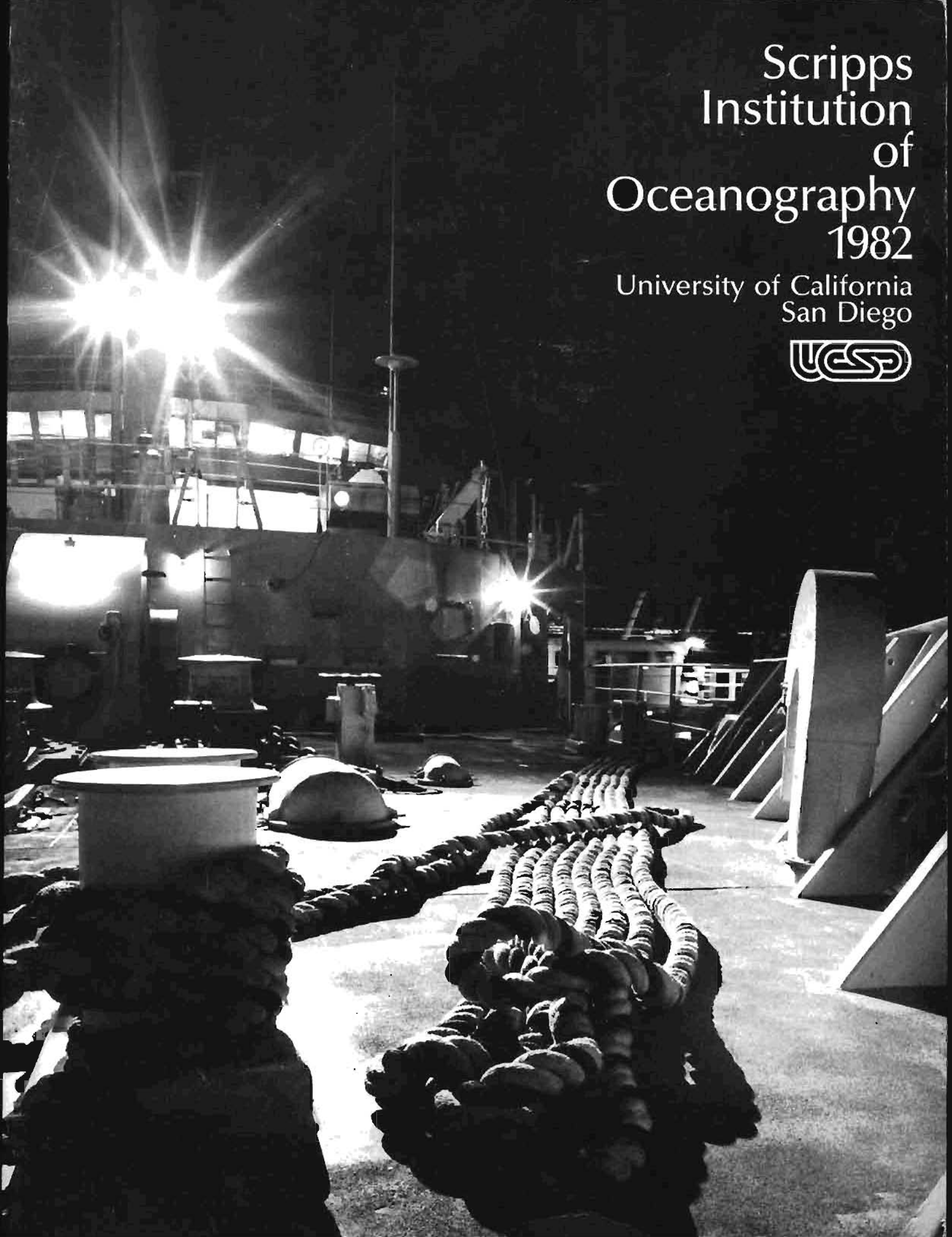
Scripps Institution of Oceanography 1982

University of California
San Diego



Cover: Night aboard R/V *Melville*.
Taken at 21°N during
the Oasis 82 expedition
in the Pacific Ocean.

COVER BY L. D. FORD

DEDICATION

In 1957 the eastern North Pacific Ocean was a few degrees warmer than normal. Weather patterns, sportfishing, and commercial fishing were affected, and oceanographers were puzzled. The late Professor John D. Isaacs called together a large group of scientists to talk about these remarkable conditions. Among those at the Rancho Santa Fe symposium in June 1958 was Dr. Jerome Namias. "It became apparent," he said later, "that the ocean contained the potential for affecting the weather substantially over vast areas."

Dr. Namias has pursued the complex relationship between the oceans and the weather for many years. His long-range forecasts are front-page news.

The vagaries of New England weather, as illustrated to him in Fall River, Massachusetts, piqued his boyhood curiosity. A stimulating high-school physics teacher and a scholarly amateur meteorologist encouraged his interest. The enthusiastic student set up his first weather station when he was sixteen. He went on to the Massachusetts Institute of Technology, where he participated with Carl Gustof Rossby and Hurd C. Willett in a five-year effort to develop methods of long-range forecasting—an outgrowth of the Dust Bowl disaster of the 1930s.

In 1941 Dr. Namias was called to Washington, D.C. to set up the Extended Forecast Section of the U.S. Weather Bureau. His participation in forecasts for Atlantic convoys and Allied invasions led to his receiving a citation from the Secretary of the Navy in 1943.

Dr. Jerome Namias

CHICAGO PHOTOGRAPHERS

In 1952 Jerome Namias, as chief of the U.S. Weather Bureau's Extended Forecast Section, works out a long-wave wind problem on a glass map.

Professor Isaacs was instrumental in bringing Dr. Namias to Scripps in 1968, when the North Pacific Buoy project was in progress. From 1974 to 1980 Dr. Namias was head of the Climate Research Group, and since then he has continued as a research meteorologist. The first of his experimental seasonal forecasts for the entire United States, based on air/sea interaction research, was made in 1976. Some say he has a keen sixth sense.

Dr. Harald U. Sverdrup, former director of Scripps, was keenly interested in the relation between the oceans and the weather. So it seems appropriate that Jerome Namias was awarded the Sverdrup Gold Medal of the American Meteorological Society in 1981.

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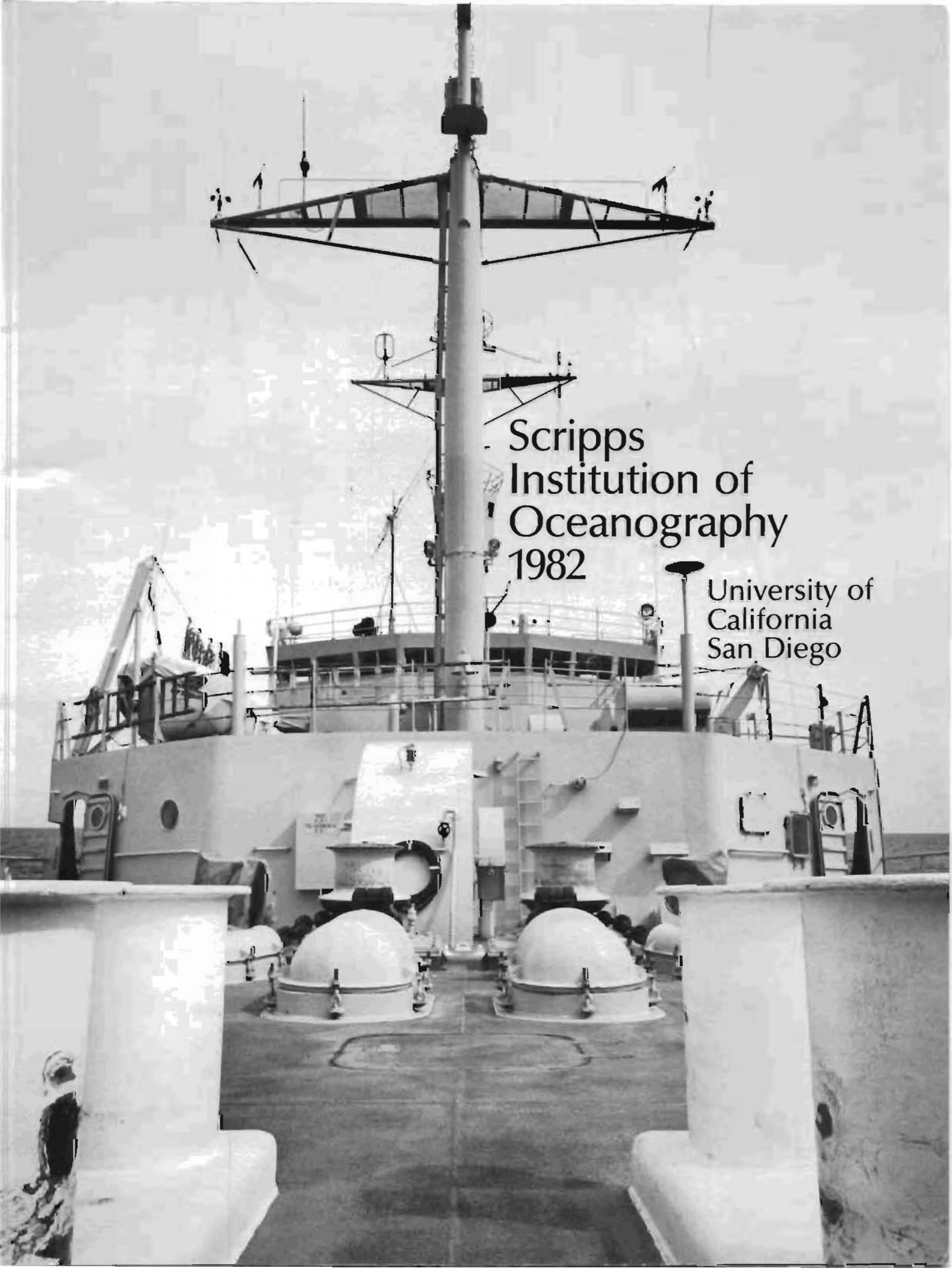

Scripps Institution of Oceanography 1982

University of California San Diego

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INTRODUCTION

This past year has been a very successful one for the institution in a number of ways. One is the initiation of an awards program, from the Andrew W. Mellon Foundation, for postdoctoral fellows. This is a three-to-four-year program, which we hope the foundation will continue—particularly in view of the excellent quality of the candidates who have come. It has also been the year that we have started up the Tinker Foundation Program, whose purpose is to bring predoctoral and postdoctoral researchers from Central America and South America to work in our institution.

This is also the year that we have started another wave of returning valued research groups such as PACODF back to the campus. It is also this year that Sea Beam became fully operative on R/V *Thomas Washington,* turning out marvelous and unique results and, like the Scripps Satellite-Oceanography Facility, placing our institution in the van of oceanographic research.

The Sea Beam array caps the full complement of multichannel equipment and the other standard geophysical apparatus that makes R/V *Thomas Washington* the most advanced and capable geophysical vessel in the Academic Fleet. But we are not standing still. We now have the resources to equip the vessel with inertial navigation, which will supply the navigational precision needed to complement Sea Beam.

Given the financial stringency of the times and the heavy external budget restrictions, we did surprisingly well. Our spending increased over the previous year by six percent despite a small decline for the rest of the campus. However, the bad news is that we anticipate rough financial going in the next several years. A severe shortage in state financial income is expected to be visible before the end of 1982, and some retrenchment will be required. There are also severe perturbations imminent in the federal funding of the oceanographic effort.

An unusually large number of deaths have been recorded this past year, more than I care to mention in this introduction. But I would like to make special note of just two: Theodore Enns and "Swede" Larson, both of whom have served the institution long and valiantly in different capacities.

There were the usual quota of honors and awards; I mention just one—that received by Harmon Craig. He was the first oceanographer to receive NSF's special creativity award. This provides a much envied several years of continuous funding without review.

I use this Introduction for the first time to point out that we have fifteen members of the National Academy of Sciences on our rolls—more than all the other oceanographic institutions combined.

There are many new initiatives we would like to entertain in the coming year, but decisions will have to wait until the financial picture is clearer.

William A. Nierenberg

William A. Nierenberg, Director
Scripps Institution of Oceanography

Dr. William A. Nierenberg

WEDDELL SEALS IN WINTER

> I have mentioned that Weddell's Seal during the winter months spends most of its time in the water beneath the ice. . . Again and again while sitting up at night as meteorological observers, in the silence that reigned when others were asleep, we would hear the gurgling, bubbling, guttural notes of Weddell's Seals beneath the ship, sounds which we knew so well from having often watched the seals as they made them. (Edward Wilson, 1901)

Edward Wilson was chief scientist and physician on Captain Scott's first polar expedition, the National Antarctic Expedition (1901-1904). He and other crew members had the unique opportunity to observe Weddell seals throughout the winter, and often heard their underwater vocalizations through the hull of their ship, *Discovery*, as it lay frozen into the ice in Winter Quarters Bay on Ross Island. Although McMurdo Sound was frozen with 2 m of sea ice and appeared lifeless to an observer on the surface, beneath the ice the lives of Weddell seals continued uninterrupted.

As Wilson noted, the seals seldom leave the water throughout the winter, and for good reason: the air temperature can drop below −70°C, and fierce blizzards may howl for days. But in the water the temperature is stable at −1.89°C. Weddell seals' superb adaptation to life beneath the ice enables them to survive throughout the winter with little more than a 10-cm hole in the ice for breathing.

Eighty years after Edward Wilson's observations, a team of Scripps scientists spent the winter in Antarctica specifically to study the winter ecology and behavior of Weddell seals. The team included Dr. Gerald L. Kooyman, Dr. Michael A. Castellini, Marcus Horning, Maria P. Davis, and the writer, Dr. Randall W. Davis. In our previous studies we had concentrated on the diving behavior of free-ranging seals during the summer, when the sun shines 24 hours a day. We found that the foraging dives of adult Weddell seals usually last 15-25 minutes, are sustained by aerobic metabolism, and may reach depths of 600 m.

How does the winter change this behavior? How do the seals orient themselves and locate prey underwater during the winter darkness? A seal must relocate its breathing hole after a dive or, like any other mammal, it will drown. Weddell seals have large, well-developed eyes and probably rely on visual orientation during the summer when sunlight penetrating the cracks and holes in the ice can be seen from great depths in the clear Antarctic seas. But during the winter darkness, visual orientation must be greatly limited.

R. W. DAVIS

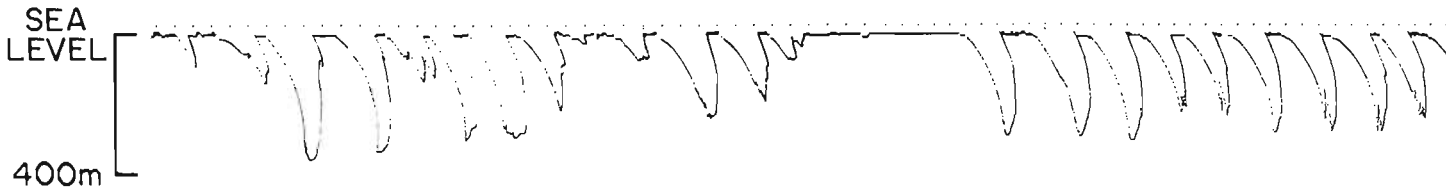
Dr. Gerald L. Kooyman in the process of capturing a seal from which he will remove a depth recorder.

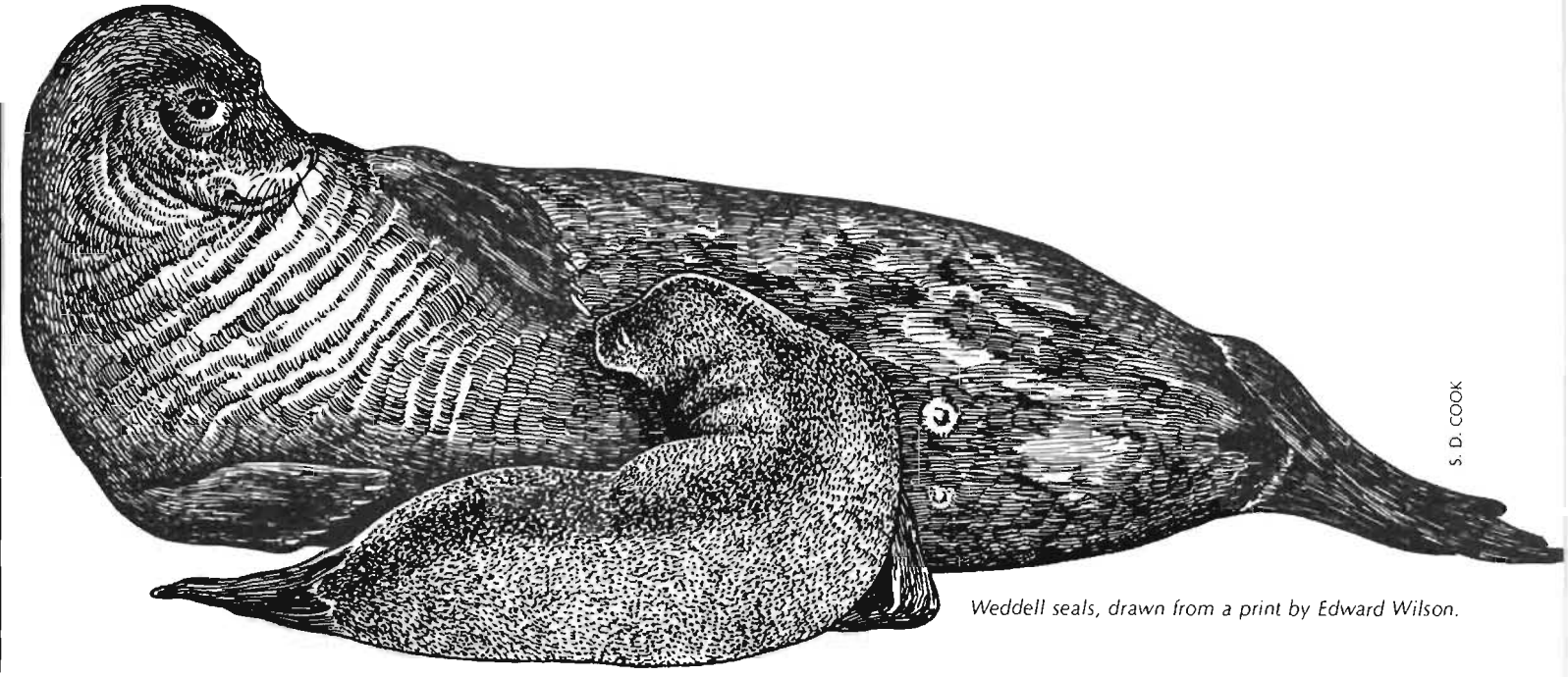
Back in the laboratory at Scripps, Drs. Randall W. Davis and Gerald L. Kooyman are pressure calibrating a time depth recorder.

The variety of Weddell seals' underwater vocalizations and their possible use for echoranging has long been a source of speculation. Many of the calls are thought to be social and are often heard around rookeries during breeding. But some of the calls are very powerful and may be a source of acoustic information for orientation and foraging.

Our questions about diving behavior and under-ice orientation prompted us to spend the winter in a field camp at White Island, where a small group of Weddell seals lives throughout the year.

DIVING DEPTH





Weddell seals, drawn from a print by Edward Wilson.

The island is surrounded by the Ross and McMurdo ice shelves and is essentially cut off from open water by 20 km of permanent ice. How seals originally arrived at White Island remains a mystery. They may have crawled over the ice from McMurdo Sound or followed cracks that no longer exist. However they arrived, the small population of 20-30 seals at White Island appears unable or unwilling to leave.

Our field camp consisted of two 5x6-m huts as living quarters and a Jamesway (quonset hut) garage to house the tracked vehicle and two diesel electric generators. An ice hole 1.2 m in diameter beneath one of the huts penetrated 16 m of ice and was maintained throughout the winter. It was used for oceanographic measurements, biological sampling, and hydrophone recordings. The camp supported four scientists and permitted the first year-long study devoted strictly to Weddell seals.

At every opportunity, the field team made trips along the northern shore of White Island to deploy and recover time depth recorders (TDRs) and depth histogram recorders (DHRs). The TDRs record and store the depth and duration of every dive for ten days. The DHRs record only the maximum depth of every dive, but continue to log data for up to three weeks.

Often we hiked in the darkness along the tidal crack searching for seals by moonlight. When we found a seal, we briefly immobilized it by placing a large canvas bag over its head while we attached a small anklet with the recorder. When released, the seal usually entered the water through a hole in the tidal crack. The instrument had to be recovered to obtain the dive data, and so we would search, daily if possible, in the hope of eventually relocating the seal and retrieving the instrument. However, some recorders were not recovered for up to 7 months.

We deployed and recovered five instruments through the early winter, with a total time monitored of 67 days. We also obtained three midwinter records from McMurdo Sound in early August. The McMurdo results covered a total of 20 days of diving. These recordings provided data on the seals' preferred feeding depths.

While seeking seals on which to deploy recorders, we carefully examined haul-out areas for feces. These formed the basis of a scatological study to determine the preferred food. The seals' diving depths as well as the otoliths recovered from their feces indicated that the major food item was *Pleuragramma antarcticum*, the Antarctic smelt.

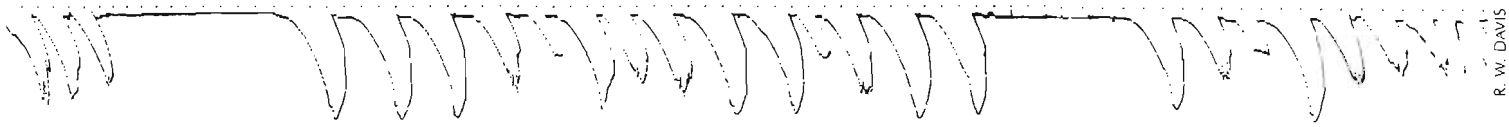
We made routine hydrophone recordings throughout the winter to estimate seal density and distribution. These recordings were made mainly at the station, but several were made at different locations along the coastline. The recordings as well as the various sightings during the winter confirmed that the White Island population was resident throughout the year and did not migrate north during the winter.

Because of the ice conditions, winter survival seemed to be a remarkable feat. The thinnest known ice was along the tidal crack, and even there it was 2 to 3 m thick at the break between land and sea. Elsewhere, ice thickness in areas where seals were known to dive ranged to over 100 m. We made a detailed survey of ice movements, and we made depth soundings along the northwest coast of the island. Where possible, we also observed under-ice conditions with scuba.

At White Island as well as McMurdo Sound, the under-ice conditions and the bottom were surveyed with a deep-submersible camera developed for this project. With this camera system we obtained under-ice-surface photos down to 200 m. Bottom photos were obtained in a variety of areas ranging from depths just beyond the reach of scuba (40 m) to the bottom of the sound (540 m).

All of these data are being used to develop a comprehensive understanding of Weddell seals' diving and feeding behavior under different seasonal and geographical conditions and to define and describe the problem of under-ice orientation.

As we learn more about the natural history of the Weddell seal, we can begin to see how this species has adapted itself to the unique requirements of life beneath the Antarctic sea ice.



A graph of the diving depths versus time of a Weddell seal. The duration between every two dots is 12 minutes.

WINGS UNDER HARBORS

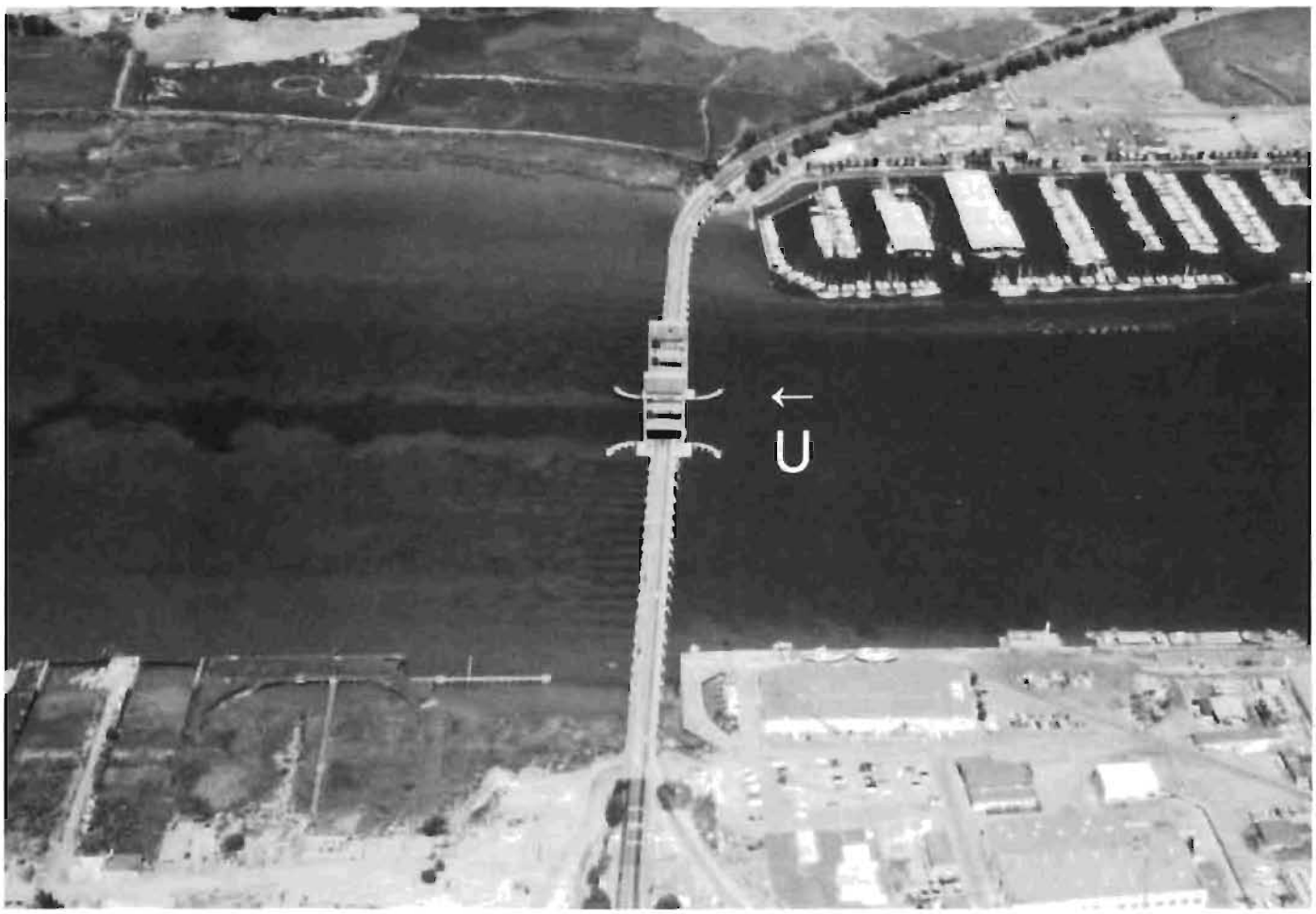
Most of our present-day harbors were sited several hundred years ago in the embayments and quiet waters around drowned river mouths. Although the natural water depth in these harbors was adequate for the 6-m-draft wooden sailing ships of that era, ships' drafts have since more than doubled. Indeed, a fully loaded supertanker, aircraft carrier, or nuclear submarine may draft almost as much as 14 m.

Few of the historic harbors provide or maintain that much deep water through natural circulation and scour; those that do, such as in San Francisco, Puget Sound, or San Diego, still have local shallows, shoals, and inlet bars requiring artificial deepening. Other historic harbors were once natural deepwater harbors, but are no longer. An example is Charleston, South Carolina, where upstream the Cooper River has been diverted for a hydroelectric plant, resulting in as much as 5 m of annual shoaling in Charleston Harbor. The sediments are, of course, the continual byproduct of erosion and weathering; their transport pathway down the rivers to the sea is intercepted by the artificially deepened harbors.

With the advent of steam power and the first deep-draft iron-hulled ships, the first suction dredges also appeared, and it became easier to dig than to relocate the harbors. Deepening our harbors by overdredging has diminished the bottom velocities and stresses caused by natural circulation and has thereby retarded the transport of sediment bound for the sea. Thus the deeper a harbor is dredged, the more rapidly subsequent sedimentation acts to refill it.

Also, after 150 years of dredging, places to dump all the sediments are scarce. The problem is compounded by recent environmental constraints since it has been learned that these sediments tend to concentrate heavy-metal toxins, halogenated hydrocarbons, pesticides, and huge amounts of anaerobic bacteria. The contaminants are released back into the water by the bottom agitation of dredging activity. These factors combine with rising energy costs to render continual maintenance dredging too expensive or too hazardous to the environment.

The Innovative Sediment Management Group [led by the writer, Dr. Scott Jenkins] is working at the Center for Coastal Studies under Professor Douglas Inman to develop passive alternatives to maintenance dredging. These alternatives attack the sedimentation problem at its base, namely the insufficient bottom stresses of an artificially deepened harbor. Several years ago our group studied the flow of the Napa River through a bridge structure across Mare Island Strait at the northeast end of San Francisco Bay. Here the classical wake vortices shed from the bridge's support piles were observed to resuspend large amounts of sediment on the downstream side. A follow-up fathometer survey revealed that scour trails as deep as 3 m had been cut into the bottom behind each pile, extending almost 600 m downstream from the bridge. The average depth in this area is now about 8 m. U.S. Geological Survey bathymetric surveys of Mare Island Straits in 1930, prior to construction of the bridge, revealed that in its natural state the bottom was once only 5 m deep. There has been no dredging in



CENTER FOR COASTAL STUDIES

Vortices are shed from the bridge piles as the water flows past. These vortices resuspend sediment as shown at the lee of the bridge.

L. FORD

Dr. Scott Jenkins watches as the velocity field at the trailing edge of the forward vortex foil is measured with a dual axis current meter. Note the dye being released from the aft vortex foil.

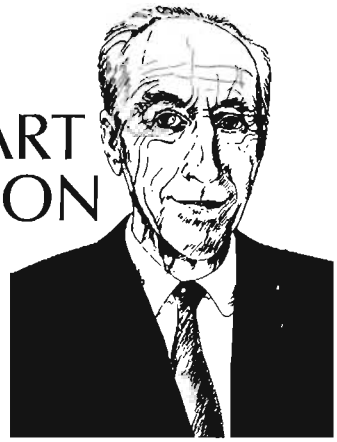
this area since the late 1960s. We therefore concluded that the increased bottom stress caused by wake turbulence from the bridge was responsible for the local deepening of the river. Annually, about 23,000 cubic meters of sediment had apparently been prevented from depositing, without the expense of a single kilowatt hour of dredging. Since the resuspended material did not remain on the bottom long enough to become cohesive nor to concentrate contaminants, no environmental danger resulted from the bridge turbulence.

Because it is impractical to obstruct harbors and navigation channels with vertical turbulence-generating structures such as piles, we began looking for an alternative vortex-generating structure. It turns out that a wing is a very efficient vortex generator, and also imparts a net vertical deflection to the turbulent trailing wake, commonly known as downwash in the case of an airplane. We reasoned that if the airplane wing were turned upside down and placed near the bottom, then a turbulent upwash would be released behind the wing to resuspend sediment. If many wings were arranged like flocks of inverted geese along the bottoms of harbors and shipping channels, then it might be possible to keep sediment suspended until it has bypassed the harbors and reached either the sea or channels where strong natural currents still prevail. In this way the wings would mimic the higher bottom stresses that once maintained the harbor at its shallower, natural steady-state depth.

Although simple in principle, the physics of this passive-resuspension concept have required detailed testing and design development both in the field at Mare Island Naval Shipyard and in the Scripps Hydraulics Laboratory's new Stratified Flow Channel. The turbulent upwash behind the inverted wing, or "vortex foil," manifests itself as a downward hydrodynamic force on the wing, which acts against its net positive buoyancy. To maximize the upwash we want to maximize this downward dynamic force by using inverted high-lift airfoils. These airfoils produce pitching that flattens out the wings and diminishes the upwash. We are learning to counter this undesirable effect by the proper arrangement between the mooring point and the center of buoyancy, which can be tricky in a near-bottom shear flow having a dense sediment suspension. We have also learned to maximize scour efficiency by flying the wings near the bottom in a partially stalled configuration with significant leading edge sweepback, thereby adding additional vortices to the wake.

We have recently taken these results to the field at Mare Island where we have deployed 2.5-m- and 6-m-span foam sandwich foils to prevent sedimentation around a drydock entrance. Here these foils removed 2 m of shoaling in the first month following installation. We are now eagerly awaiting the onset of the 1982-1983 winter and rainy season when high sedimentation rates will provide a definitive long-term evaluation of this array of vortex foils.

ECKART DISSERTATION PRIZE



N. HULBIRT

Dr. Carl H. Eckart

The Eckart Dissertation Prize was established in 1975 by Scripps to honor the memory of Carl H. Eckart, to recognize students who prepare outstanding doctoral dissertations, and to provide a learning experience for students who serve on the selection committee.

Dr. Eckart (1902-1973) was a pioneer in the field of quantum mechanics and underwater acoustics. He established the Marine Physical Laboratory (MPL), which became a research unit of Scripps in 1948 when Dr. Eckart was simultaneously director of the laboratory and of the institution. He served as a professor of geophysics from 1948 to 1973, and as director of Scripps from 1948 to 1950. He was UC San Diego's first vice-chancellor for academic affairs, and he chaired the university's academic senate for two years.

Primarily a physicist, Dr. Eckart was elected into the National Academy of Sciences in 1953, and received several other honors and medals. The building that houses the Scripps library is named the Carl Eckart Building in his memory.

The Eckart Prize was originated by Director William A. Nierenberg and Dr. Joseph R. Curray. It carries an award of $1,500 for the most original and stimulating dissertation of the year. The choice is made on the basis of coherence, brevity, and clarity. The selection committee consists of one graduate student from each of the seven curricular groups and one faculty member, who is chosen by the chairman of the graduate department. Prizewinning dissertations are kept in a special collection in the Scripps library.

Past recipients of the Eckart Dissertation Prize are:

1975—Douglas W. Oldenburg
1976—Richard L. Salmon
1977—David M. Gardiner
1978—David M. Karl
1979—Paul H. Yancey
1980—Patricio A. Bernal

In 1981 the prize was awarded to Robert J. Olson for his dissertation entitled "Studies of Biological Nitrogen Cycle Processes in the Upper Waters of the Ocean with Special Reference to the Primary Nitrite Maximum." The following section is Dr. Olson's description of the work that led to his winning dissertation.

Studies on the Primary Nitrite Maximum

The nitrite maximum layer found throughout much of the world's ocean is intriguing because it occurs at a depth where many important physical, chemical, and biological parameters are all showing marked changes: light intensity approaches the minimum necessary for photosynthesis; temperature, density, and nitrate gradients occur; and a chlorophyll maximum is usually present.

The existence of a nitrite maximum layer was noted early on by chemical oceanographers. For most of this century there has been speculation as to the origin of this phenomenon. At first I questioned the origin and stability of the primary nitrite maximum in ocean water. My curiosity led me to study the transformation of nitrite and the cycling of all the major nitrogenous nutrients.

Nitrite is an intermediate in several reactions in the nitrogen cycle, and so can result from a variety of biological mechanisms. In stratified waters, elevated nitrite concentrations are found only near the bottom of the euphotic zone, but in high latitudes—where mixing is strong—nitrite can occur throughout the upper water column. On the basis of the relationship of nitrite to other factors such as nitrate, light, density, and chlorophyll, some researchers suggest that nitrite is a product of ammonia oxidation by chemoautotrophic nitrifying bacteria, or that it is excreted by phytoplankton during the assimilation and reduction of nitrate. Nitrate reduction by anaerobic bacteria has also been suggested, although the "primary" nitrite maximum is found in well-oxygenated waters (there is a deeper secondary maximum in some oxygen-depleted waters, which *is* formed through denitrification).

My first approach was to relate the position of the nitrite maximum to these other parameters. The quarterly cruises of the Food Chain Research Group in the Southern California Bight offered excellent opportunities for this work because the group performed extensive analyses on the same water samples I used to obtain nitrite data. Soon, however, it became clear that too many things were varying together, and that this approach would not produce unequivocal evidence as to the source of nitrite.

At about this time I took Dr. Ted Enns's course in isotope tracer techniques and found that he had built a mass spectrometer to measure the stable isotope ^{15}Nitrogen. This instrument can measure small enrichments in ^{15}N content, and so enables one to conduct tracer experiments by incubating a water sample in the presence of ^{15}N labeled substrates, and then examining the products (nitrite here) for ^{15}N enrichment. A homemade mass spectrometer is not always the most tractable of instruments, but much time and guidance on the part of Dr. Enns resulted in a very sensitive system. To look specifically at nitrite, I had to isolate it from seawater samples and convert it to nitrogen gas; I was fortunate to be able to draw on the chemical expertise (and hardware) of Dr. Peter Williams during this phase of the study.

With a workable ^{15}N method, I did some incubation studies in coastal waters, and received a travel grant from Scripps to spend a month in the central North Pacific on R/V *Thomas Washington* with Dr. Williams. More experiments with samples from the nitrite maximum in southern California waters were subsequently done, and all pointed to one conclusion: at the depth of the nitrite maximum, ammonia oxidation far outweighed nitrate reduction as a source of nitrite. This finding agreed with laboratory studies (done with Dr. Kiefer) demonstrating that a marine diatom excreted nitrite maximally only at *high* light intensities.

Two cruises to the Antarctic were made possible by my advisor, Dr. Osmund Holm-Hansen, and provided some keys to understanding the whole picture. In these waters nitrite was present all the way to the surface, allowing rate measurements to be carried out at several depths rather than just in a discrete layer. The results here showed that (1) nitrate reduction by phytoplankton was important near the surface, (2) ammonia oxidation was dominant in deeper waters (as before), and (3) ammonia oxidation was apparently inhibited by light near the surface. Subsequent lab incubations of water samples obtained just offshore of Scripps confirmed these tendencies and enabled me to construct a conceptual model consistent with previous lab studies done with pure cultures of phytoplankton and nitrifying bacteria. An essential concept of the model—that nitrite-oxidizers (which consume nitrite) are more susceptible to inhibition by light than are ammonia oxidizers (which produce nitrite)—explains how nitrite accumulates at a depth determined by light penetration. Thus I had found the answers to some of my questions.

RESEARCH ACTIVITIES

A brief overview of the many scientific projects being conducted at Scripps is given in this Research Activities section. The majority of these studies are being funded by the National Science Foundation, Office of Naval Research, Department of Energy, Department of Commerce, and other governmental agencies.

Scientific papers listed in the Publications section will lead the reader to a more in-depth coverage of the topics discussed in the Research Activities section.

Marine Physical Laboratory

Research in the Marine Physical Laboratory (MPL) is directed by Dr. Kenneth M. Watson, and includes the effects of the ocean and its interfaces on the generation, propagation, and application of acoustic energy. Marine technology has advanced especially in the development of new platforms and instruments: the Doppler sonar, signal processing, acoustic arrays, and sea-floor navigation.

In collaboration with Dr. William R. Young, Dr. Watson is analyzing the transport of energy and energy sources in the ocean's internal wavefield. They are studying how mesoscale currents modify the internal wave spectrum. The vertical shear associated with baroclinic flow appears to enhance energy transport within the internal wavefield at longer wavelengths, and to retard it at shorter wavelengths.

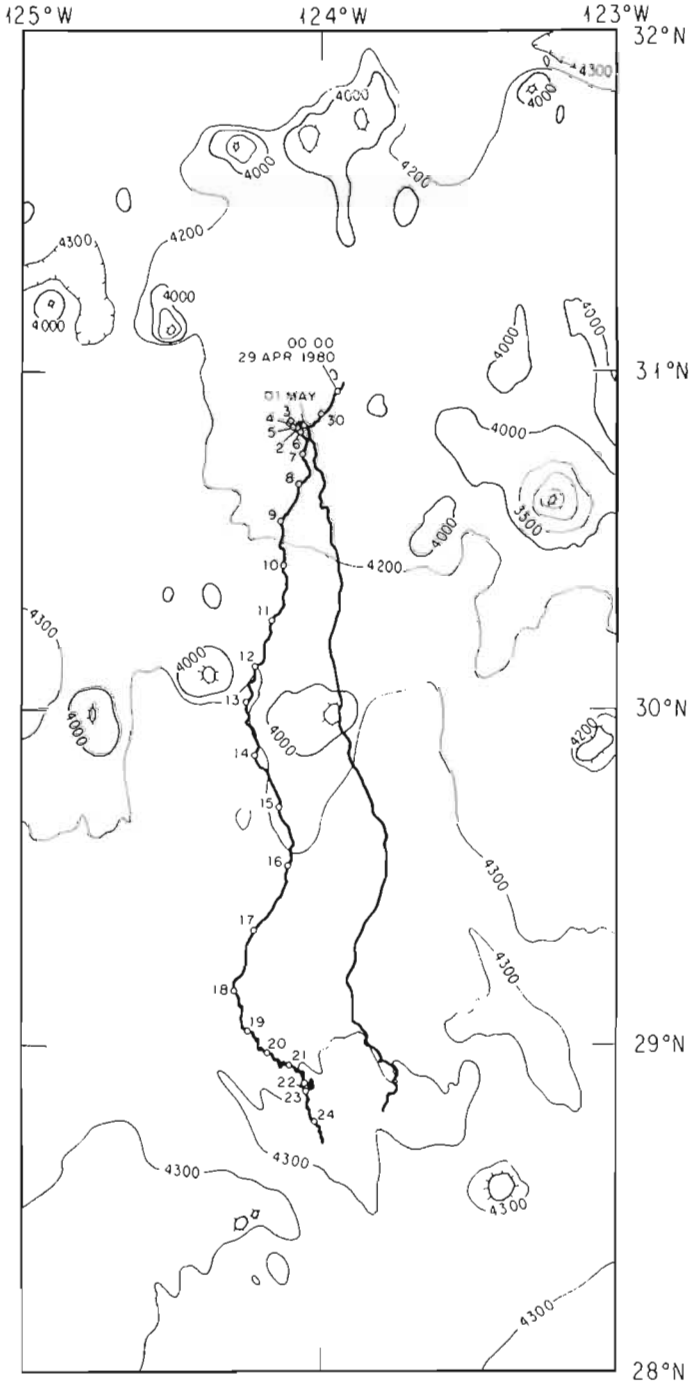
Dr. Robert Pinkel's research group is investigating the physics of internal wave motions in the top kilometer of the sea. High-power Doppler sonars mounted on the research platform FLIP are used to profile the oceanic velocity field. These sonars transmit in a narrow beam; the sound energy scatters off plankton in the sea. From the Doppler shift of the returning echo, the velocity of the scatterers, and hence the water mass, can be determined.

Recent work has been focused on the analysis of a large data set. One of the surprises from this data analysis surfaced when the Doppler sonar velocity measurements were compared with the track of FLIP's drift. Loran C was used for navigation. FLIP's velocity with respect to the volume of water 200 to 500 m deep, as determined by the sonars, was integrated in time to form a right-hand track. If the deep water was stationary, the two tracks should agree. A slight discrepancy can be accounted for if one assigns a 2 cm/sec westward speed to the 200- to 500-m water depth. The agreement in the small-scale details in the two tracks established that both the sonars and the Loran were working with high accuracy.

Dr. Fred H. Fisher's group is investigating environmental effects on long-range acoustic propagation. The group is also studying normal-mode propagation in shallow water, and is developing a large-aperture, 64-element digital acoustic array to replace the 20-element vertical array deployed from FLIP, in addition to a 7-element towed thermistor array for thermal profiling studies in conjunction with the acoustic propagation work. Dr. Fisher is also using electromotive-force conductance and acoustic absorption data to study ion pairing of mixed-electrolyte solutions, including seawater.

Dr. R. Bruce Williams is analyzing deep-ocean ambient noise and sound propagation data to design the next 64-element array. Dr. Williams and Michael R. Layton have conducted a seagoing experiment in shallow water to obtain background data prior to full-scale normal-mode studies. Layton is continuing scale-model studies in the laboratory, modeling rough surface and rough bottom conditions in a tank.

During the past year, Dr. William S. Hodgkiss's research group continued to focus on the field of signal processing. The MPL Dynamic Beamformer is being applied to the processing of data from towed line arrays. Presumed to be perfectly straight, towed arrays actually have shapes that vary dynamically with time, even when the tow ship is pursuing a straight course.



MARINE PHYSICAL LABORATORY

A tracking map of FLIP's drift. The bold line to the left represents the time series of FLIP's position as determined by Loran C navigation. Numbered circles indicate the date. The right-hand track is the progressive vector formed by time integrating the 200-500-m deep, averaged Doppler velocities sensed by sonars.

Dr. Hodgkiss and colleagues are also investigating adaptive filtering concepts that are being applied spatially and temporally. Spatially, the capability of adaptive array processors to cancel (null) the surface reverberation return from an active sonar is being studied. That return from the patch of sea surface illuminated by the sonar pulse is considered interference because it can be strong enough to mask returns caused by other reflectors of interest. Temporally, the applicability of adaptive high-resolution spectral analysis techniques to the Doppler sonar problem is being investigated.

Dr. Robert C. Tyce worked on data reduction for the Coherent Recombination Project, which involves multi-path arrival angle

determination for shot noise arriving at a 20-channel vertical array suspended beneath FLIP during an experiment. Through detailed ray trace modeling, arrival paths have been separated, and data analysis is proceeding to determine seismic velocity and attenuation as functions of depth in the thick sediments of an experimental site off Monterey, California.

For the Residual Noise Program, Dr. Tyce has developed a 1500-m-long array with 200 hydrophones and 20 microprocessor telemetry channels, inside a Kevlar fiber net 3 cm in diameter.

Dr. Tyce's research group also helped install and improve the Sea Beam multi-beam echo-sounding system on R/V *Thomas Washington*. Sea trials were successful, and the Sea Beam system is collecting excellent bathymetric data. Processing of the data is possible ashore and aboard ship, with contour maps being produced in a near-routine manner.

Activities of the Deep Tow Group included a cruise to examine two sites in the axis of the Middle America Trench, off Acapulco and off Guatemala, which had been targets of the Deep Sea Drilling Project. The Deep Tow operation, led by Drs. Peter F. Lonsdale and Gregory F. Moore, successfully photographed the seabed and collected high-resolution sonar images from a 6000-m depth for a detailed study of the structural framework and sedimentary environment of the areas.

As part of the MANOP project, Dr. Lonsdale used a submersible to dive on a field of manganese nodules in the Guatemala Basin, and into the calderas of young volcanoes near the crest of the East Pacific Rise. The dives were guided by previous Deep Tow surveys at these sites. Highlights of the dives into the volcanoes, which rise to summit depths of 2000 m, included discovering active hydrothermal vents discharging warm water, and sampling extensive copper and zinc-rich sulfide deposits exposed in the walls of pit craters. Dr. Lonsdale also mapped several other deep-sea volcanoes and an extensive section of the East Pacific Rise between 20°S and 3°S with the new Sea Beam echo-sounding system of R/V *Thomas Washington*. Sea Beam was used on a cruise from Tahiti to Panama to survey sites for future deep-sea drilling on the rise flank.

A short test cruise supported the development of the new Deep Tow acoustic backscattering equipment, and confirmed that the new Sea Beam sounding system operated effectively with the deep-tow and acoustic transponder navigation.

Dr. Victor C. Anderson is developing a remotely controlled undersea vehicle, which can operate on the ocean floor down to 6000 m below the surface. The vehicle incorporates new uses of materials and innovative design concepts. An example is the fiberglass hydraulic manipulator boom. Made of lightweight materials—aluminums and fiberglass-reinforced plastics—and using seawater as the hydraulic fluid, the boom has a very low in-water weight. The hydraulic pressure is supplied by a conventional deepwell centrifugal pump, and pilot-operated plastic sprinkler valves are programed by a microprocessor for delicate control of four rotary joints that determine the boom's shape and position.

Using a multiple opening-closing plankton net, Dr. Paul R. Greenblatt completed his studies of the horizontal variability of zooplankton biomass. Plankton hauls taken at 90 m during a four-day period showed evidence of day-to-night increase in zooplankton abundance. Variance-to-mean ratio for large copepods and euphausiids was higher at night than during the day, whereas the opposite was true for chaetognaths and pteropods. Many samples were also obtained with a 87.5-kHz sonar operating 87 m deep to provide information about volume scattering of marine organisms.

Neurobiology Unit

The Neurobiology Unit is associated with the Marine Biology Research Division and the Marine Biomedical Program. The common denominator of the group's work is neuroethology—the analysis of behavior and its neural basis, especially species-characteristic behavior that determines the place and success of a species in its ecological setting. Most work has involved fishes or crustaceans; however, some projects focused on the study of manatees, penguins, turtles, frogs, cephalopods, and gastropods.

Mary M. Hagedorn produced a thorough description of the annual cycle of concentration, dispersion, sexual differences in activity and electric organ discharge, and growth and predation in a species of electric fish in Panama. Graduate students William G. Wright and Alan L. Shanks worked out the factors that mediate site recognition in the fight-vs-flee decision of the territorial limpet, *Lottia*. Apparently *Lottia's* recognition of its own trail, and location-associated learning resulting from having been pushed

Fred H. Uhlman compares boom section of the remotely controlled undersea vehicle model to the real boom now under construction.

Ronald C. Horn and Dr. Victor C. Anderson examine a scale model of the remotely controlled undersea vehicle.

away by a larger limpet are combined as the animal chooses between evasive and aggressive responses. Dr. William Evans showed that a polar species of pinniped, the leopard seal, uses its unique form of vocalization—ultrasonic frequency-modulated tones and clicks—when engaged in exploratory behavior or when novel objects or live fish are put into its pool, suggesting the possibility of echolocation. Ann E. Bowles continued studying vocal communication in Adélie and emperor penguins, using recording and playback, and observing agnostic responses. Others in the unit studied field and laboratory behavior of sea slugs, crab larvae, sting rays, manta rays, and electric fish.

Another group of projects carried on by unit scientists centers on the anatomy of the brain. It is noteworthy that the field of comparative neurology—vertebrate as well as invertebrate—is in a renaissance, with greatly increased activity resulting from a whole battery of new experimental methods based on the metabolism of living nerve fibers. Several members of the unit have applied such methods to lower vertebrates. The techniques they have used include intracellular injection of dyes, extracellular injection of a peroxidase taken up by the nerve cell and distributed throughout its processes, and systemic injection of radioactive 2-deoxyglucose, which results in autoradiographs of regions that were stimulated. The results have yielded important information about the evolution of the brain in electric fishes, catfishes, carps, and rays, particularly regarding the pathways by which electric, auditory, and equilibrium senses project to the midbrain, cerebellum, and forebrain.

Electrophysiological recording from single nerve cells, from sense organs, and from populations of brain cells continues to be useful for testing whether a modality such as hearing or electroreception is present in a species. The recording further indicates what the parameters are for detectable stimuli, where the pathways and brain centers are for these sensory systems, and some of the dynamic properties of these cells and centers. Dr. Theodore H. Bullock and associates have used the population activity measure to determine the presence and properties of hearing in lampreys, sturgeons, polypteriform fish, and manatees, as well as to search for electroreception in myxinids, notopterids, pantodontids, cichlids, uranoscopids, synbranchids, and cyprinids. Electroreception was not found in most of this last list; however, absence is difficult to prove.

Both the population and the single cell activity measures were used to examine the responses of catfish cerebellum to input from the eye and forebrain. The effect of sex hormones on the electric organ discharges in *Sternopygus* was studied, and scientists found that male hormones decrease the frequency. Receptor potential and single cell recording were used to quantify the most effective frequency for stimulating the electroreceptors, for example, the receptor tuning, normally closely matched to the discharge frequency. The researchers found this hormone also lowers the "best frequency" of the tuning curve; this is the first breakthrough in respect to plasticity of receptor tuning, and opens up new questions.

Ocean Research Division

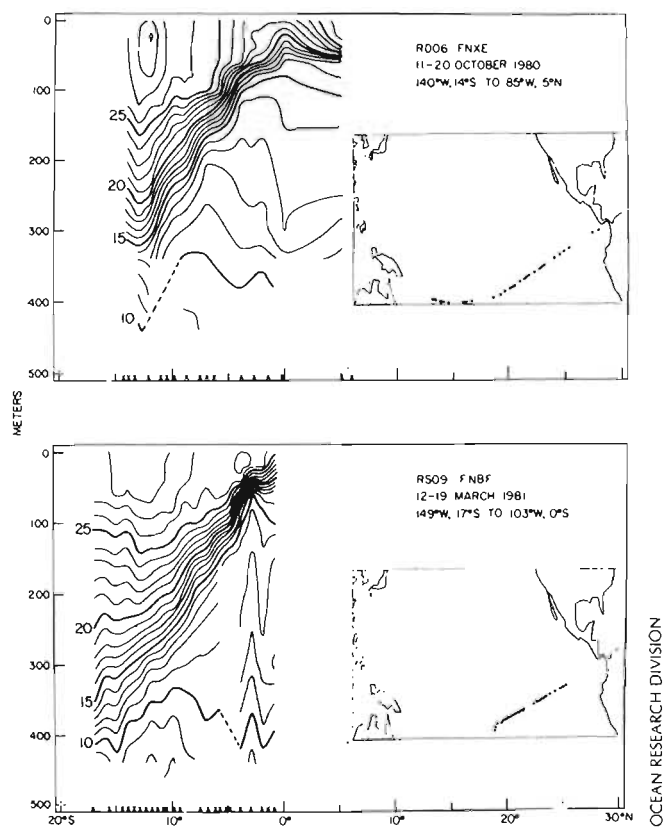
The Ocean Research Division (ORD) includes research of individual investigators in marine biology, marine chemistry, physical oceanography, and climatology. Despite the diversity of disciplines, each project is conducted in situ (in other words, in the ocean) and so is influenced by the others. For example, benthic ecologists are concerned about both the physical and chemical environment in which organisms live. ORD's investigators often take an interdisciplinary approach to their studies. This year's report focuses on only a few of the projects within ORD. Other research will be described in future reports.

Ocean Monitoring Group

Through a variety of physical processes, heat stored in the upper layers of the Pacific Ocean influences the short-period climatic changes of the United States and possibly of the globe. An international effort to monitor heat storage and to determine which processes are most important has been developing for many years. Drs. Warren B. White, Robert L. Bernstein, and Gary A. Meyers have assumed leadership in this effort by establishing an ocean monitoring system in which the temperature field is observed and mapped on basinwide scales. This is done by using a network of volunteer merchant vessels equipped with expendable bathythermographs. These merchant vessels are used because the region is too vast to be covered by other means.

Recruitment of new ships into the network has recently concentrated on transequatorial routes. The importance of equatorial temperature extremes caused by El Niño has been recognized for decades. Recently, the description and understanding of variability in the region has progressed rapidly. Observed patterns of variability have been interpreted in the context of hydrodynamic models in both the ocean and atmosphere. Even though past observations are too sketchy and the models probably too simple, the apparent convergence and synthesis of observational and theoretical studies have stimulated a need to observe the region in greater detail and more regularly.

Many of the ships on transequatorial routes stop at islands of the South Pacific. In order to use the ships effectively, France and the U.S. have set up a cooperative effort with financial support provided by both countries. The French Office de la Recherche Scientifique et Technique Outre Mer (ORSTOM) Centre de Nouméa, New Caledonia, maintains oceanographic research facilities in the islands. Dr. Jean-René Donguy, ORSTOM, and Dr. Meyers directed the initial phase of the field operations and data assimilation. Variability of the temperature field observed during the first two years was dominated by annual cycles. These cycles appear to be atmospherically forced by heat flux through the sea surface in some regions, and by the divergence of directly wind-driven currents in others.



Temperature (in centigrade at left) along the shipping route (insets on right) from Tahiti to Panama. Variability at the equatorial crossing plays a role in short-period climatic change in the U.S. and possibly around the globe.

James A. Schmitt repairs a CTD.

A temperature/pressure calibration is done on a CTD unit for the National Marine Fisheries Services by Robert T. Williams.

Frank M. Delahoyde adjusts plotter as it maps TTO data recorded by the CTD.

Physical and Chemical Oceanographic Data Facility

Technicians in the Physical and Chemical Oceanographic Data Facility (PACODF) completed a seven-month expedition in the North Atlantic after occupying 250 stations. This expedition, the North Atlantic Study of the Transient Tracers in the Ocean (TTO), was designed to sample a suite of anthropogenic constituents of seawater that are useful as tracers to verify models of oceanic circulation. These tracers—including tritium, krypton-85, carbon-14, argon-39, and halogenated hydrocarbons commonly known as freons—were produced by either nuclear devices or industry over a rather short, well-known period of time. Their concentrations in seawater tend to decrease rapidly, either through mixing processes or by radioactive decay. Thus the opportunity to measure some of their parameters will be available for a few decades at most.

In addition to the collection of samples for tracer measurements, PACODF produced a set of high-quality hydrographic data including measurements of temperature, salinity, dissolved oxygen, phosphate, silicate, nitrate, alkalinity, and total carbon dioxide. Continuous profiles of temperature, salinity, dissolved oxygen, and suspended particulates were also taken at all stations. Surface properties and meteorological parameters were recorded at one-minute intervals during the expedition.

Last year, the TTO work took PACODF personnel to the ice-covered waters of the Greenland Sea off Spitsbergen. In 1982 a joint U.S.-Canadian expedition set out for the same area, but in late winter rather than summer. The ship employed in this work was the Canadian research vessel CCS *Hudson*, operated by the Bedford Institute of Oceanography, Halifax, Nova Scotia. Joseph L. Reid was the senior American scientist aboard this cruise, which was designed to investigate water mass formation and modification, and the overall distribution of hydrochemical properties at the time when surface water density was at its maximum.

Climate Research Group

Dr. Tim P. Barnett investigated the interaction of the monsoon and Pacific trade wind fields and found that low-frequency modulations of the massive convergence over Indonesia lead to subse-

quent changes in the tropical Pacific (for example, El Niño). The results have clearly established the strong coupling between the two major wind systems and suggest that the tropical ocean responds to the atmosphere and not vice versa.

Dr. Barnett also identified an apparent pattern of global sea-level rise. Using estimates of rate of sea-level increase, he has been able to establish rates at which the earth's pole of rotation should be migrating if all sea-level change were caused by melting of the polar caps. The observed displacements of the pole of rotation are in remarkable agreement with these theoretical calculations. He concluded, therefore, that a prime cause of the observed changes in sea level over the last hundred years is the melting of both polar caps.

Dr. Jerome Namias and his group have extended their efforts in studying short-term climatic variability and associated air-sea interactions. A most interesting case, the development of the extensive North American heat wave and drought in summer 1980, has been analyzed from the standpoint of upstream and downstream influences in the North Pacific and North Atlantic, and compared with past occurrences of summer drought in the Great Plains. Also, the severe winter in North America and western Europe during 1981-1982 was described and discussed in a workshop hosted by the Climate Research Group. The invited experts diagnosed the fundamental causes, interactions, and impacts of the winter weather.

To develop seasonal forecasts two seasons in advance, Dr. Namias has employed a blend of physically based empirical and statistical methods, including oceanic indicators. The first four such experimental forecasts of seasonal temperature departure have been quite encouraging. An improved data set of monthly sea-surface temperature over the North Atlantic for the period 1949-1972 was constructed, and studies to examine the degree of coupling with the overlying atmosphere are under way. A continuing investigation of the seasonal variability of West Coast United States winter precipitation is aimed at understanding the development of extreme wet and dry years and improving seasonal forecasting techniques.

Dr. Geoffrey K. Vallis carried out numerical and theoretical research into the intrinsic limits of atmospheric predictability. The atmosphere, aside from being a highly turbulent fluid, is characterized by the presence of planetary, or Rossby, waves and by baroclinic instability. It is essentially the turbulent, or nonlinear, aspects that limit our ability to forecast details of atmospheric conditions beyond a few days. Dr. Vallis's work is concerned with the extent to which the linear properties of wave propagation and instability modify atmospheric predictability. He found that wave propagation acting alone will extend the period of useful forecasts because of the inhibiting effects of wave motion on nonlinear energy transfer, but that baroclinic instability significantly reduces the inherent forecast limits even in the presence of wave activity. Dr. Vallis has also used idealized models of the climate system to study the effects of cloud feedback in climate change. Preliminary results suggest that only small changes in cloud cover are caused by changes in temperature, except in polar regions where surface albedo may significantly change.

Dr. John O. Roads carried out theoretical research on the forced, linear, stationary-wave response to diabatic heating and mountains in numerical models of the atmosphere. The models extend from the surface to 100 km and include multilevel and spherical barotropic models. One interesting finding of this research is that blocks and stratospheric warmings may be related to large-amplitude persistent regimes of atmospheric circulation.

Research was also initiated by Drs. Roads and Vallis on the diagnosis and parameterization of clouds in large-scale models. As a first step, they constructed a simple energy-balance climate model in order to describe the surface boundary's influence on low-level cloudiness.

Dr. Richard C. J. Somerville and Dr. Roads have investigated the predictability of the large-scale waves in global barotropic models. Solutions in global and hemispheric models were examined to determine how the incomplete set of waves in the hemispheric models would give rise to errors on short time scales. Further work with global models is in progress to determine if the presence or absence of satellite-observed winds in the tropics can affect short-range weather forecasts.

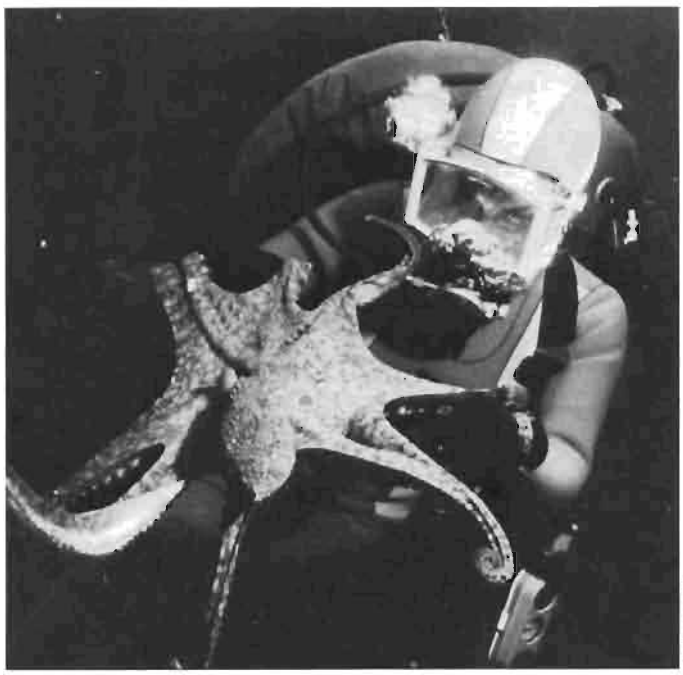
Dr. Somerville, in collaboration with Dr. David H. Hathaway, Sacramento Peak Observatory, New Mexico, carried out a theoretical study of thermal convection. They considered a layer of fluid uniformly heated from below and subject to rotation as an extremely idealized model of small-scale convection that can drive large-scale average motions. The three-dimensional, time dependent flow in the layer was simulated by numerical solution of the Boussinesq equations, including all Coriolis terms. At high latitudes, rotation reduces the horizontal scale of convective elements and decreases vertical heat flux. In the tropics, rotation elongates the cells and produces opposite mean flows near the surface and aloft, together with equatorward fluxes of heat and angular momentum.

Benthic Ecology Group

Dr. Paul K. Dayton's group of benthic ecologists is focusing on organisms in nearshore habitats. Dr. Dayton has completed his long-term studies of patch dynamics and stability of southern California kelp forest communities. He evaluated the persistence, inertia, and resilience of patches composed of turf and kelps with prostrate, stipitate, or floating canopies. Dr. Dayton also continues to analyze data from his long-term Antarctic research program.

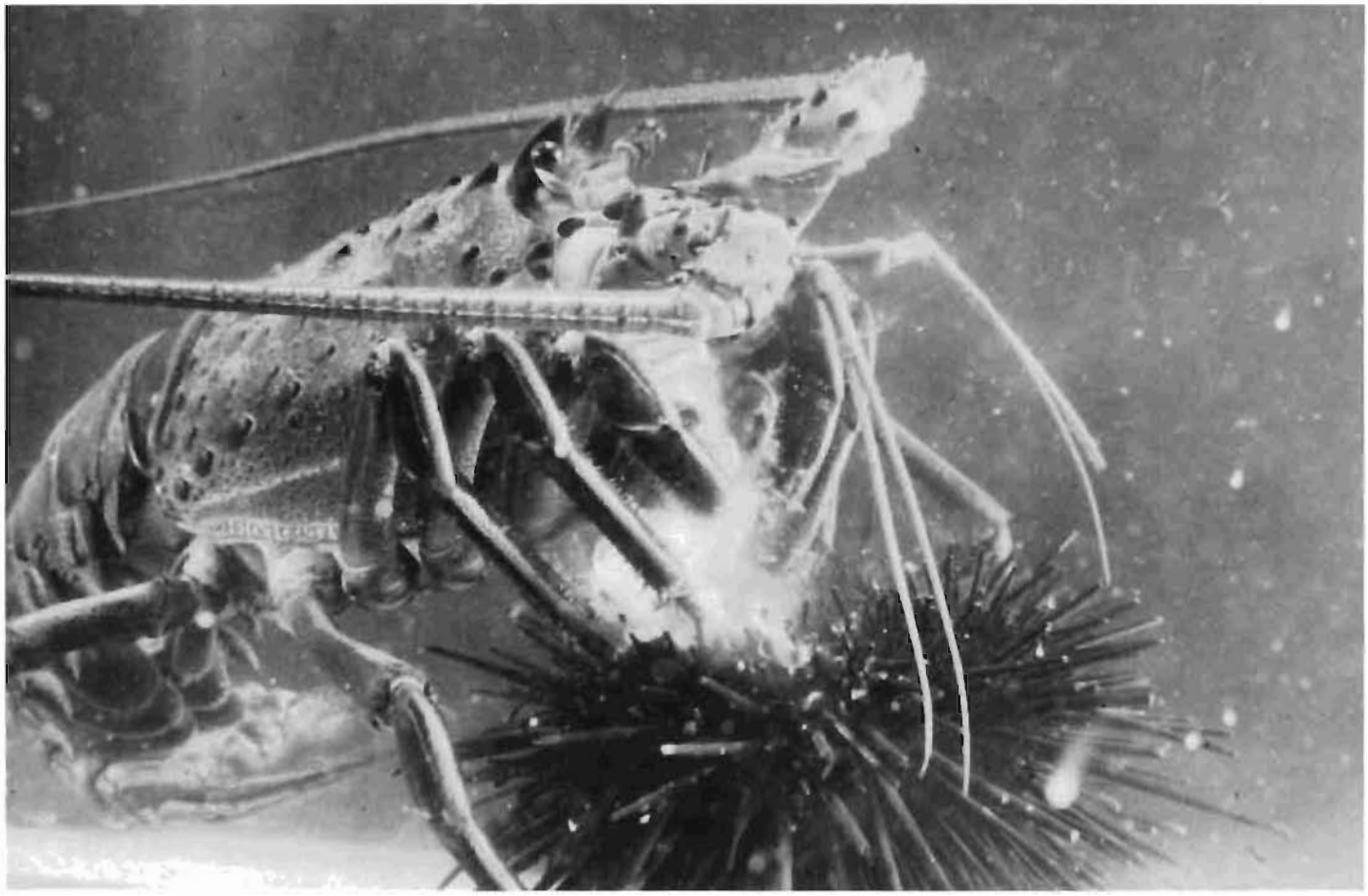
Dr. Mia J. Tegner's research is centered on the major herbivores of southern California kelp forest communities—sea urchins and abalones. The most important sea urchin predators are spiny lobsters, *Panulirus interruptus,* and the California sheephead, *Semicossyphus pulcher,* which are both subject to commercial and sport fisheries. Gut content studies indicate that sea urchins are the primary food of sheephead in this area, but laboratory experiments demonstrate that lobster predation can create the red urchin population structure observed in the field. In an attempt to determine the relative importance of these two predators, sheephead are being removed from a reef near Point La Jolla.

Dr. Tegner and her associates have also been studying the factors controlling abalone populations, to determine the scientific and economic feasibility of enhancing severely depleted populations of this valuable mollusc. The slow recovery of green



E. HANAUER

Dr. Mia J. Tegner grapples with an octopus.



A spiny lobster, Panulirus interruptus, *attacks a red sea urchin,* Strongylocentrotus franciscanus, *through the short-spined region around its mouth.*

abalone *(Haliotis fulgens)* populations near Palos Verdes, California, suggested that this species is limited by poor larval dispersal from healthy populations. The results of a drift-bottle experiment supported this hypothesis. Red abalone *(H. rufescens)* populations at Palos Verdes appear to be limited not by recruitment but by high predation rates on two-to-three-year-old animals. A study of native and hatchery-reared red abalones suggests that octopus predation is controlling the recovery of this species.

Graduate student Lisa A. Levin completed her research on the life history and dispersal patterns of the infaunal polychaete community at the Kendall Frost Marsh Preserve in Mission Bay, San Diego. She concluded that successful species in isolated back-bay habitats are those with life-history characteristics conferring reduced dispersal ability. Even when life-history features confer potential for long-distance dispersal, local circulation patterns in Mission Bay limit larval movements. She found that both juvenile and adult stages may play an important dispersive role. Life history and mobility patterns enable the Kendall Frost species to respond rapidly to disturbance and maintain high infaunal densities.

The ecology of temperate, subtidal, encrusting communities where sponges dominate is the subject of graduate student Janice E. Thompson's research. She is examining individual and group defense mechanisms against propagule settlement on sponge surfaces and adjacent free space. Thompson has demonstrated that sponges exude allelochemicals into seawater at rates sufficient to inhibit local propagule recruitment, and that multispecies combinations of waterborne allelochemicals are more effective than those of a single species. Concurrent research examines the secondary use of these chemical weapons by opisthobranch predators. Much of this research has been done in collaboration with natural-product chemists Dr. D. John Faulkner and his associates.

Graduate student Robert K. Cowan is observing the feeding ecology of the sheephead, *Semicossyphus pulcher,* and the fish's varying importance as a predator in different geographical locations. The effect of sheephead's feeding on a given community varies as a consequence of the prey's relative importance within that community, which varies geographically. Cowan is also examining the effect of the environment on sheephead biology. He is attempting to learn why some populations of these fish appear to have slower growth rates than others and what the consequences are for reproduction.

Physiological Research Laboratory

The physiological and biochemical adaptations of aquatic and terrestrial animals constitute a central research theme at the Physiological Research Laboratory. Laboratory scientists engage in cooperative projects with the UC San Diego School of Medicine and other domestic and foreign institutions.

Studies of free-ranging behavior and physiology of marine birds and mammals continued in Dr. Gerald L. Kooyman's group. Basic hydrodynamic characteristics such as drag forces under various conditions were determined for seals. This information aids in assessing the power requirements and efficiency of swimming animals.

Dr. Randall W. Davis studied the source of power, investigating the metabolic pathways of resting and diving seals. The acquisition and transfer of energy was the main emphasis of Dr. Daniel P. Costa's studies of lactation and cost of feeding in female fur seals and elephant seals. He observed the animals in their natural habitats near Año Nuevo Island, off Año Nuevo Point, California, and the Pribilof Islands, Alaska. These various studies of the physical characteristics and metabolic requirements of aquatic animals are being incorporated into a broad analysis of

how available energy is used. Detailed dive records for several species of marine mammals have been obtained. These records are being used to study the animals' preferred dive depths and durations, as well as their limitations.

Dr. Harold T. Hammel, James E. Maggert, and two West German scientists continue to explore how changes in the body fluids of marine birds affect their salt-gland secretion. Recent work has shown that changes in the interstitial fluid have a major effect.

Studies on circadian and seasonal metabolic cycles continue in the laboratory of Dr. Fred N. White. Torpid, sleeping, hibernating, or aestivating animals exhibit low metabolic levels associated with carbon dioxide retention and increased acidity of body fluids. The laboratory group has shown that the carbon dioxide retained during such states is responsible for a substantial fall in metabolism either through direct effects of carbon dioxide or indirect effects on acidity. Circadian or seasonal rhythms of carbon dioxide levels in body fluids have been found in snails, reptiles, and mammals—including man—during sleep. The phenomenon of cyclical alterations in acid-base status of the body fluids thus occurs widely in animals and may play an important role in the biochemical energetics of organisms.

Dr. Jeffrey B. Graham continued investigating the physiology of albacore tuna on board the Southwest Fisheries Center's *David Starr Jordan*. Dr. Graham and a colleague obtained the first estimates of oxygen consumption of swimming albacore, which have a metabolic rate more than twice that of other active fishes like sockeye salmon. The metabolic rate of albacore increases in proportion to weight raised to a power of 1.18, a value that is much higher than that found in most other fish species. Dr. Graham and two graduate students completed a comparative study of the body muscle systems of scombrid fishes (tunas and mackerels) to determine how the maintenance of endothermy by tunas has affected the design of their locomotor muscle system. Tunas, unlike all other fish species, have their red muscle (the portion of each myotome that principally powers sustained aerobic swimming) located anteriorly in the body and deeply, adjacent to the backbone. In other species, including ectothermic scombrids such as bonito and mackerel, this muscle is located posteriorly and along the flanks of the body. Results of this study suggest that muscle efficiency is greatly enhanced by endothermy. As body size increases, both drag and the power needed to swim increase. In ectothermic scombrids relative red muscle mass increases with body size, whereas in the five examined species of tunas it decreases.

Dr. Edvard A. Hemmingsen and a graduate student investigated gas bubble formation in biological liquids, single cells, and primitive organisms to better understand the early etiology of decompression sickness. One objective is to assess the notion that preformed gaseous nuclei may play a role in initiating bubbles in organisms. The results obtained indicate that such nuclei are far less prevalent than generally assumed, and that bubbles may form spontaneously at only a few atmospheres of gas supersaturation.

Dr. A. Aristides Yayanos and his colleagues studied the effects of temperature, pressure, and ionizing radiation on marine bacteria. The bacteria originated from depths between 2000 and 10,500 m in the North Pacific Ocean. The researchers have established that the bacteria are barophilic—growing best or exclusively at pressures greater than atmospheric. The degree of barophily is, indeed, somewhat correlated with the depth (and hence the pressure) of origin of the bacteria. Results have also shown these bacteria to be ubiquitous in the ocean at depths greater than 1400 m. The characteristics of barophily and of psychrophily—preference for low temperatures—serve as hallmarks of the bacteria that are true inhabitants of the deep sea. It may thus be possible to distinguish true inhabitants from bacteria entering the deep ocean from shallower waters.

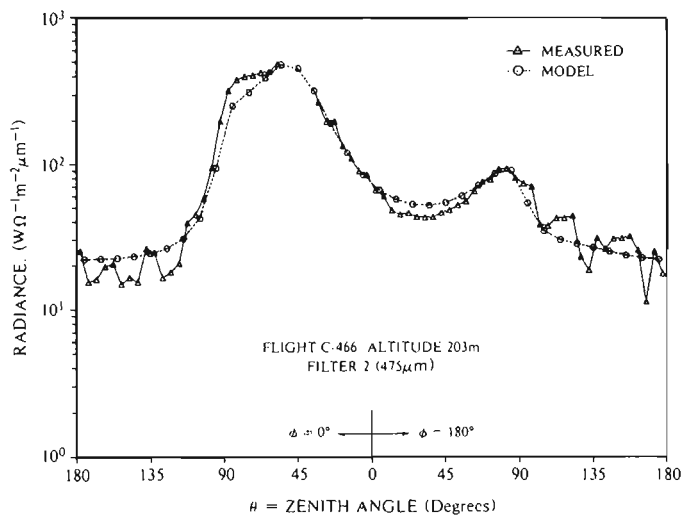
The sensitivity of deep-sea life to ionizing radiation has never before been directly studied. Understanding the growth physiology of deep-sea bacteria under simulated deep-sea pressures and temperatures now allows for a systematic investigation of their radiation biology. Researchers determined the loss of viability in cultures exposed for various times to gamma rays. Deep-sea bacteria are nearly as radioresistant as are shallow-water bacteria. The radioresistance of bacteria is inversely proportional to their depth of origin.

Visibility Laboratory

Scientists at the Visibility Laboratory continue to study the optics of the atmospheric and oceanic environment, the digital processing of image information, and the optical remote sensing of the oceans.

Richard W. Johnson's group has been working to understand and predict atmospheric effects on the propagation of visible and infrared radiation through the lower troposphere. This research has proceeded from the clear-day meteorological state toward the more difficult regime of turbid and cloudy atmospheres.

Techniques for predicting the atmospheric effects on visible image transmission have been improved and extended by Wayne S. Hering. His computationally fast model calculates changes in the sun, sky, and terrain radiance distribution and the directional contrast transmittance distribution resulting from changes in the multiple scattering and absorption properties of atmospheric aerosols. Hering has developed model algorithms to estimate the atmospheric propagation effects from conventional weather observations and forecasts. Model development and validation are based on an extensive series of coincident optical and meteorological measurements gathered by laboratory scientists. These measurements were collected in the United States and western Europe with instruments on board a plane and on the ground.



A comparison between measured and model calculations of sky and terrain radiance. Flight was under clear sky over farmland with a solar zenith angle of 48°.

Dr. Bruce W. Fitch is analyzing tropospheric and surface aerosol size distributions to identify and classify the typical characteristics occurring within his extensive set of airborne and ground-based measurements. The use of the aerosol volume distribution (for example, the use of particle volume—or mass—as opposed to particle diameter) as the display format illustrates a commonly recurring middle-mode distribution located in the vicinity of 1-m particle radius. Researchers hope to understand the source mechanisms related to this middle-mode distribution in order to identify the characteristics as a local or regional artifact.

Johnson is directing the development of specialized instrumentation to support studies in atmospheric effects. An ingenious, yet uncomplicated, electro-optical system has been devised for

real-time monitoring of the atmosphere's optical state. The system is built around three solid-state transducer assemblies interfaced with a microprocessor. The basic components are a compact, multichannel nephelometer and two staring fisheye scanners.

The vertical and horizontal distribution of the optical properties of North Atlantic waters was studied by Roswell W. Austin, Gerald D. Edwards, Jeffrey W. Nolten,and Albert L. Chapin. They obtained vertical profiles of the optical and related physical and biological properties of the upper 200 m of the ocean at 21 stations along a 9600-km trackline while on board USNS *Bartlett*. Continuous along-track data on surface pigment concentration were taken to provide longitudinal scale information on surface optical properties. Initial processing of this extensive station data set was used to model the vertical distribution of the optical attenuation coefficient and integrated loss to depth. The model relates these properties to the surface attenuation, which may be inferred from optical remote sensing.

The Coastal Zone Color Scanner (CZCS) remains vital for optical remote sensing of the oceans. Austin is developing algorithms to remove atmospheric effects on the signal received by the satellite sensor. Theodore J. Petzold conducted a corollary study of an apparent change in the sensor's sensitivity, using data received at the Scripps Satellite-Oceanography Facility over the 45-month life of the sensor. This study identified the magnitude and temporal nature of changes in the several spectral channels. Consequently, the useful life of this unique sensor can be significantly extended.

Benjamin L. McGlamery used the image data from the CZCS to develop a computer library of optical attenuation properties of ocean waters. This data base will provide a unique resource to optical oceanographers requiring knowledge of the spatial distribution and temporal variability of ocean optical properties. These data are also of interest to those who study the heat budget of surface waters, and to biological oceanographers, for the open-ocean optical properties are uniquely coupled to chlorophyll-like pigment concentration.

Center for Coastal Studies

The Center for Coastal Studies serves as an organizational focus for research in coastal dynamics. The center incorporates the Shore Processes Study Group, Scripps Hydraulics Facility, and the Marine Archaeology Program. Scientists in the Shore Processes Group are concentrating on field experiments and selected theoretical and modeling studies to clarify the complex interactions of waves, winds, and currents with each other, the sedimentary boundaries, and run-off products from the land.

Dr. Douglas L. Inman, director of the center, continues to study the wave climate and sand erosion and transport processes in the Nile Littoral Cell extending from Alexandria, Egypt, to north of Haifa, Israel. This work is part of the cooperative marine technology program for the Middle East sponsored by the U.S. Agency for International Development.

On the local coastline, Dr. Reinhard E. Flick and an associate expanded their coverage of coastal beach profiles to include the southern California cities of Oceanside and Carlsbad. A program at Del Mar has yielded background information on natural beach fluctuations that will be useful for assessing the performance of the Longard Tube erosion control device installed in early 1981.

In detailed studies on nearshore waves, Dr. Robert T. Guza and graduate student Joan Oltman-Shay are investigating the dynamics of oscillations with periods of several minutes. These motions, known as surf beat, can have velocities exceeding 50 cm/sec and may contribute substantially to beach erosion during storms. Data from arrays of current meters in the surf zone are being analyzed to determine the distribution of surf beat energy in frequency-wavenumber space, and the relationship between surf beat and higher frequency wind waves.

Drs. Clinton D. Winant and Russ E. Davis continue their participation in the Coastal Ocean Dynamics Experiment (CODE), a study of wind-forced coastal currents and related dynamical balances. This year the research program is in its second stage, directed toward acquiring field observations of winds, currents, and other variables of dynamical importance. CODE is an experiment involving investigators from Scripps and four other institutions. Drs. Winant and Davis are acquiring and analyzing current-meter and drifter data. The experimental phase of CODE is completed, but a data analysis and integration phase continues.

The Innovative Sediment Management Group, under the direction of Dr. Scott A. Jenkins, completed a five-year research effort on the sediment barrier curtain at Mare Island Naval Shipyard in northern California. The curtain was designed to passively alter the tidal circulation in a berthing area partially enclosed by finger piers. The sedimentation rate was successfully reduced by 70% with no effect on ship movements. Flow dynamics at Charleston, South Carolina; Mayport, Florida; and Kings Bay, Georgia, are being studied to determine the applicability of barrier curtains and other sediment management systems developed by the group.

Activity at the Scripps Hydraulic Facility centered around construction of the Stratified Flow Channel. The new channel greatly enhances research capability by providing for steady flows of up to 1.4 m/sec in each of two layers of constant but different temperature and salinity. The overall length of the channel is 30 m, with a 16-m test section, and 1.1-m-square cross section. In addition, the test section can be tilted by 1° along its axis to simulate gravity effects for sedimentation studies. The channel was constructed with funds provided by the Fleischmann Foundation.

The center's Marine Archaeology Program is under the direction of Dr. Patricia M. Masters, who organized an international symposium on topics related to human settlement of the continental shelf during periods of low sea levels and migrations over land-sea bridges into previously uninhabited land areas. Sixty-eight participants (including 31 invited speakers) from the U.S., Canada, Australia, Europe, Israel, and the USSR discussed information from coastal archaeological sites, marine geology, shore processes, and sea-level chronology. This symposium was the first interdisciplinary conference on continental shelf prehistory.

Deep Sea Drilling Project

The past year has been one of accomplishment for the Deep Sea Drilling Project (DSDP). In the 14th year of operation with drilling vessel *Glomar Challenger*, it is rewarding to see the continuing and accelerating currents of scientific knowledge and international cooperation that flow from the work.

After more than half a decade of worldwide exploratory drilling, the emphasis of DSDP shifted to a thematic series dealing with ocean crust, oceanic paleoenvironments, and active and passive margins.

Scientists on board leg 80 of the DSDP cruise studied the nature, age, and subsidence history of the continental and oceanic basements near their juncture, and documented the significance of sediments deposited during and after the rifting of the Bay of Biscay. They also studied and dated a series of unconformities that separate seismic sequences across the margin.

The Bay of Biscay was opened as a small ocean basin, connected to the then narrow Atlantic, by the counterclockwise rotation of Spain away from France, about 150 million years ago. The Goban Spur, the particular feature drilled in the northwestern Bay of Biscay, exhibited a stepwise series of tilted and subsided blocks. Drilling reached into the original old continental material on two of these blocks nearest land. A third drilling, clearly seaward of the zone of stretched and subsided continental edge, confirmed the presence of oceanic basalt crust. Surprisingly, a fourth site, drilled on the outermost tilted block (expected to be continental material) was terminated in basalt; careful studies will be made to determine if this basalt is characteristic oceanic crust basalt.

By drilling two holes into deeply submerged and buried blocks of old continental material, scientists recovered the post-uplift erosional surface—a pebbly, iron-rich zone bored by marine, rocky-shore organisms. The burrows of these organisms are filled with the much younger (100 million years old) sequence of the Bay of Biscay-Atlantic Ocean sediments.

Studies such as those carried out during leg 80 examine characteristic but accessible ocean-continent margins to determine the timing of their geometric and sedimentary development in response to events and processes deep in the earth and in response to global oceanographic and climatic changes. The studies thus integrate knowledge of the factors responsible for oil and gas formation; this information becomes applicable to other areas in which conditions, such as much thicker sediments, are more favorable for the formation of reservoirs of oil and gas. Such knowledge aids the petroleum industry in its explorations.

The deeply foundered Rockall microcontinent in the mid-North Atlantic between Greenland and the British Isles was studied by *Glomar Challenger* scientists during leg 81. Eight holes were drilled at four sites forming a transect across the west margin.

Results from the cruise show that the edges of the microcontinent, now 2500 m below sea level, lay at, or close to, sea level some 52 million years ago. At that time, Greenland and Rockall formed a single continent. Before the continents drifted apart, volcanic eruptions produced vast floods of lavas and sediments that accumulated as thick as 4 km in perhaps only 500,000 years.

Results of the studies demonstrate that intense volcanism probably took place in a 3-million-year-long interval over the 2000-km length of the continental margins of Greenland and northwestern Europe. Comparable features now thought to be present also off the eastern U.S., southwestern Africa, southern Australia, and Antarctica suggest that the phenomenon may have been extremely widespread during the initial rifting of the continents.

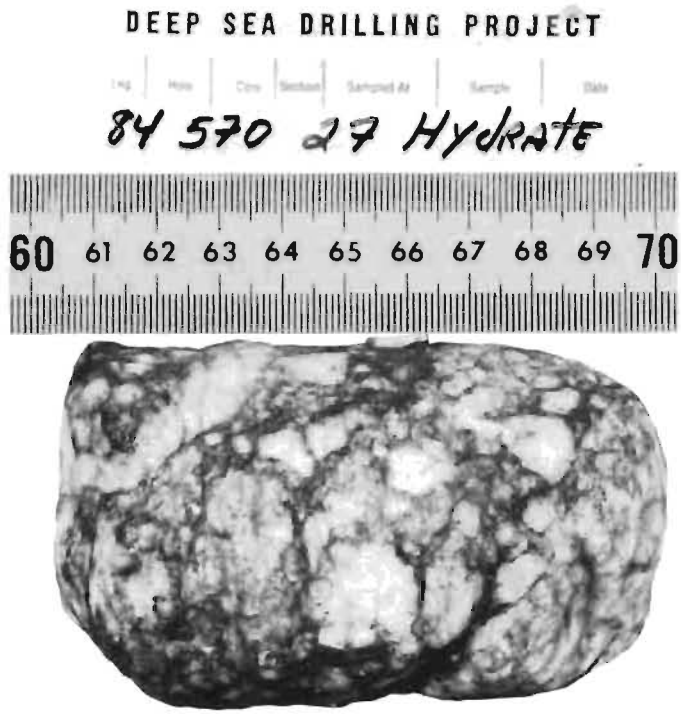
During leg 82 *Glomar Challenger* researchers drilled nine sites on the west flank of the Mid-Atlantic Ridge west and southwest of the Azores. The major objective of this leg was to map the boundary between "abnormal" basalts related to the Azores topographic high and "normal" basalts formed in a more typical mid-oceanic ridge setting. Trace element abundances now indicate that this boundary is complex, even involving interlayering of varieties in the same hole. Evidence was found for downflow of seawater into the crust after the sediment cover was pierced by drilling. Such downflow had been observed before, and circulation of seawater through the crust, including some extremely hot circulation, is becoming an important field of study.

Perhaps the most unexpected result was the recovery of gabbros and serpentinites—rocks normally expected from very deep in the crust—from less than 100 m penetration. The drilling on leg 82 suggests that the crust in the Atlantic is structurally more complicated than previously supposed.

Workers aboard during leg 83 broke all previous records for DSDP penetration into oceanic basement by deepening hole 504B in the eastern Pacific to 1350 m beneath sea floor—1075 m into basalt. The leg 83 staff cored from the base of the pillow lavas, through a transition zone, and then nearly 300 m into the sheeted dikes and massive units of Layer 2C. Hole 504B is located on 6.2 million-year-old crust with conductive heat transfer; bottomhole temperatures were approximately 160°C. Evidence was found for several states of hydrothermal alteration, at temperatures as high as 300°C. In the transition between pillows and dikes, scientists cored a mineralized stockwork with pyrite crystal up to 1 cm across—possibly analogous to economic hydrothermal ore deposits formed in ophiolites.

An extensive suite of geophysical experiments documented for the first time the division of the basaltic layer into Layers 2A, 2B, and 2C.

Work done during leg 84—near the active margin of the Mid-America trench off Guatemala and Costa Rica—confirmed the existence of the igneous continental framework of Central America to the base of the landward trench slope, and demonstrated the absence of recent accretion in this convergent margin. Ophiolitic rocks were recovered at seven holes. The basement drilled is not a product of the present convergent margin, rather it represents older ocean crust, tectonized and emplaced more than 70 million years ago.



DEEP SEA DRILLING PROJECT

This massive methane hydrate was recovered during leg 84. Water and methane combined to form a solid (like packed snow) at high pressure and low temperature. At room temperature and pressure the hydrate would melt–yielding more than 100X its volume in the gas methane.

Gas hydrate was visibly recovered at three sites and detected at five of the six sites drilled on leg 84. At Site 570, a spectacular 1-m core of massive white hydrate was recovered from a 3-m-thick unit. Physical properties of gas hydrates were measured and logged.

Legs 85 and 86 were designed as stratigraphic/paleoenvironmental transects. The hydraulic piston corer recovered undisturbed Cenozoic sediments in the equatorial Pacific Ocean and the northwestern Pacific. These sediments are sensitive recorders of the interplay between tectonism, oceanic circulation patterns, fluctuations in biological productivity, dissolution, and diagenesis. The research on the cores includes high-resolution biostratigraphy; magnetostratigraphy; and carbonate, seismic, and stable isotope stratigraphy. The results should give more insight into oceanographic circulation, the effects of glaciation, the closing of the Isthmus of Panama, the origin of fine-scale cyclicity in the sediments, evolution of microorganisms, diagenesis of siliceous and carbonate sediments, and the significance of one abrupt transition between the Cretaceous and the Tertiary.

Leg 86 researchers also successfully tested a new Woods Hole Oceanographic Institution-designed miniaturized, microprocessor-based, heat-flow probe that fits into a cavity in the wall of the core cutter and can collect a temperature reading with every core.

The National Science Foundation recognized the value of scientific ocean drilling by passing a resolution to establish an Advanced Ocean Drilling Program, and to seek continued international scientific participation and financial support. DSDP's work is based on the scientific planning of the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), a group of U.S. and foreign institutions organized to foster and plan scientific ocean drilling.

Geological Research Division

Studies in the Geological Research Division cover almost every aspect of geology. This year scientists concentrated on the geology, geophysics, and geochemistry of deep-sea hydrothermal vents. They also worked on earthquake prediction and plate tectonics, and installed a seismometer inside a Deep Sea Drilling Project borehole.

Drs. John A. Orcutt and Thomas H. Jordan and graduate student Richard G. Adair participated in a pioneering experiment to install a seismometer in a deep-sea borehole. The seismometer was placed in a 5-year-old hole drilled as part of the Deep Sea Drilling Project. The instrument was inserted over half a kilometer into the oceanic crust; it recorded data for more than a day. The data revealed important information about sea floor noise and the elastic structure of the complex Atlantic crust.

The properties of the oceanic crust-mantle transition were investigated by Dr. Orcutt and graduate student Kevin R. MacKenzie. They used seismic refraction and reflection data and found the region to be very transitional, and similar to many exotic ultramafic rock bodies emplaced on continents and believed by many to be remnants of ancient oceanic crust. Dr. Orcutt and graduate student Marilee Henry exploited their new seismic stacking algorithm to study the complex data collected in a forearc basin in southeast Asia by other investigators in the division. A newly developed seismogram inverse method was used by Dr. Orcutt and graduate student Peter R. Shaw to understand details of compressional and shear velocity structure near Great Slave Lake, Canada. Working with graduate student Mark A. Riedesel, Dr. Orcutt has further delineated the vertical structure of the volcanic magma chamber underlying the East Pacific Rise near the famous hot-water vents at 21°N.

In January Dr. Peter F. Lonsdale led an international group of geologists, geochemists, and biologists on a diving expedition to the active hydrothermal field in Guaymas Basin, Gulf of California, which had been mapped in 1980. During 10 dives with Woods Hole Oceanographic Institution's DSRV *Alvin* to the 2000-m-deep sea floor large quantities of metal-rich mineral deposits, vent animals, and discharging water (at up to 315°C) were collected. A distinctive feature of this deep-sea vent area is that many of the hydrothermal fluids and precipitates are rich in petroleum, which has been recently produced at high temperatures in the young underlying sediments.

Dr. Yu-chia Chung has been working on geochemistry and radioisotopes of the East Pacific Rise (EPR) hydrothermal system, including hydrothermal fluids and precipitates; and on earthquake prediction in southern California by monitoring radon, helium, and other dissolved gases in groundwaters. Some selected EPR hydrothermal vents collected by *Alvin* were sectioned in millimeter scale to measure detailed Pb-210 and stable Pb profiles. Large concentration variations were observed among different vents and also within each vent. The Pb-210 activities generally decrease exponentially from the surface to the interior of the vent wall, suggesting a fairly uniform outward growth rate of about 0.1 mm per year, assuming the Pb-210 flux to be constant. However, stable Pb measurements indicate a variable rather than a constant flux. The ages of chimneys estimated from Pb-210 data are probably an upper limit. This project was in collaboration with Dr. Robert C. Finkel.

Dr. Harmon Craig and the members of the Isotope Laboratory continued their studies of mantle volatiles in the oceans and oceanic margins. Their main effort was with *Alvin* dives at the 21°N EPR hydrothermal vent field. Graduate student Kyung-Ryul Kim and Mexican scientist Dr. Sergio Mercado were in the submersible when a new vent field—named "Hanging Gardens" for ts florid display of tube worms—was discovered. On this set of dives, three of the hydrothermal vent fish were captured and brought back to Scripps. Dr. John A. Welhan participated in the dives and measured gas concentrations; for the first time, he found higher hydrocarbons in the vent fluids. Following the dives, Kim and Dr. Craig collaborated with Dr. Yoshio Horibe, Tokyo University, to search for vents in the Mariana Trough while on board R/V *Hakuho Maru*. Kim measured methane concentrations while aboard the ship and conclusively demonstrated the pres-

A view into the projector housing for the Sea Beam system after it was attached to the hull of R/V Thomas Washington *in dry dock. (bottom) Workmen fitting the cover onto the Sea Beam hydrophone housing on the hull of R/V* Thomas Washington.

ence of active hydrothermal vents in this off-ridge area, the first time such activity has been seen.

Robert J. Poreda mapped high concentrations of mantle helium 3 in the Aleutian Islands. Dr. William Rison measured high helium 3 to helium 4 ratios in rock samples from Samoa, showing that Samoa is yet another "high helium 3" plume, the third oceanic area thus discovered. Dr. Chun-chao Chou and Dr. Craig continued their studies of polar ice cores, showing that methane contents in the trapped air in polar ice, back to 30,000 years old, are about half the amounts in present-day air.

Dr. Robert D. Willis of the Isotope Laboratory continued his work at Oak Ridge National Laboratory to develop an ultrasensitive noble gas detector with isotopic selectivity. Applications of the laser-based detector include measurements of ^{39}Ar in ocean water and ^{81}Kr in polar ice and groundwater samples.

Dr. Devendra Lal is currently studying the cosmogenic radionuclides ^{10}Be in marine sediments to answer questions relating to (1) influx of ^{10}Be to oceans caused by melting of polar snow, and (2) changes in global production of ^{10}Be resulting from changes in the dipole magnetic field of the earth and other causes (for example, a nearby supernova event). Dr. Lal and his associates carried out these studies using both the conventional beta-counting method and the newly developed accelerator dating method. The intercomparison of the two methods was very instructive. Using these results, scientists are beginning high-sensitivity ^{10}Be studies in sediments and nodules.

Studies on ^{10}Be in a well-preserved box core from the North Atlantic indicate influx of a significant amount of ^{10}Be from meltwaters during the Holocene interglacial; the excess signal amounts to 18% after corrections for variations in $CaCO_3$ content and for changes in magnetic field intensity during the period of sedimentation. This work was performed in collaboration with Dr. Wolfgang H. Berger.

A 1.4-m long, 13-cm diameter sediment core from the Central Equatorial Pacific was examined for ^{10}Be activity. Power spectrum analysis (maximum entropy method) revealed distinct periodicities of 0.2, 0.3, and 0.5 million years. The cause of these variations has yet to be ascertained.

The measurements of ^{32}Si activities in ocean water samples in vertical profiles collected during the Atlantic, Pacific, and Indian Ocean GEOSECS expeditions are continuing. Data on three Atlantic profiles were completed this year. The work is being performed in collaboration with Dr. Craig.

Dr. Richard N. Hey and associates continue their research into both fine-scale and large-scale plate tectonic evolution. They have completed their analysis of the Juan de Fuca area, off Washington and British Columbia, and are presently extending their investigations. Dr. Hey and graduate student Martin C. Kleinrock are investigating the large-scale tectonic evolution of the North Pacific. It appears that many of the great Pacific fracture zones (as well as smaller ones) were terminated by rift propagation, and there is evidence that at least some may originate this way. Other current investigations include the so-called Easter plate, which appears to be a manifestation of rapid and large-scale rift propagation; the evolution of the East Pacific Rise/Gulf of California spreading system; and a Sea Beam/Deep Tow investigation (in collaboration with Dr. Fred N. Spiess and others) of the Galápagos 95.5°W propagating rift system.

Dr. Gregory F. Moore began a study of tectonic and sedimentary processes in the Middle America Trench. On leg 1 of Pluto Expedition, Drs. Moore and Peter F. Lonsdale conducted small-scale surveys of the lower trench slope off Guatemala and Mexico with the Deep Tow instrument package. Dr. Moore returned to these sites on leg 3 of Ariadne Expedition with Dr. Thomas H. Shipley. They used the new Sea Beam system to map the bathymetry of the trench slope and also collected digital seismic reflection data to define the structure and sediment distribution. Dr. Moore also continued his work on the tectonics of northeastern Indonesia and the southern Philippines with Dr. Eli A. Silver of UC Santa Cruz and Dr. James W. Hawkins.

Drs. Joseph R. Curray, Moore, and their associates continued work in the northeastern Indian Ocean, including the Bay of Bengal, the Andaman Sea, and the Sunda Arc seaward of Sumatra and Java and to Sumba, Indonesia. They analyzed regional data from the RAMA Expedition and many earlier Scripps expeditions. They carried out studies on many aspects of this area, including current channels in the Bengal Deep Sea Fan; the anomalous gravity field over the buried 85°E ridge in the western Bay of Bengal; trench sedimentation models for the western Sunda Arc; a reinterpretation of magnetic anomalies and the history of opening of the Andaman Sea; and characteristics of the plate convergence and the accretionary complex of the Sunda Arc. Graduate student Naomi Benaron completed work on forearc geophysical studies of basement rocks south of Java. Graduate students Desiree Beaudry and Char-Shine Liu also studied this region, concentrating on seismic stratigraphy and basement rock problems southwest of Sumatra. In addition, Dr. Curray and Dr. David G. Moore completed a final review of Deep Sea Drilling Project Leg 64 in the Gulf of California, offering a new model for opening of the gulf, more compatible with drilling information, offshore geological and geophysical data, and onshore geology of western Mexico and southern California.

Dr. Robert L. Fisher continued long-term field and laboratory collaboration with Dr. John G. Sclater, Massachusetts Institute of Technology, on tectonic evolution of the Antarctica/Africa plate boundary and plate motions of the southwesternmost Indian Ocean. Dr. Fisher and Dr. Henry Dick (Woods Hole Oceanographic Institution) worked on criteria for distinguishing abyssal and alpine-type peridotites. A more extensive field and laboratory study, to establish petrological and geochemical criteria for the several environments of present-day undersea ophiolite formation, and to recognize environments of their past formation, involved Italian, South African, and Russian colleagues.

The paleoceanography group (Drs. Wolfgang H. Berger, John S. Killingley, and Edith S. Vincent) worked on topics that range from Miocene carbonate fluctuations in the Pacific to pCO_2 changes in the ocean-atmosphere system, and from stable isotope stratigraphy to mixing processes in surficial sediments. An emerging focal point in their studies is the relationship between the carbon/carbonate cycle and climatic stability. Essentially, there are three ways to change atmospheric pCO_2 through geologic time: (1) by altering the partitioning between ocean and atmosphere, (2) by dissolving or precipitating carbonate, and (3) by sequestering or releasing organic carbon to the ocean-atmosphere system. These various mechanisms leave different signals in the deep-sea record. The scientists are modeling the mechanisms, and comparing expected and observed signal output.

Dr. Edward D. Goldberg and associates investigated the role of ocean and lake sediments in recording the history of environmental changes as a consequence of energy production. They focused upon the environmental dissemination of charcoal and heavy metals from fossil-fuel burning, and of the element technetium from the fissioning of uranium and plutonium.

The charcoal produced by the incomplete combustion of coal, oil, natural gas, wood, and vegetable products can be divided into two categories. Very small particles, usually less than 0.1 micron, resemble grape clusters, and are produced by the volatilization and condensation of carbon. In the second category are particles usually larger than 1 micron; their morphologies reflect the nature of the burned material or the operating conditions of the combustion process.

Dr. Goldberg's group studied the impact of fossil-fuel combustion on Lake Michigan sediments. The morphologies of the charcoal particles indicate that natural wood and brush burning were dominant before the twentieth century. Coal combustion became evident at the beginning of the twentieth century; oil charcoals were discernible in the sediments after 1928. The size distributions as well as the morphologies of the charcoal particles have changed over time. Before 1900 most of the particles were smaller than 1 micron, and were delivered great distances from

biomass burning of woods and grasses. On the other hand, larger particles, from coal and oil combustion, increased in abundance from the early 1900s to the present, and originated in energy plants near Lake Michigan. Thus, three characteristics of the sedimentary charcoals reveal past burning processes: the amounts indicate the intensity of burning; the surface morphologies indicate the type of burning; and the size distributions indicate the distances of transport from the source.

The metals in the Lake Michigan sediments display concentration as a function of time similar to that of charcoal, suggesting that a significant part of the metals are mobilized along with charcoal during fossil-fuel combustion. The metals showing this pattern include tin, chromium, nickel, lead, copper, cadmium, zinc, and iron.

Technetium is an unusual element; its occurrence on earth is almost completely the outcome of nuclear weapons testing and nuclear reactors. There are no stable isotopes of this element. Technetium levels are building up in the environment as a consequence of our entry into the nuclear age. One interesting isotope is Tc-99, with a 210,000 year half-life. Thus, the amounts that have been introduced will be around for a long time. Researchers have sought to ascertain the levels of technetium in the marine environment and have analyzed algae and sediments for this nuclide.

Dr. Goldberg's group concludes that very little technetium has been accumulated in sediments or in living organisms, but most of the element probably resides in seawater in very low concentrations. The researchers found extremely low concentrations of technetium in algae living near the discharge pipe of a nuclear reactor.

Dr. William R. Riedel and co-workers are pursuing several different lines of research on fossil radiolarians and skeletal debris of fishes. Annika B. Sanfilippo has described the radiolarian stratigraphy of the classic Oceanic Formation on Barbados, and is currently searching there for the layer of North American microtektites that has been reported to be coincident with a concentration of microfossil extinctions near the Eocene/Oligocene boundary in deep-sea cores. Jean Westberg Smith is using Deep Sea Drilling Project cores to extend her paleoenvironmental research on Miocene radiolarians from the Mediterranean to the North Atlantic. Alexis A. Budai is expanding her computer-based image-handling system by programing it to automatically evaluate certain aspects of radiolarian shapes.

Patricia S. Doyle and Michael D. Gottfried are using the microscopic teeth and scales of fishes in sequences of pelagic clays for stratigraphic correlations and to detect hiatuses in the sediment columns. They are paying particular attention to changes in the microfossil group near the Cretaceous/Tertiary boundary.

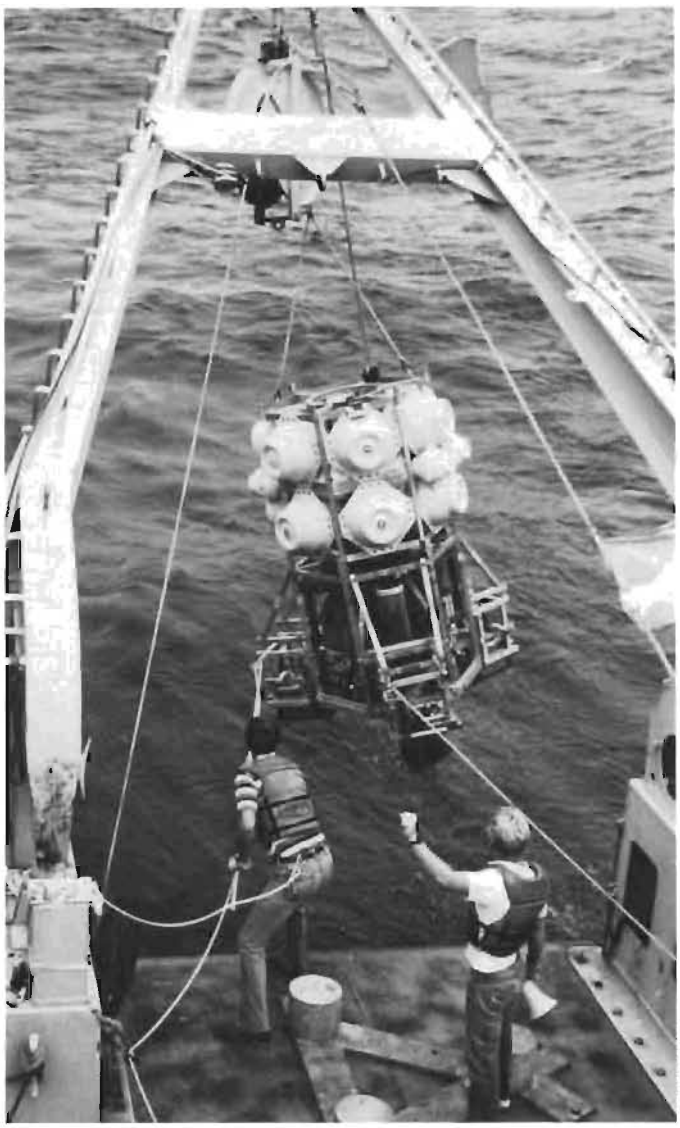
Dr. Ray F. Weiss is directing work under the NSF-sponsored Manganese Nodule Program (MANOP). The MANOP Bottom Lander is a free vehicle instrument designed to carry out in situ studies of chemical and biological processes at the sediment-water interface, and to study the relationship of these processes to the formation of ferromanganese nodules. The bottom lander is designed to operate for extended periods on the sea floor down to 6 km, carrying out chemical and isotopic tracer experiments and collecting samples of seawater, sediment, and nodules. The lander completed two deployments in the California borderland and two deployments on leg III of Pluto expedition in the eastern tropical Pacific.

Research on the oceanic and atmospheric distributions of trace gases has also continued in Dr. Weiss's laboratory. Continuous measurements of surface water and atmospheric carbon dioxide, nitrous oxide, and methane were carried out in the North Atlantic during the Transient Tracers in the Ocean (TTO) program and the joint U.S.-Canadian winter expedition to the Greenland and Norwegian seas. These data are being used to study the regional influence of air-sea exchange on the atmospheric distributions of these environmentally important trace gases, and on the composition of nascent deep and intermediate North Atlantic waters. The data are particularly important in the area north of Iceland, where the uptake of atmospheric carbon dioxide is large, and there are pronounced seasonal variations. Distributions of dissolved fluorocarbon-11 and fluorocarbon-12 in the western North Atlantic and the Greenland and Norwegian seas were measured by graduate student John L. Bullister. Because marine concentrations of these man-made gases increase in response to their atmospheric concentrations, the gases provide a new and extremely useful dating technique for studying rates of subsurface oceanic mixing and circulation.

Marine Biology Research Division

Scientists in the Marine Biology Research Division focus on experimental and descriptive biology. Studies this year included the feeding behavior of feather stars, fertilization of sea urchin eggs, and bioluminescence. Several scientists are working on the biology and biochemistry of life around the deep-sea hydrothermal vents.

Dr. Andrew A. Benson and colleagues continue to study marine detoxification of arsenic—the element that mimics phosphorus in the nutrition of marine algae. When phosphate is depleted by photosynthesis in tropical and other surface waters, its concentration drops to that of ubiquitous arsenate. Since algae cannot discriminate between phosphate and arsenate, they



J. P. DAUPHIN

Recovery of the MANOP Bottom Lander aboard R/V Melville *in the eastern tropical Pacific Ocean.*

absorb arsenate in their quest for phosphate. They avoid arsenic poisoning by methylating it to produce nontoxic trimethylarsoniumlactate derivatives in which arsenic displaces nitrogen of analogous metabolites. Dr. Francis C. Knowles discovered the chemical nature of the reduced form of arsenic, which is toxic to plants and animals. The mechanism by which the methanearsonate kills the noxious weed Johnsongrass has been uncovered. This herbicide is also a major metabolite of coral. A better understanding of the nature of the arsenic burden that seaweeds and marine algae carry, and how it is collected and removed has resulted from his work.

Dr. Ted E. DeLaca is exploring the distribution, ecology, and physiology of benthic foraminifera. His current studies concentrate on the trophic positions (sources of nutrition and losses to predation) and the metabolic rates of several large species of Antarctic foraminifera. He is investigating the effects of metazoan disturbance and predation on foraminiferal populations; these studies depend heavily on environmental analyses. Year-round studies in the Antarctic are in progress to examine seasonal fluctuations in the foraminiferas' metabolism and population dynamics. Dr. DeLaca is also studying temperate and tropical foraminifera.

Dr. Denis L. Fox continued his work on biochromy of mollusca.

Studies by Dr. Francis T. Haxo of the wavelength dependence of photosynthesis in phycoerythrin-rich cryptomonad flagellates confirm the unique adaptive nature of the cryptomonad light-harvesting pigment system. This process provides efficient absorption and utilization of photons throughout the visible spectrum. The O_2 action and *in vivo* fluorescence excitation spectra measurements reveal that this is most marked in cells grown at low irradiances where contents of chlorophyll and biliproteins are high, and blue photon capture by nonsensitizing acetylenic carotenoids (notably alloxanthin) is minimized. Reexamination of absorption and activity at the chlorophyll absorption bands suggests that decline in photosynthetic efficiency in the red and blue parts of the spectrum may be lower than previously reported. Thus such cryptomonads appear well adapted for survival in a wide range of spectrally skewed, photon-poor environments.

Dr. Robert R. Hessler and William M. Smithey concentrated on the megafauna of deep-sea hydrothermal vents, as part of the biological expedition Oasis 82. Using direct observation, photographic documentation, and temperature measurements, they recorded the distribution of the fauna in an extensive field of clams and on white smoker chimneys. Repeated temperature probing revealed that the lacework pattern of clam distribution follows a complex network of moderate-temperature vents (approximately 15°C). A more extreme adaptation is seen with Alvinellid worms, which form dense colonies of tubes on the sides of smokers and thrive at temperatures over 50°C.

Dr. Nicholas D. Holland and an Australian associate are studying the feeding behavior of feather stars (Echinodermata:Crinoidea). Animals collected from the Great Barrier Reef were fed algae in the laboratory. High-speed movies were made of suspension feeding behavior. Preliminary results indicate that particles are not captured by mucous nets, but instead stick to "glue" at the tips of the tube-foot papillae. Feather stars apparently cease feeding at food concentrations below a minimum threshold. Moreover, ingestion rates plateau above a critical level of food in the seawater.

Prochloron, the only known prokaryotic green alga, continues to intrigue Dr. Ralph A. Lewin and co-workers. *Prochloron* occurs in tropical coral-reef areas, where it lives symbiotically inside didemnid ascidians. Drs. Lewin and Lanna Cheng studied *Prochloron* at Palau, where they preserved cells while conserving their biochemical features. Another expedition participant obtained evidence from ribosomal RNA sequence data indicating that *Prochloron* may be phylogenetically closer to filamentous cyanophytes than to green-plant chloroplasts. An associate is studying the influence of exocellular polymers on the surface chemistry and flocculating potential of a marine diatom, *Phaeodactylum*, and of *Chlamydomonas* species, which may be of economic value as soil conditioners.

Researchers in the laboratory of Dr. Kenneth H. Nealson are investigating several aspects of marine microbiology, including the mechanisms of bacterial light emission, mechanisms of metal precipitation by microbes, and the activities of metal-precipitating bacteria. Graduate student Daniel H. Cohn succeeded in cloning the genes for bioluminescence, the first such application of modern molecular genetics techniques to marine bacteria. Another graduate student, Bradley M. Tebo, developed methods for quantifying rates of bacterial manganese oxidation in nature, and he showed that bacterial activities are of major importance in several marine environments.

Work in Dr. William A. Newman's laboratory has been progressing along several new fronts. Drs. John S. Killingley and Newman have demonstrated that sessile barnacle calcite is consistently enriched in ^{18}O and therefore indicates temperatures 5°C below ambient unless a modified paleotemperature equation is applied. Visiting Norwegian scholar Dr. Tor Stromgren has been introducing laboratory scientists to his laser diffraction technique for measuring minute linear growth increments in organisms. Dr. Stromgren has been able to demonstrate that diet-dependent changes in mussel shell growth occur in a matter of a few days.

Researchers in the laboratory of Dr. Richard H. Rosenblatt are applying biochemical genetics techniques to biogeographical problems. The shorefish faunas of the eastern Pacific and western Pacific are quite distinct at the species level because of the East Pacific Barrier (the islandless expanse of ocean between the Line Islands and Polynesia) and because of the American mainland. The occurrence of about 45 species of shorefishes in both areas is often attributed to occasional chance transport of larvae or adults by the Equatorial Countercurrents. But some researchers have suggested that these species were at one time worldwide and have become extinct in the Caribbean. These hypotheses can be tested by genetic analysis. If the latter hypothesis is true, eastern and western Pacific populations have been separated for several million years and should be very different genetically. Accordingly, about 30 loci coding for structural proteins have been examined in several trans-Pacific species. Preliminary results support the hypothesis of dispersal across the Pacific, since samples from Hawaii and the eastern Pacific appear to have been drawn from the same populations. This study indicates that biogeographers may be able to use genetic analysis to distinguish between relictual- and dispersal-caused discontinuous distributions.

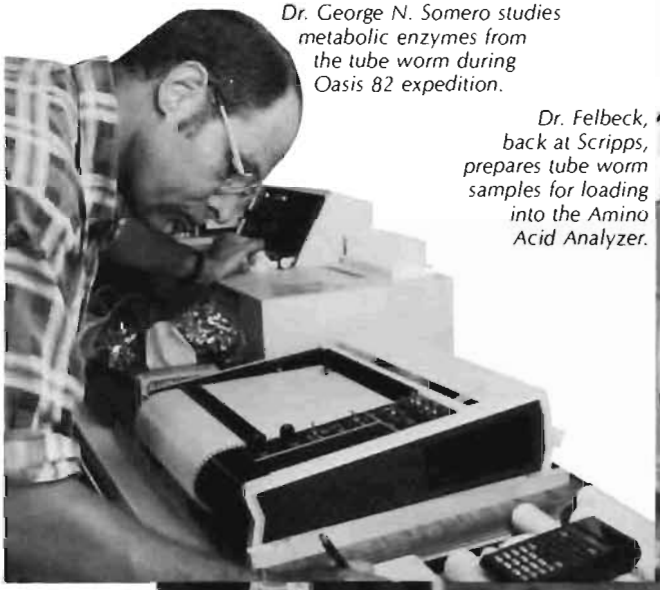
Researchers in Dr. Kenneth L. Smith's laboratory are involved in ecological energetics studies of the deep-sea benthic boundary layer in soft-bottom environments. Sediment-community oxygen consumption and nitrogenous nutrient exchange rates decrease in magnitude from eutrophic continental margin stations off southern California to oligotrophic stations in the central Pacific north of Hawaii. Concurrent measurements of organic matter input to the benthic boundary layer reveal the same proportional decrease in magnitude from east to west. These rate measurements of organic matter input and consumption in the benthic boundary layer appear directly proportional to seasonal variations in surface-water primary productivity.

Bioluminescence in three marine animals is the focus of Dr. Frederick I. Tsuji's work. One study involves a novel bioluminescence system in the oceanic squid *Symplectoteuthis oualaniensis*. Light-emitting components are membrane-bound, and light emission is triggered by potassium and sodium ions. Dr. Tsuji's goal is to isolate and identify the essential components and determine the mechanism of the reaction. A second study deals with the determination of the amino acid sequence of luciferase from the ostracod crustacean *Cypridina hilgendorfii*. The third study covers bioluminescence in the fish *Porichthys notatus* and its induction in a nonluminous form by *Cypridina* luciferin. The mechanism by which induction takes place is being studied with ^{14}C-labeled *Cypridina* luciferin.

Crew prepares for a dive in Alvin *to the hydrothermal vent field, where the tube worms originate.*

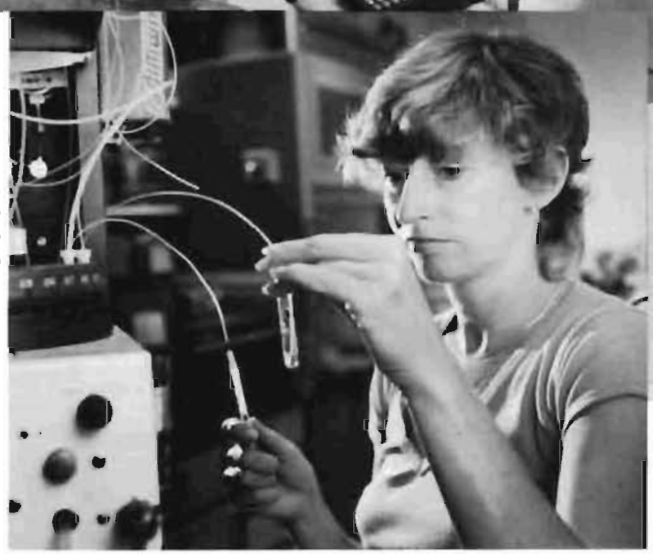
Dr. Horst Felbeck and colleagues examine a tube worm aboard R/V Melville. *The worm was retrieved from the hydrothermal vent area during the Oasis 82 expedition.*

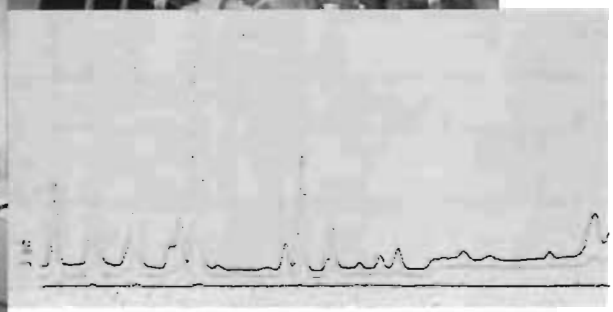
Dr. George N. Somero studies metabolic enzymes from the tube worm during Oasis 82 expedition.



Dr. Felbeck, back at Scripps, prepares tube worm samples for loading into the Amino Acid Analyzer.

Siv M. Tedro loads tube worm sample into Amino Acid Analyzer.





H. FELBECK

Amino Acid Analyzer record of metabolic compounds from the tube worm. Peaks include compounds produced by symbiotic bacteria contained within the tube worm.

Dr. Joan G. Stewart completed a series of laboratory culture experiments with species of small red algae from both intertidal and subtidal sites. Her results indicate that plants restricted to these regions, and perhaps others with limited N-S geographical distributions, do not occur in colder or warmer habitats as the result of direct effects of temperature on vegetative growth.

Studies of biochemical adaptation mechanisms were continued in the laboratory of Dr. George N. Somero. During an expedition to the 21°N hydrothermal vent site, Dr. Horst K. Felbeck studied sulfide-driven primary productivity in animal-bacterial symbiotic systems, and a colleague explored the mechanisms for preventing sulfide poisoning of vent animals. Dr. Steven C. Hand determined metabolic profiles of the organisms, and another researcher investigated adaptations of muscle actins to temperature and pressure. Other investigations in Dr. Somero's laboratory included studies of a deep-living, wood-digesting clam *(Xylophaga washingtoni);* environmental effects on energy allocation in sablefish; and the effects of pH and organic osmolytes on control of glycolysis and intracellular localization of glycolytic enzymes.

The biochemistry of sperm-egg interaction during fertilization in sea urchins and abalones is being investigated in Dr. Victor D. Vacquier's laboratory. Researchers found a novel method used by the abalone sperm to penetrate the egg surface coat: the sperm releases a small protein that binds to the egg coat and dissociates the egg coat fibers by a nonenzymatic mechanism. The researchers are also studying the proteins of the sea urchin sperm membrane to identify those that mediate the activation of the sperm when it contacts the egg. Laboratory scientists isolated and characterized the cortical granules of sea urchin eggs and developed an assay for calcium-mediated lysis of the granules.

Dr. Benjamin E. Volcani's group continued to study the role of silicon in diatom metabolism and cell-wall morphogenesis. Dr. Pinakilal Bhattacharyya separated and, using HPLC, purified the silicate ionophoretic activity in *Nitzschia alba* extracts into two chromatographically separate and distinct components. Dr. Robert F. Aline, Jr., quantitated the activities of adenylate cyclase and guanylate cyclase in *Cylindrotheca fusiformis* during the cell cycle and in response to silicate addition. Graduate student Chia-Wei Li found three forms of silica deposition in *Ditylum brightwellii* and a new cytoplasmic structure that appears to be associated with formation of the siliceous labiate process both in this organism and in a number of other centric diatoms. Christopher D. Reeves, a UC San Diego graduate student, continued characterizing the mRNA population of *C. fusiformis* and found that contrary to the report in the 1981 Scripps annual report the mRNA is polyadenylated. Visiting scholar Bo Tang Wu, South China Sea Institute of Oceanology, People's Republic of China, found physiological variations in different strains of the apochlorotic diatoms *Nitzschia putrida* and *N. leucosigma*.

Dr. Jon A. Warner, working in Dr. Nealson's laboratory, is currently developing methods for using the luminescent activity of mesopelagic organisms to monitor their population behavior and dynamics. A large data base has been created by continuous recording of real-time bioluminescent activity in the vicinity of a deepwater offshore field station. This data base is computer-processed to locate species-specific luminescent signatures and by these records document little-known activities of midwater species.

Dr. Claude E. ZoBell has been directing observations on microbial activity in the wake of oil spills, and directing research on primary film formers in OTEC (Ocean Temperature Energy Conversion) water pipes.

Marine Life Research Group

For the last 34 years scientists in the Marine Life Research Group (MLRG) have studied the biology of the California Current, as well as the climatology, physical and chemical oceanography, and the geology upon which that biology depends.

Drs. Elizabeth L. Venrick and Thomas L. Hayward are studying the relations of large-scale patterns of physical and biological structure in the North Pacific. During the May 1981 CalCOFI (California Cooperative Oceanic Fisheries Investigations) cruise in the California Current, nutrients, chlorophyll, and primary production were measured to compare their distributions with those of macrozooplankton biomass and physical structure. Spatial and temporal heterogeneity in all of these properties were observed to be much greater than in a similar set of samples taken in August 1980 from the central North Pacific. The level of environmental heterogeneity within an ecosystem is an important aspect of its structure. Species structure in the plankton is also much more variable in the California Current than in the central North Pacific. Determining the mechanisms by which the physical structure of an ecosystem affects its biological structure remains one of the central problems in biological oceanography.

Cruise data were also used to compare the effectiveness of satellite remote sensing of ocean color as an indicator of the state of the ecosystem in the California Current and central North Pacific. Ocean color is related to chlorophyll concentration as an indicator of phytoplankton biomass. The remotely sensed signal is limited to the relatively near-surface part of the ocean. Results of the comparison confirmed past observations that in the California Current the near-surface values of chlorophyll are correlated with total values of chlorophyll and primary production integrated through the euphotic zone. In the central North Pacific, however, this relationship breaks down, and the near-surface values are not correlated with integrated values of chlorophyll or primary production. This suggests that the utility of remotely sensed ocean color as an indicator of the biological state of the ecosystem may vary in different parts of the ocean.

Species of the copepod family Calanidae are primary consumers and major constituents of macrozooplankton biomass in upper layers of eutrophic (fertile) waters throughout the world ocean. Dr. Abraham Fleminger's long-term studies have shown that the ecological success enjoyed by calanids occupying regions of extreme seasonal variation in phytoplankton biomass appears to correlate with four factors: (1) calanid specializations that enhance rapid development to sexual maturity in phytoplankton blooms; (2) storage of large quantities of lipids; (3) avoidance of seasonal periods of oligotrophy (relatively infertile water conditions) by downward migration to undercurrent depths; and (4) entrance into a torpid or diapausing state until onset of a subsequent upwelling season.

Other preliminary results indicate that neoteny (the retention of juvenile characteristics into adulthood) has played a major role in the divergence of calanids from megacalanidlike ancestors; this probably reduces the time and energy required to reach sexual maturity. The family Calanidae does not appear to have had a long evolutionary history. Also, the lineages having the most species show evidence of relatively rapid, large-scale, geographical radiation into mid to low latitudes. This may be a response to seasonal increases in primary productivity that resulted from the increased meteorological and hydrographic activities of Pleistocene and Holocene times.

Halobates is the only insect genus with representatives in the open ocean. Although the five known pelagic species are widely distributed, Dr. Lanna Cheng has found that areas of high population densities are correlated with warm surface waters. Furthermore, Dr. Cheng and a collaborator have found that, although the distribution ranges of three Pacific species (*H. sericeus, H. micans,* and *H. sobrinus)* may overlap, their areas of high population densities are quite separate. Oceanic *Halobates* often contain high concentrations of the heavy metal cadmium, and Dr. Cheng and a German colleague have found that in the Atlantic, high Cd concentrations in *Halobates* appear correlated with upwelling waters.

Tetsuo Matsui and Dr. Richard H. Rosenblatt are studying the deep-sea salmoniform fish family Platytroctidae (= Searsiidae). Their revisionary work on the family Platytroctidae is nearing

completion, and includes 36 species (5 of which are new) in 12 genera. An interpretation of the family's phylogenetic relationships and distribution indicates that its early evolution probably occurred in the Atlantic Ocean, and only the most modern genera evolved in the Indo-West Pacific. Extant species of platytroctids were apparently present by the time deepwater circulation through the Panama Seaway ceased 4.5 million years ago. The Atlantic and Pacific populations of circumtropic species have probably remained isolated since then, although they are still morphologically identical.

Dr. Loren R. Haury has analyzed zooplankton and phytoplankton samples taken on two transects across an eddy 400 km off Pt. Conception in January 1981. Species typical of the cool waters of the California Current were found north and east of the eddy and in its center, but not at the edges. Warm-water zooplankton, on the other hand, were found at the edges of the eddy, carried there by offshore water entrained by the eddy's rotation. Species distributional patterns thus reflect the currents and water masses associated with the eddy and its anticyclonic rotation.

Dr. Haury, together with Dr. James J. Simpson and Dr. James Cox (UCSB) analyzed a set of closely-spaced zooplankton samples collected off Pt. Conception in an area of upwelling. Peak zooplankton biomass occurs slightly offshore of peak phytoplankton biomass. Laminarinase—an enzyme used as an indicator of zooplankton grazing activity—was distributed in inverse relation to zooplankton and phytoplankton. Knowledge of these patterns of distribution is important for understanding zooplankton's behavioral and physiological responses to phytoplankton blooms.

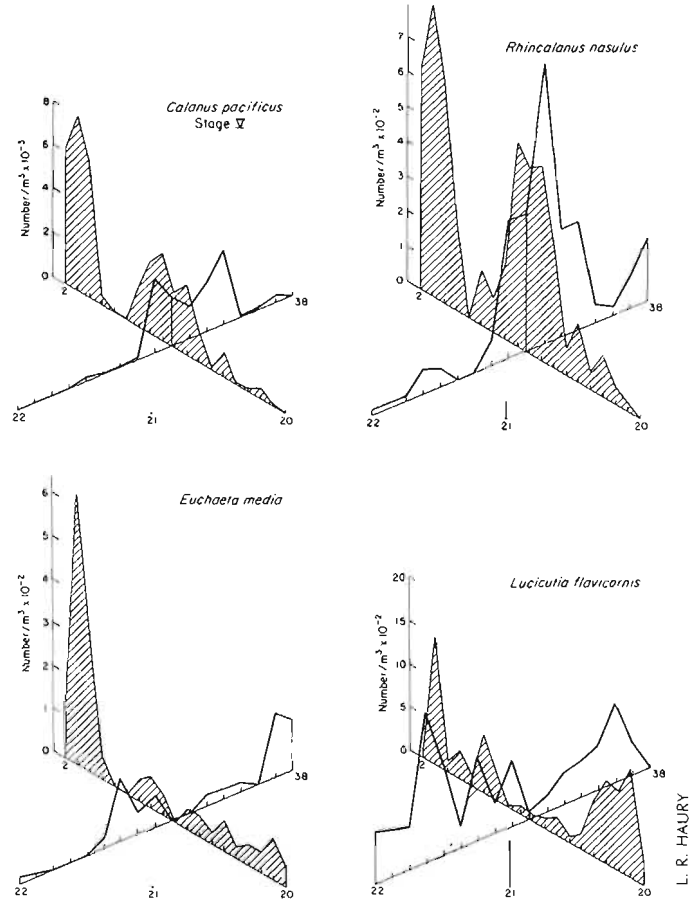
The genesis of manganese nodules was studied by Andrew Soutar and Susan Rau. Three lines of evidence were developed: (1) recovery of multiple, well-preserved samples from year-long sediment trap deployments at two sites in the eastern tropical Pacific; (2) documentation of an active layer of organic carbon, millimeters thick, at the sediment surface at the two sites; and (3) the close observation of the depositional environment and benthic biology interactions by participation in a deep-sea dive at one site. An organic-rich surface layer provides energy for surface-feeding organisms capable of disturbing nodules, and influences geochemical processes related to elemental flux through interstitial waters.

In a cooperative effort, a multi-core chronology of Guaymas Basin sediments for the past 70 years has been developed on the basis of microstratigraphy and Pb-210 dates. This chronology is useful in studies of palaeoclimate and palaeoecology.

Soutar and a colleague measured organic productivity and particle outfall in Antarctic regions of krill abundance. The measurements indicate that half of the silica productivity is immediately lost to the deep waters through euphausiid grazing and fecal pellet fall-out.

Dr. Edward Brinton's study of population biology of euphausiid crustaceans focused on regional differences in growth of the Antarctic krill *Euphausia superba*. Collections obtained by scientists aboard R/V *Melville* during 1981 showed that abundant larvae from extensive reaches of the Scotia Sea were smaller than sparser larvae of the same age from the South Shetland Islands, south of the Drake Passage. The different growth rates appear to produce adult populations with distinct body structures. Extensive commercial trawling observed near Elephant Island appeared to reduce the biomass of krill swarms by 50 to 75% over a 10-day period. The threat of the size-selective exploitation of the broader species population is being examined.

Margaret D. Knight has been investigating seasonal changes in the developmental pattern of young furcilia larvae within the southern California population of *Euphausia pacifica* during the winter-spring of 1977-1978. There is considerable variation in number and relative abundance of forms in furcilia stages I and II, both within and between the seven CalCOFI surveys of the population during this period. There appear to be marked seasonal changes in the dominant developmental pattern, however,



The abundances of zooplankton species on two transects across an eddy in the California Current off Pt. Conception. Top: cool-water species occur to the north and east of the eddy and in its central region. Bottom: warm-water species are most abundant on the edge of the eddy. Station numbers are at the bottom of each figure; the eddy center is at the crossing of the two transects.

which may be related to fluctuations in larval recruitment of the species and to changes in the environment.

High heat flow, including the very warm water from hydrothermal vents, takes place along the East Pacific Rise, which extends from near Antarctica into the North Pacific Ocean. Joseph L. Reid has found an effect of heat flow from the sea floor into the ocean at mid-depth. Near 10° to 20°S the temperature-salinity relation is interrupted by geothermal heat from the East Pacific Rise. This heat raises the temperature at mid-depth and leaves a pattern of high temperature that extends 5000 km westward from the rise. This is the first evidence of such an effect at mid-depth in the open ocean.

Reid and an associate showed that the subsurface oxygen maximum found in the open mid-latitude North Pacific in summer is well above the saturation value. They concluded that this must be caused by photosynthesis just beneath the shallow summer mixed layer. The oxygen excess, which develops during the summer, implies a greater rate of photosynthesis than traditional ^{14}C measurements have shown.

Dr. James H. Swift and collaborators have taken detailed hydrographic and geochemical samples of the Norwegian-Greenland Sea. Dr. Swift is also investigating recent temperature-salinity shifts in the deep water of the northern North Atlantic. These shifts may be tied to changes in the weather patterns since the 1950s and 1960s. Another new study is focused on the relationship of the Norwegian-Greenland Sea to the deep waters of the Arctic Ocean.

Drs. Simpson and Haury and Dr. Tom D. Dickey, University of Southern California, employed a combination of shipboard and

remote-sensing techniques to study mesoscale eddies and fronts in the California Current System (CCS). The results of these process-oriented experiments were interpreted in conjunction with the historical CalCOFI data base. The combined data show that several semipermanent, quasi-stationary offshore mesoscale eddies exist simultaneously in the CCS. Detailed measurements suggest that these eddies are in quasi-geostrophic balance (for example Rossby number ≈ 0.1). A secondary set of vertically distributed dynamical processes and water sources is required to explain the distributions of temperature, salinity, dissolved oxygen, potential density, and potential vorticity. Some hypothesize that the presence of this semipermanent, offshore, warm-core eddy field may partially explain the presence of eastern Pacific sea-surface temperature anomalies.

Daniel M. Brown has installed tide gages at Santa Catalina, San Clemente, and San Nicolas islands and at Shelter Cove in Cape Mendocino, California. His sea-level measurements are intended to monitor long-term changes, but the short-term, daily changes in sea level also prove interesting. The changes accurately document the atmospheric forces on the ocean, which are reflected in periodic rises and falls in sea level. The consequences of these changes are yet to be determined, but may be related to unusual increases in current speed.

California Space Institute

The California Space Institute (Cal Space), under the direction of Dr. James R. Arnold, is a universitywide institute of the University of California. Cal Space, headquartered on the Scripps campus, supports and engages in space-related studies. Two Cal Space statewide projects are being completed: "Coastwatch," an integrated project for remote sensing of the coastal strip off California and offshore waters; and "West Coast Regional Long-Range Forecast Development," a study of regional long-range weather forecasts for the Pacific coastal strip.

Scientists at the Scripps branch are now exploring uses of the external tanks of the space shuttle. Their goal is to find creative and practical uses for these tanks. To this end several meetings and workshops were held by Cal Space and attended by UC, government, and industrial scientists.

Dr. Catherine H. Gautier is investigating the use of satellite data for climate applications, with primary emphasis on large-scale air-sea interactions. The objectives of this Cal Space research are to measure and describe the principal processes affecting the exchanges of heat and momentum at the atmosphere-ocean interface seasonally and interannually.

Institute of Geophysics and Planetary Physics

The Institute of Geophysics and Planetary Physics (IGPP) is a University of California systemwide institute with branches on the Los Angeles, Riverside, and San Diego campuses. The San Diego branch is located at Scripps Institution of Oceanography and is intimately joined to Scripps by a variety of scientific associations.

This year, Dr. George E. Backus extended the singular perturbation theory to magnetic fields to treat mantle conductivity's effect on the electric fields generated by the dynamo in the core. The theory is used to study the lower mantle's conductivity, with data obtained from the magnetic jerk of 1969. Another project was to carry to second order the perturbation theory for P waves in homogeneous anisotropic elastic materials. The calculation led to a single scalar measure α of the amount of anisotropy in a material, and to an optimal decomposition of an arbitary elastic tensor into an isotropic part with $\alpha = 0$ and an anisotropic part with smallest possible α. Perturbation theory for the P wave is accurate only if α is much less than 1 (the perturbation series converges like $\sum_n \alpha^n$), a result that explained some disagreements of the first-order perturbation theory with measurements on single crystals of olivine, quartz, and rutile. The theory also predicts that an anisotropic material can have "second-order planes"—planes of directions in which the P velocity is constant to first order. There is a six-dimensional space of elastic tensors that shows no first-order anisotropy (all planes are second order), but except for these, no material can have more than four second-order planes, and in a well-defined sense the probability is that polycrystalline material will have no second-order planes.

Project IDA (International Deployment of Accelerometers), a global network of 17 stations for long-period seismic studies, continued under the direction of Drs. Jonathan Berger, Duncan C. Agnew, and J. Freeman Gilbert.

Dr. Agnew continued work on earth tides by developing a program for computing ocean loads. The program has been applied to gravity tides measured by the Project IDA network. Dr. Agnew also studied the effects of ground noise on measurements of g, and began a study of sea-level changes in the Aleutian Islands.

Work continues on the Anza digital telemetered seismic network, which is a cooperative project among Drs. Berger, James N. Brune, and their colleagues. Six of ten projected stations have been deployed in California's Anza area surrounding a seismic gap on the San Jacinto fault. Digital data are telemetered via VHF to a nearby 2700-m peak, from which they are relayed via microwave link to Mt. Soledad (near Scripps) and IGPP.

At the Cecil and Ida Green Piñon Flat Observatory, graduate student Frank K. Wyatt and Drs. Agnew and Berger continued to evaluate and improve instrumentation for measuring crustal deformations. The Crustal Deformation Observatory Project involves 11 institutions using techniques ranging from NASA's project ARIES to Carnegie Institution's deep borehole strain meters. Emphasis has been placed on establishing the coherence between different methods of long base length (500 m) tilt measurements. Research efforts by IGPP personnel include Wyatt's design and construction of a 535-m fluid tiltmeter.

Dr. Hugh Bradner continued work on aspects of the DUMAND (Deep Undersea Muon and Neutrino Detection) Project such as site studies, water transparency, array design, bioluminescence, and preparations for measuring cosmic ray intensity from the ocean surface to a 4-km depth.

Cooperative seismic studies with Mexico, including investigations of seismic hazard, earthquake strong motion, earthquake mechanism, and earth structure, are being continued by Dr. Brune, Dr. John G. Anderson, Dr. Michael S. Reichle, and Richard S. Simons. They are using theoretical, numerical, and physical models to understand and estimate the probabilities of large ground accelerations that might damage sensitive structures such as nuclear power plants.

Dr. Anderson and a colleague worked out the constraints that the average slip rate on a fault places on earthquake occurrence relations, and Dr. Anderson is comparing these predictions with data gathered throughout California. He also studied procedures to interpret earthquake prediction statistics, and the consequence of a prediction on statistical estimates of seismic risk. Theoretical studies of strong ground motion caused by kinematic models of faulting during an earthquake also continue.

Dr. Reichle continued his research on northern Baja California seismology in cooperation with the Centro de Investigación Científica y de Educacíon Superior de Ensenada, México. Dr. Reichle is investigating California's seismic hazards from faults on both sides of the international border. The interdisciplinary program will focus on hazards to the San Diego/Tijuana metropolitan area from known active faults southeast of Tijuana.

Drs. Alan D. Chave and Charles S. Cox have used controlled electromagnetic sources located on the sea floor to measure the electrical conductivity of the crust and mantle. They found that the conductivity to the base of the crust (Moho) could easily be measured, but deeper penetration depends on the rate at which conductivity increases with depth. Dr. Chave is also investigating the electromagnetic fields induced by the flow of seawater through the earth's magnetic field. He found that previous studies

are in error because of incorrect assumptions about electrical conductivity under the ocean. Dr. Chave is investigating the use of the fields produced by ocean tides to study the earth's conductivity structure.

Dr. John W. Miles continued his work on nonlinear waves and diffraction theory. He is currently considering the diffraction of surface waves by a periodic row of submerged ducts—a configuration of practical importance for wave-power absorption.

Dr. John A. Orcutt and graduate student Allen H. Olson have developed an important new method for predicting strong ground motion in the vicinity of an earthquake or buried explosion. The technique, unlike any other computational method, allows the hypothetical earth structure to be completely arbitrary in the vertical direction and is important in studying shaking from large California earthquakes. Drs. Orcutt, Brune, and Thomas H. Jordan established a new experimental laboratory at IGPP dedicated to the collection and exploitation of a growing global digital seismic data base.

A theory for the large-scale mass distribution in the ocean, based upon a postulate of maximum entropy, was developed by Dr. Richard L. Salmon. The theory is in agreement with preliminary numerical simulations and hydrographic observations.

Dr. Robert H. Stewart uses radio waves to study the dynamics of ocean waves and surface currents.

Drs. Walter H. Munk, Peter F. Worcester, Robert A. Knox, Michael G. Brown, and John L. Spiesberger continued their work in ocean acoustic tomography. They completed an experiment using this method of acoustic remote sensing of the ocean's interior to map mesoscale fluctuations of sound speed (or density) in a 300x300-km region southwest of Bermuda. The acoustically derived maps compared favorably to maps produced from independent conventional measurements. A new experiment in which mesoscale currents rather than density perturbations will be sensed is almost ready for deployment.

Institute of Marine Resources

The Institute of Marine Resources (IMR) acts to stimulate interaction among all the University of California campuses to enhance the university's ability to investigate the marine environment and human interactions with it, and to communicate the resulting understanding to those who may benefit from it. This university-wide organization, directed by Dr. Fred N. Spiess, has its headquarters and major operating units at Scripps; however, an executive committee provides representation from each of the eight major campuses.

Phytoplankton Resources Group

With increasing population pressures worldwide, it will be necessary to augment energy and protein supplies. One way of achieving these goals is to use solar energy to produce biomass by plant photosynthesis. Various schemes of biomass production have been envisaged. One of these is to grow microalgae in outdoor ponds and harvest them for their energy and protein content. The algae are appealing because they generally use sunlight more efficiently than higher plants, and give higher yields per unit of illuminated area.

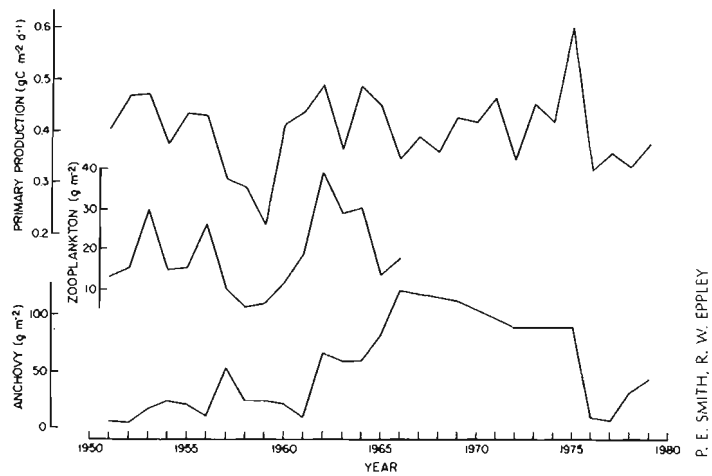
Dr. William H. Thomas, with support from the Solar Energy Research Institute, Colorado, has assembled the Phytoplankton Resources Group to perform basic laboratory studies that might be helpful in setting up outdoor algae ponds. Six microalgal species have been considered for maximum yields and efficiencies, for the best in outdoor applications. The highest yield (equivalent to some 30 tons dry weight per acre per year) was obtained with a marine diatom, *Phaeodactylum tricornutum*. Dr. Thomas estimates that if this yield could be sustained or enhanced using natural sunlight and seawater, about 1 quadrillion BTUs of energy could be obtained per year from ponds covering 1 million acres (an area 48 km x 48 km). Since the U.S. presently uses 78 quadrillion BTUs per year, microalgae on this scale could supply greater than 1% of present energy needs. Protein would be a valuable byproduct of such operations.

The group is presently investigating algae that grow in U.S. desert areas. In the desert there are abundant supplies of land and sunlight and also considerable resources of saline water that cannot be used for conventional agriculture. Dr. Thomas emphasizes that, unlike nuclear energy applications, biomass production by algae is relatively nonpolluting, and presents no waste disposal problem.

Food Chain Research Group

Scientists in the Food Chain Research Group (FCRG) evaluate the roles of bacterioplankton, phytoplankton, and zooplankton in the dynamics of the marine pelagic food web. Investigations center around the distribution and metabolic activities of these organisms. FCRG goals include describing the routes and fluxes of organic matter between trophic levels and the study of the physical/chemical environment as it affects the distributions and activities of organisms in the ocean.

Dr. Richard W. Eppley and his associates collaborated on two biological time series for the Southern California Bight: one for primary production by phytoplankton (1920-1979) and one for anchovy biomass (1951-1979). The primary production time series is similar to the existing CalCOFI (California Cooperative Oceanic Fisheries Investigations) zooplankton time series. All



Graph shows estimated annual primary production, annual mean CalCOFI zooplankton concentrations, and anchovy total biomass in the Southern California Bight.

three time series indicate low biological production in the climatically warm-water years 1957-1958. Primary production peaked in the climatically cold-water years 1933 and 1975. About half of the variation in the number of anchovy larvae in the bight could be accounted for by fluctuations in zooplankton and primary production.

Dr. Eppley and co-workers used ship data and satellite images of chlorophyll in the bight to assess the spatial variability in phytoplankton and to determine how representative (synoptic) the ship chlorophyll data are compared with the essentially instantaneous satellite images.

Dr. Farooq Azam continues to study the role of marine bacteria in food-web dynamics and energetics. He used a new technique, developed for measuring bacterial secondary production, to determine the patterns of bacterial production in Southern California Bight and Scotia Sea waters. Results from these studies show that 15-50% of the photosynthetically-fixed carbon in the areas studied was channeled through bacteria—presumably to the higher trophic levels. This means that bacteria are a major pathway for energy and material transfer in marine food webs.

Dr. Azam and his colleagues are studying bacterial mineralization of dissolved and particulate matter. They measured the rates

of bacterial decomposition of dissolved proteins and found that in the Southern California Bight bacteria degrade dissolved proteins in close metabolic proximity to the cell rather than by secreting proteases into the seawater. This study indicated that dissolved proteins may "buffer" bacterial nutritional regimes by providing usable food for bacterial growth at night when direct input of photosynthate stops.

Dr. Angelo F. Carlucci's group continued studies on the chemistry and microbiology of surface film formation, composition, and alteration. The group measured bacterial turnover times of glutamic acid and leucine in surface films of oligotrophic and coastal waters off the coast of Baja California. In oligotrophic waters, turnover times ranged between 109 and 3128 hours for glutamic acid and 92 to 280 hours for leucine. In four of six determinations with each amino acid, shorter turnover times were noted in 10-cm deep control waters. Turnover times of these amino acids in euphotic coastal waters were up to two orders of magnitude shorter in both surface films and 10-cm control waters. Solar radiation apparently did not inhibit these turnover rates. The scientists conclude that surface films contain bacterial populations that are highly active in utilizing amino acids.

Dr. Osmund Holm-Hansen's studies on carbon and nitrogen metabolism of phytoplankton suggest that heterotrophic nanoplankton are very important in assimilating and degrading particulate organic material. Dr. Holm-Hansen's group has developed a technique for determining the numbers and biomass of photosynthetic and heterotrophic organisms. The heterotrophic nanoplankton cells are important in recycling nutrients, including the production of ammonia from nitrogenous compounds.

Dr. Holm-Hansen continued investigating the photobiology of natural phytoplankton populations. In conjunction with Charles R. Booth, he has been analyzing the distribution of phytoplankton with depth (as determined with a submersible fluorometer) and correlating it with the extinction coefficient of light in the water column, in addition to nutrients, particulate organic material, and absolute light levels.

Dr. Holm-Hansen's studies in Antarctic waters encompass four main topics: (1) factors controlling the distribution and photosynthetic activity of phytoplankton; (2) the rate of recycling of organic carbon and nitrogen by microbial cells, particularly nanoplankton populations; (3) the floristic composition of the phytoplankton population as influenced by physical/chemical conditions and by zooplankton grazing effects; and (4) the seasonal and geographical availability of food resources as related to krill feeding requirements.

The roles of various microzooplankton in pelagic food-web activities are subjects of research by Dr. John R. Beers. He initiated a study of the biological activities of nonloricate oligotrichous ciliate protozoans in order to understand their dynamic function in the planktonic trophic web. These forms have not been fully examined, although they are commonly the dominant ciliates in pelagic environments. Successful laboratory cultures of several forms have now been established, and some preliminary feeding studies undertaken. Dr. Beers examined the microzooplankton population structure and abundances in the Scotia Sea (Antarctica). The data suggest that, at least in some instances, these small phagotrophs can be an important primary consumer link in Antarctic food webs.

Zooplankton feeding, production, and distribution are being assessed by Dr. Michael M. Mullin's group. They have completed a study of the production and vertical migration behavior of *Calanus pacificus,* a local zooplankton species. The study was designed to calibrate a rapid method for estimating zooplankton production; the results are encouraging, and suggest that the method is viable. Other results of this study showed how diel vertical migration behavior of *Calanus* develops during its life cycle, and how the amplitude of the migration is affected by food availability.

Dr. Mark E. Huntley and a visiting scholar have continued studies on selective feeding abilities of *C. pacificus* and have shown that this species has a sophisticated behavioral repertoire in response to the quality of food with which it is presented. This species is also able to "choose" particles of high nutritional quality over those of low quality.

Dr. Huntley and Elaine R. Brooks collaborated with an Oregon State University scientist to study the molting behavior of *Calanus pacificus*. They found that molting is sometimes synchronized with a diel cycle, and that the synchrony phenomenon varies with the season.

Dr. Peter M. Williams's group continued its studies on the chemical composition and in situ physical-chemical properties of the sea-surface microlayer. Relatively small variations in the basic organic and inorganic components of natural noncontaminated films in the coastal and open-ocean waters off Baja California, coupled with fast film-formation rates (seconds to minutes), suggest short residence times of films at the sea surface. The magnitude and rates of exchange, and chemical modifications of natural and anthropogenic materials (gases, chemicals) across the air-sea interface are partly dependent on film residence times.

Dr. Williams also studied vertical profiles of the amino acid and carbohydrate composition of the dissolved and particulate organic matter in the Santa Monica Basin.

Dr. George A. Jackson, in collaboration with Dr. Clinton D. Winant, is studying water motion in kelp beds. Giant kelp, *Macrocystis pyrifera,* is a large seaweed that can grow in stands as large as 7 km parallel to shore and 1 km across. The high drag associated with such a kelp stand can reduce coastal currents to a third of what they would be without the kelp. These diminished currents lessen the flow of substances such as plant nutrients that are supplied to the bed from outside.

Dr. Jackson has also been studying oxygen and nutrient exchange in the San Pedro-Santa Monica Basin area, a relatively isolated submarine valley just offshore of Los Angeles. Waters in the deeper regions of the basin have very low oxygen concentrations because circulation is poor and because the water that does enter comes from the oxygen minimum layer outside. Understanding basin exchange processes will allow estimation of the influence of human discharge.

Marine Natural Products Group

The Marine Natural Products Group explores the chemistry and biology of secondary metabolite synthesis in marine organisms. Under the direction of Dr. William H. Fenical, this group has engaged in extensive investigation of the toxins and other unique substances produced mainly by soft-bodied marine plants and invertebrates. The group's interests center on organic chemistry and the strategies of chemical defense in the sea. This group cooperated with a French marine chemistry group to study algal metabolites from Mediterranean sources.

Dr. Aiya Sato is conducting a comprehensive investigation of the biologically active indole alkaloids produced by certain bryozoans. Several new and unusual substances have subsequently been defined from this group of infrequently studied marine invertebrates.

Nearshore Research Group

The Nearshore Research Group, headed by Dr. Richard J. Seymour, continued to focus on wave climatology and nearshore sediment transport. Dr. Seymour investigated the influences of the threshold velocity on initiating sediment motion in a number of sediment transport applications and demonstrated when this phenomenon can significantly affect the magnitude of the transport. He also continues investigating cross-shore sediment transport and has developed a model for predicting shoreline position changes given the wave height and tide range.

The group began investigating shoreline changes in the California region from Dana Point to the Tijuana River. This will be a long-term program involving quarterly profiles of the nearshore area to a depth of approximately 10 m on about 100 ranges. Scientists will look for interrelationships between observed shoreline changes and the wave climate as measured by five

directional wave arrays that are part of the group's wave climatology program.

David Castel and Dr. Seymour investigated the conditions for initiating density driven flows for entraining bottom sediments, which may apply to harbor entrance maintenance. They have also completed a study of the episodicity of longshore sediment transport as inferred from long-term directional wave measurements made by the group at nine stations on the Atlantic and Pacific coasts.

The coastal wave network, under the direction of Meredith H. Sessions, has expanded into the Pacific Basin with wave measuring buoys off the coasts of Oregon, Washington, and Hawaii. The computer-controlled automatic data-gathering techniques developed for waves have now also been applied to current measurement.

California Sea Grant College Program

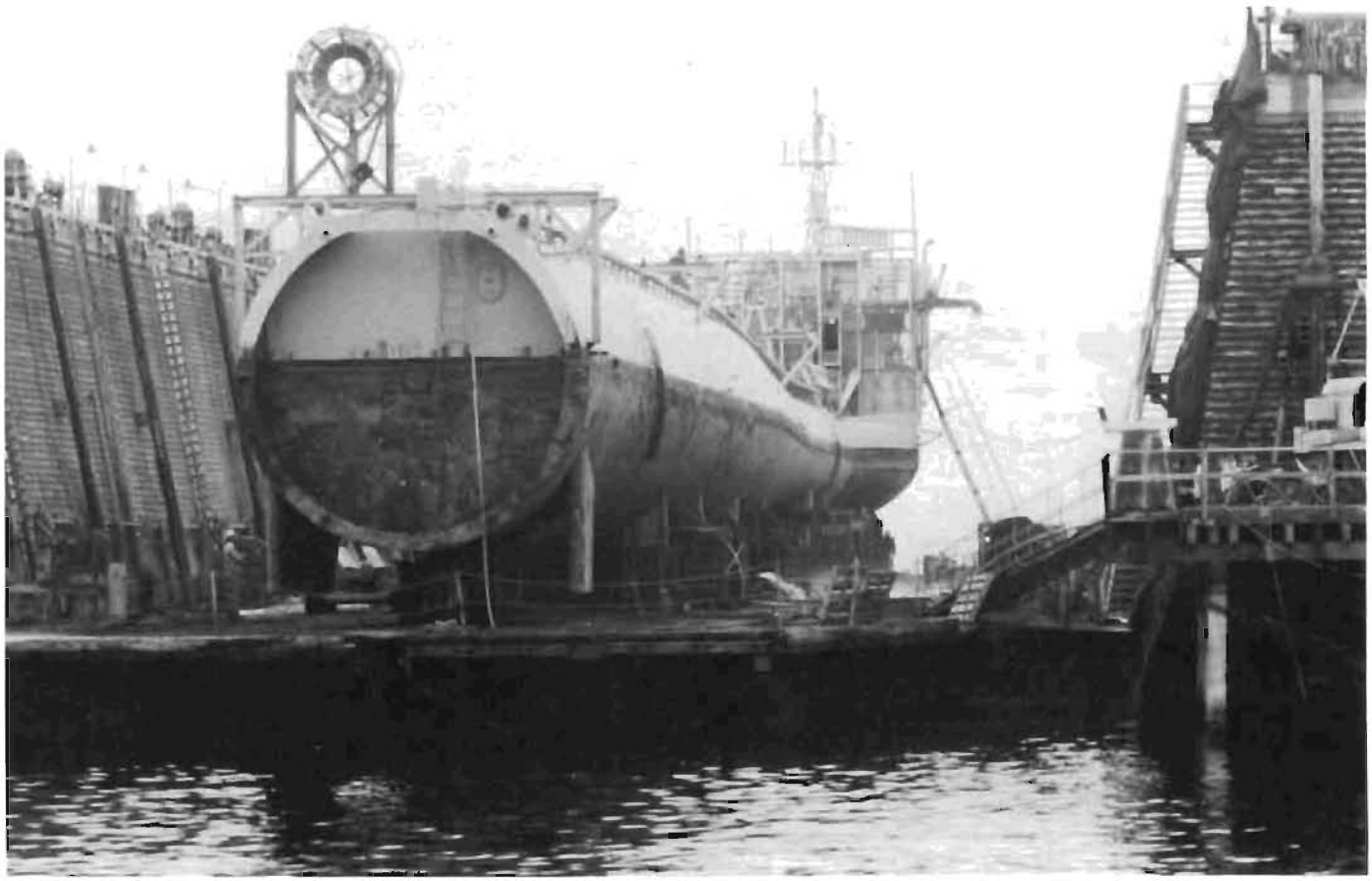
California's Sea Grant Program, directed by Dr. James J. Sullivan and administratively headquartered on the Scripps campus, is the largest of 29 Sea Grant programs currently under way in more than half of the nation's states and Puerto Rico. Its purpose is to accelerate sound development of marine resources by supporting a unique combination of marine research, education, and advisory activities throughout the state. This year 46 projects were supported at 11 California universities and colleges, covering fisheries, aquaculture, coastal resources, new marine products, ocean technology, and marine affairs. Fifteen of these projects were carried out by Scripps researchers. Reports of all the projects are available from the Sea Grant office at Scripps.

Other IMR Research Activities

Dr. H. William Menard continued his study of volcanoes, particularly volcanic islands, as indicators of tectonic processes and the evolution of oceanic lithosphere. He determined that the size-distribution of volcanoes is related to the age and, thus, the penetrability of the lithosphere. The abundance of small volcanoes does not increase significantly on crust older than 10 million years, thus they can penetrate only hot, thin crust. The largest volcanoes, such as Hawaii and Iceland, can penetrate anywhere. Intermediate sizes (3 to 4 km high) are very sensitive indicators of penetrability. For example, the extinct volcanoes of the Baja California Seamount Province are bounded on the north by the Murray fracture zone. The reason for the boundary is that the crust to the north was much colder, thicker, and less penetrable when the region drifted over mantle hot spots of intermediate size. Thus the volcanoes did not penetrate until the thin, young crust south of the fracture zone drifted over the hot spots. Dr. Menard also studied volcanic islands as markers of vertical movement of the islands and of the surrounding deep-sea floor.

This year Sargun A. Tont concentrated on identifying certain species of diatoms and dinoflagellates that could be used as tracers of climatic change along the coast of southern California.

Dr. Misuki Tsuchiya studied the circulation of the upper waters of the Pacific Ocean by mapping the distributions of the geostrophic flow and various water properties along the $240 \times 10^{-8} m^3 kg^{-1}$ isanosteric surface, which lies in the main thermocline. The maps show a double-cell subtropical anticyclonic circulation pattern in the North Pacific, with the poleward cell along about 30°N and the equatorward cell along 20-25°N, both extending eastward from the western boundary, where the two cells are joined together. The poleward cell is associated with the Kuroshio and its westward return flow and terminates at 180-170°W; the equatorward cell extends all the way to the coast of Baja California. The South Pacific exhibits a single subtropical anticyclonic gyre, which extends across the ocean and is roughly symmetric with the equatorward cell of the North Pacific gyre. There is no obvious indication of a poleward cell in the South Pacific.



MARINE PHYSICAL LABORATORY

Twenty-year-old FLIP, *in dry dock, is prepared for future expeditions.*

SEAGOING OPERATIONS

R/V *New Horizon*

DATE	EXPEDITION	AREA OF OPERATION	WORK PERFORMED	PORTS OF CALL	CHIEF SCIENTIST	CAPTAIN
7/9-7/19/81	Surface film 3	W. coast Baja California	Studies of sea-surface film	San Diego	P. Williams	L. Davis
7/23-8/9/81	CalCOFI 8108NH	Baja California	Survey of pelagic fish stock	San Diego	J. Schmitt	C. Johnson
9/13-9/20/81	Project Diana	Local	Equipment test	San Diego	B. Watters (BB&N)	C. Johnson
9/29-10/581		So. Calif. Bight	Food chain studies	San Diego	F. Azam	C. Johnson
10/19-10/22/81	Project Diana	Local	Equipment test	San Diego	B. Watters (BB&N)	A. Pelz
10/27-11/15/81	Project Diana	Local	Acoustic studies	San Diego	J. Barger (BB&N)	A. Pelz
11/20/81		Local	SDSU student cruise	San Diego	K. Bertine (SDSU)	A. Pelz
11/25-12/4/81		California coast	Physical oceanography	San Diego	J. Richman (OSU)	A. Pelz
1/8-1/14/82		Local	Student cruise	San Diego	R. Wilson	A. Pelz
1/23-2/11/82	Pluto Leg 7	East Pacific Rise	Seamount survey using DSRV *Alvin*	San Diego, Mazatlan, San Diego	P. Lonsdale	A. Pelz
3/3-3/15/82		Local	Benthic biology	San Diego	K. Smith	A. Pelz
3/23-3/31/82		So. Calif. Bight	Biology & chemistry	San Diego	P. Williams	A. Pelz
4/13-4/27/82	Oasis Leg 1	East Pacific Rise	Biology with DSRV *Alvin*	San Diego Mazatlan	G. Somero	A. Pelz
5/2-5/17/82	Oasis Leg 2	East Pacific Rise	Biology with DSRV *Alvin*	Mazatlan, San Diego	G. Somero	A. Pelz
5/20/82		Local	Equipment test	San Diego	T. Hayward	A. Pelz
5/26-6/28/82		So. Calif. Bight	Benthic biology	San Diego, Honolulu	K. Smith	T. Desjardins

TOTAL DISTANCE STEAMED: 21,228 nautical miles OPERATING DAYS: 199

R/P FLIP

DATE	EXPEDITION	AREA OF OPERATION	WORK PERFORMED	PORTS OF CALL	CHIEF SCIENTIST	CAPTAIN
11/19-11/25/81		Local	Doppler sonar test	San Diego	R. Pinkel	D. Efird

OPERATING DAYS: 7

R/V *Melville*

DATE	EXPEDITION	AREA OF OPERATION	WORK PERFORMED	PORTS OF CALL	CHIEF SCIENTIST	CAPTAIN
7/28-7/31/81		San Clemente Basin	MANOP lander test	San Diego	R. Weiss	A. Arsenault
8/1-8/6/81		Local	Water sampling	San Diego	H. Craig	A. Arsenault
8/10-9/12/81	Pluto Leg 1	Middle Amer. Trench	Deep Tow surveys	San Diego, Manz., Acapulco, Balboa	P. Lonsdale	A. Arsenault
9/30-10/5/81	Pluto Leg 2	Panama Basin	Escort for *Alvin*	Balboa, Puntarenas	K. Smith	A. Arsenault
10/10-10/31/81	Pluto Leg 3	East Pacific Rise	MANOP lander deploy.	Puntarenas, Manz.	R. Weiss	A. Arsenault
11/6-11/30/81	Pluto Leg 4	East Pacific Rise	Escort *Alvin*, Angus survey	Manzanillo, Cabo San Lucas, San Diego	H. Craig	R. Haines
3/19/82		Local	Ship's equip. test	San Diego	———	R. Haines
3/29-3/31/82		Local	Ship's equip. test	San Diego	———	R. Haines
4/13-4/28/82	Oasis Leg 1	East Pacific Rise	Bio. of hydrothermal vents	San Diego, Maz.	R. Hessler	R. Haines
5/2-5/19/82	Oasis Leg 2	East Pacific Rise	Bio. of hydrothermal vents	Mazatlan, San Diego	R. Hessler	R. Haines
6/1-6/3/82		San Clemente Basin	MANOP lander test	San Diego	R. Weiss	R. Haines
6/5-6/11/82		Local	Geochemistry	San Diego	H. Craig	R. Haines
06/18-7/21/82	MAGMA 1	East Pacific Rise	Deploy./recovery of OBSs	San Diego	J. Orcutt	R. Haines

TOTAL DISTANCE STEAMED: 15,323 nautical miles OPERATING DAYS: 165

William L. Armitstead at work in the engine room of R/V New Horizon.

Crew retrieving a mooring line.

Scientific crew takes a specimen of bacteria from a volcanic rock. Left to right are John T. Boaz, Douglas Nelson (Woods Hole Oceanographic Institution), Mark L. Powell, and Roberta J. Baldwin.

Ship's cook Charles H. Jones prepares dinner aboard R/V New Horizon.

Life aboard the R/V *Melville* is shown during the Oasis 82 expedition to the hydrothermal vent area near 21°N in the Pacific Ocean. Three ships shown are—from left to right—Woods Hole Oceanographic Institution's R/V *Lulu* (mother ship to the submersible *Alvin*) and Scripps ships R/V *New Horizon* and R/V *Melville*.

Instrument package, including a time-lapse camera, is dropped into the ocean.

Dr. Robert R. Hessler exercises during leisure time aboard R/V Melville.

Second Officer Dennis D. McGuire takes a course reading with sextant on the bridge of R/V Melville.

Captain Robert B. Haines, center, on the bridge aboard R/V Melville.

R/V *Ellen B. Scripps*

DATE	EXPEDITION	AREA OF OPERATION	WORK PERFORMED	PORTS OF CALL	CHIEF SCIENTIST	CAPTAIN
7/9-7/10/81		Off Catalina Isl.	Free vehicle implacement	San Diego	C. Smith	T. Whitman
7/10/81		Local	Student cruise	San Diego	R. Dunbar	T. Whitman
7/11/81		Local	Student cruise	San Diego	R. Dunbar	T. Whitman
7/13-7/18/81		California coast	Seismic studies	San Diego, Port Hueneme, San Diego	W. Prothero (UCSB)	T. Whitman
7/20-7/25/81		California coast	Benthic biology	San Diego	K. Smith	T. Whitman
8/13-8/18/81		California coast	Seismic studies	San Diego, Port Hueneme, San Diego	W. Prothero (UCSB)	T. Whitman
8/26-8/28/81	SABRAT XII	Local	Benthic biology	San Diego	R. Wilson	T. Whitman
8/31-9/7/81		No. Calif. coast	Recovery of CODE moorings	San Diego, Yerba Buena, San Diego	A. Bratkovich	T. Whitman
9/10/81		Local	Retrieve/reset buoy	San Diego	A. Bratkovich	T. Whitman
9/14-9/17/81	SABRAT XIII	Local	Benthic biology	San Diego	K. Sullivan	T. Whitman
9/21-9/24/81		California coast	Seismic studies	San Diego, Port Hueneme, San Diego	W. Prothero (UCSB)	T. Whitman
10/15/81		Local	Student cruise	San Diego	P. Fiedler	T. Whitman
10/19-10/23/81		California coast	Seismic studies	San Diego, Port Hueneme, San Diego	W. Prothero (UCSB)	T. Whitman
11/3-11/5/81		Local	Benthic biology	San Diego	R. Wilson	T. Beattie
11/30-12/13/81	Pluto Leg 5	Off Mazatlan, Mex.	Study of marine snow with DSRV *Alvin*	San Diego, Cabo San Lucas, Mazatlan	A. Alldredge	T. Whitman
12/30/81-1/27/82	Pluto Leg 6	Guaymas Basin	Geology with DSRV *Alvin*	Mazatlan, Santa Rosalia, San Diego	P. Lonsdale	T. Whitman
2/2-2/3/82		Local	Student cruise	San Diego	M. Clifton	T. Whitman
3/3-3/8/82		Off coast of Mex.	Seal census	San Diego	B. Le Boeuf (UCSC)	T. Whitman
3/29-3/30/82		Local	Free vehicle recovery	San Diego	L. Levin	T. Beattie
4/6-4/7/82		Local	Fish traps	San Diego	R. Wilson	T. Beattie
4/12-4/13/82		Catalina Basin	Free vehicle recovery	San Diego	C. Smith	T. Beattie
4/20-4/24/82		Local	Video/CTD tows	San Diego	W. Johnson	T. Beattie
5/10-5/15/82		California coast	Seismic studies	San Diego, Port Hueneme, San Diego	W. Prothero (UCSB)	T. Beattie
5/18-5/19/82		Local	Fish traps	San Diego	R. Wilson	T. Beattie
5/22/82		Local	Student cruise	San Diego	R. Rosenblatt	T. Beattie
6/2-6/3/82		Off Catalina Isl.	Free vehicle recovery	San Diego	L. Levin	T. Beattie
6/9-7/6/82		Pacific Northwest	Seal census	San Diego, Santa Cruz, Seattle, Port Angeles, San Diego	B. Le Boeuf (UCSC)	T. Beattie

TOTAL DISTANCE STEAMED: 11,347 nautical miles OPERATING DAYS: 148

R/V *Thomas Washington*

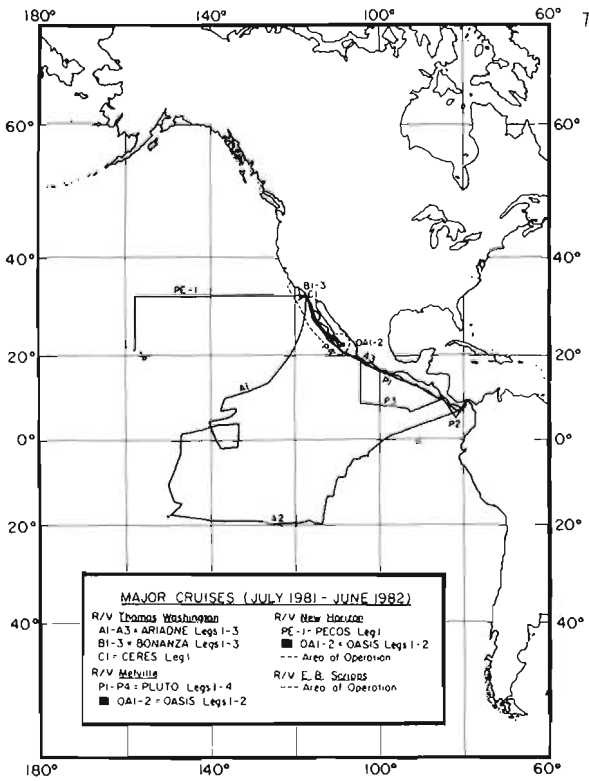
DATE	EXPEDITION	AREA OF OPERATION	WORK PERFORMED	PORTS OF CALL	CHIEF SCIENTIST	CAPTAIN
6/20-7/2/81	Rama Leg 15	N. Pacific Ocean	Various water samples/ deploy/recover fish traps	Dutch Harbor, San Diego	J. Burke (WHOI)	C. Johnson
10/20-10/25/81	Project Diana	Local	Acoustic work	San Diego	C. Gogos (BB&N)	C. Johnson
10/28-11/16/81	Project Diana	Local	Acoustic work	San Diego	C. Gogos (BB&N)	C. Johnson
12/12-12/13/81		Local	Sea Beam test	San Diego	R. Tyce	C. Johnson
12/17-12/22/81		Local	Sea Beam test	San Diego	J. Mammerickx	C. Johnson
1/11-2/10/82	Ariadne 1	E. Equat. Pacific	Drilling site surveys	San Diego, Papeete	T. Shipley/ G. Moore	C. Johnson
2/14-2/15/82	Ariadne 1A	Papeete Harbor	Sea Beam surveys	Papeete	S. Robert (CNEXO)	C. Johnson
2/16-4/3/82	Ariadne 2	East Pacific Rise	Sea Beam surveys	Papeete, Balboa, Puntarenas	P. Lonsdale	C. Johnson
4/6-4/28/82	Ariadne 3	Mid. America Trench	Sea Beam surveys	Puntarenas, San Diego	T. Shipley/ G. Moore	C. Johnson
6/5-6/6/82	Bonanza 1	San Clemente Canyon	Sea Beam surveys	San Diego	B. Luyendyk (UCSB)	C. Johnson
6/7-6/13/82	Bonanza 2	Local	Sea Beam surveys	San Diego	P. Lonsdale	C. Johnson
6/13-6/19/82	Bonanza 3	Local	Sea Beam surveys	San Diego	J. Mammerickx	C. Johnson
6/25-6/30/82	Ceres Leg 1	Local	Deep tow test	San Diego	F. Spiess	C. Johnson

TOTAL DISTANCE STEAMED: 24,773 nautical miles OPERATING DAYS: 165

RESEARCH VESSELS OF SCRIPPS INSTITUTION OF OCEANOGRAPHY

	MELVILLE	*NEW HORIZON*	*ELLEN B. SCRIPPS*	*THOMAS WASHINGTON*	FLIP	ORB
TYPE:	Oceanographic research	Oceanographic research	Offshore supply	Oceanographic research	Floating Instrument Platform	Oceanographic Research Buoy
HULL:	Steel	Steel	Steel	Steel	Steel	Steel
YEAR BUILT:	1969	1978	1964-65	1965	1962	1968
YEAR ACQUIRED BY SCRIPPS:	1969	1978	1965	1965	1962	1968
OWNER:	U. S. Navy	University of California	University of California	U.S. Navy	U.S. Navy	U.S. Navy
LENGTH:	74.67m	51.81m	28.95m	63.70m	108.20m	21.03m
BEAM:	14.02m	10.97m	7.31m	12.00m	6.09m	13.71m
DRAFT:	4.87m	3.65m	1.82m	4.39m	3.35/91.44m	fwd. 1.48 m aft. 1.63 m
DISPLACEMENT FULL (Metric tons):	1,882	698	212	1,235	1,359	294
CRUISING SPEED (Knots):	10	10	9	10	varies*	varies*
RANGE (Nautical miles):	9,000	6,000	5,100	9,000	varies*	varies*
CREW:	23	12	5	23	6	5
SCIENTIFIC PARTY:	29-39**	13 or 19**	8, 10, or 14**	19	10	10

1981-82 Total days at sea: 684
1981-82 Total nautical miles steamed: 72,671
*Depends on towing vessel
**With berthing vans



Trackchart.

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 seven curricular programs through which the student may pursue a five-year Ph.D. degree. Each of these curricular groups has requirements for admission in addition to the departmental requirements. The curricular programs are described below. For admission requirements and more information, please write to: Graduate Department, A-008, Scripps Institution of Oceanography, La Jolla, California 92093.

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 Engineering and Computer Sciences, on the UC San Diego campus. Engineers are provided a substantial education in oceanography, and oceanographers receive training in modern engineering. The instruction and basic research include the applied science of the sea and structural, mechanical, material, electrical, and physiological problems operating within the ocean.

Biological Oceanography. Biological oceanographers are concerned with the interactions of marine organisms with the physical-chemical environment. Research and instructional activities in this curriculum range from food-chain dynamics and community structure to taxonomy, behavior, physiology, and zoogeography of oceanic organisms.

Geophysics. This curriculum is designed to educate the physicist (theoretician or experimentalist) to understand the sea, the solid earth on which the waters move, and the atmosphere with which the sea interacts. The program assists the student in understanding the nature of the earth and in mastering the new field, laboratory, and mathematical techniques.

Marine Biology. The marine biology curriculum places particular emphasis on the biology of marine organisms—animals, plants, and prokaryotes. The research and teaching encompass a range of biological disciplines, including behavior, neurobiology, developmental biology, and comparative physiology/biochemistry.

Marine Chemistry. Marine chemists are concerned with chemical processes operating within the marine environment: the oceans, the marine atmosphere, and the sea floor. Research programs are based on the interactions of the components of seawater with the atmosphere and sedimentary solid phases, and with the chemical constituents of marine plants and animals.

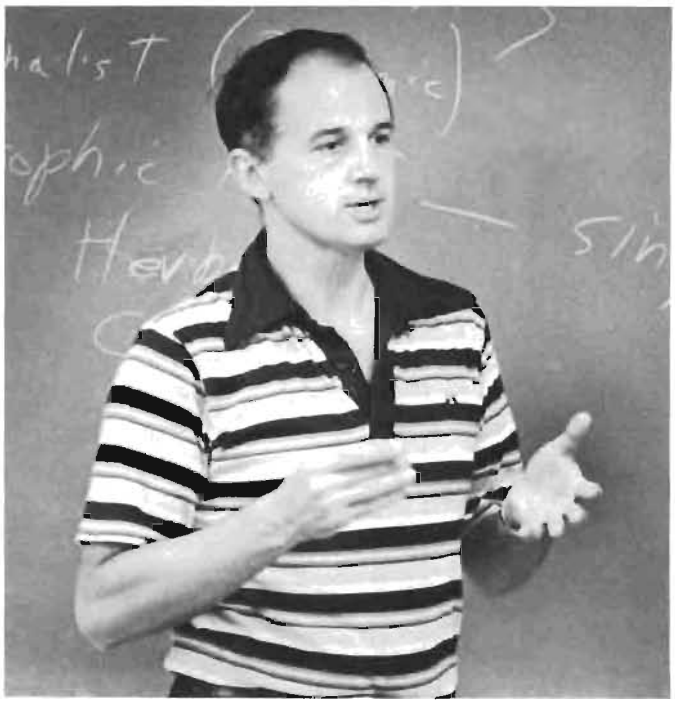
Geological Sciences. This curriculum applies observational, experimental, and theoretical methods to the understanding of the solid earth and solar system and their relationship to the ocean and the atmosphere. Principal subprograms are marine geology and tectonics, sedimentology, micropaleontology and paleoceanography, petrology, geochemistry, and cosmochemistry. Expedition work at sea, and field work on land are emphasized as an essential complement to laboratory and theoretical studies.

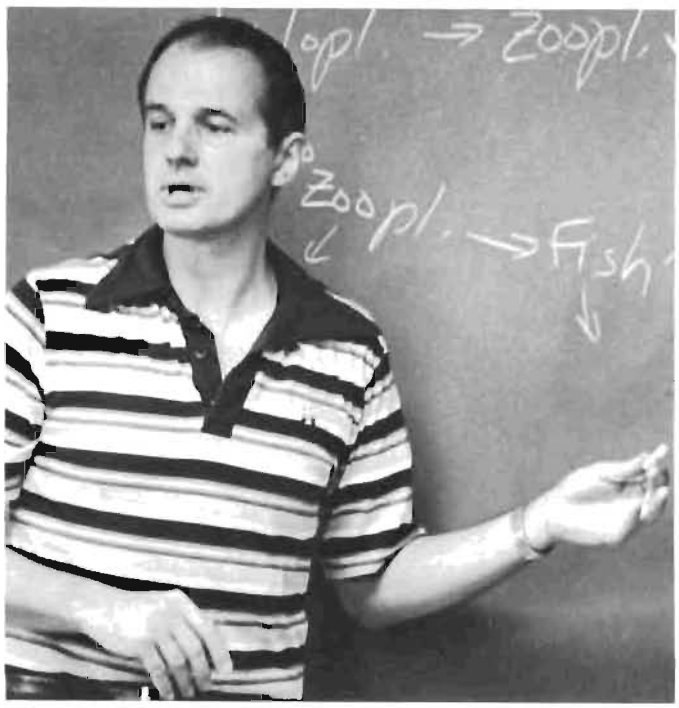
Physical Oceanography. Studies in physical oceanography include the observation, analysis, and theoretical interpretation of the general circulation of ocean currents and the transport of heat and of dissolved and suspended substances by the ocean; the distribution and variation of properties of the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

GRADUATE STUDENTS AND DEGREE RECIPIENTS

In the fall of 1981, 39 new students were admitted to graduate study. Of these, 8 were in marine biology, 5 in geological sciences, 5 in marine chemistry, 4 in geophysics, 4 in physical oceanography, 7 in applied ocean sciences, and 6 in biological oceanography. Enrollment at the beginning of the academic year was 197. Thirteen Master of Science degrees and 27 Doctor of Philosophy degrees were awarded by UC San Diego to the students listed.

Dr. Michael M. Mullin teaches the Marine Communities and Environments class.





Doctor of Philosophy Degrees Awarded, with Titles of Dissertations

Earth Sciences

Paul A. Baker, "The Diagenesis of Marine Carbonate Sediments: Experimental and Natural Geochemical Observations."

Miriam Baltuck, "Mesozoic Pelagic Sedimentation in a Tethyan Continental Margin Basin, Pindos Mountains, Greece."

Sherman H. Bloomer, "Mariana Trench—Petrologic and Geochemical Studies: Implications for the Structure and Evolution of the Inner Slope."

Benjamin F. Chao, "Symmetry, Excitation and Estimation in Terrestrial Spectroscopy."

Robert B. Dunbar, "Sedimentation and the History of Upwelling and Climate in High Fertility Areas of the Northeastern Pacific Ocean."

Jerry L. King, "Observations on the Seismic Response of Sediment-Filled Valleys."

Allen H. Olson, "Forward Simulation and Linear Inversion of Earthquake Ground Motions."

Paul G. Silver, "Optimal Estimation of Scalar Seismic Moment."

Marine Biology

Lee-Shing Fang, "The Blue-Green Pigment in the Blood Serum of a Marine Fish, *Clinocottus analis:* Identification, Metabolism and Biological Significance."

Roger P. Hewitt, "Spatial Pattern and Survival of Anchovy Larvae: Implications of Adult Reproductive Strategy."

Joanne A. Matsubara, "Electrolocation in Weakly Electric Fish: A Neuroethological Analysis."

Oceanography

Jay P. Barlow, "Methods and Applications in Estimating Mortality and Other Vital Rates."

Keir Becker, "Heat Flow Studies of Spreading Center Hydrothermal Processes."

Alan W. Bratkovich, "Tidal Variability in the Current and Temperature Fields on the Southern California Continental Shelf."

Michael G. Brown, "Inverting for the Ocean Sound Speed Structure."

David C. Chapman, "Some Effects of Steep Topography on Linear Waves in a Stratified Ocean."

Douglas A. Coats, "The Absolute Flow Field in the Pacific Ocean from a Consideration of Potential Vorticity."

Alfred T. Dengler, Jr., "Spatial Distributions of Phytoplankton: Limitations of Power Spectrum Techniques."

Paul C. Fiedler, "Fine-Scale Spatial Pattern in the Coastal Epiplankton: Description and Functional Significance."

Michael H. Freilich, "Resonance Effects on Shoaling Surface Gravity Waves."

Jed A. Fuhrman, "Patterns of Bacterioplankton Growth in the Sea."

Kim A. Kastens, "Structural Causes and Sedimentological Effects of 'Cobblestone Topography' in the Eastern Mediterranean Sea."

Richard D. Methot, Jr., "Growth Rates and Age Distributions of Larval and Juvenile Northern Anchovy, *Engraulis mordax,* with Inferences on Larval Survival."

James G. Ogg, "Sedimentology and Paleomagnetism of Jurassic Pelagic Limestones ('Ammonitico Rosso' Facies)."

Steven S. Pawka, "Wave Directional Characteristics on a Partially Sheltered Coast."

Alan M. Shiller, "The Geochemistry of Particulate Major Elements in the Santa Barbara Basin and Observations on the Calcium Carbonate-Carbon Dioxide System in the Ocean."

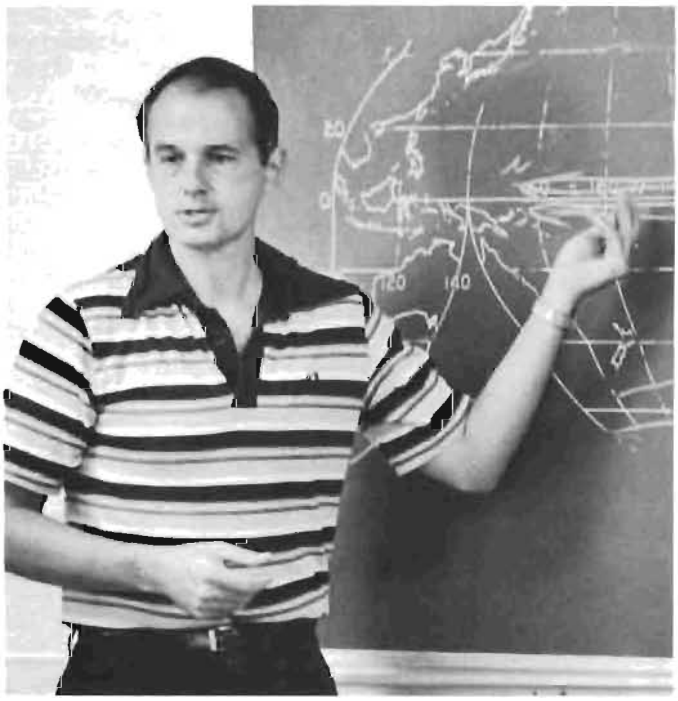
Roger P. Walker, "The Chemical Ecology of Some Sponges and Nudibranchs from San Diego."

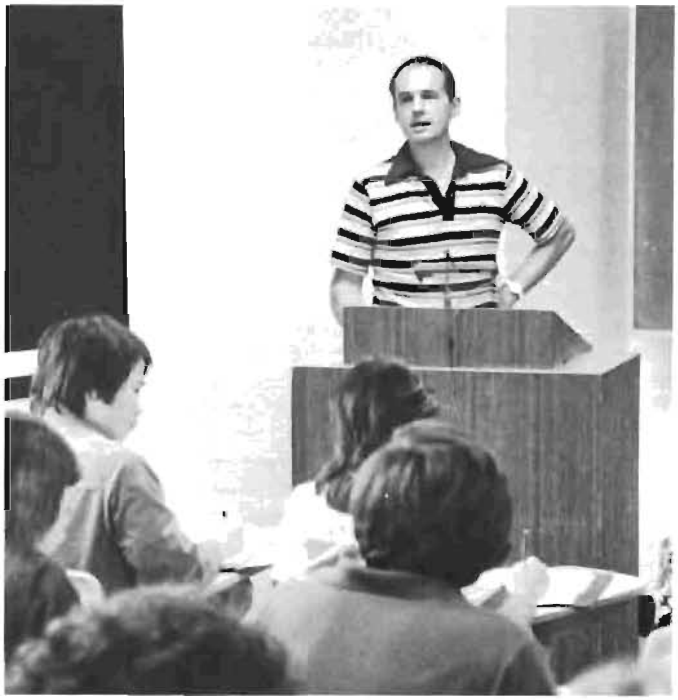
Master of Science Degrees

Earth Sciences
Naomi Benaron
Hans E. Sheline

Marine Biology
Morris D. Roberts

Oceanography
Vittorio Barale
Christian P. deMoustier
Stephen L. Elgar
Charles W. Jerde
Torgny A. M. Mellin
Mustafa O. Moammar
Albert J. Plueddemann
Allan W. Sauter
William A. Stone
Marco M. P. Weydert





SHORE FACILITIES AND SPECIAL COLLECTIONS

Facilities

Analytical Facility. Instruments at the facility include an automated X-ray diffractometer; automated X-ray spectrometer; Atomic Absorption Spectrometer (A.A.); heated graphite atomizer (attachment to A.A.); amino-acid analyzer; gas chromatograph; gas chromatograph/mass spectrometer; carbon-dioxide analyzer; a Cambridge S-4 scanning electron microscope with energy dispersive X-ray spectrometer; a Hitachi H-500 STEM with energy dispersive X-ray spectrometry and CAMECA 3-scanner electron microprobe. The facility offers complete sample preparation laboratories, including "wet" chemistry and rock-processing laboratories, a tabletop HP-97 computer, and geological field equipment.

Cardiovascular Research Facility. This shared facility of the Physiological Research Laboratory and the UC San Diego School of Medicine consists of an experimental animal colony, equipment for measuring circulatory and cardiac functions in conscious unrestrained animals, and a cardiovascular instrumentation development laboratory.

Diving Facility. The diving program is housed in two separate facilities that contain the mechanical gear, wet equipment storage locker, and showers.

The scientific diver training and certification program, which originated at Scripps in 1951, is the oldest of its type in the country.

The program consists of a nonrecreational 100-hour training class in the use of open circuit scuba, which may lead to University of California research diver certification. This class is open to faculty, staff, and students who must conduct underwater research. Each year there are, on an average, 130 Scripps/UCSD personnel in the scientific diving program. These individuals conduct their research throughout the oceans of the world, including the Antarctic.

Experimental Aquarium. Used by faculty, research staff, and graduate students for studies of living plants and animals, the experimental aquarium is provided with ambient and chilled seawater, and is equipped with 5 rooms for controlled environmental studies, 20 tanks, and 9 seawater tables.

Hydraulics Laboratory. This laboratory has a wind-wave channel 43x2.4x2.4 m in size with a tow cart for instrument and model towing; a two-layer stratified flow channel, test section 1.1x1.1x16m; a 15x18-m wave-and-tidal basin with an adjustable simulated beach; a 40-m glass-walled, wave-and-current channel; a granular fluid mechanics test facility that consists of a 6x12x3-m concrete basin; a 10x1x1-m fluidizing channel; three sand-storage and calibration tanks each 4 m high by 5 m in diameter, all serviced with a high-flow, slurry pumping system; and an insulated, refrigerated, cylindrical seawater tank 10 m deep and 3 m in diameter. All wave generators in the laboratory incorporate servo systems and can be computer or magnetic-tape controlled. Microcomputer based data acquisition and data processing systems are used in conjunction with the various facilities.

Kendall Frost Mission Bay Marsh Reserve (Mission Bay, San Diego). Approximately 20 acres of marshland in Mission Bay that belong to the university constitute a marsh preserve and wildlife refuge designated for teaching and research. The reserve is a unit of the University of California Natural Land and Water Reserve System. A small laboratory is on the preserve.

Marine Science Development and Outfitting Shop. This shop is equipped with precision tools and machinery. A staff of toolmakers and diemakers designs, develops, and fabricates research equipment and instrumentation in support of the various laboratories at Scripps and other educational and governmental organizations throughout the United States.

Mass Spectrographic Equipment. Nine mass spectrometers are available. They include two 15-cm, Nier-type spectrometers, and one 6-cm Micromass instrument for isotopic analysis of light elements; a 15-cm, Nier-type spectrometer for rare gases; a 25.4-cm double-collection mass spectrometer for He^3/He^4 ratio measurements; a gas chromatograph-quadrupole mass spectrometer for qualitative separation and analysis of organic compounds; a 30-cm-radius, solid-source, mass spectrometer for geochronology and isotope dilution analysis; a small, portable, helium mass spectrometer for field use; and a 3-cm mass spectrometer for stable isotope tracer measurements.

Petrological Laboratory. This facility provides thin-sectioning, microprobe sample preparation, and rock-surfacing services to staff, students, and associated research groups. All types of submarine and subaerial igneous, metamorphic, and sedimentary materials in various states of lithification are prepared here using plastic-vacuum techniques and other types of impregnations.

Physiological Research Laboratory Pool Facility. This facility includes a holding pool for large marine mammals and fish; a ring pool of 10-m radius equipped with a variable-speed trolly to carry instruments for various hydrodynamic and biological studies of mammals and man; and a pool for echolocation studies and animal training. A central island within the ring pool contains small, dry laboratories and a "wet" laboratory equipped to handle large animals. A flow channel through the island permits transfer of animals from the ring pool intoa the laboratory.

Radio Station WWD. Owned and operated by Scripps and licensed to the National Marine Fisheries Service (NMFS), station WWD provides communications services worldwide to both Scripps and NMFS and to other governmental and institutional ships. Weather advisories are provided routinely to the fishing fleet as well as to scientific vessels. Western Union services (TWX-Telex) are provided to the San Diego campus.

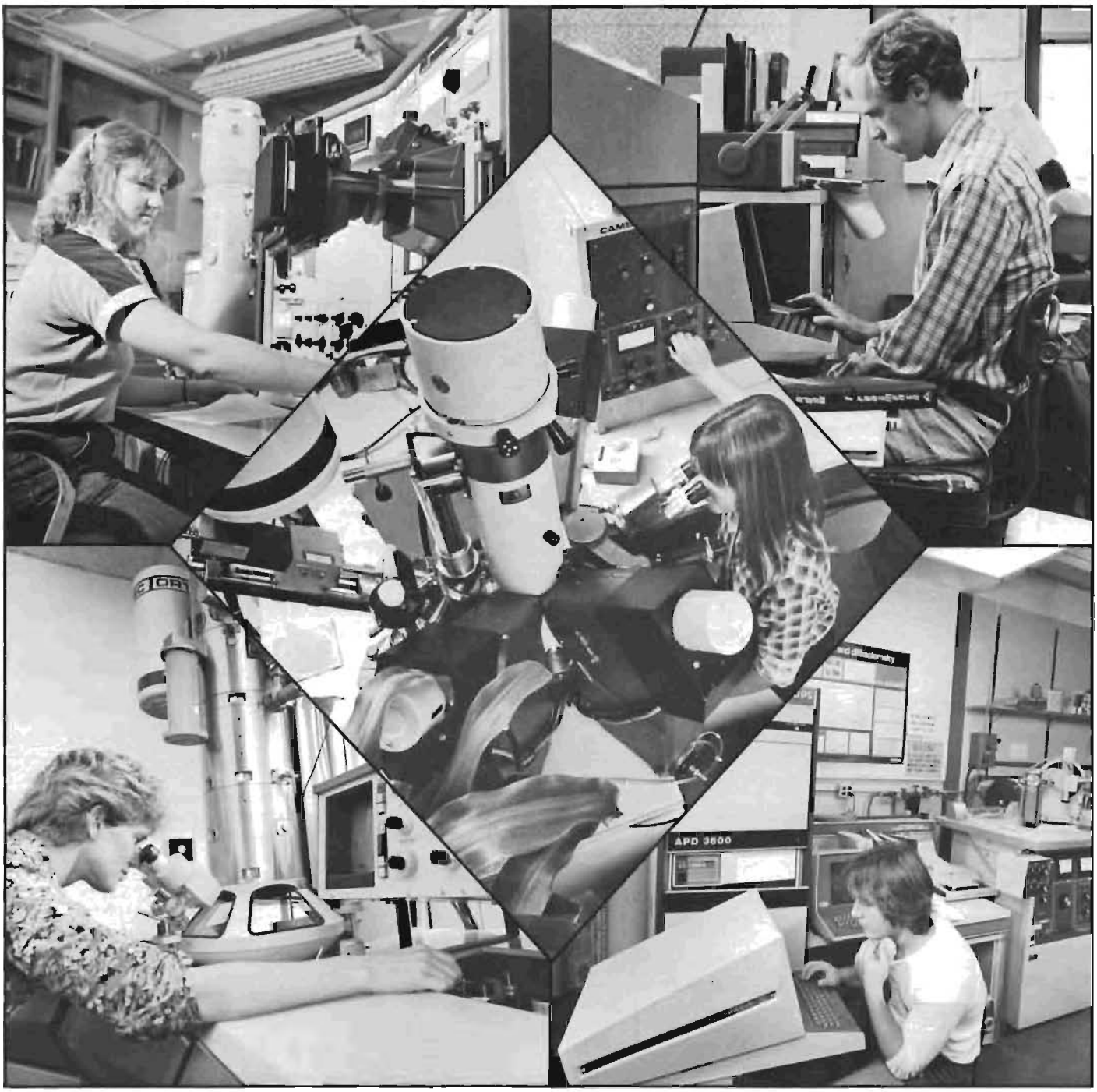
San Vicente Lake Calibration Facility. (48 km from Scripps.) This facility, operated by the Marine Physical Laboratory, is equipped for testing and calibrating acoustic transducers used in oceanographic research. The equipment is located on an 8x15-m enclosed platform in 40 m of water and offers 1,372 m of unobstructed range.

Satellite-Oceanography Facility. This facility enables oceanographers to directly receive and process satellite imagery. Data transmitted in real time by the NOAA and NIMBUS polar orbiting satellites are received by the 5-m tracking antenna and stored on computer-compatible tapes. In addition to real-time coverage, retrospective archives of worldwide data are also available. The most commonly used sensors include the Advanced Very High Resolution Radiometer (AVHRR) and Coastal Zone Color Scanner (CZCS), which provide information in the infrared and visible portions of the spectrum. The Scanning Multichannel Microwave Radiometer (SMMR) data, from which sea surface winds may be derived, are also processed at the facility. The System Central Processor is an HP 3000 Series II computer dedicated to the facility. This processor has 512 kilobytes of main memory and 250 megabytes of disk storage. Tape drives capable of operating at 800, 1600, or 6250 bpi densities 317 cm per second assure complete versatility. A high-resolution color display station allows the user full interaction with the satellite imagery at near-real-time rates for most common operations. Current applications include tracking of drifting buoys via the ARGOS data collection system, near-real-time support of research vessels and aircraft by remote detection of chlorophyll concentrations, and sea-surface temperature determination. A four-day course, taught every quarter by the facility staff, gives potential users an overview of the available tools as well as several hours of hands-on experience.

Scripps Library. The library has outstanding collections in oceanography, marine biology, and marine technology. It also specializes in publications on atmospheric sciences, fisheries,

Graduate student Nancy W. Hinman operates the scanning electron microscope.

Dr. Sherman H. Bloomer completes a research project on the x-ray fluorescent spectrometer.



Analytical Facility equipment in use. Alison M. Srull at the scanning transmission electron microscope.

(Center) Graduate student Cynthia A. Evans at work at the electron microprobe in the Analytical Facility.

UCSD student David P. Lesmes surveys mineralogical data files on the x-ray diffractometer.

geology, geophysics, and zoology. The library currently receives nearly 3,400 serial titles and has a catalogued collection of 140,000 volumes, as well as an extensive Documents, Reports, and Translations Collection, a Maps and Charts Collection emphasizing nautical information, and a Rare Book Collection with numerous accounts and journals of famous voyages of discovery.

The library also houses the Archives of the Scripps Institution of Oceanography, which includes official Scripps records, personal papers, photographs, and other material documenting the history of oceanography and Scripps.

Scripps Pier. The 305-m pier serves as a launching site for small boats used for local oceanographic work and provides space for on-site observational studies.

Seawater System. Pumps located on Scripps Pier deliver seawater to the laboratories and aquaria of Scripps and the Southwest Fisheries Center. The seawater system utilizes two high-speed sand filters and two concrete storage tanks with a total capacity of 439,060ℓ. Delivery capacity is 5,300 ℓ per minute.

Shipboard Computer Group. This group of computer programers, engineers, and technicians supports four IBM 1800 computers and, as required, other computer systems at Scripps through programing, interface design, and maintenance. Computers are installed permanently on R/V *Thomas Washington* and R/V *Melville* and on campus. The IBM 1800 computer systems are interfaced to ship's course and speed and to satellite navigation receivers for precise determination of data location. Scientific instruments interfaced to the computer for automatic data acquisition and storage include XBT (Expendable Bathythermography), magnetometer, transponder-ranging inputs for the Marine Physical Laboratory's Deep Tow vehicle, radio-relayed sonobuoy wide-angle reflection signals, and the R/V *Thomas Washington* Sea Beam system.

Digital seismic-reflection systems are available to sample either 2 or 24 analog signals and record them on digital magnetic tape.

A Prime 750 computer system on campus is well adapted to economical number-crunching with a 3.2μs floating point (64 bits) multiplier, three megabytes of memory, 900 megabytes of disk, and an array processor. Its use is primarily by CRT terminals.

Thomas Wayland Vaughan Aquarium-Museum. The aquarium-museum helps to increase public understanding and appreciation of the ocean through exhibits of living marine animals from both local waters and the Sea of Cortez, museum displays on oceanographic topics, and a variety of educational programs.

Scientists at the aquarium-museum study marine animal maintenance systems, fish coloration, and fish diseases. Through its collecting facility, the aquarium supplies university scientists with living specimens.

This year more than 35,000 students in educational groups toured the aquarium-museum. The aquarium is open to the public daily; admission is free.

A public membership group, the Scripps Aquarium Associates, provides lecture series, local and foreign study excursions, and a quarterly newsletter.

Underwater Research Areas include:

Scripps Shoreline Reserve. Scripps Shoreline Reserve consists of a 100-acre tract of seashore and ocean where marine plants and invertebrates are protected for scientific purposes. Employees and students of the university may collect from this area with a permit from the aquarium-museum director's office. This reserve is also identified by the California Department of Fish and Game as the San Diego Marine Life Refuge.

Scripps Submerged Land Area. This area of approximately 2.5 km is leased by the University of California from the city of San Diego. It lies seaward and to the north of Scripps.

Special Collections

Benthic Invertebrates. The collection contains some 28,000 lots of specimens sorted into major taxonomic groups such as Coelenterata, Echinodermata, and Mollusca. All are catalogued with collection data, and more than 35 percent are identified according to species. Specimens are available to qualified students and researchers for study.

Deep Sea Drilling Project Core Repository. Scripps houses the West Coast Repository for cores collected by DSDP from the Pacific and Indian oceans. Core samples are made available to qualified researchers throughout the world under policies established by the National Science Foundation.

Geological Core Locker. This geological "library" contains a collection of several thousand deep-sea sediment cores kept under refrigeration, and bulk assemblages of rocks and manganese nodules dredged from the major ocean basins. These materials are available to scientific investigators and students.

Geological Data Center. Most of the geological/geophysical data collected by Scripps vessels while under way are processed and archived at this location. Navigation, depth, and magnetic data are computer-processed for entry into the digital data base and for production of cruise reports and plots. Seismic profiler records are microfilmed, blown back at reduced scale, and reassembled by geographic area to permit rapid retrieval and evaluation. Index track charts, with overlays of the various data types, contain more than one million nautical miles of Scripps cruises, as well as tracks of DSDP's *Glomar Challenger*. The data center also maintains a multidisciplinary index of all samples and measurements made on major Scripps cruises.

Marine Botany Collection. A small herbarium of marine benthic algae is composed of specimens from the U.S. Pacific coast, chiefly from the San Diego area, or collected during Scripps expeditions in the Pacific Ocean. There are some 1,600 sheets of pressed seaweeds, identified and arranged in taxonomic order. The specimens, although primarily used for teaching, are available for examination by any botanist or interested student.

Marine Invertebrates. Included in this collection of more than 60,000 documented whole zooplankton samples are accessioned holdings from the continuous CalCOFI Program, expeditions, and special projects. Samples represent zooplankton, collected with nets, ranging from surface neuston to bathypelagic mid-water trawls. The major emphasis of the collection has been in the N.E. Pacific, but an increasing number of samples are also available from other oceanic and continental slope regions. The collection includes identified specimens for some of the major taxonomic groups. Samples are supplemented with physical and chemical data.

Marine Vertebrates. This collection contains more than 2 million specimens, with 3,200 catalogued species, including 128 primary types. Approximately 500 collections are added each year. Although the collection is worldwide, it specializes in deep-sea and eastern Pacific shorefishes. It contains large holdings of shorefishes from the Gulf of California and Panama and an extensive skeletal collection of both dried preparations and cleared-and-stained specimens in glycerin.

Oceanographic Data Archives. Tide-gage records have been taken daily from the Scripps Pier since 1925. Records from January 1980 to the present are held at the Scripps Diving Locker in one-month data rolls. Records prior to 1980 may be obtained by writing Chief of the Datums and Information Branch, James R. Hubbard, C-233 NOAA/NOS, 6011 Executive Blvd., Rockville, MD 20852.

Temperature and salinity records, taken daily, and records for various years from other California shore stations, along with data from more than 20,000 hydrographic casts from Scripps cruises, are managed by the Physical and Chemical Oceanographic Data Facility.

Historical meteorological and oceanographic data for the Pacific are kept in the NORPAX data library. These data include marine weather and sea-surface temperature observations from 1854 to the present; National Oceanographic Data Center files to 1976; and monthly pressure, temperature, and precipitation at selected World Meteorological Organization stations.

PUBLICATIONS

Introduction

The results of research conducted at Scripps are published in many different forms that range from short contractual reports to long taxonomic descriptions. Scripps publications are distributed by subscription, exchange, or government contract.

Below is a complete listing of Scripps publications for fiscal 1982. Detailed information on the availability of each series is included.

Bulletin

The *Bulletin of the Scripps Institution of Oceanography* is an irregularly published series for lengthy, in-depth scientific papers written by Scripps scientists. For information about subscriptions and a list of volumes available please write: University of California Press, 2223 Fulton Street, Berkeley, California 94720.

The most recent volume is listed below.

V.24 **Johnson,** G. David. The Limits and Relationships of the Lutjanidae and Associated Families. 117p. 1981.

CalCOFI Atlas Series

The *California Cooperative Oceanic Fisheries Investigations* (CalCOFI) *Atlas Series* provides processed physical, chemical, and biological measurements of the California Current region. The series reflects the work of the CalCOFI program, in which Scripps cooperates with the California Department of Fish and Game and the National Marine Fisheries Service.

These atlases are distributed at no charge to research institutions, university libraries, and qualified research scientists active in oceanographic fields relating to the CalCOFI program. Editions are limited to 650 copies. Institutions or libraries interested in acquiring atlases should write to: Dr. Abraham Fleminger, Scripps Institution of Oceanography, A-001, La Jolla, California 92093.

The atlas issued this year is listed below.

No. 29 **Namias,** J. Teleconnections of 700 mb height anomalies for the Northern Hemisphere. August 1981. 270p.

Contributions

This annual publication is a compilation of selected reprints authored by the Scripps faculty and staff. The *Scripps Institution of Oceanography Contributions* is available ONLY on an exchange basis to other scientific, research, and educational institutions. For exchange information please write: University of California, San Diego, Library Gifts and Exchange Department, C-075a, La Jolla, California 92093.

The articles listed below were published in the 1981 volume and may be found in the publications cited. Information about a specific reprint can be obtained by writing directly to the author in care of: Scripps Institution of Oceanography, La Jolla, California 92093.

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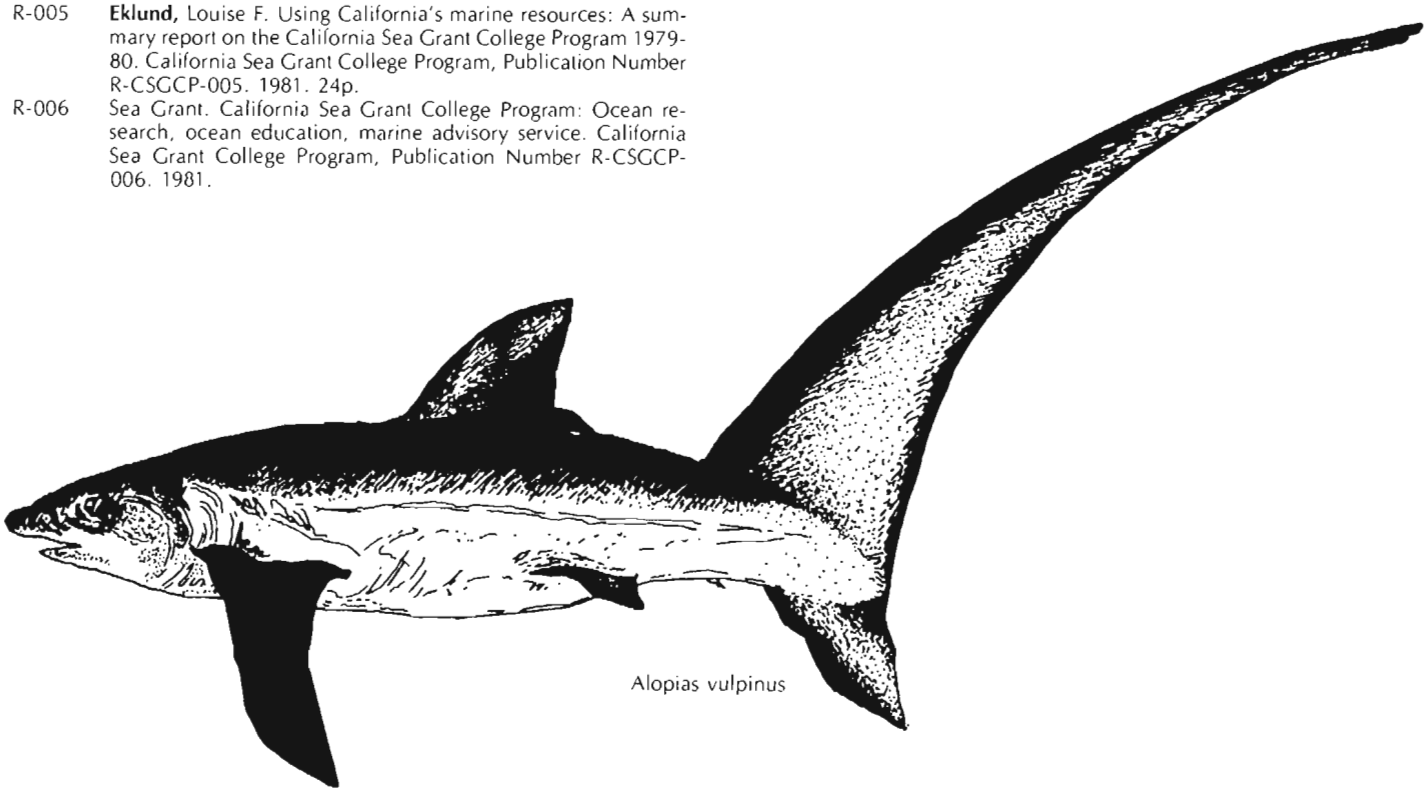

Alopias vulpinus

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July 1, 1981, to June 30, 1982

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CS—California Space Institute
CCS—Center for Coastal Studies
DO—Director's Office
DSDP—Deep Sea Drilling Project
D-SIO—Department Scripps Institution of Oceanography
EECS—Electrical Engineering and Computer Sciences
GRD—Geological Research Division
IGPP—Institute of Geophysics and Planetary Physics
IMR—Institute of Marine Resources
IPAPS—Institute for Pure and Applied Physical Sciences
MBRD—Marine Biology Research Division
MLRG—Marine Life Research Group
MPL—Marine Physical Laboratory
NR—Natural Resources
NU—Neurobiology Unit
ORD—Ocean Research Division
PRL—Physiological Research Laboratory
SC—Scientific Collections
SGP—Sea Grant Program
SOMTS—Ship Operations and Marine Technical Support
SPP—Science and Public Policy
VL—Visibility Laboratory

In Memoriam

Leonard P. Cigainero. February 21, 1982. He was an electronics technician and marine radio officer with Marine Facilities from 1964 to 1978.

Gary Hobson Dobbs III. December 31, 1981. He received his Ph.D. in marine biology at Scripps in 1974, and was an associate professor at Washington and Lee University.

Theodore Enns. January 20, 1982. His degree was in physics, but his major scientific work was in physiology, especially on the transport of gases, water, and electrolytes in tissues. Dr. Enns received one of the first appointments at the Physiological Research Laboratory in 1962, and later was in the Marine Biology Research Division until retiring in 1979.


Dr. Theodore Enns

Gerald V. Howard. December 18, 1981. He was for many years the director of the National Marine Fisheries Service's Southwest Region and an international figure in fisheries. At Scripps, Dr. Howard was a research fellow from 1957 to 1962 and a research associate from 1962 to 1968.

Lewis William Kidd. June 28, 1982. He was at Scripps as an equipment designer from 1950 to the early 1960s and, among other contributions, participated in the design of the Isaacs-Kidd Midwater Trawl.

Valdemar Frick Larson. July 15, 1981. He joined the Deep Sea Drilling Project in 1969, and was head of the engineering development program from 1971. He was closely involved with nearly every technical innovation of that program.

Annette Pickens. March 26, 1982. She was a secretary and administrative assistant in the Ocean Research Division, Geological Research Division, and the Graduate Department from 1966 to 1981.

Edith Roden. January 31, 1982. She provided translation of foreign literature, especially Russian, to many people at Scripps for a number of years.

Philip Rudnick. June 10, 1982. He was a research physicist in the Marine Physical Laboratory from 1949 to 1969. Dr. Rudnick made substantial contributions in marine physics and signal processing, and he provided the theoretical basis for the design of FLIP.


Dr. Philip Rudnick

John L. Usher. July 25, 1981. He was associate chief scientist for science services at the Deep Sea Drilling Project from 1976 until his retirement in January 1981.

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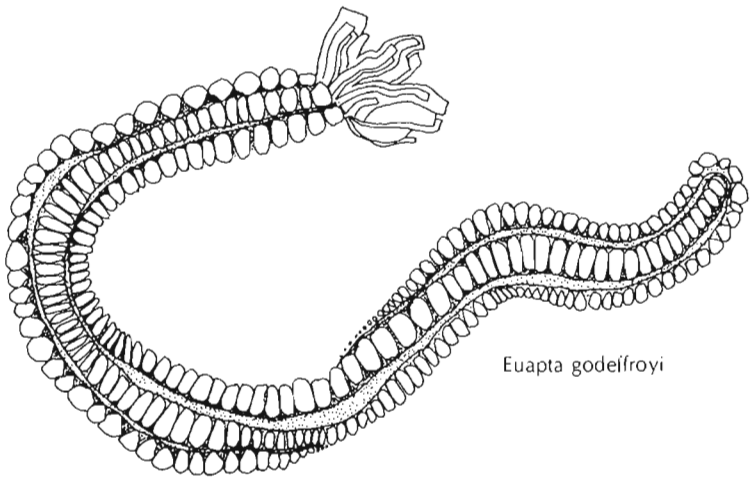
Euapta godeifroyi

APPENDIX C

Major Awards and Honors

Dr. Harmon Craig
Received first Special Creativity Award in Oceanography from the National Science Foundation.
Dr. Richard W. Eppley
Elected president of the American Society of Limnology and Oceanography.
Dr. Frederick H. Fisher
Elected president of the Acoustical Society of America.
Jeffery D. Frautschy
Awarded the University of California, San Diego Chancellor's Associates Award for Excellence in Public Service.
Dr. Miriam Kastner
Awarded a Guggenheim Fellowship.
Dr. John W. Miles
Awarded the 1982 Timoshenko Medal by the American Society of Mechanical Engineers.
Dr. William A. Nierenberg
Awarded the Distinguished Public Service Medal by the National Aeronautics and Space Administration.
Selected to present the fall 1981 Charles H. Davis Lecture.
Frances L. Parker
Received the Joseph A. Cushman Award from the Cushman Foundation for Foraminiferal Research.
Dr. Claude E. ZoBell
Elected to honorary membership in the American Society for Microbiology.

APPENDIX D

The Regents of the University of California

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Mike Curb
Lieutenant Governor of California

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APPENDIX E
Current Funds Expenditures 1981–1982

Agency	Scripps Institution of Oceanography	INSTITUTES: Geophysics and Planetary Physics	Marine Resources	Cal Space	Total	Percentage of Total
FEDERAL GOVERNMENT						
National Science Foundation	$30,957,220	852,866	558,920	11,737	32,380,743	52.2
Navy, Department of the	7,537,945	369,029	21,212	—	7,928,186	12.8
National Aeronautics and Space Administration	318,245	53,802	23,453	115,860	511,360	.8
Army, Department of the	—	—	533,276	—	533,276	.9
Energy, Department of	353,851	—	464,465	—	818,316	1.3
Air Force, Department of the	430,554	—	—	—	430,554	.7
Interior, Department of the	53,978	378,326	—	—	432,304	.7
Health and Human Services, Department of	536,257	1,615	2,825	—	540,697	.9
Commerce, Department of	709,109	29,856	1,305,206	4,947	2,049,118	3.3
Other	59,556	—	23,147	—	82,703	.1
Total Federal Government	40,956,715	1,685,494	2,932,504	132,544	45,707,257	73.7
STATE AND UNIVERSITY FUNDS	7,799,117	382,399	694,351	529,733	9,405,600	15.2
LOCAL GOVERNMENT	13,220	—	67,826	—	81,046	.1
PRIVATE GIFTS AND GRANTS	4,192,157	66,902	228,858	61,547	4,549,464	7.4
ENDOWMENT FUNDS	508,885	13,769	40,377	—	563,031	.9
SERVICES, RESERVES AND MISC.	1,497,295	63,597	124,935	—	1,685,827	2.7
Total Current Funds Expenditures	$54,967,389	2,212,161	4,088,851	723,824	61,992,225	100.00

Scientists at work aboard R/V Melville during Oasis 82 expedition

All correspondence pertaining to this specific report should be directed to:
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