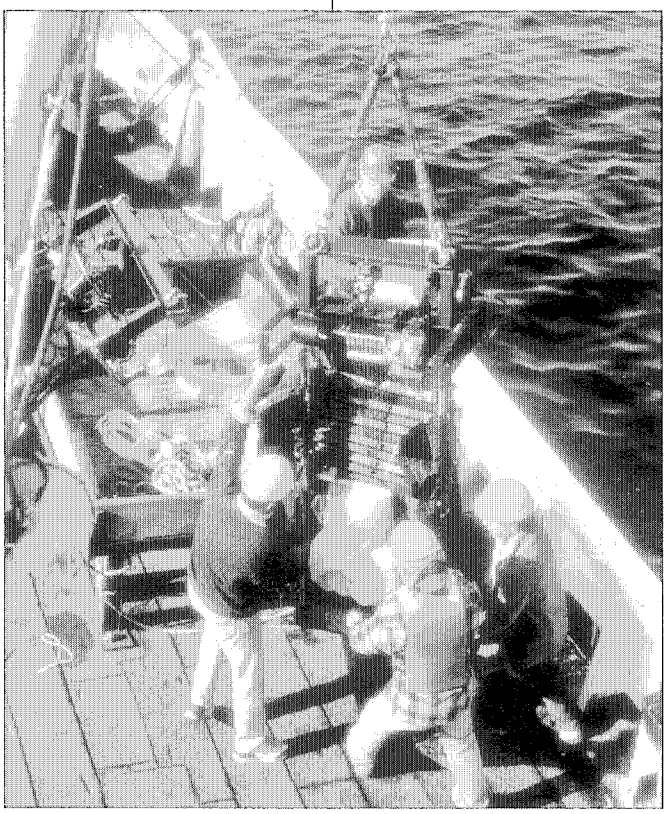

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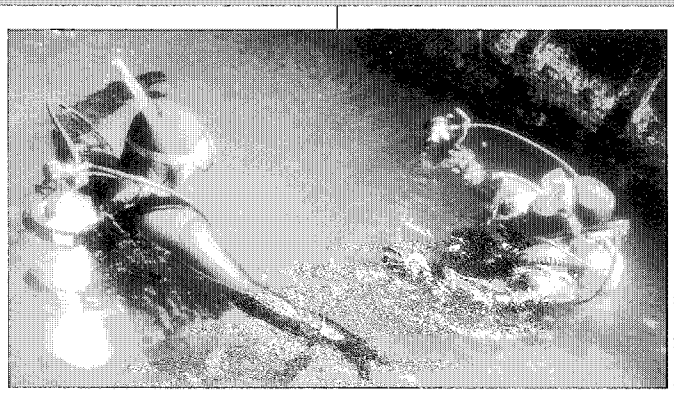

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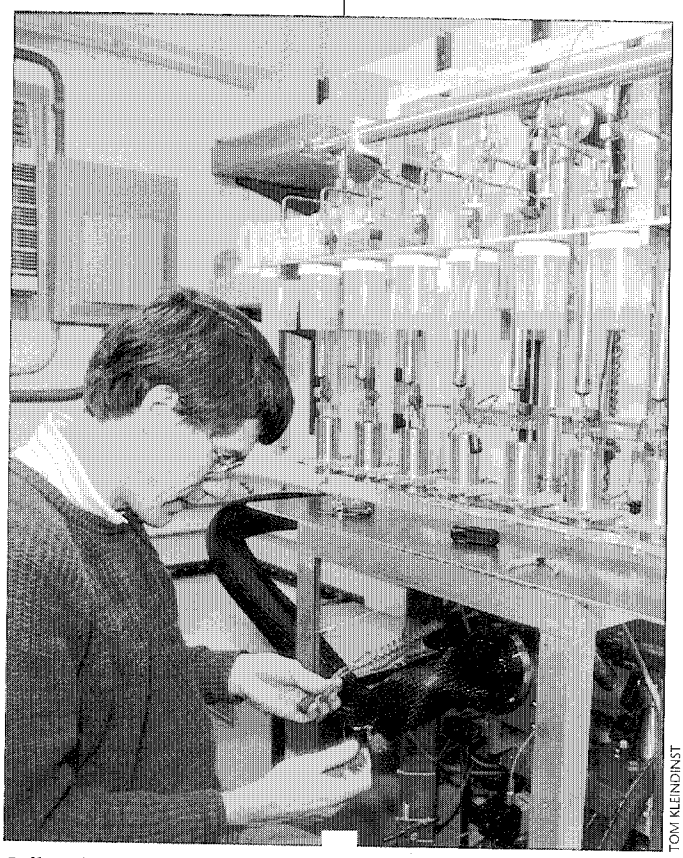

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Table 1
Sources of Revenue
(Exclusive of Knorr-Melville Refit)

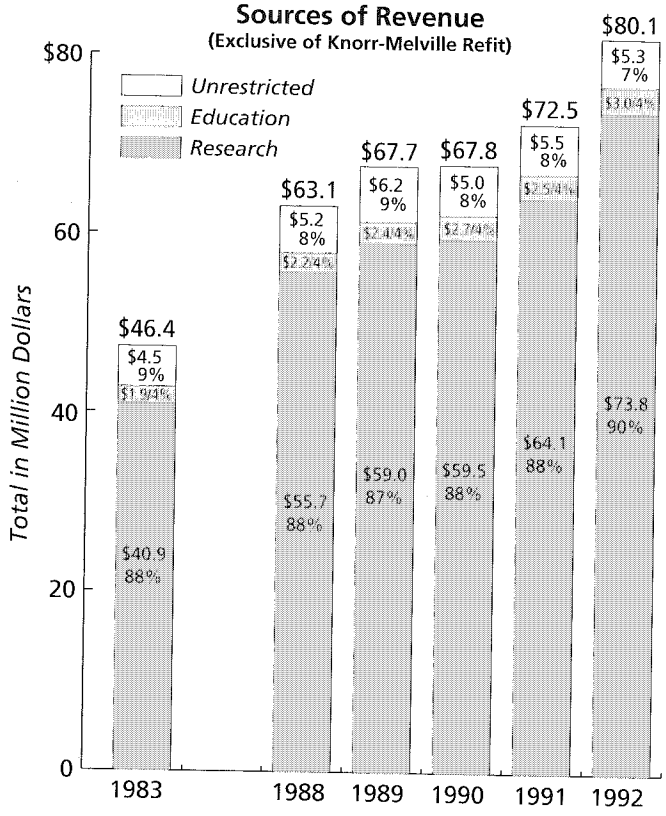


Table 2
Sources of Research Funding

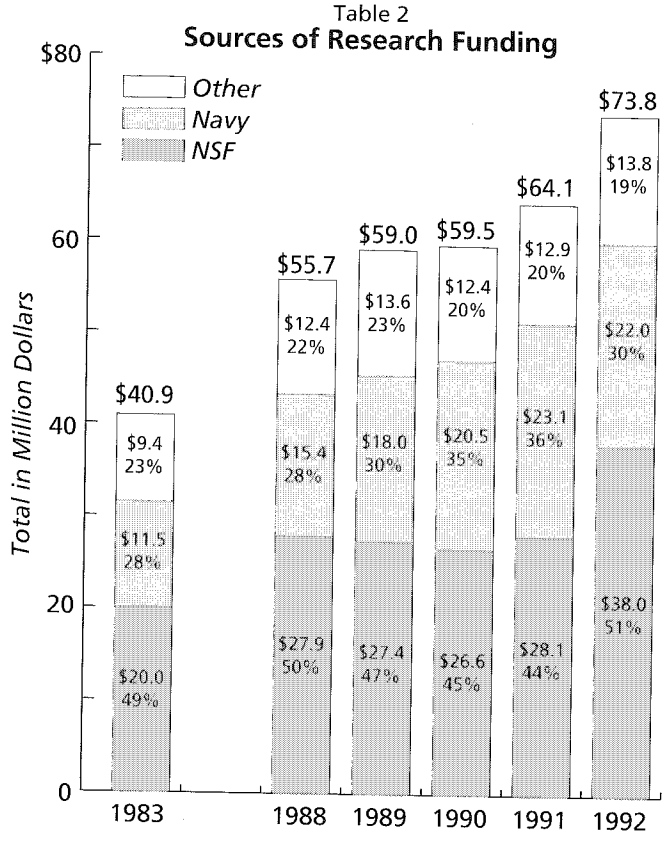


Table 3
Gifts and Grants from Private Sources

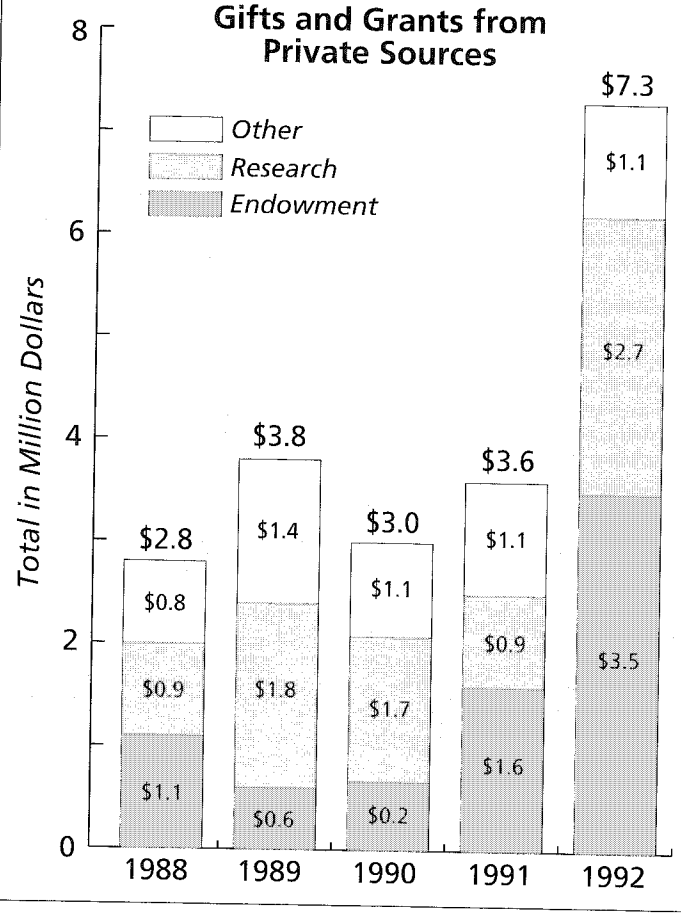
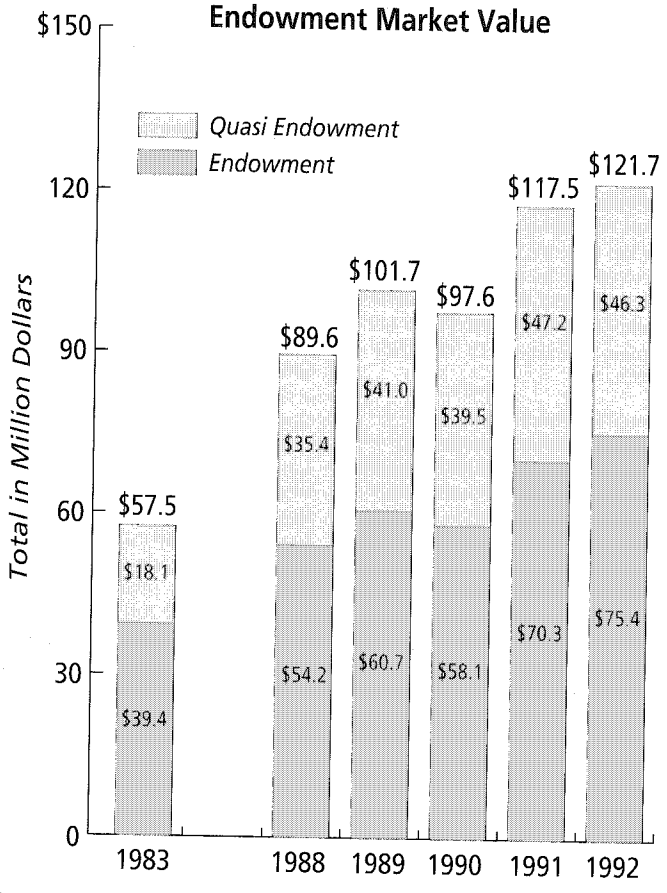


Table 4
Endowment Market Value



FINANCIAL STATEMENTS

In spite of a variety of financial pressures in 1992, the Institution's budget showed a modest surplus after transfers. In addition, we have been able to resolve the *Knorr-Melville* contract dispute, enhance reserves for future contingencies, and show an increase in endowment market value and our unrestricted fund balances. Revenues from government contracts and from private fund raising continue to increase substantially.

Institution revenues grew by 8.8 percent in 1992 to $90.4 million, reflecting continued strong support for our work by government and donors. Sponsored research continues to be the primary source of income, representing 81.6 percent of the Institution's total revenue compared to 77.1 percent in 1991. *Sponsored research increased by 15.2 percent in 1992.* (See Tables 1 and 2 for an overview of the sources of revenue to the Institution.) Unrestricted income declined by 3.4 percent, continuing the decline of recent years because of reductions in the fund balances earning interest income and the decline in interest rates.

The dollar value of grants and contracts in hand for the coming year, excluding the vessel refit, increased $6.9 million to $42.1 million. This substantial increase is a very positive indicator of sponsored research activity in 1993.

Fundraising for the Institution has been very encouraging. In 1992, gifts and grants from private sources (excluding pledges) increased to $7.3 million, compared to $3.7 million in 1991 and $3.0 million in 1990. (See Table 3.) Outstanding pledges alone at the end of 1992 were $4.7 million, compared to $3.1 million at the end of 1991.

The market value of the endowment, including new gifts, increased by 3.6 percent to $121.7 million. As a result of generous support from our many friends and benefactors, new gifts of $3.6 million were added to the endowment in 1992, compared to $1.6 million in 1991 and $0.2 million in 1990. (See Table 4.) The total return on the endowment under professional management was 7.1 percent. Of that total return, $4.3 million (income) supported operations while $3.5 million (appreciation) has been reinvested in the endowment prior to the transfer discussed below.

Capital expenditures stayed constant at $2.2 million. Funds for capital expenditures are provided from depreciation recovery.

The two primary sources of expendable fund balances are the Unrestricted Current Funds Balance and the Unrestricted Plant Fund Balance. After several years of substantial declines, those fund balances have grown modestly in 1992. (See Table 5.) The Unrestricted Current Fund increased from $1,196,000 to $1,239,000 and the Unrestricted Plant Fund increased from $2,671,000 to $3,005,000. The two fund balances combined increased from $3,867,000 to $4,245,000.

During the year the Institution faced various financial uncertainties: the lack of resolution of the *Knorr-Melville* dispute, declining yields on endowment and cash because of lower interest rates and reduced fund balances, uncertainties regarding Federal research funding and overhead reimbursements, and the short-term stress associated with the conservative decision to charge capital campaign expenses to the operating budget.

The final results for 1992 included a transfer of $2.9 million, from prior years' earned surpluses residing in quasi-endowment, to fund the final settlement of the *Knorr-Melville* dispute, to accommodate unanticipated employee medical expenses, and to enhance reserves for special contingencies. We feel confident that we have addressed some of the most significant financial issues and can look forward to a more stable financial future. The major remaining uncertainty facing the Institution is the nature and extent of federal financial support for the kind of scientific research in which WHOI has traditionally excelled.

In conclusion, during 1992:

- We have resolved several major financial issues. In the future, we still face three uncertainties which are controlled largely by external factors:

1) The ongoing uncertainties of Federal research support,
2) The need to absorb in our operating budget some ongoing administrative costs charged previously to overhead but no longer allowed under revised government practices, and
3) Uncertainty about overhead reimbursement rates for 1993 and beyond.

- Our endowment assets are growing. Our other unrestricted fund balances have stabilized.
- The Institution's new fund-raising initiatives are already helping improve the fiscal base of the Institution.

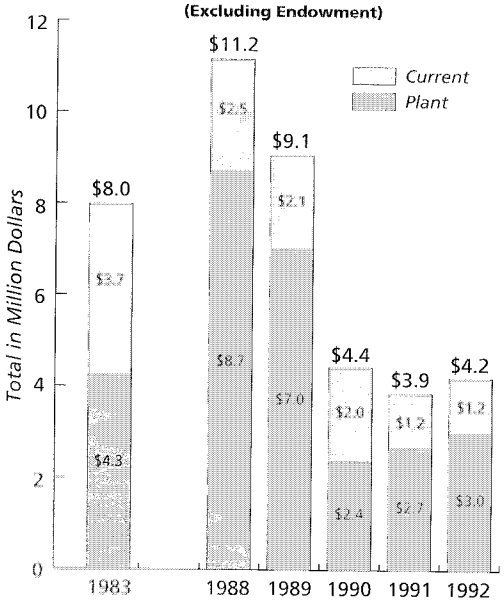
You are invited to review the Institution's audited financial statements and accompanying notes presented on the following pages.

Lawrence R. Ladd
Associate Director for Institution Operations

Karen E. Lauritzen
Controller

April 27, 1993

Table 5
Unrestricted Fund Balances
(Excluding Endowment)



FINANCIAL STATEMENTS

Statements of Current Fund

Revenues, Expenses and Transfers
for the years ended December 31, 1992 and 1991

Revenues

	1992	1991
Sponsored Research:		
Government	$66,654,520	$56,461,106
Nongovernment	7,155,906	7,622,201
	73,810,426	64,083,307
Knorr/Melville refit	8,238,152	10,693,042
Education funds availed of	3,023,691	2,830,835
Total restricted	85,072,269	77,607,184
Unrestricted:		
Fees	449,074	463,530
Endowment income	1,106,438	1,224,916
Gifts	929,126	884,439
Tuition	1,809,280	1,748,693
Investment income	231,148	292,147
Oceanus subscriptions	262,245	351,462
Other	559,756	570,598
Total unrestricted	5,347,067	5,535,785
Total revenues	**90,419,336**	**83,142,969**

Expenses

Sponsored research:		
Salaries and fringe benefits	22,788,260	20,180,151
Ships and submersibles	10,482,377	7,575,185
Material and equipment	9,090,725	9,056,008
Subcontracts	2,393,772	2,854,788
Laboratory overhead	8,986,363	7,994,335
General and administrative	7,922,360	6,735,345
Other	12,146,569	9,687,495
	73,810,426	64,083,307
Knorr/Melville refit	8,238,152	10,693,042
Education:		
Faculty expense	1,569,591	1,656,837
Student expense	1,430,450	1,157,913
Postdoctoral programs	419,453	452,161
Other	508,837	438,270
	3,928,331	3,705,181
Unsponsored research	1,801,843	2,280,721
External affairs	1,935,823	1,963,706
Other activities	3,924,930	1,918,204
Total expenses	**93,639,505**	**84,644,161**
Net increase/(decrease) before transefers ...	(3,220,169)	(1,501,192)
Transfers - (to) from:		
Designated reserves	354,115	631,935
Endowment fund	2,909,572	-
Total	**3,263,687**	**631,935**
Net increase/(decrease) unrestricted current funds	**$43,518**	**$(869,257)**

Balance Sheets

December 31, 1992 and 1991

Assets

	1992	1991
Current fund (Note A):		
Cash	$19,335,773	$9,454,770
Accrued interest and dividends	906,717	851,002
Reimbursable costs and fees:		
Billed	3,097,833	2,122,501
Unbilled	1,746,005	2,407,318
Other receivables	995,073	624,939
Inventories	627,480	572,477
Deferred charges and prepaid expenses	891,254	993,667
Deferred fixed rate variances	(795,324)	515,591
Due to other funds	194,332	(2,498,208)
	26,999,143	**15,044,057**
Endowment fund (Notes A and B):		
Investments, at market	106,732,763	110,858,023
Cash and cash equivalents	18,246,005	6,706,253
Due from current fund	(3,281,920)	(249,991)
	121,696,848	117,314,285
Annuity investments, at market	-	208,289
	121,696,848	**117,522,574**
Plant fund (Note A):		
Land, buildings, and improvements	39,654,127	38,192,039
Vessels and dock facilities	7,399,444	7,403,251
Laboratory and other equipment	6,667,094	6,658,785
Work in process	120,148	258,250
	53,840,813	52,512,325
Less: accumulated depreciation	(26,006,227)	(24,102,012)
	27,834,586	28,410,313
Due from current fund	3,087,588	2,748,199
	30,922,174	**31,158,512**
Total all funds	**$179,618,165**	**$163,725,143**

Liabilities and Fund Balances

	1992	1991
Current fund:		
Liabilities:		
Accounts payable and other liabilities	$6,254,252	$3,691,060
Accrued payroll and related liabilities	4,517,261	4,329,432
	10,771,513	8,020,492
Contingency (Note I):		
Fund balances:		
Restricted - unexpended:		
Sponsored research	10,965,992	833,347
Education program	2,919,445	3,497,098
Designated	1,102,888	1,497,333
Unrestricted	1,239,305	1,195,787
	16,227,630	7,023,565
	26,999,143	**15,044,057**
Endowment fund:		
Endowment:		
Income restricted	73,352,087	68,645,664
Income unrestricted	2,000,802	1,391,866
Pooled income fund	46,794	47,061
Quasi-endowment:		
Income designated	18,834,025	17,902,844
Income unrestricted	27,463,140	29,326,850
	121,696,848	117,314,285
Annuity	-	208,289
	121,696,848	**117,522,574**
Plant fund:		
Invested in plant	27,834,586	28,410,313
Unexpended:		
Restricted	82,286	77,003
Unrestricted	3,005,302	2,671,196
	30,922,174	**31,158,512**
Total all funds	**$179,618,165**	**$163,725,143**

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

Statement of Changes in Fund Balances
for the year ended December 31, 1992

	Current Funds				Endowment	Plant Fund		Total all Funds	
	Restricted	Designated	Unrestricted	Total	Fund	Invested in Plant	Unexpended	1992	1991
Increases:									
Gifts, grants and contracts:									
Government	$84,019,807			$84,019,807				$84,019,807	$57,570,609
Non-government	7,449,714		$929,121	8,378,835	$3,453,361		$25,477	11,857,673	8,555,867
Endowment and similar funds	2,974,139		1,106,443	4,080,582				4,080,582	4,508,580
Net increase (decrease) in realized and unrealized appreciation					3,188,336			3,188,336	17,706,346
Supplemental retirement plan					436,898			436,898	536,805
Other	143,271		3,311,503	3,454,774	5,251			3,460,025	3,675,553
Total increases	94,586,931		5,347,067	99,933,998	7,083,846		25,477	107,043,321	92,553,760
Decreases:									
Expenditures	(85,072,269)		(8,567,236)	(93,639,505)				(93,639,505)	(84,644,160)
Depreciation (Note A)						($2,762,874)	2,501,059	(261,815)	(261,811)
Plant asset additions						2,187,147	(2,187,147)		
Other									(50,013)
Total increases (decreases)	(85,072,269)		(8,567,236)	(93,639,505)		(575,727)	313,912	(93,901,320)	(84,955,984)
Net change before transfers	9,514,662		(3,220,169)	6,294,493	7,083,846	(575,727)	339,389	13,142,001	7,597,776
Transfers – additions/(deductions):									
Current revenues to:									
Designated reserves			2,909,572	2,909,572	(2,909,572)				
Endowment funds		$(354,115)	354,115						
Other transfers	40,330	(40,330)							
Total transfers	40,330	(394,445)	3,263,687	2,909,572	(2,909,572)				
Change in fund balances for year	9,554,992	(394,445)	43,518	9,204,065	4,174,274	(575,727)	339,389	13,142,001	7,597,776
Fund balance, December 31, 1991	4,330,445	1,497,333	1,195,787	7,023,565	117,522,574	28,410,313	2,748,199	155,704,651	148,106,875
Fund balance, December 31, 1992	**$13,885,437**	**$1,102,888**	**$1,239,305**	**$16,227,630**	**$121,696,848**	**$27,834,586**	**$3,087,588**	**$168,846,652**	**$155,704,651**

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

Report of Independent Accountants

To the Board of Trustees of
Woods Hole Oceanographic Institution:

We have audited the accompanying balance sheet of Woods Hole Oceanographic Institution as of December 31, 1992 and the related statements of changes in fund balances, and of current fund revenues, expenses and transfers for the year then ended. We previously audited and reported upon the financial statements of the Institution for the year ended December 31, 1991; totals for that year are shown for comparative purposes. These financial statements are the responsibility of the Institution's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with generally accepted auditing standards. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinion.

In our opinion, the financial statements referred to above present fairly, in all material respects, the financial position of Woods Hole Oceanographic Institution as of December 31, 1992, the changes in its fund balances, and its current fund revenues, expenses and transfers for the year then ended, in conformity with generally accepted accounting principles.

Boston, Massachusetts
April 5, 1993

Coopers & Lybrand