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UNIVERSITY OF CALIFORNIA, SAN DIEGO

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Scripps Institution of Oceanography Explorations informs and educates the public, our alumni, the scientific community, and Scripps's friends about ongoing research and events. Explorations is mailed four times a year. Summer, fall, and spring we publish magazine editions, with the Scripps annual report included in the spring edition. Winter we produce a video edition.

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SCRIPPS INSTITUTION OF OCEANOGRAPHY

EXPLORATIONS

Global Discoveries for Tomorrow's World

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New Director of Scripps Named

As Scripps approaches the millennium, a new director will be standing at the helm. Charles F. Kennel, physicist, member of the National Academy of Sciences, and—until recently—executive vice chancellor at the University of California, Los Angeles, has been selected as the ninth director of Scripps. He also will serve as vice chancellor of marine sciences, dean of the graduate school of marine sciences, and professor in the Scripps graduate department.

Kennel succeeds Edward A. Frieman as director of Scripps. Frieman, who retired after 10 years of service in August 1996, continues as a research professor at the institution.

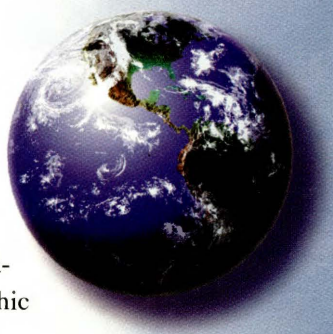
"Charles Kennel is a preeminent scientist who has made significant contributions to science policy at the national level, which positions him well to provide leadership into the next century of oceanographic research," said UC San Diego Chancellor Robert Dynes, in announcing Kennel's appointment.

During his tenure at UCLA, Kennel studied fundamental plasma physics combined with space physics and astrophysics. His areas of interest included basic plasma turbulence theory and collisionless shocks, the physics of the solar wind and planetary magnetospheres, and the physics of pulsar magnetospheres and active galactic nuclei. Kennel also served from 1994 to 1996 as associate administrator for NASA's Mission to Planet Earth, the world's largest environmental science program.

Kennel received a bachelor's degree in astronomy from Harvard College in 1959 and a doctoral degree in astrophysical sciences from Princeton University in 1964. He was appointed an associate professor of physics at UCLA in 1967 and a professor in 1971. Kennel became executive vice chancellor at UCLA in 1996.

Kennel was named Fellow of the American Association for the Advancement of Science in 1992. His other memberships include the American Astronomical Society, the American Geophysical Union, and the American Physical Society. He has won the NASA Distinguished Service Medal, the Aurelio Peccei Prize from the Italian Academy of Sciences, the James Clerk Maxwell Prize from the American Physical Society, and has been selected to receive the 1998 Hannes Alfvén Medal of the European Geophysical Society. Kennel has been a Guggenheim Foundation Fellow, a Fulbright Senior Lecturer in Brazil, and an Alfred P. Sloan Foundation Fellow.

A Message from the Director



I accept the directorship of Scripps Institution of Oceanography fully aware of its place as the world's leading oceanographic institution. Scripps's greatness lies first and foremost in the intelligence, creativity, and dedication of its faculty, staff, and students working together to advance understanding of the world's oceans. In the process, these men and women serve their country and state and educate the next generation of scientific leaders.

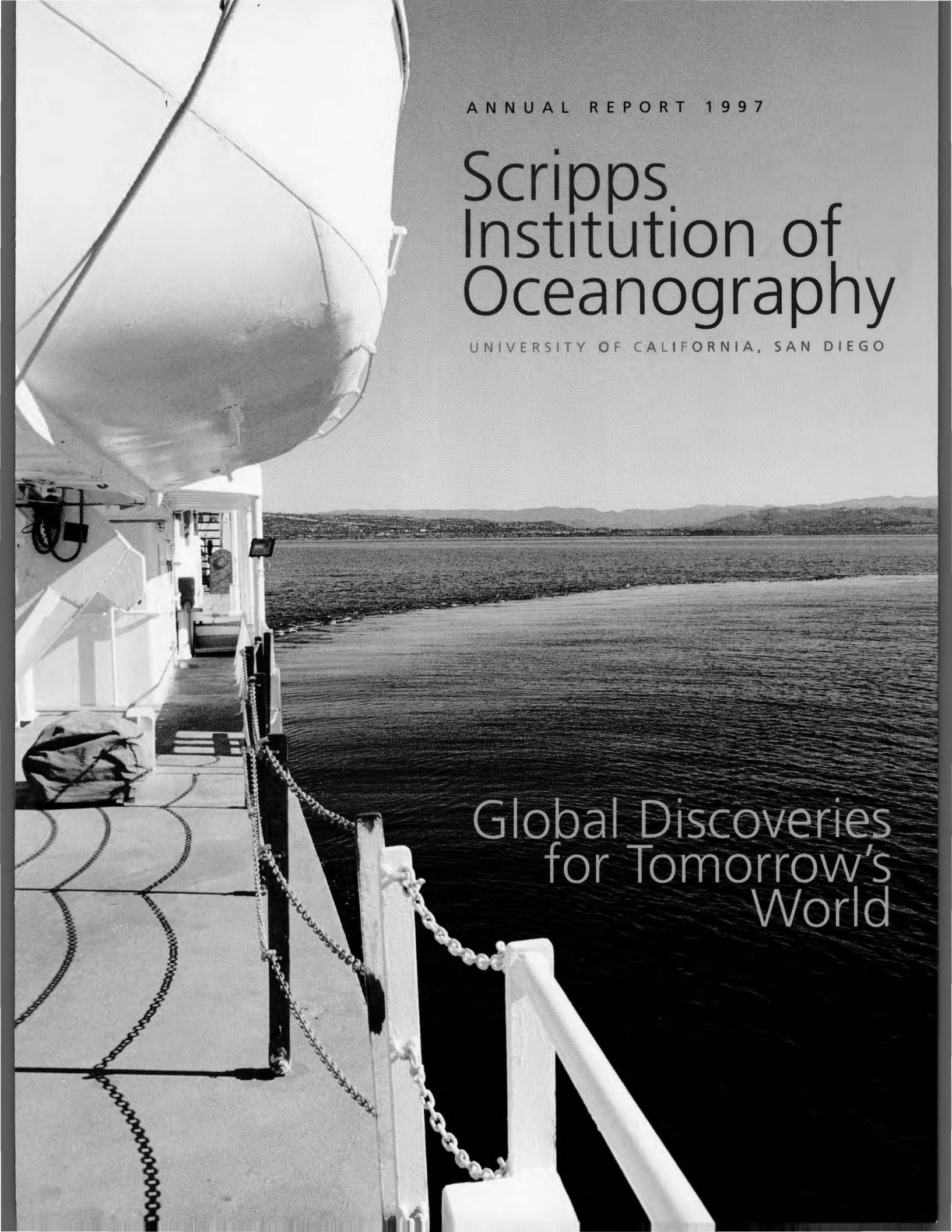
The tradition and culture that built Scripps have served it extraordinarily well. I also understand that to stay "number one" we must remain alert to new possibilities. All great institutions find a dynamic balance between continuing and emerging areas of leadership. As we begin to think together about that balance, let us keep in mind several broad trends: the world's entrance into the information age, the ongoing globalization of research, and the increasing importance of interdisciplinary research efforts. Specific scientific goals and directions must and will continue to evolve according to the ideas of our talented investigators, but increasingly in a framework of international collaboration on large-scale, integrative, and interdisciplinary research programs.

These efforts will use and complement the strengths of the institution's oceangoing fleet and the more than 300 individual projects of Scripps researchers. These collaborations will enable us to understand our planet with a depth, breadth, and precision not possible in the past. Also, environmental stewardship promises to replace military security at the heart of the international policy agenda. These thoughts will be with me as I begin my discussions with the faculty, students, staff, government and foundation sponsors, partners and collaborators, and friends of Scripps.

We will continue to communicate the needs and importance of a strong research agenda to the government, the country at large, and others around the world. Our superb institutional outreach programs, including those of the Scripps Oceanographic Society and the Birch Aquarium, will continue to communicate the fascination of Scripps's work to the public. I personally invite all interested to join the Scripps family in our global adventure. There is literally a whole world to explore.

Charles Kennel

Charles F. Kennel
Director, Scripps Institution of Oceanography

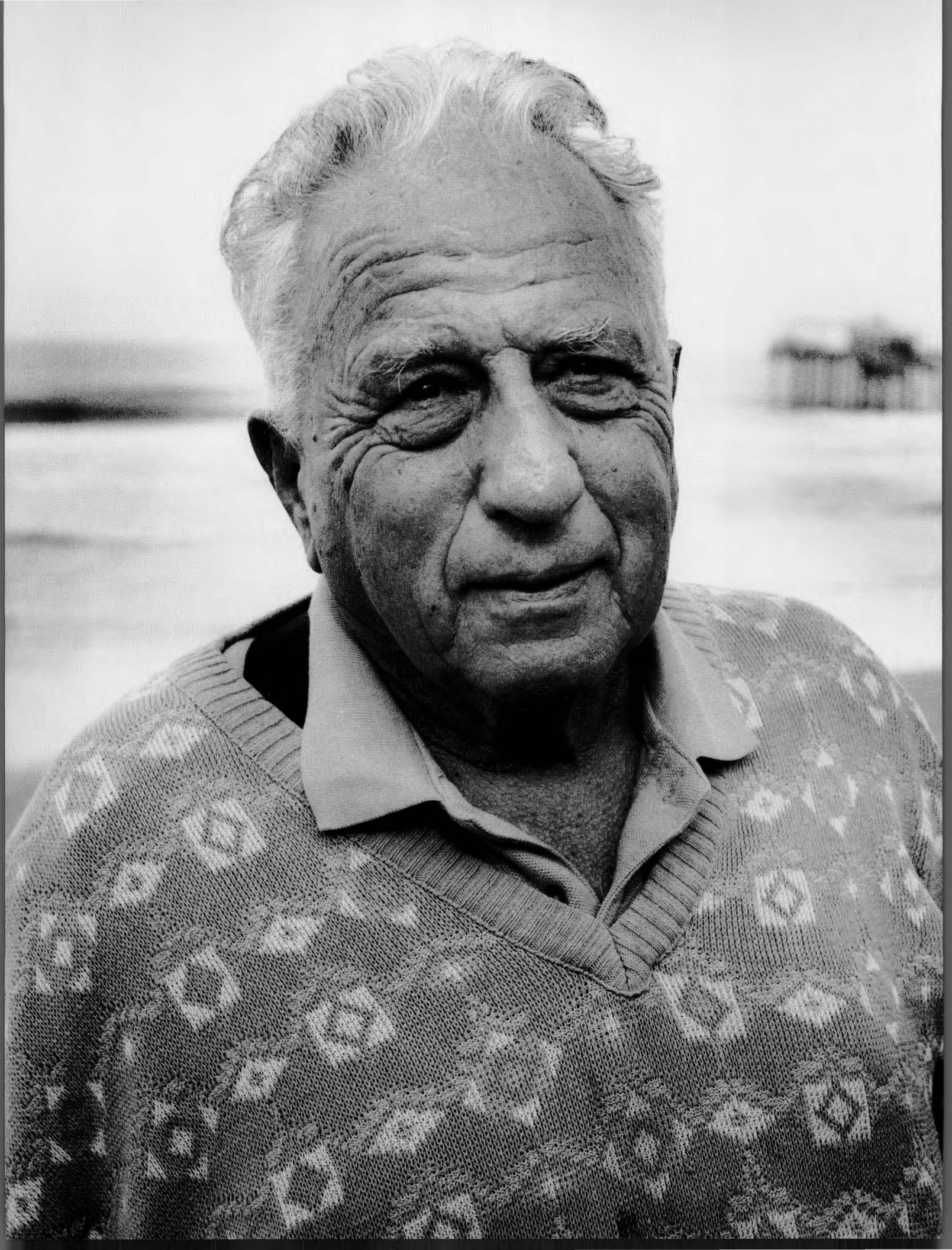


ANNUAL REPORT 1997

Scripps Institution of Oceanography

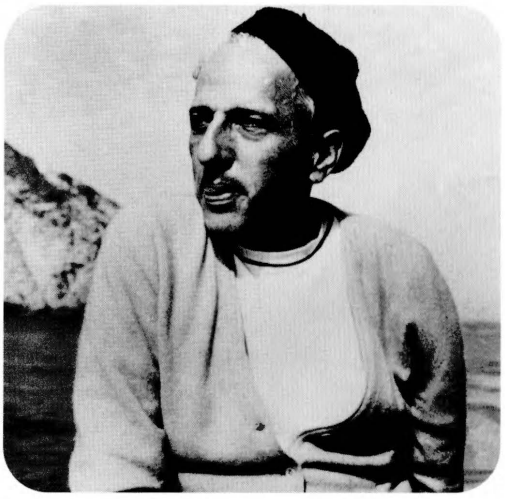
UNIVERSITY OF CALIFORNIA, SAN DIEGO

Global Discoveries for Tomorrow's World



Dedication

ED GOLDBERG



Ed Goldberg, France, 1969

When he is not traveling the world conducting research, convening and chairing conferences, or advising governments on aspects of marine science and ocean pollution, Professor Emeritus Edward D. Goldberg can be found at Scripps. If he is not in his lab or office, he may be found out and about taking a brisk walk or a quick ocean dip, as he has done many days for nearly 50 years. For he has had only one job, and he's done it well indeed.

A world-renowned expert on ocean pollution, Goldberg has made pioneering contributions to marine chemistry and is a leader in integrating basic research into public policy. He has devised and carried out novel analyses of environmental problems and has laid his beliefs on the line, even though they have sometimes run counter to mainstream opinion. He is often quoted, by friends and foes alike, for his views that the oceans are a more reasonable disposal option than land for some waste materials and that they are not in trouble or dying.

A California native, Goldberg received a bachelor's degree from UC Berkeley in 1942 and spent World War II as a naval officer. As a graduate student at the University of Chicago, he joined in the creation of modern geochemistry. Soon after receiving a doctorate in 1949, Goldberg came to Scripps just as Roger Revelle was launching the golden age of oceanography.

At Scripps, Goldberg went on a geochemical treasure hunt, studying the complex chemistry of ocean waters and the underlying sediments and rocks, the exchanges of elements and compounds between the oceans and atmosphere and between land and sea, and the chemical transformations that take place in the marine ecosystem.

Much of Goldberg's early research required devising highly sensitive and precise ways to measure minuscule amounts of elements and compounds. Working with Scripps chemist Minoru Koide, he developed several new laboratory techniques. While analyzing seafloor sediments, Goldberg showed that winds carry vast amounts of materials to the oceans, which led him to study the composition of the dust. In 1968, he co-authored a paper on wind transport and oceanic deposition of DDT and other pesticides—an early publication on ocean pollution resulting from human activity. From then on, pollution became Goldberg's principal interest, and its control his chief professional passion. DDT was banned in the U.S. in 1972, at least partly as a result of his findings.

Goldberg directed a workshop, which resulted in the book *Marine Pollution Monitoring: Strategies for a National Program,* in 1972. This was the springboard for his surveillance program on U.S. coastal marine pollution, called "The Mussel Watch." The scheme was to determine levels of contamination by collecting mussels, which feed by filtering material from seawater, and analyzing the concentration of heavy metals and other pollutants in their tissues. The first U.S. Mussel Watch took place from 1976-1978 at more than 100 stations and identified several hot spots of pollution. The methodology was later incorporated into the National Oceanic and Atmospheric Administration's on-going Status and Trends Program that monitors chemical contamination and human impacts on coastal and estuarine areas. Similar efforts have been initiated in China, India, Russia, and many developing countries.

Also in the mid-1970s, Goldberg published *The Health of the Oceans,* acknowledged as the definitive statement on marine pollution and the ocean's capacity to absorb wastes. He then convened workshops during which it was concluded that the assimilative capacity of U.S. coastal waters for nontoxic waste disposal was underused, and that there were acceptable locations for disposal that would not produce harmful biological impacts. These conclusions have been background for many laws and policies.

In the 1980s, increasing incidents of deformities and die-offs of some marine organisms in harbors near boat marinas caused alarm. Goldberg sampled water in more than 60 California locations and identified the source of trouble as tributyltin, a highly toxic chemical that was being added to most antifouling paints to protect the bottoms of both pleasure craft and commercial vessels. It subsequently was banned or regulated in France, the United Kingdom, and parts of the United States.

Goldberg has been a Guggenheim Fellow, a senior NATO Fellow, a National Academy of Sciences Exchange Scholar, and an international lecturer at universities and conferences. Among his many honors are the Tyler Prize for environmental achievement and membership in the National Academy of Sciences.

BY CHUCK COLGAN

Research Highlights

BY MARIO AGUILERA

CALIFORNIA SPACE INSTITUTE

CENTER FOR ATMOSPHERIC SCIENCES

CENTER FOR COASTAL STUDIES

CENTER FOR MARINE BIOTECHNOLOGY AND BIOMEDICINE

CLIMATE RESEARCH DIVISION

GEOSCIENCES RESEARCH DIVISION

INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS

MARINE BIOLOGY RESEARCH DIVISION

MARINE LIFE RESEARCH GROUP

MARINE PHYSICAL LABORATORY

MARINE RESEARCH DIVISION

NEUROBIOLOGY UNIT

PHYSICAL OCEANOGRAPHY RESEARCH DIVISION

The Research Highlights include a summary of current scientific activities at Scripps. Each department, division, center, and research unit or group is represented by a general overview of the activities of its scientists and by a detailed highlight of one scientist or project. Highlighted scientists have been selected by their departments for this recognition. Readers interested in more in-depth coverage of the topics discussed here should consult the scientific papers listed in the Publications section. More information on individual departments can be found at http://sio.ucsd.edu/res_groups/.

Jürgen Lobert (facing page) tests a sun tracker that holds three shaded radiometers used for measuring the various spectral regions of sunlight. Lobert's studies are part of an effort to refine current understanding of the global solar radiation budget.

California Space Institute

The California Space Institute (CalSpace), a multicampus research unit of the University of California, supports space- and Earth-related sciences, education, and technology research. CalSpace maintains close ties with many departments at UC San Diego and other UC campuses through scientific collaboration and joint faculty appointments.

CalSpace scientists conduct both pure and applied research in many interdisciplinary, space-related fields. The main emphasis for some CalSpace researchers is on space plasma physics and planetary science. Others study the atmosphere and atmosphere-ocean interactions. CalSpace researchers use space activities and accomplishments to stimulate and motivate students, and they invite university students from all levels to join in creating programs in this area.

From sea-ice maps and sea-surface temperature readings to cloud maps and real-time satellite support, the Arctic and Antarctic Research Center (AARC), administered by CalSpace, is an important information clearinghouse for the polar regions. Established by remote-sensing specialist Robert H. Whritner in 1987, the AARC's polar antennae have gleaned more than 70,000 overpasses from polar-orbiting satellites, archiving information that is used by ship captains and scientists alike.

With one satellite tracking station at McMurdo Station and one at Palmer Station, the AARC system continuously records data from spacecraft launched by the National Oceanic and Atmospheric Administration (NOAA) and the Defense Meteorology Satellite Program (DMSP).

CalSpace research scientist Dr. Dan Lubin is interested in both sides of the AARC equation. He is part of the team that compiles and satisfies the steady flow of requests for data, and he is an AARC researcher—using the unique capabilities of the AARC system to study the Arctic and Antarctic environments.

"These antennae routinely collect about 20 overpasses from polar orbiting satellites per day and all of the data come back to Scripps, are archived here, and are made available from this laboratory to anyone who's interested," said Lubin. "During the past year we have provided all kinds of real-time satellite support to ships operating in the Antarctic. We've provided our sea-ice maps and weather maps to captains, chief scientists, and others who have found them helpful."

Hundreds of requests for the AARC data have been received from a variety of educational, governmental, and scientific organizations. Scientists using AARC data come from all polar-related disciplines, including oceanography, atmospheric science, space physics, marine biology, and ecology. Scientists at the National Aeronautics and Space Administration (NASA) are using AARC satellite data to study ozone hole formation.

Lubin is working to improve the AARC's capability. The AARC support team has developed an 85-gigahertz algorithm for the DMSP data that will double the resolution of the satellite imaging "footprint" of Antarctic sea ice. This allows for more accurate ice-edge identification. The improved microwave imaging capabilities also will enable the system to "see" more clearly through the atmosphere and clouds.

Armed with an improved AARC system, Lubin has been preparing to embark on a study of the effect of the ozone hole on phytoplankton around the Antarctic continent. The project teams Lubin and Scripps researcher Dr. Osmund Holm-Hansen with a colleague at NASA's Oceans and Ice Branch at Goddard Space Flight Center.

"During the early spring the sea ice begins to recede and phytoplankton are released from it into the water column. Thus, where the sea ice is determines where the phytoplankton are, and where we need to map with the satellite," said Lubin. "A second component the satellite data will give us is the ozone abundance in the stratosphere; it will allow us to map the biologically active solar ultraviolet radiation getting through the ozone hole."

With Holm-Hansen providing knowledge of the phytoplankton climatology and the NASA colleague supplying ecological models of phytoplankton biomass, the team will use the satellite data to provide maps of stratospheric ozone and tropospheric cloud cover, which block ultraviolet radiation.

"We will be studying the primary production [of phytoplankton] throughout Antarctica," said Lubin. "By combining the ultraviolet radiation fields, which we get from satellite data and our own models, with biological information, we will be able to make an assessment of the impact of the ozone hole on the entire Southern Ocean. That is something that's never been done before."

More information about CalSpace can be found on the Internet at http://deimos.ucsd.edu/calspace.html. The Arctic and Antarctic Research Center has a Web site at http://arcane.ucsd.edu/.

Center for Atmospheric Sciences

The Center for Atmospheric Sciences (CAS) focuses on fundamental research in the atmosphere as it relates to large-scale climate change. In this context, the research includes a balance of field experiments, satellite observations, and computer modeling. Investigators make use of surface observatories, aircraft, and ships, as well as remote sensing by satellite technology. CAS scientists use regional and global models of the atmosphere to interpret observations and to understand and predict changes in climate patterns. Areas of research within CAS include the climate feedback process, water vapor and clouds, and tropospheric aerosol and trace gas science.

The Indian Ocean offers one of the world's best natural laboratories to study climate change and the impact of man-made pollutants. During half of the year, the southwest monsoon carries pristine air from the Southern Hemisphere into the Indian Ocean, while during the other half, the northeast monsoon sweeps down polluted air from the Indian subcontinent.

Scientists from around the world will exploit this dual character during a $25 million international project called the Indian Ocean Experiment, or INDOEX. CAS director Dr. Veerabhadran Ramanathan and Scripps researcher and Nobel laureate Dr. Paul Crutzen are the two principal INDOEX project investigators. INDOEX is organized by the Center for Clouds, Chemistry and Climate (C^4), a special research group at Scripps and an integral part of CAS.

Dr. Jürgen M. Lobert, a CAS researcher, is one of the assistant project scientists for INDOEX. Lobert is in charge of establishing the project's central observatory on Kaashidhoo, an island in the Republic of Maldives. His "hands-on" duties include instrument analytics, specifying the observatory's design, and organizing part of the actual experiment.

Lobert will coordinate ground-based measurements in the Maldives, which complement an assortment of aircraft, weather balloons, buoys, satellites, and ships that will record data around the Interhemispheric Tropical Convergence Zone (ITCZ)—where northern and southern hemispheric air masses collide.

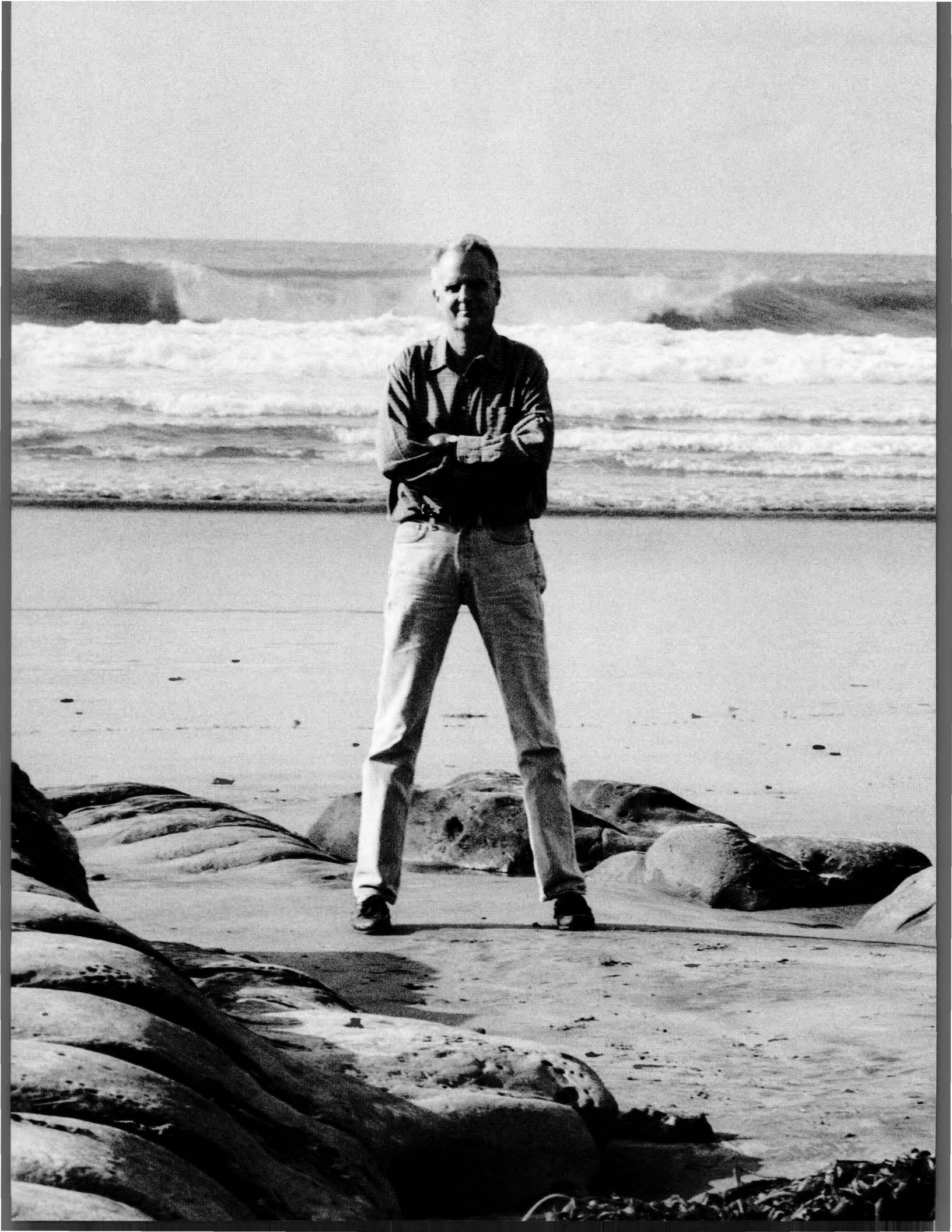
"Issues we're trying to understand include how the ITCZ influences the exchange of aerosols and trace gases between the hemispheres and how it affects the exchange between the surface and higher levels of the atmosphere," said Lobert, who will apply his training in atmospheric chemistry to the project. "The main goal of INDOEX, however, is to understand how the interaction between pollution and clouds affects the climate in general and particularly the solar energy budget in the atmosphere."

Lobert has purchased and calibrated several pieces of equipment including a gas chromatograph, an instrument with two detectors that measures man-made trace gases such as chlorofluorocarbons (CFCs) and sulfur hexafluoride (SF_6); a carbon monoxide (CO) analyzer, which continuously monitors surface concentrations of CO (an indicator of fossil fuel emissions and natural hydrocarbons); and a suite of radiometric sensors that measure the intensity of sunlight in different spectral regions.

INDOEX's intensive field phase will take place from January through April of 1999, with a two-month test experiment in early 1998 and continuous observations for a period of two years. However, Lobert's work began in January 1997. "I am setting up the main observatory site and actually have designed the building and everything inside," said Lobert. "I can't complain that this job is boring because I'm an architect, a plumber, an organizer, an instrument calibrator—you name it—and yes, a scientist too."

While Lobert acknowledges that a three-month experiment will give the team only a partial view of the year-round climatology, he says the breadth of data and the variety of instruments will give the researchers a much better understanding of the influence of aerosols and trace gases on the solar radiation budget and climate.

For those interested in further reading on these subjects, Lobert suggests the following Web sites: http://www-c4.ucsd.edu/ for information about C^4, and http://www-indoex.ucsd.edu/ for INDOEX information.



Center for Coastal Studies

Scientists in the Center for Coastal Studies (CCS), an interdisciplinary research center, focus on the physical and sedimentary processes along the coastlines of the world. Research at CCS concerns fluid-sediment interactions responsible for sand transport along beaches and over the continental shelf; processes affecting circulation of coastal waters, in semi-enclosed seas, and in the straits that connect them to larger ocean basins; and coastal meteorology, surface gravity waves, and wave-induced currents in shallow water. CCS manages the Hydraulics Laboratory.

Recent CCS research sites have included the Santa Barbara Channel, San Francisco and San Diego Bays, the Nile Delta, the Indonesian Archipelago, and areas offshore from North Carolina and southern California.

Coastal oceanographers, such as Clinton Winant (facing page), are involved in efforts to generate models and predictions of coastal sea circulation.

To understand the dynamics of coastal sea circulation it is necessary to measure and synthesize a variety of forces: wind, waves, water temperature, and currents.

Dr. Clinton D. Winant, along with a team that includes Drs. Myrl C. Hendershott and Clive E. Dorman, began recording data in 1992 for a project that would create models of circulation patterns in the Santa Barbara Channel, a major transportation lane for the Los Angeles metropolis and an area of intense oil development.

The idea of developing circulation pattern models is similar to a forecast in meteorology. The implications of this research are valuable for the Winant group's partner, the Department of Interior's Minerals Management Service, which is charged with analysis and rapid response planning for spill risks associated with oil activities and transportation collisions. The team's circulation predictions are often tapped by the U.S. Coast Guard when people fall off of boats and drilling platforms.

The group uses four types of information-gathering tools to arrive at pattern predictions. The first is a set of meteorological towers secured on oil platforms, buoys, and islands. These towers contain equipment that analyzes surface conditions, including air temperature, humidity, and barometric pressure. Each tower is equipped with a wind vane on top and an electronic package at the base.

The second and most expensive measuring tools are moorings, which measure current vectors. They are comprised of a buoy at the surface, an anchor, and several current meters and temperature sensors distributed throughout depths ranging from 330 to 660 feet (100 to 200 m). Each mooring is equipped with a downward-looking 75 kHz Acoustic Doppler Current Profiler (ADCP) that relays real-time vector data through a meter connected by cable to a radio transmitter. The information is sent to a satellite and passed on to Scripps scientists and to a Web page for public viewing (http://www-ccs.ucsd.edu/ccs). Every six to eight months Winant's team heads to sea to refurbish each buoy.

While at sea they conduct current surveys, the third information source. Using sensitive ship instrumentation, including a downward-looking 150 kHz ADCP, an upward-looking 1.2 MHz Doppler profiler, and a conductivity-temperature-depth profiler, the researchers measure "snapshots" of the channel's currents. This gives them various location readings in addition to the stationary moorings.

The fourth element, called the "drifter," is the most mobile of the information gathering tools. Set out 12 at a time, drifters are propelled by large sails and carry electronic monitoring packages that report current trajectories. Some drifters circle the channel in two to three days, some eventually drift off to Mexico, and some run aground, but the majority give the researchers vital information on the circulation of currents.

The circulation patterns deduced from these data are extremely valuable when decisions must be made concerning which methods of containment to use, such as during an oil spill. While grounded measuring equipment might point to the need for containment in one area, the drifters may in fact show the need for containment in another. Winant's team has been able to synthesize and develop four circulation representations for the Santa Barbara Channel.

The team has already turned the coastal corner and begun work on developing characteristics for the Santa Maria Basin. Winant is on track to complete that project in 2001, which would mark the end of 10 years of research.

Center for Marine Biotechnology and Biomedicine

The Center for Marine Biotechnology and Biomedicine (CMBB), housed at Scripps, is a UC San Diego campuswide center dedicated to exploration of the biotechnological and biomedical resources found in the world's oceans. The center includes faculty and researchers from Scripps and other campus departments, including biology, chemistry, medicine, neuroscience, pediatrics, and pharmacology.

The CMBB program in marine biomedicine involves the UC San Diego School of Medicine and focuses on marine drug discovery (with an emphasis on cancer), marine pharmacology, physiology, neurobiology, and the molecular events associated with reproduction.

CMBB researchers investigate new biotechnologies ranging from the special properties of deep-sea marine microbes to the genetic engineering of commercially important marine animals. They also stress basic research, participate in student education, and provide support for the local biotechnology industry.

During the course of a dive, marine mammals and birds swim, find and catch prey, and return to the sea surface all on a single breath of air. Seals, for example, tolerate oxygen levels low enough to render a human unconscious. Deep-diving species routinely encounter pressures high enough to cause decompression sickness (the bends), nitrogen narcosis, and high pressure nervous syndrome in humans.

Dr. Paul J. Ponganis wants to know how the animals do it. Part of his interest in the diving phenomenon is rooted in his work as an anesthesiologist, a job in which oxygen delivery to the patient is crucial. Knowledge of diving also is essential to understanding the physiological limits of deep-diving species' behavior and ecology, factors that could play a key role in their survival and conservation.

Diving capacities of different animals are based on oxygen storage in the body and on the regulated depletion of that oxygen during diving. Ponganis has been examining how the distribution and magnitude of oxygen stores in the lung, blood, and muscle compartments vary with species. Emperor penguins, for instance, store the majority of their oxygen in muscle and air sacs, while seals concentrate it in blood and muscle. The consumption of oxygen in blood is predominantly controlled by heart rate and blood flow to body organs, while muscle oxygen consumption is primarily dependent on muscular effort.

"I am looking at how swim speed, heart rate, and blood flow are manipulated during different dives so that these oxygen stores can allow energy metabolism to remain aerobic and not to resort to anaerobic processes," said Ponganis.

Research techniques used by Ponganis include computerized tomographic scans of anesthetized animals for anatomical studies, biochemical and microscopic analyses, and remote recordings to collect data while animals free dive at sea. The recorders are especially important because they monitor variables such as swim speed, temperature, oxygen level, heart rate, and electrocardiograms. Some of Ponganis's recent findings show that elephant seals drop their swim speed to zero during a 1,320-foot (400 m) dive, and seals from Lake Baikal in Russia decrease their heart rates to five beats per minute for the last five minutes of a 25-minute dive. "The goal is to design equipment that does not interfere with routine activities," said Ponganis. "This way experiments can take advantage of an animal's natural diving behaviors."

Recently, Ponganis adapted an ECG (electrocardiogram) Holter moniter to record the ECG of J. J., an orphan gray whale cared for by San Diego's Sea World of California since her rescue. The ECG information should increase Ponganis's understanding of heart rate regulation and diving ability in whales.

Ponganis sees the unique adaptations of these diving mammals and birds as potentially applicable to many aspects of medicine. In the example of the Lake Baikal seals, the animals' ability to withstand low levels of blood flow and oxygen, and to resume normal functioning, may eventually improve the understanding and treatment of conditions such as shock and stroke. Ponganis says the information may even be applicable to improved organ preservation for transplantation. The fact that seals' lungs collapse and re-expand during dives may be relevant to various human respiratory distress syndromes.

"In the meantime," said Ponganis, "this research betters our understanding of diving endurance and the limits it places on the behavior and ecology of these fascinating animals."

Paul Ponganis (facing page, third from left) and Sea World trainers attach suction-cup electrodes to J. J., a young gray whale calf, in order to record the whale's electrocardiogram.

Climate Research Division

In the Climate Research Division (CRD), scientists study phenomena spanning time scales from a few weeks to several decades. Research themes include diagnosing and predicting the natural variability of climate and understanding the consequences of man-made increases in the greenhouse effect. In the climate system, interactions among the atmosphere, the seas, the land, and the world of living things are tightly joined. To understand these interactions, CRD researchers use a team approach in areas including meteorology, oceanography, and hydrology.

Current research includes developing coupled global ocean and atmosphere models, assessing the role of cloud-radiation feedbacks in climate change, exploring the connections of the atmosphere and ocean to land surface hydrology, and modeling and predicting seasonal-decadal climate variability.

CRD scientists stress research on how global change impacts regional and transient phenomena, emphasizing those aspects of climate that are potentially predictable.

Information related to the El Niño Southern Oscillation (ENSO) phenomenon continues to be revealed by scientific study; climate researchers already have developed solid patterns linking the tropical ocean and atmosphere to a chain of weather anomalies. A clear association has been documented in which warm tropical waters force atmospheric changes that displace normal weather patterns throughout North and South America.

Dr. Arthur J. Miller has directed his scientific efforts to some less obvious and more challenging changes in the ocean-atmosphere interplay. Miller develops models that simulate decades of changes in the enigmatic North Pacific Ocean midlatitude region, a temperate zone between roughly 30 degrees north and 60 degrees north.

"My main thrust now is to look at data and models together to try to find these interesting long-timescale variations in the ocean and eventually to use them to better understand what goes on in the atmosphere," Miller said. "My feeling is that if you can discover some interesting effect both in observations and in a model at the same time, there is a better chance of it being real."

Miller believes using observations by themselves can be distorted by measurement "noise," such as instrument and sampling errors, while using models by themselves carries the possibility of inadequate physics and imprecise forces, such as wind or heat. Thus, he weaves the two together.

In one example, Miller is working with Dr. Niklas Schneider on a project comparing ocean-atmosphere models that simulate several decades of Pacific Ocean behavior. The models analyze the relationship between sea-surface temperature, ocean currents, and the thermocline—the body of water that separates warmer, oxygen-rich surface water from cold, oxygen-poor deep water. Ultimately, Miller and Schneider hope to discover whether the ocean and atmosphere feed changes to each other, whether they act independently, or whether the ocean is subservient to the atmosphere. Yet another possibility is that variability in the tropics causes fluctuations in the atmosphere, which carry "teleconnected" changes into the mid-latitude Pacific over decades.

In a separate project Miller, with Drs. Daniel R. Cayan and Timothy R. Baumgartner, is studying the role of ocean physics in fish population fluctuations. This team investigates whether ocean physics has a direct link to fish populations, rather than an indirect connection—in which physics controls upwelling, which controls nutrients, which affect phytoplankton, zooplankton, and, finally, fish.

"What we want to do is look at these hindcasts, looking back 30 or 40 years, to study the variations in ocean velocity, variations in horizontal and vertical currents, and the variability of the sea surface and subsurface temperatures," said Miller. "We'll use a model to get some idea of what is controlling the fish population to see if different things happen during different epochs of fish populations."

Using Miller's ocean model gives the researchers valuable information about the ocean from past climate regimes that were sparsely measured. Baumgartner's sediment-core analyses of fish-scale abundance provide statistics about fish populations, while Cayan's research on atmospheric-forcing functions guides the ocean model's fluctuations.

Geometry, linear physics, nonlinear physics, and statistical analysis are the tools of Miller's analytical work. Virtually all of Miller's research is conducted on computers as he must contend with complex nonlinear equations and vast sets of data. Inverse methods of analysis, performed in conjunction with Dr. Bruce D. Cornuelle, allow Miller to match his ocean models to observations. This computer-intensive technique often demands model processing across several computers simultaneously.

Miller's work in developing climate models of the past is useful as a solid supporting base for interpreting and producing accurate climate prediction models, which are the ultimate goal of CRD science.

Geosciences Research Division

Scientists in the Geosciences Research Division (GRD) address the physical and chemical processes occurring in the earth's mantle and crust, especially in the seafloor; interactions within and between the oceans and the atmosphere; and the reconstruction of ocean and climate history. They carry out detailed studies concerning marine geology; petrology; tectonics; geophysics; isotope geology; geochemistry; remote sensing; mantle and crustal evolution; fluid processes; climate history; global biogeochemical cycles; global change; microfossil evolution and systematics; and marine, atmospheric, and solar system chemistry.

Studying the chemical evolution of the ocean gives scientists a glimpse into the historical interplay between Earth's surficial and internal processes. Information that can be derived from analyzing the chemical history of seawater includes shifts in sea-surface temperature, variations in erosion rates, and changes in submarine hydrothermal activity.

Dr. Miriam Kastner searches for marine minerals that reliably record seawater composition in her quest to uncover the record of ocean behavior hundreds of thousands to millions of years ago. Examples of chemical and isotopic processes that can give such clues are strontium to calcium concentration ratios and stable isotope ratios of strontium, oxygen, carbon, and chlorine.

"When we identify potentially suitable marine minerals, we first have to show that the concentrations and isotopic composition of the chemical components give us reliable data on modern ocean composition, and thus on some of its processes; then we test the geochemical 'memory' of the minerals," said Kastner. "For example, the strontium isotope composition provides us with insights on the present and past interplay between submarine hydrothermal activity and surface erosion rates."

Kastner analyzes solids and fluids using various instruments and methods, including x-ray diffractometers, electron microscopes, mass spectrometers, and wet chemical techniques such as Inductively Coupled Plasma-Mass Spectrometry.

Another area of Kastner's research concerns gas hydrates. These are crystalline compounds of water that form a cage-like structure with "guest" molecules; in the ocean, these molecules are usually methane. Interest in gas hydrates has rapidly increased, according to Kastner, for three primary reasons: their potential as a fossil fuel resource, their effects on global climate change, and their role as potential submarine "geohazards" that cause earth slumps and slides.

Kastner stated that gas hydrates contain the largest accumulation of natural fuel on Earth, with nearly 10,000 gigatons of methane carbon existing in continental margin sediments. Methane is one of the two important carbon-containing greenhouse gases. Thus, small changes in the stability of the methane hydrate reservoir could result in a positive or negative greenhouse feedback, affecting global warming or cooling from the release of methane into the atmosphere. Gas hydrate decomposition also could affect the stability of margin sediments in the continental slopes through the formation of a "zone of weakness," in which gravitational loading or seismic disturbance could result in submarine landslides.

Scientists in Kastner's laboratory also focus on the role of fluids in earthquake-prone subduction zones, regions where one Earth plate slips underneath another. Kastner works with geophysicists to determine what role fluids play in subduction zones, at what depths in relation to seismogenically active zones these fluids are released, and the relation of fluids to earthquake cycles. Her research focuses on the chemical and isotopic compositions of subduction zone fluids and on related fluxes into the ocean and mantle. Kastner's research on these fluids may ultimately help seismologists understand the mystery of earthquakes.

Institute of Geophysics and Planetary Physics

The Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics is located at and strongly linked to Scripps. This branch is part of the University of California IGPP and houses the systemwide office. Other branches are located at the Los Angeles and Riverside campuses and at the Los Alamos and Lawrence Livermore National Laboratories.

IGPP research at Scripps spans many disciplines, including seismology, space and terrestrial geodesy, geomagnetism, global seismic networks, fluid mechanics, marine acoustics, marine geophysics, geodynamics, space physics, nonlinear dynamics, and theoretical geophysics. IGPP operates a global network of seismic stations; several modern seismic arrays in places such as Saudi Arabia, Kyrgyzstan, and Anza, California; and a permanent space geodesy network in California. IGPP scientists maintain an active seagoing program including the measurement of absolute gravity on the seafloor, seafloor electromagnetic and seismic measurements, multichannel seismology, and the Acoustic Thermometry of Ocean Climate (ATOC) project.

A seismologist by training, Dr. Jean-Bernard Minster's interests span a variety of subjects: earthquake studies, plate tectonics, the attenuation of seismic waves, the structure of Earth's interior, and space geodesy. Other areas within his research scope include laser altimetry, synthetic aperture radar, and nuclear treaty verification.

Some of Minster's most ambitious projects include work with laser and radar instruments to monitor changes in Earth's surface. For one project, he uses an airborne laser altimeter to map subtle elevation changes in the extensive volcanic terrain at Long Valley caldera near Mammoth Lakes, California. Using custom designed systems built at NASA's Goddard Space Flight Center, Minster and colleagues have mapped Earth's surface topography to an unusually high degree of accuracy. Their results have proven superior to those obtained by conventional mapping methods.

The systems work by measuring the round-trip travel time of an extremely short (a billionth of a second) pulse of laser light from a plane to a land, water, cloud, or ice surface. Data processing requires calculating the aircraft's trajectory to a precision of a few inches using the Global Positioning System (GPS). Results obtained by Minster, graduate student Jeff Ridgway, and postdoctoral researcher Michelle Hofton demonstrate that the water level of a lake can be reliably measured from 1.9 miles (3 km) overhead to an accuracy of within 1.2 inches (3 cm).

This team is preparing for a space mission in 2001 called the Geoscience Laser Altimetry System, or GLAS.

"The main purpose of GLAS will be to monitor change in the volume of Earth's ice sheets," said Minster. "This is used as a proxy, a marker index, for global warming and sea-level change by providing a measure of the influx of water into the oceans."

Minster also is working in the Campus-Laboratory Cooperation (CLC) project to assess seismic exposure and vulnerability at several California university campuses. The alliance teams UC San Diego, San Diego State University, UC Riverside, UCLA, UC Santa Barbara, and the Lawrence Livermore National Laboratory. In the past year, the CLC drilled three wells, one 300 feet (90 m) and two 150 feet (45 m) deep, near the UC San Diego campus to install seismometers that monitor seismic waves as they approach the surface. Minster says such a project will enable the team to ask specific questions, such as: If there's an earthquake on the Rose Canyon Fault, what motion might we expect at the surface, near buildings?

"This should yield more quantitative information than the standard formulas used under the seismic building code," said Minster.

Minster also is principal investigator for a proposed synthetic aperture radar spacecraft that will map Earth's tectonically active areas, ice caps, and glaciers. It is hoped that the $106 million Earth Change and Hazard Observatory project will break new ground in detecting Earth surface changes by systematic, repeated radar mapping.

"This is the chance of a lifetime to construct evolving pictures of Earth by combining radar images taken in successive overhead passes by the spacecraft," said Minster. "For instance, if an earthquake happens between two passes, you can see and map the difference, and that is a spectacular technique."

Minster is also vice chairman of the board of the Southern California Earthquake Center and director of the IGPP system. His other research projects include measuring ionospheric waves using GPS, applying evolutionary programming to evaluate earthquake prediction models, and studying the onset of chaos in systems with nonlinear friction laws.

Marine Biology Research Division

Scientists in the Marine Biology Research Division investigate the taxonomic, ecological, physiological, cellular, biochemical, and genetic characteristics of marine bacteria, protozoans, plants, and animals and the fundamental processes affecting life and energy flow in marine ecosystems. They examine organisms in a variety of habitats including the deep sea, coastal ecosystems, and Antarctica.

Some of the ongoing studies involve anatomy and mechanics of marine invertebrates, mechanisms of invertebrate egg and sperm interaction, and the symbiotic relationships between diverse bacteria species and their invertebrate and fish hosts. The potential large-scale, long-term effects of global change on the productivity and diversity of marine ecosystems and on the distribution and abundance of marine organisms also are being studied.

How and why phytoplankton thrive and prosper is a fundamental issue in biological oceanography. The phytoplankton's position near the bottom of the food chain means that the biological processes that affect phytoplankton can change the entire ecosystem.

Dr. Brian P. Palenik is using the tools of molecular genetics to study conditions in which phytoplankton cells are thrown into a state of alarm. Two circumstances under evaluation include when phytoplankton cells become stressed by a foreign material, such as copper, and when cells begin to run short of nitrogen, a necessary nutrient for growth. Thus far, Palenik's research has concentrated on two green algae, *Thalassiosira pseudonana* and *Emiliania huxleyi*.

"Our goal is to identify proteins that are 'turned on' under these special circumstances," said Palenik. "We purify those proteins to make antibodies, which we can then use as a probe for that stressful circumstance. Antibodies are used this way in the health field as probes, for pregnancy tests, for example."

The study of stresses placed on phytoplankton by environmental contamination has become an increasingly important practical aspect of Palenik's research, as governments and regulators have become more sensitive to coastal pollution.

Palenik's research team begins its laboratory study by growing phytoplankton cultures. Adding copper to a sample causes the stress proteins to "turn on" in comparison with proteins of unstressed cells. Careful steps are taken to ensure that copper is the single stressor causing a protein alert and to exclude other possible influences, such as silver or mercury.

Three proteins have been identified thus far in Palenik's laboratory. With the proteins identified, the researchers can develop antibodies to those proteins. Palenik then adds the antibodies to seawater samples to test how many phytoplankton cells contain these stress proteins.

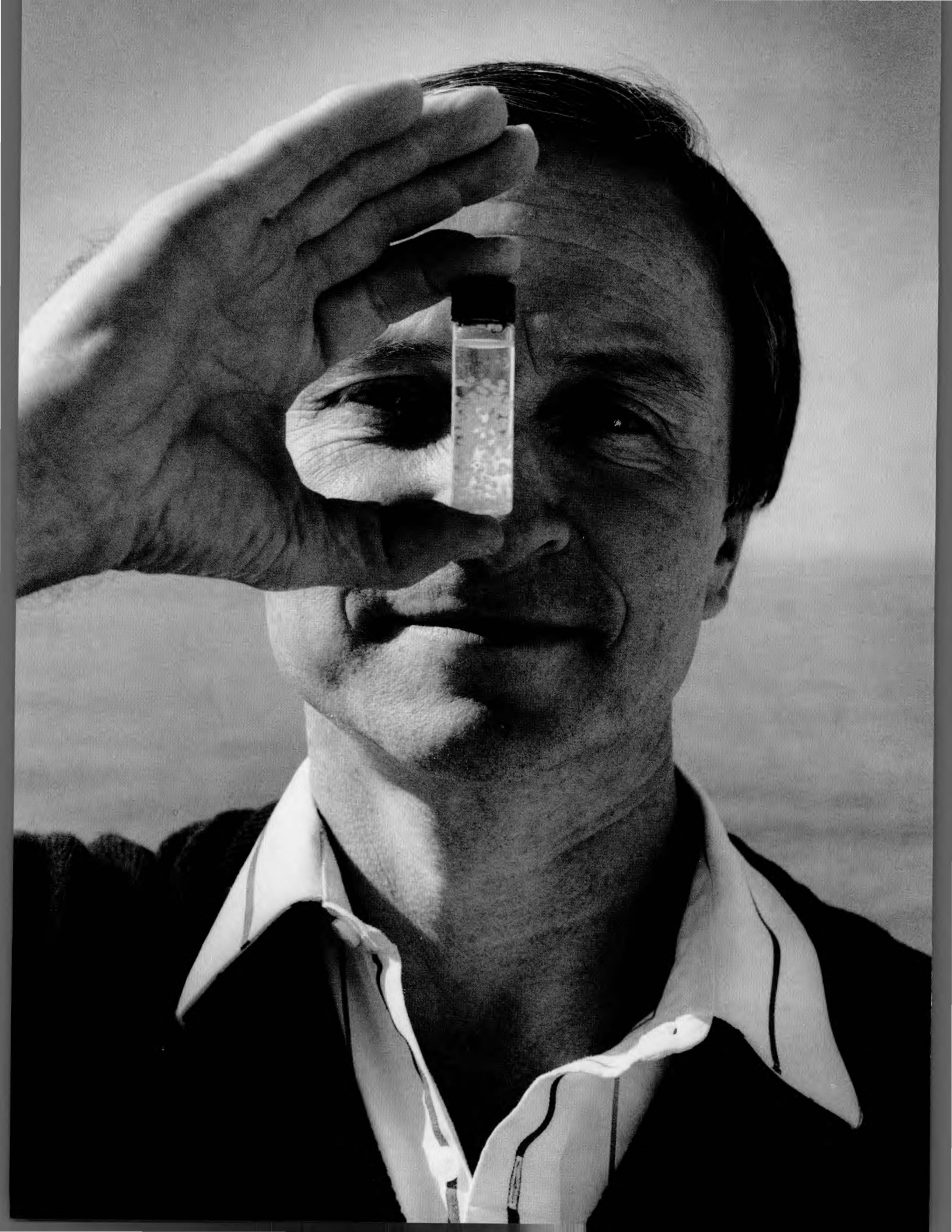
A second antibody is introduced that tags the first antibody, and thus the original protein, with fluorescent properties. From there the work moves to a laboratory instrument called a flow cytometer, which uses a high-speed flow system and a laser beam to identify the fluorescent proteins, cell by cell, and count those that have attached to antibodies. The results show how heavily the copper is impacting the phytoplankton.

"Copper pollution standards are all based on concentrations, yet if copper is bound up in the environment and not stressing organisms, even at high concentrations, then it's not really affecting the environment," said Palenik. "But on the other side there might be lower concentrations that are affecting the environment and we're not worrying about it—and we should, based on the organism's reaction."

Another of Palenik's research studies deals with nutrient stress, but concentrates on environments where cells become alarmed because of nitrogen deficiency, rather than a toxic element. In such a situation, stress sends phytoplankton cells searching for a replacement for the nitrate form of nitrogen, such as an amino acid, or for another environmental source, such as urea. Other nitrogen-specific stress responses also are possible.

Palenik said tracking down this type of stress can lead to an understanding of why phytoplankton thrive in certain parts of the ocean and struggle in others.

"That's a basic oceanography question that goes back more than 100 years," said Palenik.



Marine Life Research Group

Scientists in the Marine Life Research Group (MLRG) cooperate with the California Department of Fish and Game and the Southwest Fisheries Science Center of the National Marine Fisheries Service in the California Cooperative Oceanic Fisheries Investigations (CalCOFI). This study of the California Current system provides one of the world's most complete time series of data (nearly 50 years) from an oceanic ecosystem. The data enable scientists to examine variability in the physics, chemistry, ecology, and fisheries of this eastern boundary current system from the annual scale, to the interannual scale (such as El Niño events), to multidecadal trends. High-resolution analysis of sediment cores extends some data back in time for centuries, making possible the study of properties and processes over much longer timescales.

For investigators outside of the program, the CalCOFI cruises provide a platform for biological oceanographic studies and also a base of environmental data from which to interpret their specialized measurements.

David Checkley (facing page) holds a sample of sardine eggs collected using the Continuous Underway Fish Egg Sampler.

The study of pelagic fishes, such as anchovy and sardine, has multidimensional significance. Anchovy and sardine are economically important to California, which has invested heavily in monitoring their numbers. These fishes also are vital to the ecology of the ocean as food for larger fishes, marine mammals, and birds. Furthermore, knowledge of anchovy and sardine spawning habitats can provide clues to how fishes respond to global climatological phenomena, including El Niño and global warming. Finally, the anchovy and sardine off California's coast are similar to pelagic species in many other parts of the world. This similarity allows advances in understanding the dynamics of local species to be applied elsewhere.

Dr. David M. Checkley is interested in the effects of ocean physics on the spawning and growth patterns of fishes. While part of Checkley's recent research has concerned wind-driven circulation patterns and their effects on plankton, his focus now is on developing and using systems to study anchovy and sardine spawning.

Checkley has codeveloped one of the most advanced systems for surveying anchovy and sardine eggs. The Continuous Underway Fish Egg Sampler, or CUFES, has been used effectively off North Carolina, South Africa, and, for the past two years, off California.

"The distribution of these eggs is used in the estimation of population size for fisheries purposes, because if you know the number of eggs produced per female, you can estimate the number of spawning females, and that's used for management purposes," said Checkley. "Knowledge about the spawning habitat is crucial for understanding how fish respond to global changes, as well as management of fisheries on a year-to-year basis."

CUFES, which took Checkley and colleagues from the U.S. National Oceanic and Atmospheric Administration and the Canadian Bedford Institute of Oceanography more than five years to develop, is made up of three sections: a pump, a concentrating device, and a sample collector.

CUFES's submersible pump can extract water over the side of a ship or up through a ship. It pumps approximately 17 cubic feet (.48 m^3) of seawater per minute through a 3-inch (7.6 cm) hose attached to a steel pipe. From the pump the water flows into a concentrator, in which a Nitex mesh net oscillates laterally at a rate of 6 hertz. Nearly 97 percent of the water is filtered free of eggs and returns to sea through tubes on the side of the concentrator. Fish eggs and large zooplankton are retained in the remaining three percent and forwarded to a mechanical sample collector linked to computers and electronic devices that record date, time, location, and physical and biological variables such as temperature, salinity, and chlorophyll fluorescence.

Checkley uses the physical and biological measurements to match egg occurrence with satellite imagery. This allows him to investigate ocean physics associated with spawning. CUFES provides continuous, underway measurements in contrast to the conventional egg sampling technique of net towing at discrete stations. This feature has led Checkley to propose CUFES use in Mexico, Peru, Chile, and other areas where cross-referencing data could play a crucial part in understanding world spawning patterns.

"We can compare the systems very simply in a way that hasn't been done easily before," said Checkley, "and therefore try to understand what causes regional and temporal variations."

Marine Physical Laboratory

Scientists in the Marine Physical Laboratory (MPL) apply knowledge of the ocean and its boundaries to solve problems in ocean acoustics, ocean optics, marine physics, marine geophysics, signal processing, and ocean technology.

Researchers in ocean acoustics quantify environmental limitations on acoustic systems and study how these affect design and operation of oceanographic systems. Scientists investigating marine physics focus on effects of the oceanic environment on undersea systems. Marine geophysicists clarify the environmental parameters affecting search, detection, and navigation systems. Research in signal processing includes the collection, manipulation, and output of both analog and digital data. MPL scientists also are interested in cloud cover and detection of surface and air targets through marine atmosphere.

Marine geophysicists emphasize the basic physical processes and properties of the oceans to clarify the environmental parameters affecting search, detection, and navigation systems. Research in signal processing encompasses all aspects of the collection, manipulation, and output of both analog and digital data. Development of advanced ocean technology both for environmental measurement programs and for testing of new engineering concepts is another major MPL focus.

A team of scientists in MPL's Adaptive Beach Monitoring Program set out recently to study the dynamics of sound in the surf region. Using a set of sensitive sound devices called seismoacoustic arrays, the group focused on monitoring current and wave dynamics and beach surf conditions. Their goal was to provide the military with insight into conducting amphibious missions augmented with covertly deployed onshore and offshore acoustic sensors and wave and current sensors.

Dr. Gerald L. D'Spain and a team of researchers emerged from the study not only with details of land signals recorded by underwater acoustic sensors, but also with surprising results concerning naturally occurring biological sounds generated in the offshore setting.

The seismoacoustic systems simultaneously measured the underwater field offshore, the seismic field on land, and the acoustic field in the air off Camp Pendleton Marine Base near Oceanside, California. The systems included two 64-element hydrophone line arrays on the ocean floor at approximately 1 mile (1.6 km) and 2.2 miles (3.4 km) offshore, two-dimensional arrays of ocean bottom seismometers, a bubble plume sensor system, and a line array of four pairs of hydrophones in the surf zone.

Among the noteworthy results from the experiment, D'Spain found that land vehicle activity can indeed be clearly detected and tracked using data from underwater hydrophone arrays located as far as 2.2 miles (3.4 km) offshore.

"We believe we can go on the order of 6.2 miles (10 km) offshore and track these vehicles," said D'Spain. "We're not sure how far inland we can listen to them, but that's an interesting research question and an active area right now."

D'Spain said the listening devices picked up not only military vehicles on the marine base, but also sounds from sanitation pumps as far away as 43.4 miles (70 km) on Catalina Island. The group intends to continue researching unknown signals that were monitored. "A big part of this is detective work about what caused the things we're hearing," D'Spain said.

The most surprising of D'Spain's findings came from signals recorded underwater, where the team expected to hear mostly breaking waves and surf-related noise. To their surprise, the dominant noises instead were biological sounds, specifically "knocking" sounds created by fish.

Members of the Sciaenidae (croaker) family conducted group knocking, or chorusing, behavior that started one to two hours before sunset and continued consistently throughout the night until decreasing near sunrise. The knocks were recorded predominantly in the 400 to 450 hertz frequency band and periodically increased by 10 decibels over 15 to 20 seconds.

"This very strange chorusing behavior starts with a few knocks and picks up until it sounds like a whole stadium full of people stomping their feet or clapping," said D'Spain.

Within the knocking observations, D'Spain discovered an association between the rate at which the fish knocked and the overall chorusing level. As the overall level increased, the rate at which the fish knocked increased, possibly leading to an interpretation that the fish were engaged in a knocking competition. D'Spain also noted that when the fish reached a depth close to the ocean floor, their knocking generated vibrations on the bottom akin to mini-earthquakes. D'Spain has studied how these vibrations travel along the ocean bottom and has used the results to determine the properties of some ocean bottom materials.

Marine Research Division

Studies in the Marine Research Division (MRD) span the disciplines of biological oceanography, marine chemistry, and physical oceanography.

MRD scientists investigate the large-scale circulation of the South Atlantic Ocean, study the characteristics of Earth's earliest ocean and atmosphere, and elucidate the organic carbon cycling in the oligotrophic gyres of the North Atlantic and Pacific Oceans.

They study theoretical and applied problems in marine optics, the geochemistry of borehole fluids, the natural products chemistry of marine invertebrates and marine bacteria, and the role of bioactive chemicals in the marine environment. MRD researchers also focus on the medical and pharmaceutical applications of marine organisms.

Several scientists investigate the inhibition of red-tide dinoflagellate growth in California's Santa Cruz Harbor and the performance of a breakwater at Fisherman's Wharf in San Francisco Bay. Other MRD researchers concentrate on the Antarctic coastal ecosystem.

Answers to some of science's most vexing mysteries may be revealed by some of its tiniest living organisms. Phytoplankton, which float or swim weakly in the world's oceans, are being examined because of their importance as the base of the marine food chain and as key organic carbon producers.

The focus of Dr. Maria Vernet's research is the role of phytoplankton in the ocean's carbon cycling system. She concentrates on the high latitude regions, in order to take advantage of the natural ocean-atmosphere laboratory offered by Arctic and Antarctic conditions.

"There's a consensus among scientists that changes in the environment, such as increases in atmospheric temperature, are going to be felt first and most dramatically in places like the Arctic and Antarctic," said Vernet. "The more we know about the environment there and the more we can predict about how these changes will affect the environment, the better prepared we will be to deal with the consequences."

Vernet conducts much of her research in the field, although she works in her laboratory to develop experimental methods and prepare for and evaluate data from research cruises.

Vernet's equipment includes chromatographs to analyze the phytoplankton's photosynthetic pigments, microscopes for phytoplankton identification and enumeration, and gas chromatographs to measure particulate carbon and nitrogen. She estimates dissolved inorganic nutrients in seawater with an auto analyzer. Chemical concentration levels can be gauged inside the auto analyzer, which is calibrated using known chemical standards.

For several years, Vernet has been comparing phytoplankton's carbon uptake and excretion in the high latitude region to that in temperate areas. Having proved they are indeed different, Vernet has embarked on describing how and why this is so. She has investigated whether sulfur compounds in phytoplankton cells are being used as "cryoprotectants" that defend against the frigid temperatures of the Arctic and Antarctic.

Vernet also is studying the effect of ultraviolet (UV) radiation on carbon cycling by phytoplankton. Vernet uses spectrophotometers, spectrofluorometers, and surface and underwater light meters to measure light intensity in the visible and ultraviolet regions of the spectrum at different depths. "We put together a group of people in Latin America, who are already measuring UV radiation on the ground, to make a regional network of UV measurements," said Vernet. "That was exciting because it was a new area—there's been nothing like that in the Southern Hemisphere."

The ultimate goal of Vernet's research is to provide clues about environmental changes—whether man-made or natural. "If we can make society aware of where we're heading, then we can give people a choice," said Vernet. "Do we want to continue on the same route or do we want to make some changes before we get to a point where it might be too late?"

Neurobiology Unit

The survival, distribution, and ecological role of animals depend on their ability to sense the environment; to integrate, calculate, interpret, and recognize stimuli; and to control adaptive behavior. The Neurobiology Unit (NU) includes several laboratories at Scripps that focus on the nervous systems, sense organs, and behavioral mechanisms of animals. NU scientists participate in the Center for Marine Biotechnology and Biomedicine, and some are associated with the UC San Diego School of Medicine.

Graduate student Katherine Moortgat conducts in-vitro experiments on pacemaker cells in a long-nosed black ghost knifefish *Apteronotus leptorhynchus.*

Four of the five doctoral students who were part of Dr. Walter F. Heiligenberg's laboratory in the Neurobiology Unit when the researcher died in September 1994 have graduated. When the fifth candidate, Katherine Moortgat, completes her doctoral thesis on the neural properties of electric fish, the Heiligenberg laboratory will close.

Moortgat said she was immediately attracted to the excitement in Heiligenberg's laboratory, where she first witnessed the mystery of electric fish and decided to make these fish her research focus. Her work is centered on *Apteronotus leptorhynchus,* commonly known as the brown ghost knifefish, one of a family of fishes that uses electric sense to navigate and communicate. The knifefish produces electric fields from its tail and waits for a return signal to make radarlike judgments about its environment.

What drew Moortgat to the knifefish was not only its high electric frequency, but the fact that its signal production is regular, down to a level of sub-microseconds. Moortgat and a colleague from the Salk Institute for Biological Studies in La Jolla, California, devised a sensitive measuring tool called an Adjustable Schmitt Trigger, which can monitor the fish's digital pulse down to 0.05 microseconds.

"What's so stunning about this is that you can look at a heart rate or even a computer CPU and see that they are quite regular, but they are not as regular as the brown ghost knifefish," said Moortgat. "Now if you compare this fish to an atomic clock, the fish doesn't appear very regular, but as a biological oscillator, it is regular down to fractions of a microsecond—and we don't know of any other biological system that is."

Moortgat is characterizing the neurological properties of the electric organ in the knifefish's tail and exploring how its regularity is controlled by the pacemaker nucleus, the brain's "command center." The answers that Moortgat finds may help scientists to understand the capabilities of neurons. She hopes the studies also will shed light on the firing irregularities of neurons and how they fire in illnesses such as epilepsy.

Moortgat credits Professor Theodore H. Bullock for his help in coordinating the laboratory since Heiligenberg's death.

Physical Oceanography Research Division

Scientists in the Physical Oceanography Research Division (PORD) study a range of observational and theoretical topics related to the physics of the ocean. Many PORD investigators hold joint appointments in other areas at Scripps, which provide for cross disciplinary research and communication.

Some PORD researchers study the large-scale circulation of the world's oceans or the specifics of smaller environments such as the continental shelf, marginal seas, straits, estuaries, or the surf zone of open shorelines. Others examine the interaction between the ocean and the atmosphere. Theoretical studies range from classical fluid dynamics problems to models of large-scale ocean circulation or the atmospheric marine boundary layer. PORD scientists also develop new sensors and measurement technology for ocean studies such as autonomous drifters, bottom pressure and electromagnetic sensors, and new versions of Acoustic Doppler Current Profilers.

To some oceanographic scientists, research demands an array of recording equipment, monitors, 3-D graphical modeling tools, and high speed computers. For Dr. Paola Cessi, a simple pencil and paper do just fine.

As a physicist within PORD, Cessi uses theories and observations to develop models of the oceanic general circulation that cover periods spanning decades to millennia. One area of Cessi's research involves the water movement patterns created by temperature and salinity, known as thermohaline circulation. Rising temperatures tend to make water lighter, while salinity makes water denser and heavier. These two properties result in a temperature-salinity battle that influences global circulation patterns over centuries.

On the equatorial belt, high temperatures create lighter water. But because it is hotter, there is more evaporation and less rain, leading to concentrations of salt that make the ocean water heavier. In high latitudes, the colder temperatures create heavier water, yet melted ice and rain dilute the water's saltiness, making it lighter.

"So depending on which one wins, you have water that can sink at the pole and come up at the equator and vice versa," said Cessi. "But it is interesting that in the present climate those two effects are almost exactly counterbalancing each other."

Cessi said the forces are in such a delicate balance that a slight change in either direction can cause broad changes. In one example, water diverted from the Mississippi River to the St. Lawrence estuary caused a shift in freshwater distribution and reduced surface salinity. Thus, water in the North Atlantic became lighter.

"So the water stopped sinking and that made a tremendous difference because that was water that usually sinks," said Cessi. "These changes can occur very abruptly but cause a total change that lasts for centuries."

In a separate project looking at circulation patterns over decades, Cessi is analyzing variability in the wind-driven movement of the ocean in the mid-latitude regions, centered around 45 degrees north and 45 degrees south of the equator. Cessi has hypothesized that wind and storm tracks at the surface of the ocean affect the temperature within the entire mid-latitude region. She believes that changes in the storm track induce wind variations, which alter the ocean flow responsible for the circulation of sea-surface temperature. In turn, the transport of heat by ocean currents (such as the Gulf Stream) and the ocean-atmosphere interplay alter storminess.

To prove her hypothesis, Cessi has dispensed with previous coupled general circulation models (CGCMs) that take many atmospheric processes into account and instead developed a "stripped down" model proposing that increased ocean heat transport leads to decreased storminess.

Cessi's results indicate that the entire mid-latitude storm system fluctuates over decades, rearranging both the ocean currents and the atmospheric temperature distribution. Cessi plans to compare her simplified model against state-of-the-art CGCMs. She is collaborating with Dr. Niklas Schneider of CRD to compare her results with 100 years of data from a model developed at the Max Planck Institute for Meteorology in Hamburg, Germany.

"Although general circulation models are irreplaceable tools for predicting the state of the atmosphere and the ocean," said Cessi, "we believe that simplified models, such as the ones formulated here, are an essential step for shaping our expectations about the climate system."

Graduate Department

The Graduate Department of the Scripps Institution of Oceanography offers instruction leading to Ph.D. degrees in oceanography, marine biology, and earth sciences. Because of the interdisciplinary nature of the ocean sciences, the department provides a choice of eight curricular programs through which the student may pursue a Ph.D. degree. Each of these curricular groups has prerequisites for admission in addition to the departmental requirements. The curricular programs are described on the following pages.

An overview of Scripps's graduate program may also be found on the Internet at http://www-siograddept.ucsd.edu/. For application procedures and more information, please write to

University of California San Diego
Scripps Institution of Oceanography
Graduate Department
9500 Gilman Drive Dept 0208
La Jolla CA 92093-0208.

Graduate student Shannon Cass-Calay (facing page) examines a California scorpionfish, *Scorpaena guttata,* during the Biology of Fishes course.

Marine Chemistry graduate students Helene Vervoort and David Rowley (above)

Curricular Programs

Applied Ocean Sciences

This interdepartmental curriculum combines the resources of the Scripps Graduate Department with those of the Department of Applied Mechanics and Engineering Sciences and the Department of Electrical and Computer Engineering, on the UC San Diego campus.

Engineers gain a substantial education in oceanography, and oceanographers receive training in modern engineering. Instruction and basic research include the applied science of the sea and structural, mechanical, material, electrical, and physiological problems within the ocean.

Biological Oceanography

In the biological oceanography curriculum, the interactions of marine organisms with the physical-chemical environment and with each other are studied. Research and instruction in this curriculum range from food-chain dynamics and community structure to taxonomy, behavior, physiology, biogeography, and physical-biological interactions.

Climate Sciences

The climate sciences curriculum concerns the study of the climate system of the earth with emphasis on the physical, dynamical, and chemical interactions of the atmosphere, ocean, land, ice, and the terrestrial and marine biospheres. The program encompasses changes on seasonal to interannual timescales and those induced by human activities, as well as paleoclimatic changes on timescales from centuries to millions of years. Examples of current research include interannual climate variability; physics and dynamics of El Niño; studies of present and future changes in the chemical composition of the atmosphere in relation to global warming and ozone depletion; effects of cloud and cloud feedbacks in the climate system; paleoclimate reconstructions from ice cores, banded corals, tree rings, and deep-sea sediments; the origin of ice ages; air-sea interactions; climate theory; and terrestrial and marine ecosystem response to global change.

Geochemistry and Marine Chemistry

The geochemistry and marine chemistry curriculum emphasizes the chemical and geochemical processes operating in the oceans, the solid earth, the atmosphere, marine organisms, polar ice sheets, lakes, meteorites, and the solar system. This program, designed for students with undergraduate majors in either chemistry or geology, features diverse areas of advanced study and research. These include the physical and inorganic chemistry of seawater; ocean circulation and mixing based on chemical and isotopic tracers; marine organic and natural products chemistry; geochemical interactions of sediments with seawater and interstitial waters; geochemistries of volcanic and geothermal phenomena; chemical exchanges between the ocean and the atmosphere; geochemical cycles of carbon, sulfur, nitrogen, and other elements; isotope geochemistry of the solid earth and meteorites; atmospheric trace gas chemistry; paleoatmospheric composition recorded in polar ice cores and in sediments; and chemistry of lakes and other freshwater systems.

Geological Sciences

Students in this curriculum apply observational, experimental, and theoretical methods to the understanding of the solid earth and solar system, and study how they relate to the ocean and atmosphere. Principal subprograms are marine geology and geophysics, tectonics, sedimentology, micropaleontology and paleoceanography, petrology and geochemistry, and isotope geology. Expedition work at sea and fieldwork on land are emphasized as essential complements to laboratory and theoretical studies.

Geophysics

Students in the geophysics curriculum study the physics of the solid earth, including the earth's magnetic field, the mechanics of tectonic processes, earthquakes and the waves they produce, the physics of the earth's interior, and mathematical methods for analyzing data and interpreting them in terms of models of the earth. The program emphasizes physical and mathematical approaches to geophysical research.

Marine Biology

The marine biology curriculum focuses on the basic biology of marine organisms—animals, plants, and prokaryotes. Research and teaching cover the entire range of biological disciplines, including molecular biology, microbiology, comparative physiology and biochemistry, developmental biology, neurobiology, biomechanics, evolution, genetics, systematics, behavior, and ecology.

Physical Oceanography

Studies in physical oceanography include observation, analysis, and theoretical interpretation of the general circulation of ocean currents and the transport of dissolved and suspended substances and heat; the distribution and variation of oceanic properties; the propagation of sound and electromagnetic energy in the ocean; and the properties and propagation of ocean waves.

Student Enrollment

In the fall of 1996, 25 new students were admitted to graduate study. Of these, 7 were in marine biology, 4 in geological sciences, 1 in geochemistry and marine chemistry, 5 in geophysics, 4 in physical oceanography, 2 in biological oceanography, and 2 in climate sciences. Enrollment at the beginning of the academic year was 176. UC San Diego awarded 26 doctor of philosophy degrees and 13 master of science degrees to the students listed in this section.

Graduate Students and Degree Recipients

Doctor of Philosophy Degrees Awarded, with Titles of Dissertations

EARTH SCIENCES

Jeffrey M. Babcock
"Magma Chamber Structure and Moho Reflections along the East Pacific Rise."

Glenn Eli Baker
"The Effects of Near-Receiver Structure on Teleseismic and Regional Waveforms."

Harold F. Bolton
"Long Period Travel Times and the Structure of the Mantle."

Eric L. Canuteson
"An Interferometer for Use in Absolute Gravity Meters, the Construction and Testing of an Ocean Bottom Absolute Gravity Meter, and a Method of Seismometer Calibration by Reference to a Falling Mass."

Philip E. Janney
"Geochemistry of Mesozoic Basalts from the Western Pacific Ocean: Local and Regional Effects of the Widespread Cretaceous Volcanic Event."

Daniel A. Levitt
"Lithospheric Bending at Subduction Zones and Geophysical Investigations of the Pukapuka Volcanic Ridge System, Altimeter Gravity Lineations and South Pacific Superswell Depth Anomaly."

Michael S. O'Brien
"Representation and Hypothesis Testing in Core and Crustal Geomagnetism."

Andrew D. Walker
"Statistics of the Earth's Magnetic Field and Applications."

Jie Zhang
"Continuous GPS Measurements of Crustal Deformation in Southern California."

MARINE BIOLOGY

Frederick I. Archer II
"Morphological and Genetic Variation of Striped Dolphins (*Stenella coeruleoalba,* Meyen 1833)."

Ron Caspi
"Molecular Biological Studies of Manganese Oxidizing Bacteria."

Grieg F. Steward
"The Ecology of Marine Bacteriophages and their Contribution to Bacterial Mortality."

Timothy J. Welch
"A Molecular Analysis of Bacterial Pressure Sensing."

OCEANOGRAPHY

Guillermo Auad
"Circulation in the Santa Barbara Channel: Description Mass and Heat Budgets and Forcing during 1984."

Nickolay G. Baturin
"Dynamics and Effects of Tropical Instability Waves."

Nicholas M. Carbone
"Inverting for Geoacoustic Seabed Parameters Using Ambient Noise."

Alexey V. Fedorov
"Nonlinear Effects in Surface and Internal Waves."

Edith L. Gallagher
"Observations of Seafloor Evolution on a Natural Barred Beach."

Guillermo Gutiérrez de Velasco
"Wind Forcing and Circulation in the Gulf of Mexico."

Sabine Harms
"Circulation Induced by Winds and Pressure Gradients in the Santa Barbara Channel."

Kevin D. Heaney
"Inverting for Source Location and Internal Wave Strength Using Long Range Ocean Acoustic Signals."

Michael G. Hinton
"Standardizing Catch and Effort Statistics Using Physiological, Ecological, or Behavioral Constraints, and Environmental Data, with Applications to Blue Marlin *(Makaira nigricans)* and Swordfish *(Xiphias gladius)* of the Pacific Ocean."

Dongseon Kim
"Biogeochemical Cycling of Carbon, Phosphorus, and Silica in California Continental Slope Sediments."

Yolande L. Serra
"Small-Scale Tropical Cumulus Cloud Systems and the Atmospheric Boundary Layer: An Observational Study."

Vitalii A. Sheremet
"Analysis of a Nonlinear Barotropic Wind-Driven Ocean Circulation Problem."

Christopher P. Weaver
"Dynamical and Thermodynamical Controls on Large-Scale Cloud Radiative Forcing over Northern Hemisphere Extratropical Oceans."

Master of Science Degrees

EARTH SCIENCES

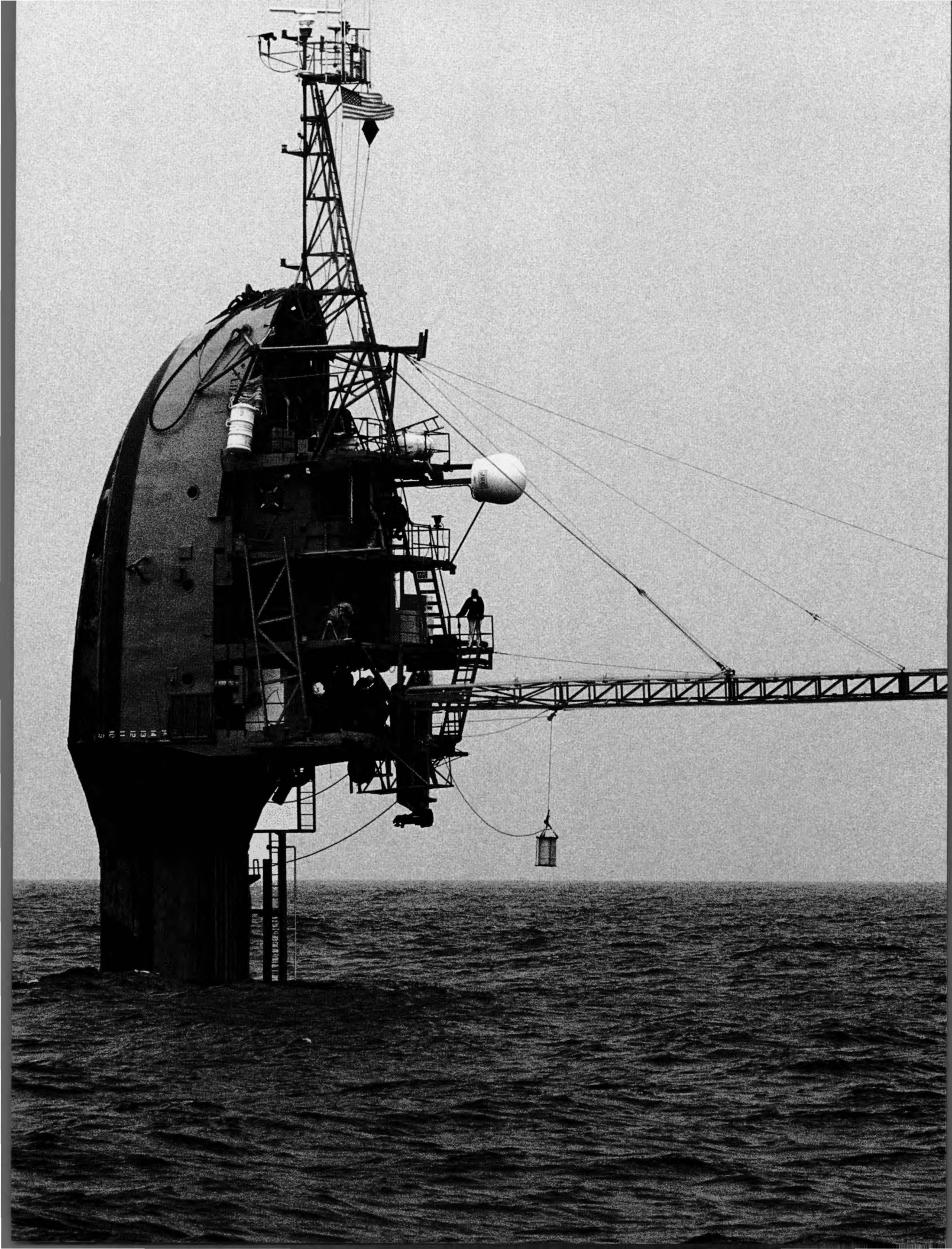
Richard E. Jayne

MARINE BIOLOGY

David A. Guay

OCEANOGRAPHY

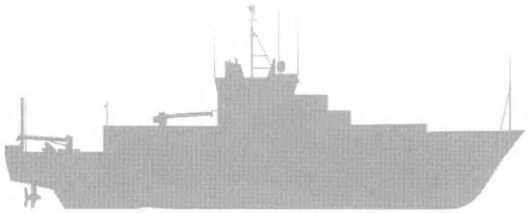
Wendi A. Eastman
Chelle L. Gentemann
John E. Gilson
Alan L. Heath
Christina S. Johnson
Andrew R. Keyes
Noah Knowles
Michele L. G. Lyons
Kari E. Richards-Dinger
Axayacatl Rocha Olivares
Robert F. Vroom



Seagoing Operations

The Scripps oceanographic fleet is at the hub of the institution's research efforts. Four research vessels and one platform provide this important support. Our ships traveled more than 121,470 nautical miles in fiscal year 1997 and operated a total of 854 days.

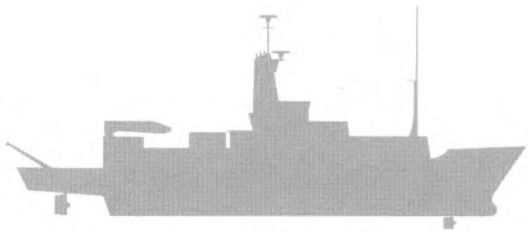
Research platform FLIP (clockwise from left) on station. Under tow. Scripps divers being ferried between FLIP and tow vessel.



R/V *Roger Revelle*

R/V *Roger Revelle,* Scripps Institution's newest long-ranging ship, was delivered to San Diego on July 31, 1996. Following delivery, the ship embarked on several shakedown cruises to test onboard equipment and the ship's capabilities. During its first year of operation in fiscal 1997, R/V *Roger Revelle* supported 11 research expeditions with 15 chief scientists. Research activities included phytoplankton studies on behalf of CalCOFI, SEA BEAM mapping, seismic studies, piston coring, and CTD, MOCNESS, and biomapper studies. Research was conducted off San Diego, in the California Current, along the southern California coast, and in the waters off Central America. Thomas Desjardins was captain. Albert Arsenault was relief captain.

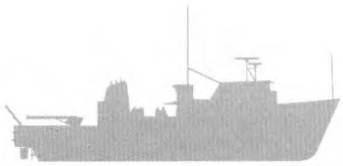
Type	Oceanographic research
Yr. Built	1996
Yr. Acquired by Scripps	1996
Owner	U.S. Navy
Length	275′
Beam	52′6″
Draft, full	17′
Displacement, full (tons)	3,350
Cruising Speed (knots)	12.5
Range (nautical miles)	13,000 @ 10 knots
Crew	22
Scientific Party	37
Total Distance Traveled	39,079 nautical miles
Operating Days	194



R/V *Melville*

Seven chief scientists led seven expedition legs aboard R/V *Melville* during the fiscal year 1997. Research sites included areas in the South Pacific and the Indian Ocean. Research activities included SEA BEAM data collection, OBS recovery, and WOCE mooring recovery. R/V *Melville* was used for research by several other institutions during the year, including UC Santa Barbara, Brown University, Texas A&M University, Woods Hole Oceanographic Institution, University of Hawaii, and Oregon State University. Eric Buck was captain. Christopher Curl was relief captain.

Type	Oceanographic research
Yr. Built	1969 (refitted, 1992)
Yr. Acquired by Scripps	1969
Owner	U.S. Navy
Length	278′10″
Beam	46′
Draft, full	16′6″
Displacement, full (tons)	2,958
Cruising Speed (knots)	12
Range (nautical miles)	12,000 @ 10 knots
Crew	23
Scientific Party	38
Total Distance Traveled	46,404 nautical miles
Operating Days	249



R/V *New Horizon*

Eighteen chief scientists led 18 scientific explorations aboard R/V *New Horizon* during the 1997 fiscal year. An extensive array of research and testing was conducted, including phytoplankton and midwater crustacean studies, paleoceanography studies, gravity measurements, seafloor geodesy, array recovery, benthic biology, Seasoar towing, coring, Deep Tow operations, and physical oceanography studies. Research destinations included the Juan de Fuca Ridge, the Southern California Bight, Point Conception, San Nicholas Basin, Tanner Banks, and the waters off Hawaii, Eureka, Mazatlán, and San Diego. Other institutions conducting research aboard the ship included UC Santa Barbara, UC Irvine, University of Massachusetts, University of Washington, Woods Hole Oceanographic Institution, Harvard University, and the University of Hawaii. John Manion was captain. Relief captains were Christopher Curl, David Murline, Robert Haines, and Curtis Johnson.

Type	Oceanographic research
Yr. Built	1978 (refitted, 1996)
Yr. Acquired by Scripps	1978
Owner	University of California
Length	170′
Beam	36′
Draft, full	12′8″
Displacement, full (tons)	1,080
Cruising Speed (knots)	10
Range (nautical miles)	4,100
Crew	12
Scientific Party	17
Total Distance Traveled	24,543 nautical miles
Operating Days	241

R/V *Robert Gordon Sproul*

Fourteen chief scientists embarked on 26 research projects aboard R/V *Robert Gordon Sproul* during the 1997 fiscal year. The ship traveled from the waters off San Diego to the Santa Barbara Channel, the Southern California Bight, the Columbia River, and the waters off Point Conception and Astoria. Research efforts included acoustical and optical studies, equipment tests, benthic biology, physiological studies, clam collection, tiltmeter tests, instrument recovery and deployments, sediment sampling, seismic profiling, animal collection, and a student cruise. Other universities and organizations conducting research aboard R/V *Robert Gordon Sproul* included the University of Washington, Woods Hole Oceanographic Institution, U.S. Geological Survey, the U.S. Navy, and the Wadsworth Center for Laboratories and Research. Louis Zimm was captain. The relief captain was Christopher Curl.

Type	Oceanographic research
Yr. Built	1981
Yr. Acquired by Scripps	1984
Owner	University of California
Length	125′
Beam	32′
Draft, full	9′6″
Displacement, full (tons)	696
Cruising Speed (knots)	9
Range (nautical miles)	3,250
Crew	5
Scientific Party	12
Total Distance Traveled	10,616 nautical miles
Operating Days	151

R/P FLIP

R/P FLIP was towed to sea in fiscal 1997 in support of two research cruises, both in the vicinity of San Miguel Island, off the coast of southern California. These cruises supported the ONR marine mammal program. FLIP also supported a one day at-sea equipment test. The lead scientists for the project were with Scripps's Marine Physical Laboratory. Tom Golfinos was officer in charge of FLIP throughout the year.

Type	Floating instrument platform
Yr. Built	1962
Yr. Acquired by Scripps	1962
Owner	U.S. Navy
Length	355′
Beam	20′
Draft,full	12′/300′
Displacement, full (long tons)	700
Cruising Speed (knots)	varies*
Range (nautical miles)	varies*
Crew	5
Scientific Party	11
Total Distance Towed	830 miles
Operating Days	19

* Depends on towing vessel

Birch Aquarium at Scripps

The Birch Aquarium at Scripps has a threefold mission: to provide ocean science education, to interpret Scripps research, and to promote ocean conservation.

In the 1997 fiscal year, the aquarium advanced all aspects of its mission, while maintaining financial stability and expanding community outreach. Some highlights of the year are described on the following page.

Scenes from the Birch Aquarium (clockwise from below) Pacific seahorses, *Hippocampus ingens,* are raised at the aquarium. Aquarium Executive Director Ned Smith and the Planet Earth Express. Role-playing activity at the aquarium's *Destination: Tropics* exhibition. Scripps researcher Jeffrey Graham dissects a great white shark. Aquarium staff pose with special guest President Bill Clinton.

Birch Aquarium Statistics Fiscal 1997

On-site visitors: 358,920 (including 45,000 school children)

Public education activities: 97, with 4,167 participants

Outreach programs: 192, with 6,403 participants

Scripps Oceanographic Society: 6,154 memberships

Earned income: $2,381,519

Gifts and grants: $748,517

Operating expenses: $2,265,937

Volunteer hours: 29,420

• Of the 220 events held at the aquarium this year, the highlight was a luncheon for President Bill Clinton following his commencement address at UC San Diego. Aquarium Executive Director Ned Smith toured the hall of fishes with the President, who remarked that the tanks were among the best he had ever seen.

• The Reef Fauna Project, an ongoing cooperative research project with the Universidad Autónoma de Baja California Sur, received new grant support this year and provided links for Scripps researchers to work with colleagues in La Paz, Mexico.

• The aquarium celebrated the 1997 International Year of the Reef with *Destination: Tropics,* an exhibit that replicated a live cross section of a barrier reef. A unique arch-tank entrance, distinctive photography, and special hands-on activities for young children enhanced this exhibition.

• The Planet Earth Express, the aquarium's new outreach van, is a unique addition to its existing outreach program. It enabled the safe transport of live animals for educational use in classrooms and community centers throughout the county.

• More than 250 volunteers contributed hours equivalent to 15 full-time staff employees in the past year. They served in every area of aquarium operations.

• The husbandry staff continued its successful propagation program, raising 29 fish species to adulthood. Specimens of the giant Pacific seahorse, a particular success, were sent to eight facilities—most notably the Berlin and Vancouver Aquariums.

• Dr. Jeffrey Graham, a Scripps marine biologist, dissected a great white shark as part of the public education program during the aquarium's annual Shark Discovery Days. Scripps researchers also provided seven "Meet-the-Scientist" presentations over the past year, on topics ranging from global warming to the Scripps fleet.

• In collaboration with Scripps's Center for Clouds, Chemistry, and Climate, *Forecasting the Future—On-Line,* an electronic service, linked teachers and students to Scripps researchers who answered questions about ocean and atmospheric sciences. Participants in this program were using the aquarium's curriculum, *Forecasting the Future: Exploring Evidence for Global Climate Change,* in their classrooms.

For further information about the Birch Aquarium at Scripps, call 619/534-FISH or visit our Web site at http://aqua.ucsd.edu/.

Financial Support

Private gifts and grants to Scripps provided important support for a variety of programs during the past year. As Scripps prepares for the next century of discovery, philanthropy will play an increasingly critical role in funding research and education programs at the institution.

The W. M. Keck Foundation Center for Ocean Atmosphere Research under construction at Scripps

Phase I of the Scripps Centennial Fund Campaign was completed in fiscal 1997 over target and one year ahead of schedule. More than $5 million in pledges, gifts, grants, and gifts-in-kind were received during this period. The total for the first four years of the campaign reached almost $28 million in gifts and pledges, with an additional $3.5 million in revocable planned gifts. The original goal for Phase I of the Centennial Fund was $24.45 million to be raised by June 30, 1998.

Gifts during Phase I of the Centennial Fund Campaign included

- $7.4 million for construction of the W. M. Keck Foundation Center for Ocean Atmosphere Research,
- $9 million for research support,
- $2 million for fellowships,
- $1.9 million for the Birch Aquarium at Scripps, and
- $1.1 million for operating support.

The largest gifts received during the past year, more than $2 million, came from the estates of Lois and E. Turner Biddle. These funds will be used to complete construction of the Nierenberg Hall Annex and to establish a Biddle endowment.

The G. Unger Vetlesen Foundation continued its support of global change research at Scripps. In June, the UC San Diego Foundation honored the Vetlesen Foundation with its *Civis Universitatis* award.

Charmaine and Maurice Kaplan provided funding to expand drug discovery efforts at Scripps's Center for Marine Biotechnology and Biomedicine (CMBB). Their gift will help create the Charmaine and Maurice Kaplan Cancer Drug Discovery Laboratory. The Kaplans also established an endowed fellowship for first-year students at CMBB.

The Moore Family Foundation, the Tinker Foundation, and the Robins Family Foundation combined forces to underwrite a project in the Sea of Cortez involving the Birch Aquarium and the Universidad Autónoma de Baja California Sur at La Paz. The project, designed to help preserve this unique area, includes a study of Sea of Cortez reef fishes, the establishment of a scientific dive training program in La Paz, and an international symposium to address marine environmental issues in the region.

The Capital Group Companies established an endowed fellowship in memory of Robert L. Cody, who died in December 1996. Cody—great-nephew of founding Scripps director William Ritter—with his wife, Bettie, established several endowments at Scripps including the Cody Award, the Ritter Fellowship, and the Ritter Chair.

David C. DeLaCour created a $1 million charitable remainder annuity trust naming Scripps as the beneficiary. His long history of involvement with the ocean and his knowledge of Scripps led him to create the trust, which will provide unrestricted discretionary funds for the Scripps director.

Other notable contributions during the past year included

- Donations from Science Applications International Corporation (SAIC) and the Cecil H. and Ida M. Green Foundation toward the Edward A. Frieman Chair in Global Observation Research,
- A grant from the David and Lucile Packard Foundation for operating support,
- A gift from Robert P. Scripps to support aquarium operations,
- Grants from the Los Angeles and San Diego Chapters of the ARCS Foundation for fellowships, and
- A grant from SDG&E to fund the Birch Aquarium's Planet Earth Express and educational outreach activities.

Scripps Oceanographic Society teams provided valuable support. They gave $10,000 to the Birch Aquarium to underwrite the "Santa's Polar Science Lab" program, student scholarships, and a video microscope for the education department; $10,000 to support a visiting scientist studying the distribution and evolution of life in the deepest parts of the ocean; and $15,000 in travel funds for graduate students.

These are just a few of the many donations to Scripps during the year. The names of the donors are shown on the following pages.

If you are interested in making a contribution to the institution, please contact

R. Lawrance Bailey
Director of Development
Scripps Institution of Oceanography
9500 Gilman Drive Dept 0210
La Jolla CA 92093-0210

619/534-7171.

Financial Support for 7/1/96 – 6/30/97

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In memory of Robert L. Cody
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Agency	Expenditures for 95/96*	Percent of Total	Expenditures for 96/97*	Percent of Total
FEDERAL GOVERNMENT				
National Science Foundation	**$25,479,433**	**25.09**	**$26,231,416**	**25.55**
Navy, Department of the	$15,833,011	15.59	$17,906,913	17.44
Other/Including Federal Flowthru Funds	**$9,146,653**	**9.00**	**$12,219,905**	**11.90**
Commerce, Department of	$12,519,175	12.33	$8,809,689	8.58
National Aeronautics and Space Administration	**$4,697,981**	**4.62**	**$4,003,336**	**3.90**
Defense, Department of	$7,279,077	7.16	$3,691,128	3.59
Interior, Department of the	**$1,789,555**	**1.76**	**$1,978,941**	**1.93**
Energy, Department of	$1,975,165	1.94	$1,791,856	1.74
Health and Human Services, Department of	**$1,057,364**	**1.04**	**$1,681,538**	**1.64**
Air Force, Department of the			$596,989	0.58
Army, Department of the			**$9,102**	**0.01**
TOTAL Federal Government	**$79,777,414**	**78.53**	**$78,920,813**	**76.86**
OTHER				
State General Funds	**$14,770,199**	**14.54**	**$16,060,940**	**15.64**
Overhead Funds	$2,249,603	2.21	$2,578,495	2.51
Private Gifts and Grants	**$2,205,690**	**2.17**	**$2,575,509**	**2.51**
State of California	$1,701,416	1.67	$1,425,623	1.39
Sales and Services	**($634,435)**	**-0.62**	**$990,710**	**0.96**
Endowment Funds	$767,970	0.76	$694,112	0.68
University Funds	**$263,483**	**0.26**	**$256,128**	**0.25**
Local Government	$136,348	0.13	$200,657	0.20
Reserves	**$356,621**	**0.35**	**($1,024,120)**	**-1.00**
TOTAL Other	**$21,816,895**	**21.47**	**$23,758,054**	**23.14**
TOTAL	**$101,594,309**	**100.00**	**$102,678,867**	**100.00**

*Includes Overhead

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Brian Palenik, a professor in the Marine Biology Research Division, uses protein gel electrophoresis to find stress-induced proteins.

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CCS	*Center for Coastal Studies*
CMBB	*Center for Marine Biotechnology and Biomedicine*
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CSI	*California Space Institute*
DO	*Director's Office*
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ECE	*Electrical and Computer Engineering Department*
GRD	*Geosciences Research Division*
IGPP	*Institute of Geophysics and Planetary Physics*
MBRD	*Marine Biology Research Division*
MLRG	*Marine Life Research Group*
MPL	*Marine Physical Laboratory*
MRD	*Marine Research Division*
NU	*Neurobiology Unit*
PORD	*Physical Oceanography Research Division*
SGP	*Sea Grant Program*
SOMTS	*Ship Operations and Marine Technical Support*
STS	*Shipboard Technical Support*

Awards & Honors

FAROOQ AZAM
Received the 1996 UCSD Chancellor's Associates Faculty Award for Excellence in Research. He was chosen for his internationally acclaimed research in the fields of marine microbial ecology and biogeochemistry.

CATHERINE G. CONSTABLE
Received the Price Medal from the Royal Astronomical Society. This gold medal is awarded to young scientists who are studying geomagnetism.

PAUL K. DAYTON
Received an honorary doctorate of science degree from Southampton College of Long Island University.

FREDERICK H. FISHER
Received the Distinguished Technical Achievement Award from the Oceanic Engineering Society of the Institute of Electrical and Electronics Engineers.

Honored with the America's Finest Acousticians Award from the Acoustical Society of America for his lifetime contributions to acoustics and service to the society.

EDWARD A. FRIEMAN
Presented the Department of the Navy Superior Public Service Award for his substantial contribution and outstanding service to the navy.

Received the first annual E. W. Scripps Associates Award for community service and support of Scripps Institution of Oceanography research.

KEVIN R. HARDY
Presented the annual Award for Excellence in Science Education/ University Level by the San Diego Science Educators' Association.

ROBERT R. HESSLER
Received the Crustacean Society's Research Excellence Award for lifetime achievements in marine science.

MIRIAM KASTNER
Elected a Fellow of the American Geophysical Union.

DEVENDRA LAL
Received the Sir C. V. Raman Birth Centenary Award for 1996-1997.

Awarded the V. M. Goldschmidt Medal for 1997.

WALTER H. MUNK
Received the Oceanology International Lifetime Achievement Award at the Oceanology International 97 Pacific Rim Conference.

JOHN A. ORCUTT
Named first Secretary of Navy/Chief of Naval Operations Oceanographic Chair.

Received the Outstanding Alumnus Award from the University of California, San Diego.

RICHARD L. SALMON
Elected a Fellow of the American Academy of Arts and Sciences.

DAVID T. SANDWELL
Named a Fellow of the American Geophysical Union.

LISA TAUXE
Named a Fellow of the American Geophysical Union.

BRADLEY T. WERNER
Named first Secretary of Navy/Chief of Naval Operations Oceanographic Scholar.

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v.29 **Park,** Taisoo. Taxonomy and distribution of the marine calanoid copepod family Euchaetidae. 1995. 203p.

CalCOFI PUBLICATIONS

The work of the California Cooperative Oceanic Fisheries Investigations (CalCOFI), in which the Scripps Institution of Oceanography, the California Department of Fish and Game, and the National Marine Fisheries Service cooperate, is published in a variety of formats. Peer-reviewed scientific articles are published annually in the *California Cooperative Oceanic Fisheries Investigations Reports.* Maps of physical, chemical, climatological, and biological factors measured by CalCOFI researchers during the program's 48-year history are published irregularly in the *California Cooperative Oceanic Fisheries Investigations Atlas* series. Data reports, containing the processed data from specific cruises carried out under CalCOFI sponsorship, are published irregularly in the SIO Reference Series and in the CalCOFI data report series. To obtain copies of any of these CalCOFI publications, write to
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Technical Series

Abbott, I. A., Ed. Taxonomy of economic seaweeds: with reference to some Pacific species, Volume VI. Results of an international workshop hosted by the University of Malaya, Kuala Lumpur, July 1995. Publication Number T-040. 1997. 230p. ($10)

Bakun, A. Patterns in the ocean: ocean processes and marine population dynamics. Publication Number T-037. 1996. 323p. ($24 U.S. and territories; $29 international airmail)

McArdle, D. A., Ed. California marine protected areas. Publication Number T-039. 1997. 268p. ($13)

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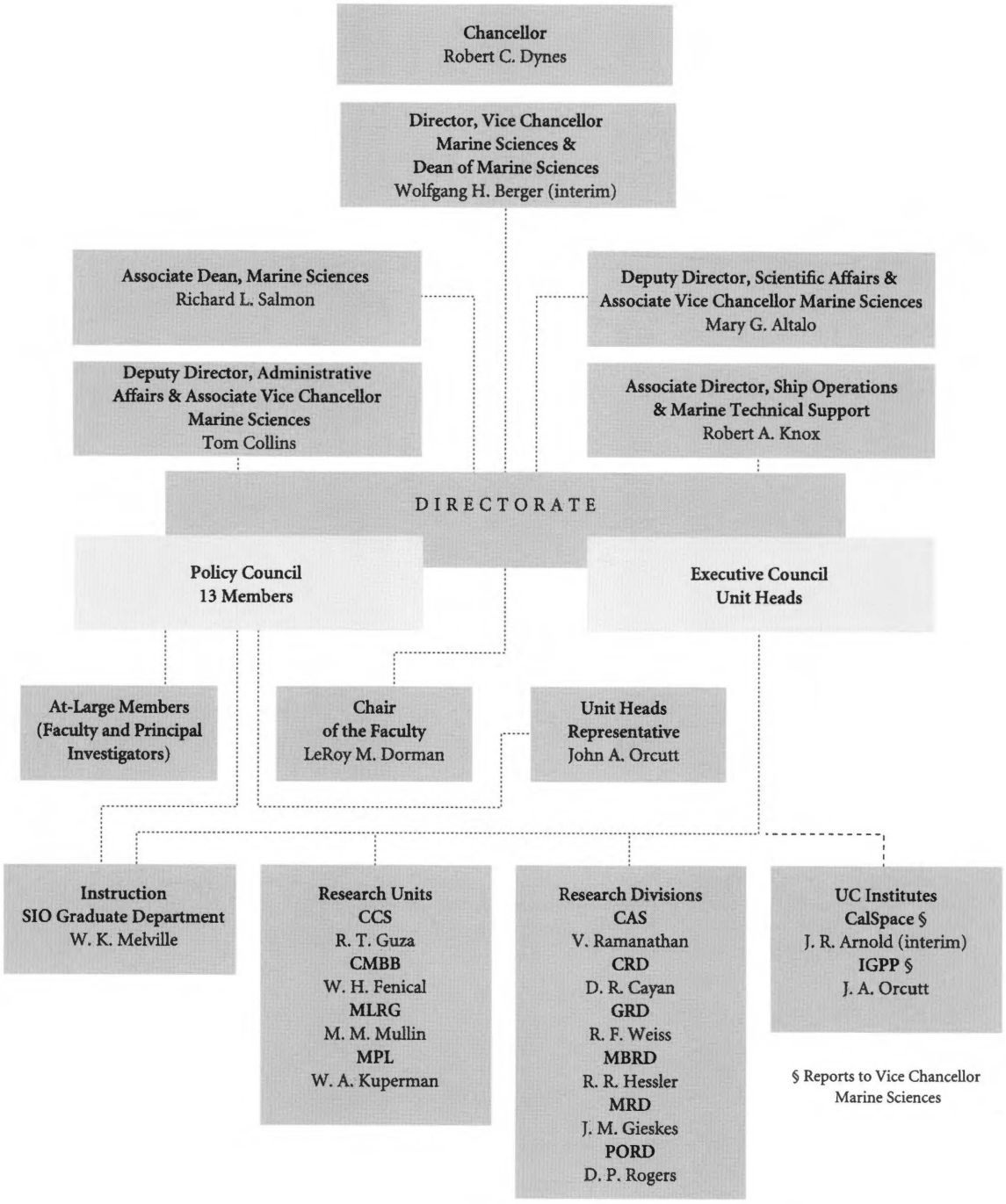
Copies of Marine Extension publications can be obtained by writing to
Sea Grant Extension
Food Science and Technology
University of California Davis
Davis CA 95616-8598.

Price, R. J., D. E. **Kramer,** and P. D. **Tom.** Processing mussels...the HACCP way. UCSGEP 96-2. 1996. 42p.

Price, R. J. and P. D. **Tom.** Chilling fish fillets in 10 to 25 pound containers. UCSGEP 96-3. 1996. 2p.

Price, R. J., P. D. **Tom,** and J. B. **Richards.** Recommendations for handling ridgeback shrimp. UCSGEP 96-1. 1996. 2p.

Organization



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CCS	Center for Coastal Studies
CMBB	Center for Marine Biotechnology and Biomedicine
CRD	Climate Research Division
GRD	Geosciences Research Division
IGPP	Institute of Geophysics and Planetary Physics
MBRD	Marine Biology Research Division
MLRG	Marine Life Research Group
MPL	Marine Physical Laboratory
MRD	Marine Research Division
PORD	Physical Oceanography Research Division

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Maria Vernet, whose research focuses on phytoplankton, collects samples from the waters beneath Scripps Pier.

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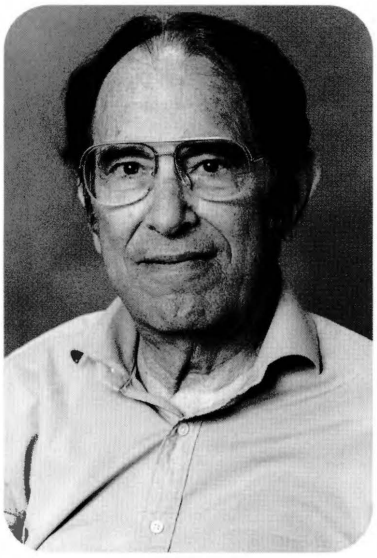

Jerome Namias

Erich Duffrin

May 1997

Erich Duffrin was a machinist at Scripps. He was responsible for the design and construction of many innovative instruments at the institution. He was hired by John Isaacs, and he retired in 1991.

Robert L. Gudgeon

August 1996

Bob Gudgeon worked for the special events set-up division of Physical Plant Services. He was famous on campus for being Santa Claus at the UC San Diego Staff Association's Annual Holiday Pancake Breakfast and Scripps holiday parties.

Paul E. Hendry

March 1997

Paul "Pappy" Hendry worked the night shift for Physical Plant Services at Scripps for more than 15 years, primarily maintaining the boilers. He retired in 1991.

Curtis Montgomery

March 1997

Curtis Montgomery was the Scripps maintenance supervisor with Physical Plant Services and was located at Scripps for 25 years. He oversaw the entire crew and all maintenance, such as the sea-water pumping system and the buildings' heating and cooling systems. He was planning to retire in June 1997.

Jerome Namias

February 1997

Jerome Namias was a pioneer in weather forecasting and an internationally renowned research meteorologist at Scripps. He joined the institution in 1971 as founding director of the Climate Research Group. He established the nation's first experimental climate forecast center and continued issuing winter season forecasts until 1989, when he retired due to illness.

Peter Trapani

May 1997

Peter Trapani served as marine superintendent at Scripps from 1956 to 1972. He played a key role in the design and construction of Scripps's Chester W. Nimitz Marine Facility.

Robert D. Tschirgi

May 1997

Robert D. Tschirgi was associate director of the NASA Specialized Center for Research and Training in Exobiology at Scripps and UC San Diego. He helped design medical schools and curricula for fledgling UC campuses in the early 1960s.