

SIO 1967

SCRIPPS INSTITUTION OF OCEANOGRAPHY
ANNUAL REPORT FOR THE YEAR ENDING
JUNE 30, 1967.

THE UNIVERSITY OF CALIFORNIA AT SAN DIEGO

One of world's foremost ichthyologists, Dr. Carl Hubbs stands on deck of Horizon during Scripps Expedition.



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About the Covers

Silhouetted across the top of the covers of this report are vessels of the Scripps fleet, from the left—T-441, Oconostota, Ellen B. Scripps, Alexander Agassiz, Thomas Washington, FLIP, Alpha Helix, Argo, and Horizon.



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A major fraction of the work reported herein was supported by the Office of Naval Research and the National Science Foundation.



Introduction

For the fifth time in its history Scripps Institution of Oceanography faces a major challenge. The extent to which it can meet this challenge in the next few years will largely determine whether it can maintain its position as one of the world's leading centers in oceanography. Three of the previous critical periods developed as a result of expansions induced by wartime activity and another was in the early 1930s when the very nature of oceanographic research underwent some basic changes.

The decisions we now face result from the great public interest in the possibility of major exploitations of the oceans. The possible magnitude of this development is indicated by the recent examples in atomic energy and space exploration efforts. Manifestations of this public interest have developed on state, national, and international levels, not excluding important efforts by communities such as San Diego. Indicative of these manifestations was the introduction of more than 20 bills concerning oceanography before the last session of the Congress of the United States. Of these bills two that have been passed are significant: one is the Sea Grant College Act; the other, the Act establishing the National Council on Marine Resources and Engineering Development and the National Commission on Marine Science, Engineering, and Resources. These actions presage an acceleration of federal activity not only in planning but in direct financial support in the area of ocean science and technology even greater than has occurred in recent years. We have available the reports of a number of commissions, at both the state and national level, advocating in the strongest terms greatly increased activity in this field. These include commissions of the Governor of the State of California as well as those of the President's Science Advisory Committee, the National Research Council and the new Commission mentioned earlier.

In one area Scripps has the unique responsibility in the State of California and we consider our major accomplishment of the year the admission of 50 students to the graduate school. This is the second consecutive year of increased admissions and is about a factor of two increase in the number that had been planned earlier. It took an unprecedented effort to obtain the facilities and support for this increase in numbers and our continuing problem will be to maintain at least this level of admissions. The problem was aggravated by the fact that

Vice President Hubert H. Humphrey visits campus in his capacity as Chairman of the National Council on Marine Resources and Engineering Development. At right, Scripps Director William A. Nierenberg; center, UCSD Chancellor John S. Galbraith.
(Photo courtesy of Virginia Moore, Institute of Marine Resources)



instead of the 240 applications for the graduate school that were anticipated there were more like 400. As a result, and based on the grade point average of their upper division performance, this class of students is the best yet to have entered the Institution. For the record we would like to indicate that the undergraduate grade point average was 3.6 for the entering students. If support can continue to be found at this rate for future classes, we should approximately double our student population in five years. As a result, long-range plans have been developed for the physical facilities of the Institution to accommodate this larger number of students and the increasing research activities. As is usually the case the timing of this program is marginal and it will require the best of luck and the cooperation of all concerned at all levels just to meet this increasing responsibility.

The growth of an institution such as Scripps is an interesting phenomenon and many important things take place without the members of the Institution being fully aware of their significance. The body of this report describes the major expeditions of the last two years. In addition there were a number of expeditions of several months' duration in connection with research by our smaller vessels. The fact that an institution, even as large as Scripps, had managed such major efforts in all parts of the world in one year, simultaneously, with ease, and with very little strain on the on-going research on shore and at the same time had discharged its responsibilities to a full teaching program involving 154 candidates for the Doctor of Philosophy degree is noteworthy. We are planning even more ambitious programs in the coming year with even larger numbers of students and I have every confidence they will go forward at least as well as the operations of the previous years.

It is profitable to speculate on the directions that the Institution will move in the immediate future. An area that will see great growth and activity is that of air-sea interaction. Transcending its importance to the field of oceanography is its application to long-range weather control. An inventory at the Institution shows that no less than eight groups are working on aspects of this problem: in the theoretical and experimental observations are wind stress, large scale synoptic thermodynamic exchanges, bathymetry, chemistry and currents. At the present time the work of these groups is coordinated by the existence of an air-sea interaction advisory group.

At the other extreme the various aspects of the benthic

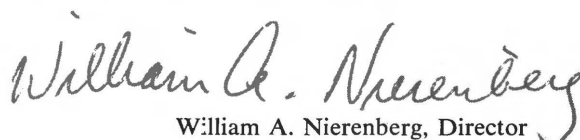
regions will be undergoing much more intensive study by a variety of new techniques being brought to bear on the problem.

Biological research in the oceans will expand at a rapid rate, particularly in the field of biological oceanography. This field is very attractive to students and part of the sharp increase in applications for admissions to the graduate school has been due to this interest. This acceleration is also geared to the important practical problem of developing the ocean food resources more fully.

The most exciting development, however, will be related to the results that are hopefully to be obtained from the Deep-Sea Drilling Project supported by the National Science Foundation. Scripps is currently the lead institution for the JOIDES group (comprising Lamont Geological Observatory of Columbia University, Woods Hole Oceanographic Institution, and the University of Miami's Institute of Marine Science as well as the Scripps Institution of Oceanography). In the current phase of drilling the ocean bottom the activity will be built around attempts to bore holes 1,000 to 2,000 feet in depth in limited and carefully selected deep ocean basins in the Pacific and Atlantic Oceans. The scientific community at large in the United States is beginning to gear itself for the large scientific effort that will be involved in evaluating and studying these samples and the results should be of prime importance in understanding the recent history of the oceans and the earth.

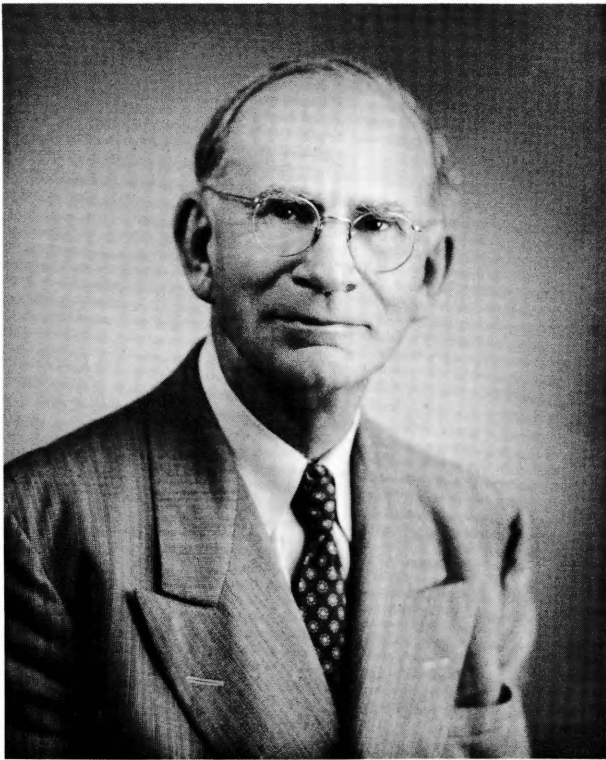
Despite the strong interdisciplinary character of all of the research and teaching at Scripps Institution, there is one area in which we simply share responsibility with other workers in related fields. It is nonetheless of great practical importance in scientific interest. This is in the area of earthquake predictions. We have foreseen expanded activity on the theoretical and experimental side in this field, particularly if the resources are made available to us.

Given the resources and given the great student interest in the field, we foresee a period of expansion in fundamental fields of research that should lay the basis for productive work for many years to come.



William A. Nierenberg, Director

Scripps Institution of Oceanography



Oldest faculty member emeritus of the Institution is Dr. George F. McEwen, 85, who joined Scripps in 1912 as an oceanographer and within five years had brought considerable attention to the Institution by his research in long-range weather forecasting.

History

Scripps Institution of Oceanography is a unit of the University of California, San Diego. Located at La Jolla, on the shores of the Pacific, the Institution conducts research into virtually every facet of marine science. At the same time, it provides a graduate department of instruction that gives students an opportunity to pursue their specialized fields of scientific interest and to take advantage of related courses that will lead them to a mastery of the interdisciplinary field of ocean science.

The Institution is an outgrowth of a program of field investigations on the animal life of the Pacific Ocean begun in 1892 by the University of California's Department of Zoology at Berkeley, under Prof. W. E. Ritter. During this period, a summer field station was established each year at a locality along the California coast.

With its transfer from San Pedro to San Diego in 1903, the enterprise became the function of the Marine Biological Association of San Diego, a private organization supported by publisher E. W. Scripps and Ellen Browning Scripps. During the Association's early years, Mr. Scripps and his half-sister provided most of the funds for the physical development of the campus and for the support of the scientific work.

In 1912, this activity was integrated into the University as the Scripps Institution for Biological Research. The functions of the station expanded under Dr. Ritter, and later under Thomas Wayland Vaughan, to include other marine sciences. The research ultimately encompassed all aspects of the study of the sea, and in recognition of this fact, the name of the Institution was changed on October 13, 1925, by the Regents to the Scripps Institution of Oceanography.

Dr. Ritter served as director until 1923 and Dr. Vaughan from then until 1936. Growth of the Institution continued, from 1936 to 1948, under the directorship of the distinguished Norwegian oceanographer, Dr. Harald U. Sverdrup. The major postwar expansion took place under the direction of Dr. Roger Revelle, with Dr. Carl Eckart and Dr. Fred N. Spiess serving immediately preceding and following Revelle's term. On July 1, 1965, Dr. William A. Nierenberg, a professor of physics at the University's Berkeley campus, was appointed director by the Regents.

From the small field station under Dr. Ritter, with its single permanent building and an 80-foot, scow-type vessel, the Institution has developed to its present 158-acre La Jolla complex of 12 permanent buildings and a fleet of eight ocean-going research vessels, plus the floating instrument platform FLIP. Sustained in its earliest years primarily by private funds and through the 1930s by the State of California, the Institution has seen a major portion of its large post-war expansion supported by the

federal government. Today, approximately 18 percent of the support of the Institution's activities comes from the State of California (as part of the University's funding) with 80 percent provided by federal funds of the U.S. Navy (primarily through the Office of Naval Research) and the National Science Foundation. Significant activity is also supported, however, by a wide range of interested federal and private sources, as shown in Table I, below.

Major activities of the Institution are carried out by various subdivisions, shown in Table II, page 8. Academic staff members conduct their research largely within the framework of the several Divisions, Laboratories, Groups, or Programs, as indicated. The formal graduate educational program, one of the Institution's major responsibilities, is administered by the Graduate Department, as discussed below. Educational activities, as they apply to post-doctoral or special students (for example, the National Science Foundation summer high school program) and graduate student research, are carried out informally throughout the organization.

TABLE I: Sponsors of research and graduate education

STATE AND FEDERAL

- University of California
- U.S. Department of the Navy
- National Science Foundation
- U.S. Atomic Energy Commission
- U.S. Department of the Air Force
- U.S. Department of Health, Education and Welfare
- U.S. Department of the Army
- National Aeronautics and Space Administration
- U.S. Public Health Service
- U.S. Bureau of Commercial Fisheries (Department of the Interior)

OTHER

- Achievement Rewards for College Scientists
- American Chemical Society
- American Heart Association
- American Optical Company
- American Petroleum Institute
- Beckman Instruments Inc.
- California Research Corporation
- Chevron Research Company
- Commonwealth Fund Foundation
- Ellen Browning Scripps Endowment Fund
- Fleet Admiral Chester W. Nimitz Fund
- Foundation for Ocean Research
- General Dynamics
- Griffis Foundation
- Humble Oil Education Foundation
- International Nickel Co.
- John B. McKee Fund
- Kennecott Copper Corporation
- Lockheed Missiles and Space Company
- National Geographic Society
- Pan American Petroleum Foundation, Inc.
- Rockefeller Foundation
- San Diego County Heart Association
- Francis P. Shepard Foundation
- Socony Mobil Oil Company, Inc.
- Standard Oil Company
- Sun Oil Company
- The Superior Oil Company
- U.S. Steel Corporation
- Westinghouse Electric Corporation

View of La Jolla Shores and the Marine Biological Station after the construction of George H. Scripps Building in 1910.



DIRECTOR-DEAN

W. A. Nierenberg

ASSOCIATE DIRECTORS

A. A. Benson
F. N. Spiess

ASSISTANT DIRECTOR

J. D. Frautschy

SUPPORT

AQUARIUM-MUSEUM
D. W. Wilkie

BIOLOGICAL AND GEOLOGICAL
COLLECTIONS
A. Fleminger
W. A. Newman
W. R. Riedel
R. H. Rosenblatt

DIVING PROGRAM
J. R. Stewart

LIBRARY
W. J. Goff

MARINE FACILITY
P. G. Trapani

PUBLIC INFORMATION
R. N. Fuller

RESEARCH

APPLIED OCEANOGRAPHY GROUP
E. D. McAlister

DEEP-SEA DRILLING PROJECT
W. W. Rand

DIVISION OF EARTH SCIENCES
H. Craig

DIVISION OF MARINE BIOLOGY
A. A. Benson

MARINE LIFE RESEARCH GROUP
J. D. Isaacs

MARINE PHYSICAL LABORATORY
F. N. Spiess

DIVISION OF OCEANIC RESEARCH
G. G. Shor, Jr.

PHYSIOLOGICAL RESEARCH LABORATORY
P. F. Scholander

SPECIAL DEVELOPMENTS GROUP
J. M. Snodgrass

VISIBILITY LABORATORY
S. Q. Duntley

INSTRUCTION

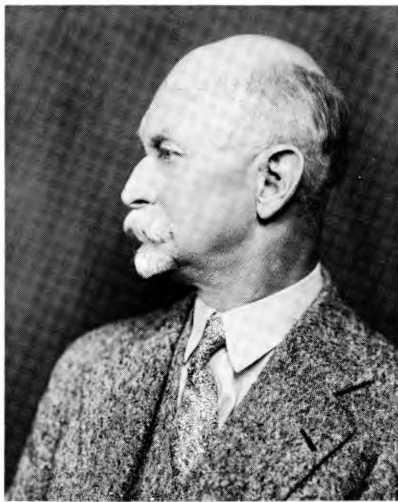
GRADUATE DEPARTMENT OF THE SCRIPPS
INSTITUTION OF OCEANOGRAPHY
W. S. Wooster, Chairman
M. N. Peterson, Vice Chairman

UC INSTITUTES ON SIO CAMPUS
INSTITUTE OF GEOPHYSICS AND
PLANETARY PHYSICS
W. H. Munk, Associate Director
INSTITUTE OF MARINE RESOURCES
M. B. Schaefer, Director (on leave)
H. W. Menard, Acting Director

TABLE II: Organization of The Scripps Institution of Oceanography



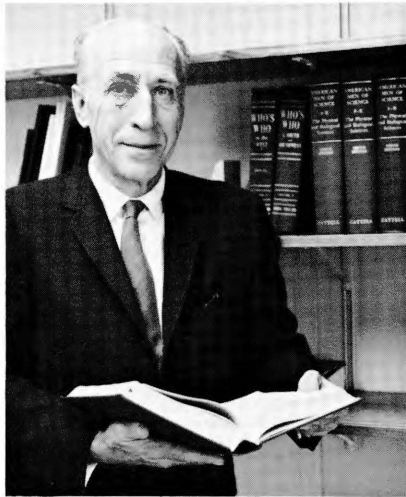
William E. Ritter
(1912-1923)



Thomas Wayland Vaughan
(1923-1936)



Harald U. Sverdrup
(1936-1948)



Carl Eckart
(1948-1950)



Roger R. Revelle
(1951-1964) (Acting 1950-51)



Fred N. Spiess
(1964-1965) (Acting 1961-63)



W. A. Nierenberg
(1965-)

Directors

These men have charted the course for Scripps Institution since its biological field station days, beginning with Dr. William E. Ritter, who saw it through its early growing pains. Under Dr. Thomas Wayland Vaughan, physical oceanography assumed its role alongside that of biological investigations, and Dr. Harald Sverdrup helped the Institution expand from a modest research laboratory with seven faculty members into a leading position in the nation's scientific community. Scripps literally "put to sea" as Dr. Roger Revelle launched the Institution into its long-range expeditions. Dr. Fred Spiess' tenure included development of several facilities, such as FLIP, the Hydraulics Laboratory, the Physiological Research Laboratory, Nimitz Marine Facility, and *Alpha Helix*. And led by Dr. William Nierenberg, the Institution has seen its first utilization of large-scale computers at sea and the reorganization and expansion of its graduate education program.



Research Organization

As indicated above (Table II), Scripps Institution's research efforts are centered in Divisions, Laboratories, Groups, and Research programs. Within these categories, scientists, engineers, technicians, and graduate students initiate and complete many, varied types of research in the marine sciences the results of which broaden man's knowledge of the sea and serve him beneficially as well. As one example, it is hoped that the Eastropac Expedition which early in 1967 began a long-range study of the eastern tropical Pacific and in which the Institution is one of several participating organizations, may lead to better understanding of the tuna fishing resources in that area.

The interests identified with the Institution's research units are outlined here:

Applied Oceanography Group (Dr. E. D. McAlister). Smallest of the research groups, this was started in 1961 to study problems of particular interest to the U. S. Navy.

Deep-Sea Drilling Project (Dr. W. W. Rand). This project is part of the National Science Foundation's National Ocean Sediment Coring Program to study the ocean floor by using samples drilled from extensive depths in the sea floor in the Atlantic and Pacific Oceans.

Division of Earth Sciences (Dr. Harmon Craig). This Division's major interests center in the marine and atmospheric sciences, geochemistry, marine geology, and tectonics, that part of geology concerned with the earth's structure.

Division of Marine Biology (Dr. A. A. Benson). This Division carries on research relating to the biological nature of the plants and animals of the sea, with interests ranging from the molecular structures of which they are composed all the way up the scale to problems relating to the growth and behavior of whole plants and animals, to their relationships to each other, and to the interrela-

tionship between the marine organisms and their environment.

Marine Life Research Group (Prof. J. D. Isaacs). Since 1949 this group has studied the interrelations of physical, chemical and biological oceanography in the eastern North Pacific, particularly the California Current system, as part of the California Cooperative Oceanic Fisheries Investigations (CALCOFI), a project sponsored by the Marine Research Committee of the State of California. MLR operates a hydrographic data collection and processing group and is responsible for training marine technicians.

Marine Physical Laboratory (Dr. Fred N. Spiess). This is the largest of the Institution's special laboratories, with groups conducting research in underwater acoustics, signal processing, marine geology and geophysics (magnetism, heat flow, seismic studies) and the physical properties of liquids.

Division of Oceanic Research (Dr. George G. Shor, Jr.). This Division constitutes the Institution's largest research unit. It supports physical oceanographers and those interested in the interaction of biological and geological problems with the marine environment.

Physiological Research Laboratory (Dr. P. F. Scholander). This laboratory was established in 1963 to pursue physiological research on a broad basis with special emphasis on marine animals. The laboratory also houses a facility for study of marine neurobiology.

Special Developments Group (J. M. Snodgrass). This group assists in the general areas of problem-solving for the staff and conducts studies for several branches of the federal government, such as the Office of Naval Research, that lead to eventual design and construction of instrumentation and equipment.

Visibility Laboratory (Dr. S. Q. Duntley). This laboratory conducts research on the transmission, scattering, and absorption of visible light through the atmosphere

and through water, and on the determination of the optical properties of these media.

University of California Institutes on Scripps Campus

Two Universitywide institutes that share Scripps staff members and are located on the Scripps campus are the Institute of Marine Resources and the Institute of Geophysics and Planetary Physics.

Institute of Marine Resources (Dr. M. B. Schaefer, Director). This Institute is concerned with the understanding and utilization of the resources of the sea. Its headquarters and a majority of its research activities are on the Scripps campus.

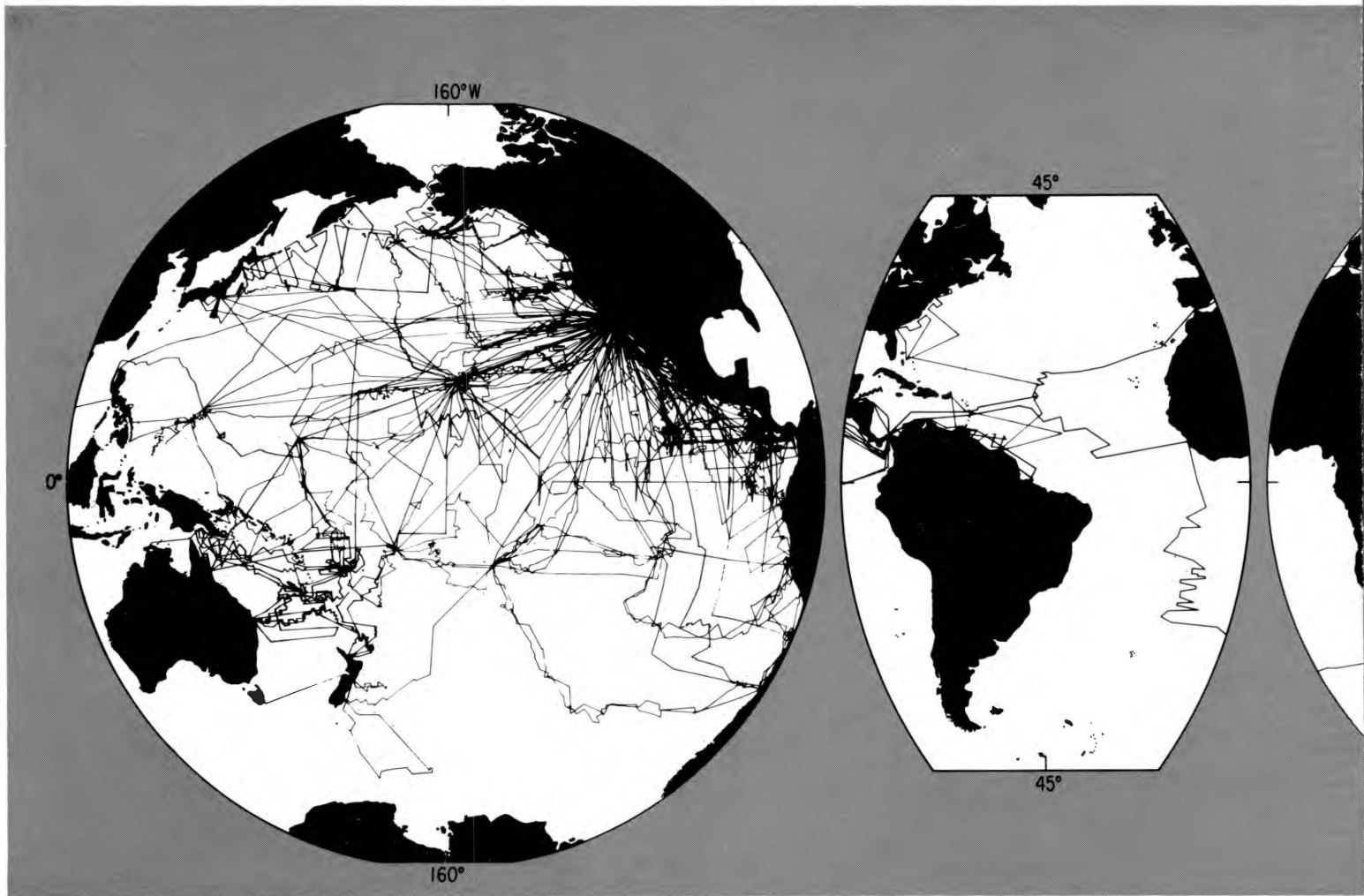
Institute of Geophysics and Planetary Physics (Dr. Walter H. Munk, Director of La Jolla Laboratories). Headquarters for IGPP are on the Los Angeles campus. The La Jolla Laboratories of IGPP are heavily involved in marine problems. About half the faculty members of these laboratories hold joint appointments in Scripps Institution of Oceanography and participate in the educational activities of the Institution.

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Organizationally separate, but sharing close affiliation with Scripps and located on the campus, is the Fishery-Oceanography Center of the U.S. Bureau of Commercial Fisheries, which houses the BCF laboratories and the headquarters of the Inter-American Tropical Tuna Commission.

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In addition, two small groups exist in close association with Scripps, although they are in fact research outposts of subdivisions of the Berkeley and Los Angeles campuses. One is the Seawater Test Facility, related to similar groups in chemical engineering at Berkeley and UCLA, and the other is the Neurobiology Group which provides a bridge between the Scripps Physiological Research Laboratory and the UCLA Brain Research Institute.



Seagoing Operations

Major Expeditions

Ocean-going vessels of the Institution conduct scores of short-duration research cruises in the course of a year which contribute to knowledge of the seas and to the development of instrumentation and techniques useful in future explorations.

The two most extensive recent expeditions were completed during 1966-67. A seven-month 27,700-mile odyssey to the Far North Pacific ended August 8, 1966, when *Argo* berthed at Nimitz Marine Facility. On November 22, *Alpha Helix* put in at Nimitz to conclude her maiden voyage, an eight-month 17,940-mile scientific expedition to Australia's Great Barrier Reef.

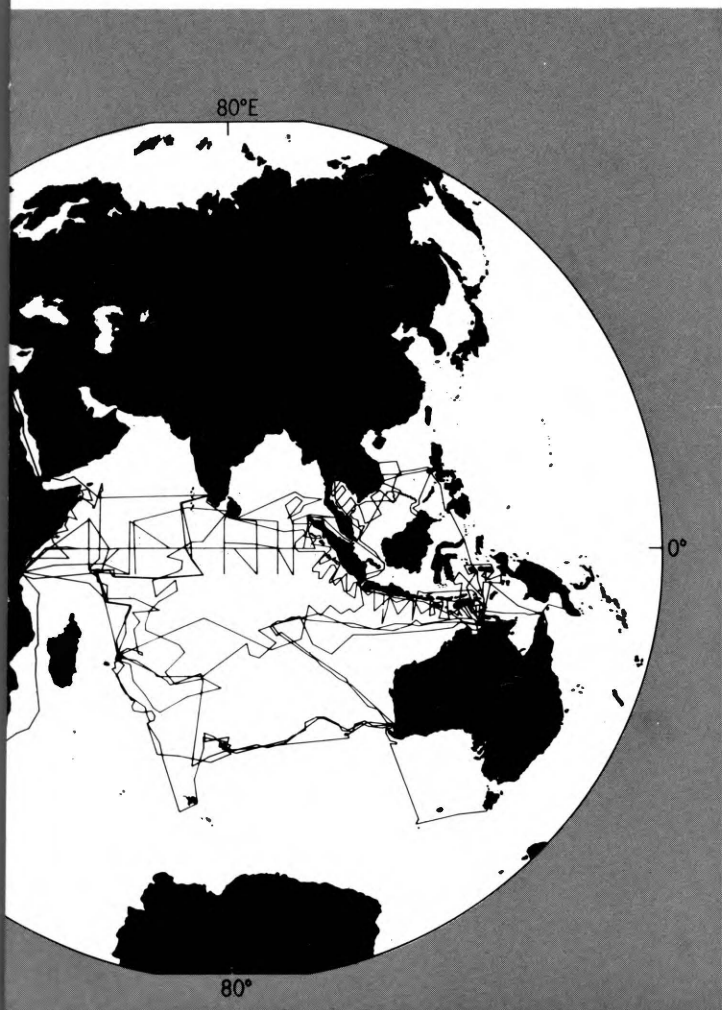
The Zetes Expedition

From January 4 to August 8, 1966, *Argo* was employed in the North Pacific Ocean for investigations covering a wide range of oceanographic studies. The expedition was called *Zetes* and it was funded by the National Science Foundation and the Office of Naval Research. Specific studies were made during the seven parts of the expedition; some programs were conducted more or less continuously. The scientific party varied from nine to 15 and included scientists from Japan and Canada as well as from the United States. *Argo* sailed from San Diego to Kodiak, Alaska, thence to Hakodate and Tokyo, Japan, and back home by way of the Hawaiian Islands.

Between Kodiak and Hakodate, from late January to early April, *Argo* performed very successfully despite the weather. She was buffeted by gale-force winds up to 70 knots and by waves as high as 40 feet. This second leg was called *Boreas* (for the Greek god of the North Wind), since its purpose was to make observations of extreme winter conditions in the northernmost parts of the western Pacific, including the western Bering Sea and the Okhotsk Sea up to the zone of dense ice cover. *Argo* steamed through ice flows under heavy going and during one period her decks were ice covered.

Coordinator for the expedition was Joseph L. Reid, Jr., research oceanographer, who also served as chief scientist for the second track. Among the main results of the expedition were these:

San Diego-Kodiak (Dr. John A. McGowan). This leg was designed to collect winter data along 155 degrees West to determine the effect of the seasonal change of



Interlacing of ship tracks in the accompanying map is indicative of the hundreds of thousands of miles logged by Scripps vessels during oceanographic investigations from 1950-1967



Scripps ships worked in tropic and Arctic climes: Argo d

temperature and flow upon the biomass by comparison with information collected in the summer of 1964 on Scripps' Ursa Major Expedition. Early reports of biological data studied, which included an analysis of the chlorophyll and phaeophytin measurements, showed that the winter "structure" is similar to that found by the summer expedition, except that chlorophyll content in the mixed layers was systematically higher at all latitudes. This resulted in a less pronounced subsurface chlorophyll maximum than was found in summer.

Kodiak-Hakodate (Joseph L. Reid, Jr.) Measurements on this leg included temperature, salinity, oxygen, phosphate, nitrate, and silicate in the upper 1,500 meters of the ocean. This area had not been investigated before in the winter season, even though some of the most striking interactions of sea and atmosphere take place there at that time. Great quantities of heat are passed from the sea to the atmosphere by evaporation and exchange of sensible heat, and the surface waters become coldest, and probably most saline, and most dense. Purpose of this leg was to demonstrate that the characteristics of the low-salinity intermediate layers of middle latitudes are derived not directly from the sea surface in high latitudes but by the vertical mixing which takes place beneath the mixed layer, just as the warmer waters that underlie the cold surface waters in high latitudes in winter have become warm by vertical mixing beneath the mixed layer in middle latitudes. Data from the expedition demonstrated this proposition.

Hakodate-Tokyo (Prof. Victor Vacquier). This segment consisted of a heat-flow and magnetic survey of the Pacific between the Japan Trench and the Emperor seamounts as part of a combined Japanese-American scientific program. More than 70 successful heat-flow stations were occupied. Data showed that the area east of Japan, including the northeast Pacific rise and the Emperor seamounts, has normal or just below normal

heat flow. This contrasts significantly with observations at stations west of Japan, which show a heat flow value much higher than the oceanic average. A magnetic and bathymetric survey of part of the Emperor seamounts between 40 and 45 degrees North indicated that they are not separated but form a continuous ridge approximately 100-120 miles long. Two groups of seamounts at about 28 degrees North, on either side of the Japanese Trench, also underwent magnetic and bathymetric surveys, results of the study of which should give information on the spreading of the Pacific Ocean floor, based on a differing in the mean direction of magnetization of separate groups of seamounts.

Japan-Bonin Trench (Dr. C. E. ZoBell). Investigations of bacteria at depths as great as 9,628 meters were carried out by American and Japanese scientists during this leg. Living bacteria were demonstrated in all samples of bottom sediments and water. This was the first time living organisms had been recovered from the bottom of the Japan-Bonin Trench, and several appear to be new species. Their occurrence, abundance, and demonstrated ability to grow at the low temperatures (about 3 deg.) and high hydrostatic pressures (nearly 1000 atm.) characteristic of the deep-sea floor suggest that bacteria might play a significant role as food for bottom dwelling animals and in the biochemical transformation of various substances. Studies are being continued on the deep-sea cultures and samples at Scripps Institution, Kyoto University, and the University of Tokyo.

Hawaiian Area (Dr. George G. Shor, Jr.). When *Argo* reached Hawaii in June, she joined Operation SHOW. This investigation was sponsored jointly by Scripps Institution, the University of Hawaii, Oregon State University, and the University of Wisconsin to study the Hawaiian arch, the low rise in the sea floor north of the Hawaiian Islands. The ships *Horizon*, *Teritu* (Hawaii), and *Yaquina* (Oregon State) and Scripps' floating instru-

Bering Sea track, Alpha Helix at Great Barrier Reef.



ment platform FLIP had already spent considerable time working in the area investigating the amount and direction of velocity anisotropy in the mantle. Between June 23 and July 12, *Argo* worked with *Horizon* and *Teritu* on continued mapping of the Hawaiian arch to determine whether areas existed in which the mantle was shallower than in the previously chosen Mohole site.

Honolulu-San Diego (Dr. Christopher G. A. Harrison). This leg was designed to obtain oriented gravity cores and heat-flow values, with heat-flow stations established in areas not previously investigated as part of an intense study of the heat flow in the eastern Pacific. The gravity cores will be used to study the history of the earth's magnetic field, using paleomagnetic techniques.

Included in some of the research carried out more or less continuously throughout the expedition were the collections of water vapor and rainwater samples for deuterium and O^{18} studies, various surface water samples for C^{14} determination, tritium, and natural cesium, and continuous filtration of surface water for cesium determination. Samples of fallout radiocesium (Cs^{137}) were continuously collected from surface water along the ship's track.

Ninety-five fallout cesium measurements were made from San Diego to Hakodate and 60 more on the latter parts of the expedition. Preliminary assays of data taken on the first two legs indicate: (1) Average fallout in the western Pacific north of 40 degrees is less than half of the average concentrations near California. This may be the effect of the major circulation in the Pacific. (2) Near Hakodate, surface concentration increased, suggesting outflow of higher concentration from the Sea of Japan into the nearby depleted waters of the western North Pacific. (3) In the eastern Pacific, a definite maximum was observed somewhat nearer California than Honolulu. This suggests the possibility of maximum transport to the south.

The Billabong Expedition

Forty-four scientists from 11 United States and eight foreign institutions conducted research on tropical mangroves, reef corals, and sea and land animals during the Billabong Expedition to the Great Barrier Reef. Twenty of the participating scientists were from Australia, New Zealand, England, Sweden, and Japan.

The scientists represented the interdisciplinary fields of biochemistry, biophysics, plant physiology, chemistry, physics, and neurophysiology. They worked not only in the biological laboratory vessel, *Alpha Helix*, moored in Princess Charlotte Bay, 180 miles north of Cairns, Queensland, but also in two air-conditioned, prefabricated laboratories set up at a shore camp 1,200 feet from the ship on a sand spit on Flinders Island. The investigators remained with the expedition for the duration of their particular investigations.

Designated Billabong, an Australian term for water-hole, the expedition was funded by the National Science Foundation and coordinated by Dr. Per F. Scholander, professor of physiology and director of Scripps' Physiological Research Laboratory.

Studies of salt water secretion in mangroves were conducted and research into reverse osmosis and its relation to the desalination process in mangroves was carried out. It was learned that a new compound, choline sulphate, is highly concentrated in salt-secreting mangroves and that the sulphate helps to move the salt through the permeable mangrove cells.

In studies of the up-take of sodium and potassium in mangrove leaves, it was determined that the mangrove follows the pattern of non-salt tolerating plants, such as barley and other common agricultural plants.

Investigations were conducted into the symbiosis of growth and metabolism of reef corals and a study made of how symbiotic algae grow in their tissues. Symbiotic algae are single-celled plants that live in all reef corals.



It was found that the algae liberated carbohydrates, which furnished the animal energy that could favorably influence the growth of reef corals.

The scientists studied the mechanisms that conserve heat in aquatic animals, as exemplified by the peculiar vascular arrangement in the dugong. The dugong is a sea cow whose blood supply to the tail consists of several hundred arteries and veins joined together in one bundle, which presumably acts as a heat exchanger. A similar system exists in the human kidney.

Studies were conducted of corals, mud crabs, and giant clams — the latter vary in size up to three to four feet in length and weigh 600 pounds — to learn how their nerve mechanisms function. The muscular strength of the giant clam also was measured by placing a pressure capsule between the lips of the clam shell and recording by a pressure gauge the full closing force of the clam. For example, it was determined that a clam weighing about 220 pounds can exert a tension of as great as 660 pounds. The ship's winch, exerting a force up to 880 pounds, was required to open the clam's shell.

The first motion picture filming of nerve excitation in coral nerve nets was made in reef coral studies.

The isolation and cultivation of photosynthetic bacteria from both fresh and salt water swamps were studied. These bacteria convert atmospheric constituents and soil compounds into organic matter with sunlight as the energy source, in a fashion similar to green plants.

The action of cell membranes was investigated by study of giant, single-celled algae.

The nature of body temperature regulation in lizards was studied and investigations were conducted to determine how the Australian mud skipper fish can spend lengthy periods on land breathing air.

Panoramic view of San Diego Bay, with Scripps' fleet home for Christmas. Moored at Nimitz Marine Facility, from left in foreground: T-441, ST-908, Ellen B. Scripps. At pier, center background: Argo and Thomas Washington. At wharf, Horizon and Alpha Helix. Alexander Agassiz and FLIP were berthed elsewhere when photo was taken.

Nimitz Marine Facility and the Fleet

The ships that put out to sea for Scripps Institution sail from the modern \$1 million Nimitz Marine Facility, situated on six acres of land leased from the U.S. Navy, on the San Diego Bay side of Point Loma. Described as one of the world's finest shore bases for supporting oceanographic research, the Facility provides berthing space for Scripps' research vessels in one location, a stone's throw from four concrete structures housing offices, shops, scientific and technical equipment, and ship's stores.

Named for the late Fleet Admiral (and University Regent) Chester W. Nimitz, the Facility was financed by funds from the Office of Naval Research and the National Science Foundation. Dedicated on March 11, 1966, and placed into immediate use, the Facility expedites the preparation of equipment and the staging for scientific expeditions that embark from the 320-foot floating finger pier or the 150-foot marginal wharf along the shore. Other segments include an administration building, an electronics shop, a warehouse and stores building, a general shop, and a large storage yard.

Scripps research vessels include the 213-foot *Argo*; the 209-foot *Thomas Washington*; the 133-foot biological laboratory ship, *Alpha Helix*; the 143-foot *Horizon*; the 180-foot *Alexander Agassiz*; the 95-foot *Ellen B. Scripps*; the 102-foot *Oconostota*; two smaller ships, the T-441 and the ST-908; and a utility boat. The *Alpha Helix* and the *Thomas Washington*, the newest ships of the fleet,

were dedicated during the same ceremony as that for the Nimitz Marine Facility. (See Appendix B for complete ship information.)

FLIP, the unique, 355-foot Floating Instrument Platform that is towed horizontally to her ocean work stations and upended for underwater acoustic research, berths at San Diego's B Street Pier.

During the calendar year 1966, the fleet operated 1,708 days and traveled 178,376 nautical miles in support of investigations conducted by the Institution's scientists near home port and in the far reaches of the world's oceans. The *Alpha Helix*, *Argo*, *Horizon*, *Ellen B. Scripps* and FLIP participated in noteworthy operations during the year.

The *Alpha Helix* arrived in San Diego from the ship-builder on March 5, 1966, was dedicated six days later, and on March 19 sailed for Australia on the Billabong Expedition. The ship remained at sea and at the scene of biological and physiological studies on the Great Barrier Reef for 254 days and she logged 17,940 miles. Expedition results are detailed elsewhere in this report.

Argo's Zetes Expedition, planned mainly for studying the biological, physical, and chemical structure of sub-Arctic waters during a winter crossing, may long be considered one of the Institution's most significant oceanographic efforts. She departed San Diego on January 4, 1966, and made stops at Kodiak, Adak, Hakodate, Tokyo, and in Hawaii, before arriving home in August. Work continued during heavy icing conditions encountered between Kodiak-Adak and en route to Hakodate. Results of the expedition are outlined in another section of this report.

The *Horizon* left San Diego on January 31, 1966, for Honolulu, with FLIP in tow, and she operated in that area until mid-September. In addition to working with Lockheed Corporation's *Swan*, *Horizon* participated in Operation SHOW during the summer. This investigation was sponsored jointly by Scripps Institution, the University of Hawaii, Oregon State University and the University of Wisconsin to study the Hawaiian arch, a portion of the sea floor north of the Hawaiian Islands. Working with *Horizon* were the *Teritu* (Hawaii) and *Yaquina* (Oregon State), as well as FLIP. In all these investigations, *Horizon* conducted sound propagation studies, sub-bottom profiling, bathymetric and magnetic surveys, seismic operations, deep sediment collections, and heat flow measurements. *Horizon* spent 253 days at sea during the year and traveled 21,648 miles.

The *Ellen B. Scripps* was acquired as a new vessel on August 14, 1965, and 1966 was her first full calendar year of operations. She was employed for coastal operations of from one to 21 days and she operated during every month except June. The *Ellen B.* proved exceptionally well adapted for carrying portable vans and for the rapid change of scientific programs that included

work for the Applied Oceanography Group; installation, test, and recovery of deep-sea tide measuring instruments; bathymetric, taut-wire moor placements and inspections; and installation of sea instruments and recorders. Her total days at sea numbered 137 and distance covered, 11,782 miles.

FLIP departed San Diego under tow of *Horizon* on January 31, 1966, and arrived in Honolulu on February 15. She operated in Hawaiian waters and was towed either by commercial tug or *Horizon* for scientific work under W. Whitney, and Drs. Spiess, Shor, Raitt, and F. H. Fisher. She returned to San Diego September 18. This FLIP operation is notable in that it marked her first lengthy operation away from home port with an operational base set up in a distant port, Honolulu. She was at sea a total of 198 days, 120.8 of them vertical, and she traveled 8,848 miles.

Remainder of the fleet — the *Washington*, *Agassiz*, *Oconostota*, T-441, ST-908 — was utilized largely in California and Baja California coastal waters.

Unreliable main propulsion engines caused the *Thomas Washington* to be unsuited for distant operations, consequently she was utilized nearer home in such work as the testing of deep-tow equipment, detailed geophysical studies using deep-towed instruments, air gun tests, and heat-flow measurements. Re-engining of the ship, scheduled for the spring of 1968, will permit her use for unrestricted world-wide operations. Investigators utilizing the *Washington* in 1966 included Drs. Bass, Curray, Cox, McGowan, Mudie, Shepard, Shor, Spiess, and Wooster. She operated at sea 156 days and logged 22,452 miles.

The *Alexander Agassiz* was utilized largely in Marine Life Research investigations under Richard V. Mead, Vaughn Wagner, U.S. Bureau of Commercial Fisheries Fishery-Oceanography Center, and William W. Mauck. Other users included Dr. Shor, for testing seismic telemetering systems; Dr. Hubbs, for biological collecting; and Dr. Shepard, for box core sampling. The ship was deactivated December 22, 1966, for a major conversion. Her total days at sea in 1966 were 231 and she traveled 32,596 miles.

The *Oconostota* was used mainly in 1966 for Marine Physical Laboratory investigations, including deep-tow work, seismic reflection operations, magnetometer testing, obstacle avoidance sonar testing, and flowmeter measurements. Vessel users included Dr. Cox, Dr. Hendershott, Dr. Mudie, Thomas Osborn, Dr. Robert Dill, of the U.S. Navy Electronics Laboratory; Dr. Spiess, Maurice McGehee, Dale A. Newhouse, Daniel K. Gibson, John C. Nickles, and Earl D. Squier. The ship was at sea 133 days and covered 11,628 miles.

The T-441, laid up most of the year, operated seven days and traveled 364 miles. Brunt of the small-craft work was assigned to ST-908, which operated 54 days and logged 1,155 miles.



Graduate students, supplementing laboratory, classroom work, haul in net cast out to get marine biological samples.

The Graduate Department

Scripps Institution has been involved, since its inception, in education within the University of California. Initially this function was carried out primarily by supporting the research activity of graduate students working for their degrees in other areas of the University (a continuing program). The first Ph.D. degree in oceanography was granted in 1930 with Scripps acting as a teaching department of the Berkeley campus of the University. This activity grew and was transferred to the cognizance of UCLA, and finally to the newly established San Diego campus. As the field grew in numbers of students and disciplinary breadth, a formal structure was established for marine science education at the graduate level. Since 1961 this has consisted of the Departments of Oceanography, Earth Sciences (strongly, but not solely, marine oriented) and Marine Biology. Most of the Scripps faculty members have carried out their teaching activities within one or more of these three groups.

Recognizing the need for greater flexibility in this growing and strongly interdisciplinary field, these three academic departments were reorganized, as of July 1, 1967, to meet the growing demands of education, industry, and government for marine scientists in the years ahead. This restructuring resulted in the formation within the University of California at San Diego of a single

Department of the Scripps Institution of Oceanography, with six curricular programs, described below. The functions and operation of the Institution's research divisions and laboratories remain unchanged.

The six curricular programs in the new Department are biological oceanography, physical oceanography, marine biology, marine geology, marine chemistry, and geophysics. Other programs will be added as the need arises. The new Department is chaired by Dr. Warren S. Wooster, professor of oceanography. Dr. Melvin N. A. Peterson, associate professor of oceanography, is vice-chairman.

Scripps' new academic plan will give students and faculty an opportunity to work in their specialized areas and yet initiate cooperative programs interrelating the viewpoints of various fields with a minimum of administrative complication. This new organization has carried forward the continuing philosophy that marine science education should primarily be carried out at the graduate level. The reason for this is the belief that in the interdisciplinary field, if one is to become a leader, it is necessary to have a strong background in a basic science, such as chemistry, physics, biology, geology, or mathematics. At this time, no specific program exists for education in application of technology to marine problems; however, cooperative activity can be carried out (as in the past) between Scripps and the engineering and applied science departments of the University.

Graduate Curricular Program

A brief description of the six, new, curricular programs, whose 46 faculty members also serve in various research divisions, laboratories, and research groups, follows:

Biological Oceanography (Dr. John A. McGowan). Biological oceanographers are concerned with the interactions of populations of marine organisms with one another and with their physical-chemical environment. Research activities in this curriculum include studies of the factors influencing primary and secondary productivity and nutrient regeneration, food-chain dynamics, community ecology of benthic and pelagic forms, population dynamics, and fisheries biology; taxonomy and zoogeography of oceanic organisms; and behavior as it affects distribution and sampling problems. The curriculum is designed to prepare students for original research and teaching in this interdisciplinary field.

Marine Biology (Dr. A. A. Benson). This curriculum is concerned with the study of the development, adaptation, and function of organisms in the marine environment. The comparative physiology, biochemistry, and developmental biology of marine organisms are stressed in the introductory course of the curriculum, "Marine Life." Students specializing in subjects from neurophysiology to barobiology will find breadth of interest and intensity and sophistication of the experimental approach as adapted to conventional and marine technology.

Marine Chemistry (Dr. E. D. Goldberg). Programs within the marine chemistry curricular group are designed to allow students to apply the concepts of modern-day chemistry to the various processes operating within the oceans. Students will be encouraged to become competent in one or more phases of chemistry as it is applied to the ocean - atmosphere, atmosphere-water reaction, solid state geochemistry, organic geochemistry, and nuclear chemistry.

Physical Oceanography (Dr. Charles S. Cox). Studies in physical oceanography include the observation, analysis and theoretical interpretation of the general circulation of ocean currents; the distribution and variation of properties of the ocean; the interchange of kinetic and thermal energy and materials across the ocean surface; the propagation of sound and light and other electromagnetic energy in the ocean; and the properties and propagation of ocean waves.

Marine Geology (Dr. H. W. Menard). The program in marine geology includes studies of the stratigraphy, structure, and morphology of ocean basins; marine micropaleontology and the mechanics of sedimentation; mineralogy and the formation and geographic distribution of sediments; the reactions of sediments and solutions; and the petrology of crustal materials. The integration of these elements of marine geology with the chemical, biological, and physical aspects of oceanography is stressed.

Geophysics (Dr. J. F. Gilbert). This curriculum is designed to develop the ability of the physicist (theoretician or experimentalist) to contribute to our understanding of the sea, the solid earth on which it moves and the atmosphere with which it interacts. The program initially assists the student in assimilating current knowledge of the nature of the earth and in gaining mastery of field, laboratory and mathematical techniques by which new information is being developed. With this basic background, the student is then expected to take part in the development of new insight into the problems of the structure of the earth and the nature of energy propagation and exchanges which take place within it. It is anticipated that the geophysical curriculum and the physical oceanography curriculum will emphasize many points in common.

Growth of Educational Program

One hundred and five Doctor of Philosophy degrees in oceanography have been granted by the University of California for work done in academic programs at Scripps Institution since the first such degree was awarded in 1930. The Institution offers only graduate instruction in oceanography. Since 1961 the University has awarded its doctoral degrees in oceanography through the San Diego campus.

The graduate educational program has grown steadily for the past few years: from 103 students in 1962-63 to 154 in 1966-67, as indicated in the table below, according to years and academic departments:

	Oceanography	Earth Sciences	Marine Biology	Total
1962-63	61	19	23	103
1963-64	67	30	19	116
1964-65	72	24	30	126
1965-66	62	26	34	122
1966-67	75	30	49	154

Breadth of the student population is evident in statistics about entering students of the Department of Oceanography in 1966-67. They were, by undergraduate majors in: biology-5; chemistry-4; engineering-1; geological engineering-1; geology-4; naval science-1; physics-4; zoology-2. They came from these states and countries: California-2; France-2; Illinois, Iowa, Israel, Maryland, Minnesota, Mississippi, Missouri, and Montana, one each; New Jersey-2; New York-3; Oregon-2; and Utah, Virginia, and Wisconsin-one each.

Recent Degree Recipients

During the two years, 1965-66 and 1966-67, 28 Doctor of Philosophy degrees were awarded by the three departments, as contrasted to ten in the 1962-64 period. Degree recipients and their thesis topics for the past two years are carried in Appendix C.

Research Activities

Scripps Institution's multi-faceted research programs that are described in this section were highlighted during the year with the activation of a major new project in deep-ocean drilling that calls for sea operations commencing in late 1968.

Deep-Sea Drilling Project

Scripps' Deep-Sea Drilling Project, a part of the National Ocean Sediment Coring program of the National Science Foundation, was proposed by the JOIDES (Joint Oceanographic Institutions for Deep-Earth Sampling) group. Its objective: to investigate the ocean floors through intensive study of core samples to be taken from considerable depths beneath the ocean floor in ocean depths of from 3,000 to 20,000 feet.

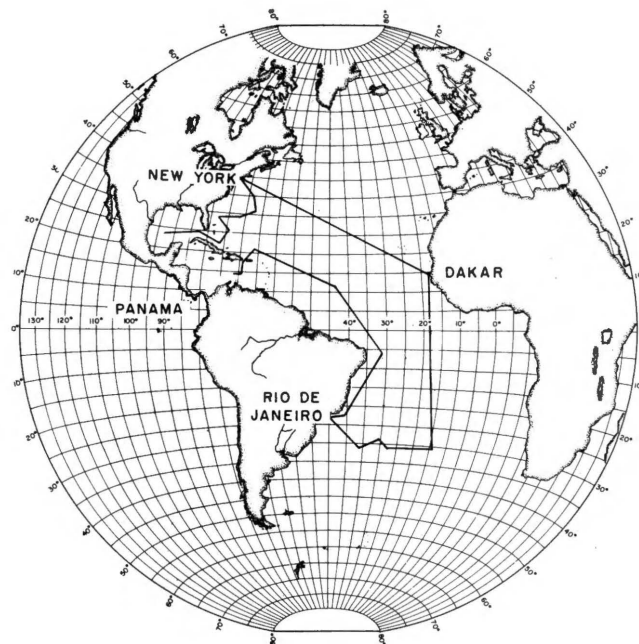
This major new program resulted from extensive cooperative effort by Scripps, Woods Hole Oceanographic Institution, Lamont Geological Observatory, and the University of Miami Institute of Marine Science. Following an initial planning period in 1963 and actual drilling operations on the Blake Plateau in the Atlantic which were successfully completed in 1965, Scripps was chosen to carry out the subsequent major program. This began to take form with the appointment in 1966 of Dr. W. W. Rand as its director. The principal activity of the year was the preparation of specifications for the drilling ship to be used.

Based on these specifications, proposals for a drilling subcontract between the Regents of the University of California and marine drilling companies were received in June, 1967, and underwent evaluation, as provided in the prime contract executed in January, 1967, by the National Science Foundation and the Regents of the University of California.

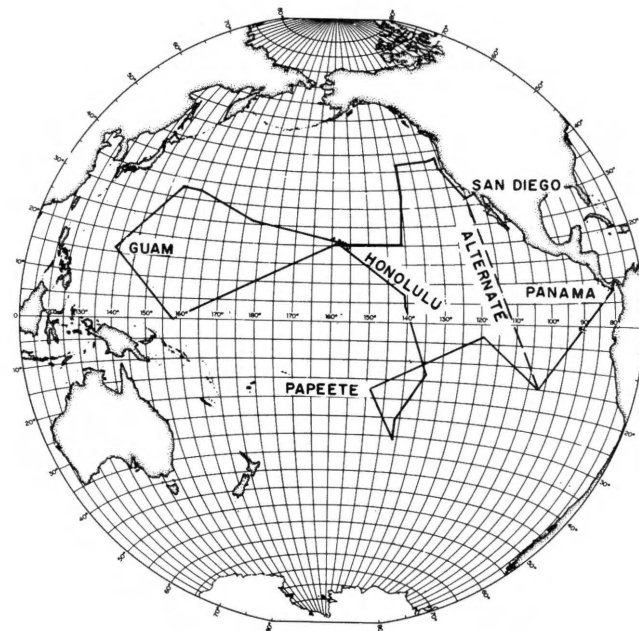
It is expected that a subcontract between the Regents and the successful drilling company will be executed, after NSF approval, by November, 1967. The work at sea should begin in the fall of 1968 and extend for 18 months of drilling operations. Approximately half the drilling sites (about 50 total) are in the Atlantic Ocean and half in the Pacific.

Scientists on board the proposed drilling vessel will make preliminary core descriptions and store the cores in portable refrigerated vans to be off-loaded at ports of call. Cores will eventually be distributed to qualified scientists for detailed analysis.

Two advisory panels, one for the Atlantic Ocean and one for the Pacific, with members chosen from throughout the geological community, have prepared drilling site selections and have assembled existing information on thickness and nature of formations, as well as tentative cruise programs.



Proposed tracks for drilling in Atlantic, Pacific Oceans in NSF's Deep-Sea Drilling Project managed by Scripps.



Advisory panels on (1) Paleontology and Biostratigraphy, (2) Sedimentary Petrology and Geochemistry, (3) Igneous and Metamorphic Petrology, and (4) Well Logging have provided advice on sampling and data reduction procedures. Active interest of the petroleum industry in the project is illustrated by the helpful participation of oil company specialists in the advisory panel conferences.

Applied Oceanography Group

The research activity carried on by this small group (two scientists and six supporting personnel) consists largely of testing and perfecting a device for measuring the energy exchange at the sea surface. This effort is supported by the Office of Naval Research, the National Science Foundation, and the Navy Oceanographic Office. Reasons for studying this problem are discussed below:

Solar energy amounting to 10^{21} calories or 10^{15} kilowatt hours is stored during one average day in the top 30 meters of the world's oceans. Its release during a 24-hour cycle depends on wind speed, cloud cover, air temperature and other factors. Where it is released geographically, the amount and time of release and its transport to other parts of the globe are factors which determine climate (the average condition) and weather (variations from the average).

It is thus important to have means of measuring this heat flow from the oceans in order to better understand weather and its long-range prediction.

Significant progress has been made in this laboratory in the development of airborne equipment which, for the first time, provides direct measurement of this heat flow. The results obtained establish the feasibility of an infrared optical method. The equipment in its present form can survey 10,000 square miles of sea surface in a 24-hour period. The accompanying photograph shows the pod mounting for the infrared radiometer on the University of California, San Diego's DC-3 aircraft. It is possible that similar equipment may be developed for satellite use, but this remains to be demonstrated.

This study was reported at the Houston meeting of the American Society for Oceanography by Dr. E. D. McAlister. The paper read, "Measurement of the Total Heat Flow from the Sea Surface with an Infrared Two-Wavelength Radiometer: Progress Report," will appear in the 1967 Proceedings of that Society.

Other activities involved studies of fronts on the ocean



Pod-mounted infra-red radiometer on UCSD's DC-3 aircraft is used to measure solar energy released from oceans.

surface, slick formation, and the influence of wind speed on water surface temperature. Special equipments used here were an airborne infrared line scanner with associated meteorological instruments, and a small wind tunnel for controlled air speeds over a water surface.

Division of Earth Sciences

Activities of the Division of Earth Sciences extend over the fields of geology, petrology, geochemistry, and atmospheric and marine chemistry; these activities are characterized by a strong and common interest in the interactions of the continents and the oceanic crust with the ocean, and in air-sea interaction studies including the exchange of moisture and gases and the atmospheric transport of particulate material. During the year the Division was deeply involved in preparations for the Nova Expedition for which Dr. Henry W. Menard is coordinator. This is a two-ship expedition (*Argo* and *Horizon*) to the Southwest Pacific involving extensive studies of the geological and geophysical history of the region between the Tonga Trench and Australia, and the geochemistry and oceanography of the west-central and south Pacific.

During the year, assembly and installation of the Division's new rare gas mass spectrometer was completed by Dr. Harmon Craig and his group. Dr. Stanley R. Hart, visiting from the Department of Terrestrial Magnetism of the Carnegie Institution, Washington, has spent the year making the instrument operational and carrying



The Scripps-developed Omegatron, a sensitive analytical gas mass spectrometer, is applied to oceanographic research.

out research on argon and helium in marine and continental rocks. The Division now has four mass spectrometers in full-time operation for geochemical studies.

Dr. Gustaf Arrhenius has continued his studies of the structure, properties, and composition of natural minerals of importance in the sea and of experimentally formed crystals, using the electron microprobe and X-ray techniques. He has recently found that a chain-structure magnesium silicate, probably palygorskite, forms when silica diffuses into seawater. Since recent studies have placed more and more emphasis on the role of silicates in regulating the composition of seawater, it is of great interest that the equilibrium concentration of dissolved silica in contact with this silicate coincides with maximum oceanic concentrations. His group has been primarily concerned with possible hydrothermal mineralization in the sea, as indicated by manganese nodules and barite in sediments and their concentrations on the East Pacific Rise. J. S. Hanor, a 1966-67 National Science Foundation post-doctoral Fellow, has, with Dr. Arrhenius, demonstrated a continuity of barite and various elements thought to be of hydrothermal origin, from the Rise into Baja California and the western United States, supporting Dr. Menard's proposal that this zone is a continuous tectonic unit.

Dr. E. D. Goldberg's group has continued to study rare gases in the sea with Bieri's omegatron. They find high supersaturation of argon, neon, krypton, and helium throughout the ocean and attribute this to mixing processes for the first three gases, and to a helium flux from the oceanic crust into the sea as proposed by Drs. Roger Revelle and Hans Suess. His group has continued their ionium-thorium dating of cores and applied this to paleomagnetic reversals. They have continued to measure rates of manganese nodule accretion by such studies and by uranium 234/238 and potassium-argon studies, and have recently completed detailed chemical analyses of 67 nodules. The results show that the phases present correlate with depth in the sea, and that the minor element composition is controlled by these phases.

Geochemical studies by Dr. Craig's group involve studies of a variety of gases and of the isotopic water molecules applied to mixing and exchange processes in and between the atmosphere and the sea, and to volcanic and geothermal processes related to the origin and history of the ocean. A. Longinelli, visiting from Pisa, and Dr. Craig have developed a method of measuring the oxygen isotope ratio in oxygen atoms bound in dissolved sulphate ions. This oxygen requires thousands of years to exchange with the surrounding water molecules, so that its isotopic composition is an excellent tracer for the history of sulphate in the ocean. The method is applicable to developing a paleotemperature scale for the oceans based on sulphate in shells. Using hydrogen and oxygen

isotopic studies, Dr. Craig has shown that the very interesting geothermal brines recently found in the bottom of the Red Sea originate from ocean water descending through evaporites 1000 kilometers away on the southern sill, and flowing under the Red Sea in response to its high density. Dr. Craig's group has continued to study the gases in seawater by mass spectrometry and has developed a sea-going portable gas chromatograph for N₂, Ar, O₂, and CO₂ work at sea which has been used on Nova Expedition. They find N₂, Ar, and Ne to be always close to solubility equilibrium in the sea, oxygen to be slightly higher than measured by conventional chemical methods, and an upper limit of about 8 percent for excess helium resulting from the flux into the ocean described above.

Geological studies by Drs. Manuel N. Bass, A. E. Engel, J. W. Hawkins, Jr., and H. W. Menard have continued to concentrate on petrology and oceanic and continental tectonic problems. Drs. Bass and Engel have been strongly involved with the study of tholeiites, the basalt type which Dr. Engel has shown to be the most common rock type of the ocean floor. Drs. A. E. Engel and Celeste Engel have continued their chemical studies of these rocks and they will collect many more samples by dredging on Nova Expedition. Dr. Bass has assembled an outstanding collection of thin sections illustrating all stages of tholeiite formation and interaction with seawater and studied these in detail. This collection has been most useful to staff and students of the Division. In addition, Dr. Bass has continued his studies of the geological structure and rock types in Central America as related to the surrounding oceanic areas. One of his major conclusions is that modern Central America is a continental block which once occupied the Gulf of Mexico and has been separated from North and South America by continental drift during the past 150 million years.

Dr. Menard's group mounted Six-Pac Expedition during the year, in addition to their extensive work on the early phases of Nova. Six-Pac involved a detailed study of the Molokai and Clarion fracture zones by Dr. Menard, T. E. Chase, and S. M. Smith. They have continued to develop and extend the OSCAR system for digital conversion and use of bathymetric data and for the routine processing of all Scripps Institution geological data. This system promises to be one of the most important instrumental developments at Scripps.

Dr. Hawkins has made a thorough study of the metamorphic and igneous rocks of the rim of the Pacific Basin on the Olympic Peninsula and the Northern Cascades, tracing the modifications of original geosynclinal marine sediments through all phases of metamorphism to their present complex of metasediments and igneous rocks with approximately average continental coast composition. Granitic rocks in this area show a progressive chemi-

cal evolution from the altered and metamorphosed geosynclinal material to intrusive igneous rocks which are granodioritic. This series of rocks is of great interest as it represents a sequence in which original oceanic sediments are continually modified by metamorphic processes to become part of the granitic continental coast, and thus provides a foundation for the detailed study of continental evolution from ocean basins.

Division of Marine Biology

The Division of Marine Biology has developed markedly since 1955, when the Rockefeller Foundation accorded to the University a \$1 million contribution for the purpose of promoting marine biology.

Marine biology is the study of life in the marine environment. In a broad sense it encompasses all conventional categories of biology such as physiology, biochemistry, ecology, and behavior. Biology in the sea demands application of the most sophisticated scientific and engineering methodology. The faculty and staff of the Division represent interests in physiology, microbiology, photobiology, developmental biology, systematic biology and ecology in the sea.

Developmental biology and the molecular aspects of growth and differentiation are being studied in the sea urchin and related simple animals by Dr. N. D. Holland. Using radioactive nutrients, he has found new stages in development of digestive organ function in the urchin gut. By electron micrography, he has observed development of cells which form mucus, an essential function of all digestive systems.



Scripps diver locates 500-lb. clam, Tridacna gigas, off Great Barrier Reef during Billabong Expedition.

Drs. Elizabeth Boden and Brian Boden study photobiology of the sea. The deep scattering layer of organisms which reflect and distort sonar communication includes crustaceans that inhabit the open ocean and make extensive daily vertical migrations. The eyes of these organisms differ considerably from those of inshore bottom-dwellers in structure, development, mechanism of action, pigments, and spectral sensitivity. During the winter of 1965-66, the Bodens examined intensively the environments, vertical distribution and spectral sensitivities of animals in the upper 1000 meters of a selected small area of ocean. Their data suggest that diverse environments may exert as great an influence on the structure and function of crustacean eyes as do phylogenetic relationships.

Dr. David Jensen's study of the hagfish's rudimentary heart and its autoregulation, *i.e.*, the effect of mechanical stretch, tension or pressure upon the pacemaker activity, has attracted widespread medical interest. His study of cardiac control in animals from molluscs through man provides important bases for understanding heart function.

Researches of Dr. D. L. Fox and his students and colleagues in the section of marine and comparative biochemistry have involved studies in the comparative selectivity of abalone and sea urchin species to various seaweeds on which they feed; fractionation and biochemical modification of dietary carotenoids in flamingos and in the scarlet ibis; and carotenoid metabolism in the colored fishes, seastars, mussels, and various sponges. Adaptations involving pigmentation are important aspects of evolutionary biology.

The giant clams, long objects of popular interest, are further noteworthy for the diversity of their mantle colorations and ability to thrive in nutritionally poor waters of the tropical reefs. The nature and significance of the green algae (zooxanthellae) which grow inside the animal's cells have puzzled biologists. On the basis of metabolic studies in light and dark in living clams (Billabong Expedition) Dr. F. T. Haxo, Dr. Leonard Muscatine of UCLA, and their colleagues have shown that these algae are sufficiently abundant and metabolically active to evolve oxygen photosynthetically at three times the rate required by the animal. In the light, the algae produce oxygen and glycerol for use by the animal's cells. The symbiosis between algae and clam or coral animal cells is a prehistoric working model for the utilization of sunlight for human nutrition in future space travel.

Membranes of cells consist of lipoprotein molecules. These proteins apparently are responsible for moving nutrients into cells and wastes or products out of them. The membrane lipids of plants, identified as combinations of sugars, fatty acids, and phosphates, are being studied

by Dr. A. A. Benson and his colleagues. Their function in salt excretion by glands on the leaves of mangroves, nasal glands in sea birds, or the gills of fishes have been investigated using radioactive tracers. Parallel studies of terrestrial plants adapted to seawater may be eventually of practical application for the production of more salt-tolerant agricultural crops.

The sea surface is a unique biologically active region. In a study of the microbiota of this layer, Dr. G. W. Harvey has developed a "steam roller skiff" apparatus for collecting the upper thousandth of an inch of the sea surface. The organisms are being studied taxonomically and ecologically, to evaluate their interactions with physical factors such as wind and salinity. Many new species have been found in this infinitesimally thin but highly concentrated layer. The growth and products of these organisms affect the reflectivity of the sea surface and many of the components of sea spray and fogs. Dr. Harvey is also measuring relative composition, turbidity, ripple, damping, and surface tension in fresh, untreated samples of surface seawater.

Dr. B. E. Volcani and his colleagues have been studying the fine structure and biochemistry of silica shell formation in diatoms, *i.e.*, how the diatom, a one-celled plant, transforms inorganic silicates into a "shell" of varied structure and complexity. These single-celled plants are responsible for the massive movement of silica in the sea, one of the important parameters of oceanography. By means of synchronously dividing cultures and biochemical and electron-microscopic studies, the metabolic and structural processes are being defined. Two apparently interrelated biochemical systems seem involved, one responsible for the transport, polymerization, and deposition of silicic acid, the other leading to the formation of an organic casing which surrounds the shell and may be responsible for its final architecture.

Dr. C. E. ZoBell has continued to investigate the characteristics and physiology of bacteria of the great depths. Their adaptation to the 14,000-pound-per-square-inch pressure of the deep sea is both remarkable and important for understanding structures of terrestrial cells. Ten species, examined during the year by Leslie Hittle in Dr. ZoBell's laboratory, have been found to differ greatly in their tolerance for hyperbaric oxygen and in their ability to grow at increased hydrostatic pressure. Dr. ZoBell collaborated with Japanese microbiologists on the Scripps Zetes Expedition to the Japan Trench, where they recovered numerous unusual bacteria from depths exceeding 9,500 meters.

In 1966-67, Dr. R. A. Lewin and two assistants concentrated on the completion of a monographic study of some 130 strains of flexibacteria isolated from marine shores, hot springs, and other habitats around the world. These have been tentatively classified into six genera and about 35 species, mostly hitherto undescribed. Flexibac-

teria are gliding microbes, containing red, orange, or yellow carotenoid pigments. They grow on the organic material falling to the sea floor. Others are parasitic to fish or predatory on bacteria. Although flexibacteria are ecologically important, they have generally been neglected in the past, largely because techniques for their isolation and culture were inadequate.

During the past year, Dr. C. L. Hubbs has published, as author or co-author, several scientific papers, notably a monographic treatment of the characters, distribution, luminescence, and food of a dwarf pelagic shark, *Euprotomicrus bispinatus*. With his junior associates, he has continued a variety of other research projects, including a monograph of the hagfishes of the Pacific Ocean, revisions of the achirid soles and of the tropical American shore fishes of the genus *Eucinostomus*. They have also done studies of an interglacial fossil deposit on Isla Guadalupe, off Baja California, Mexico, and are engaged in radiocarbon age-dating of geological and paleontological deposits.

Dr. R. H. Rosenblatt has lately investigated the shore fishes of the eastern tropical Pacific region, and in particular the deep-sea angler fishes. Revisions of certain eastern Pacific members of the groupers (*Mycteroperca* spp.) and clinids (*Starksia* and *Paraclinus*) have been completed, and work is now in progress on groupers of the genus *Epinephelus* and mud-burrowing eels of the family *Heterenchelidae*. On a recent brief trip to Panama, Dr. Rosenblatt succeeded in collecting several new species and establishing many new records for the area. The latter are particularly important in connection with surveys of population dynamics to result from the proposed construction of a sea-level, transisthmus canal.

Division of Oceanic Research

The Division of Oceanic Research consists of individual investigators and groups of investigators who work on a broad spectrum of subjects related to the ocean. Groups within the Division study ocean physics, dynamics, and chemistry; their complex interaction with the atmosphere and solid earth; and their combined effect on marine life and the transportation and deposition of sediments. Scope of the myriad types of researches conducted by this Division is indicated by the subject matter presented here.

In the fall of 1966, on Exjibia Expedition, Dr. W. S. Wooster measured current shear and other physical properties of ocean water to determine the static and dynamic stability of the water column; *e.g.*, the forces causing resistance to mixing of water from one depth to another. As a result of this experiment, he has been working on methods for accurate determination of the stability which will be utilized on future investigations. In addition, he planned and coordinated Eastropac Expedition, a multi-organizational, multi-nation cooperative investigation of air currents, water currents, and plankton and tuna re-

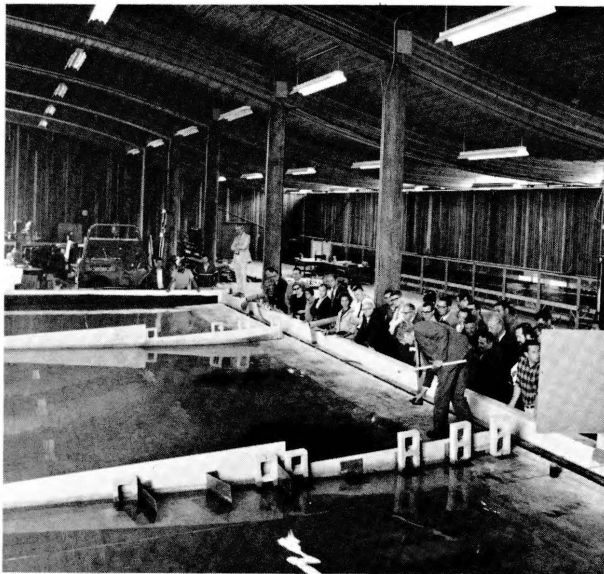
sources in the eastern tropical Pacific.

Dr. R. S. Arthur's group developed improved methods of predicting mean monthly anomalies of sea surface temperatures using perturbation analysis and studied the effects of bottom topography on the Gulf Stream and the California Current System.

Margaret Robinson produced charts showing the monthly normal temperature distribution in the world's oceans using data obtained from bathythermographic (temperature / depth) measurements, from many sources worldwide. The analysis for chart production is now being done by computer and charts for the Pacific are in press.

The research program of Dr. D. L. Inman's group studying coastal oceanography and shore processes includes field measurements of waves, currents, and sediment transport, as well as an experimental program utilizing the wave and current facilities in Scripps' new Hydraulics Laboratory.

A combined field and laboratory study during the year led to the identification and experimental verification by Anthony Bowen of the mechanism governing the generation of rip currents and their spacing along the beach. Rip currents were shown to result from the interaction of the incident surface waves with one of the many possible modes of longshore oscillation, known as edge waves. Other achievements this year included the experimental verification in and near the surf zone of the relations for the change in mean water level due to the passage of a train of surface waves (a phenomenon known as wave set-down and set-up); and the development and use of techniques that permit synoptic field measurements of the velocity of longshore currents, the transport rate of sand, and the magnitude and direction of the energy flux of the breaking waves.



Graduate student uses Hydraulics Laboratory wave basin in supporting thesis pertaining to generation of rip currents.

Dr. W. G. Van Dorn completed a theoretical and experimental study of the run-up of periodic waves on uniform slopes, a subject in which there is a great deal of current engineering interest. The run-up problem concerns the behavior of waves in the most critical phase of their history, when most of their energy is expended on the shoreline. The mathematics of shoaling waves is complicated and doubtful, and very few reliable experiments on their real behavior exist. By conducting careful experimental study of the behavior of waves in shoaling water, as well as by re-analyzing larger-scale experiments performed by the Army Corps of Engineers, it was found possible to reconcile seemingly inconsistent theoretical descriptions with real waves, and to produce a set of prediction charts suitable for general engineering use.

Drs. C. D. Keeling and Arnold Bainbridge are continuing their measurements of the increase of carbon dioxide in the atmosphere and oceans. The amount added per year, due to combustion of coal and petroleum, has been increasing steadily since 1900. If this trend continues, man, within a few centuries, will return to the atmosphere and the oceans the carbon incorporated in sedimentary rocks over hundreds of millions of years, a large-scale geochemical event which could not have happened in the prehistoric past nor can it be reproduced in the foreseeable future. The goal is to continue to document this event, and to gain sufficient knowledge of the mechanisms of transport and geochemical transformations of CO_2 so that the factors which regulate the abundance of CO_2 in the atmosphere and oceans can be established. Achievement of this goal would help in predicting the amounts of excess CO_2 which will accumulate in the atmosphere, oceans, and biosphere, and the effects which these excesses will have on the welfare of man and other life on earth.

Oceanographers have also found a good use for fallout from nuclear weapons. Some of the radioactive constituents of debris blown to high altitudes during the testing of large nuclear weapons in 1961 and 1962 can be detected now in seawater almost anywhere in the ocean's surface. By plotting the pattern left by traces of this fallout and by watching it change with time, much can be learned about fundamental behavior of the moving ocean. Dr. T. R. Folsom's group has developed rapid, easy methods to study this fallout.

Perhaps the most interesting finding is that certain of the long-lived fallout radioactivities, such as radiocesium (Cs^{137}), for example, are not penetrating into deep water as rapidly as was formerly supposed. Larger fractions, therefore, remain near the surface in layers where most of the marine organisms live. These surface layers move slowly as the ocean rotates; for example, the north Pacific rotates clockwise to bring northern water past California. Because of this, the water that experienced intense fallout in the far north in 1962 and 1963 now ap-

pears to have moved even south of California. Recent Scripps measurements indicate that areas containing the highest residual of oceanic fallout pollution now are centered some 600 miles south and west of San Diego.

Dr. Tsaihwa J. Chow has been studying a different type of fallout: the lead burned in high-octane gasoline, carried through the air and deposited on land and in the ocean. Lead pollution of the surface layers of the ocean has been building up rapidly as it has on land and in the layered snow deposits of the Greenland Ice Cap.

The Radiocarbon Laboratory, under Drs. Hans Suess and George Bien, worked on the calibration of the radiocarbon time scale using accurately dated tree rings of the Bristlecone pine (Dr. Suess), continued study of the transfer of radiocarbon between the atmosphere and the surface water of the ocean, and provided radiocarbon dates for material gathered on other projects at Scripps.

Dr. C. S. Cox and his group investigated variations of electromagnetic field and found high electrical conductivity at depths of 30 km. below the ocean floor and starting at 150 km. below the continent. This means that, at given depth below sea level, either the temperature is higher beneath the ocean than beneath the continent or the rocks beneath the two regions are chemically different; and if additional geophysical evidence is considered, both are required. In the light of the present knowledge of the properties of rocks at high pressure and temperature, the high electrical conductivity of the oceanic basement favors a highly basaltic external mantle shell extending to no less than 30 km. below the Mohorovicic discontinuity.

Many of the research projects in the Division have been related to two subjects of currently great geological interest: the effects of the last Ice Age and the significance of the peculiar mid-ocean rises in the sea floor in the older history of earth. Dr. Fred B Phleger and Frances Parker have studied the distributions of microfossils in deep sea cores in the southwest Pacific to determine the distribution of water masses and the position of the Peru Current during the last glacial age. They have also measured the rate that calcium carbonate is formed in the shells of near surface modern foraminifera, and the rate at which it is re-dissolved as the shells sink to the sea floor. Dr. M. N. Peterson has made direct measurement of the rate at which the water dissolves calcite (calcium carbonate) at various depths in the ocean. He has found that below the first 100 meters (328 feet) of the sea, the water attacks the calcite; below 3,700 meters (12,139 feet) the rate of attack becomes severe and little calcite is found in sediments on the sea floor below that depth.

Drs. F. P. Shepard, J. R. Curray, and W. A. Newman, with a group of visiting geologists, made an intensive study of the past height of sea level on south Pacific islands, to learn whether there was a time near the end



South Pacific sea-level studies on Jabor Island reveal exposed wall of artificial trench and rubble from storms.

of the glacial period when sea level was higher than it is now. Raised terraces that have been observed on some of these islands, and considered to be evidence for higher sea level, were carefully examined. These turned out to be storm ridges, created in modern times and containing World War II relics. Dr. Curray has also studied the structure of the continental shelf, which owes its present flat surface to the lowered sea level of glacial times. In many places around the world, he has found that there is a rock ridge near the outer edge of the shelf, either exposed or covered with sediments from the continent. This ridge has kept sediments eroded from the continents from reaching the deep sea floor in the past, and has trapped them to form the shelf.

The mid-ocean rises, such as the Mid-Atlantic Ridge, the East Pacific Rise, and the Indian Ocean Rise, have been a focus of attention for many of the geological and geophysical staff at Scripps, in this Division, the Marine Physical Laboratory and the Division of Earth Sciences. The concept that the sea floor is spreading away from these rises, and that new portions of the crust of the earth are continuously formed along these seams, has been based in large part on work performed here. The seismic studies of crustal structure under the rises by Dr. George Shor, Jr., and Dr. R. W. Raitt, the magnetic surveys off the western United States by Arthur Raff and Dr. Ronald G. Mason, and the correlation of reversals of the magnetic north and south poles in past time with geological age determinations from microfossils by Dr. C. G. A. Harrison and William R. Riedel, have served as basic data for these theories.

Dr. Tj. H. van Andel this year continued studies of the Mid-Atlantic Ridge, an important element in the sea-floor-spreading hypothesis. Dr. van Andel's investigation shows that such a mechanism is not impossible, but that horizontal movements of the sea floor are involved as well as vertical ones.

The central part of the Ridge, which was previously thought to be very new (less than ten million years old), apparently has had a significantly longer history.

Dr. R. L. Fisher has prepared a topographic chart of six million square miles of the western part of the Indian Ocean using depth soundings acquired by Scripps' ships and those of many other laboratories around the world that participated in the International Indian Ocean Expedition. He reports that the floor of the Indian Ocean and especially the Mascarene Plateau has been extensively broken by faulting along NE-SW trends; and that studies of this Mid-Indian Ocean Ridge and other regions of the Indian Ocean show that, as in the other oceans of the world, the sea floor is apparently spreading outward from the center of the Mid-Ocean Ridge.

William R. Riedel, studying the distribution of microfossils of radiolaria in deep-sea sediments, found that the pattern of their distribution could be accounted for by the hypothesis of sea-floor spreading.

Studies of the relationship of present-day sea life to its surroundings are being conducted by Drs. E. N. Fager, J. T. Enright, and J. A. McGowan. Dr. Fager's group has used SCUBA gear, the Navy's Sealab II project, and Cousteau's Diving Saucer to determine how many creatures of what size and species live together in the ocean at various depths and how they affect each other. Direct observation has provided information about the relative numbers of different kinds of fishes and other sea life that could not be obtained in any other way. Dr. McGowan has worked on the time and space distribution of many invertebrates, mostly plankton, in the Pacific water masses. He learned that communities of animals are found together in a particular water mass, and that boundaries can be drawn for the animal populations just as they can for the separate water masses.

Many sea creatures move up toward the surface in the evening and down to the depths at dawn. This group of animals forms a large enough mass to produce a "false bottom" return on echo sounding equipment, known as the deep scattering layer. The work by Drs. B. Boden and E. Boden on this subject is discussed elsewhere in the report of the Division of Marine Biology.

Related work by Dr. Enright consisted of laboratory studies to determine whether the plankton rose because of the darkness or because they have an "internal clock" that tells them it is the proper time to rise. A study on locally obtained plankton showed that some do each: when they were put in a large tank under controlled lighting in which night and day were shifted around the clock, most of the creatures adjusted their schedule. Then when the artificial lighting was turned off and the tank kept in "twilight," some of them continued to migrate up and down on the "wrong" schedule that had been artificially set up, thus showing that they have an "internal clock" that was re-set by the experiment.

Marine Life Research Group

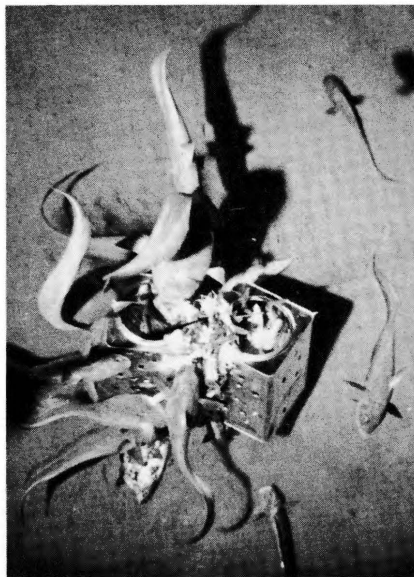
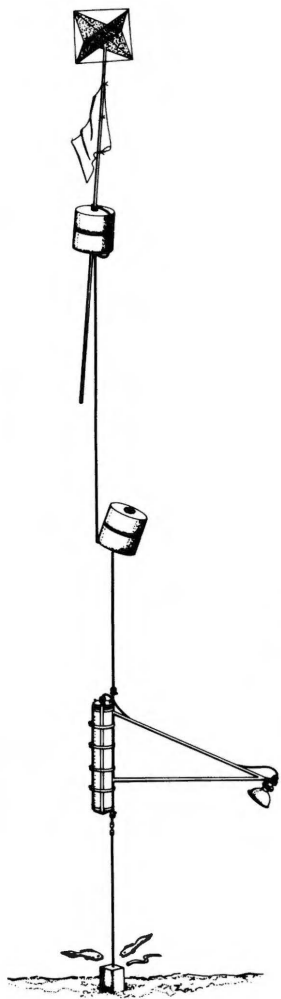
The Marine Life Research Group (MLRG) includes that portion of the research of the California Cooperative Oceanic Fisheries Investigations that is conducted by Scripps Institution. This program has been principally concerned with the ecology of the California Current System; that is, its currents and countercurrents, temperatures and temperature fluctuations, and its chemistry, plankton, climatology, and other factors. Also, MLRG has expanded its research to include other parts of the North Pacific, particularly the northeastern Pacific, the source waters of the California Current System.

Patterned cruises were begun in 1949 and continued on a monthly or quarterly basis through 1966 along the coast of California and Baja California. Many important biological and physical oceanographic publications have resulted. From the collected data, atlases are being assembled to clarify the oceanographic changes that have occurred through the years. The atlases so far published are 10 meter Temperatures and Salinities; Calanoid Copepods—Part 1; Calanoid Copepods—Part 2; Chaetognatha; Geostrophic Flow; Euphausiacea—Part 1; Pelagic Mollusca, and Thaliacea.

Within the next year there thus will be in published form the most extensive biological and physical oceanographic documentation of any oceanic region on earth. The atlases are published with particular attention to the requirements of an interdisciplinary cooperative program, so that scholars in a number of different disciplines can compare distributions and check their ideas of interaction and dependency. The atlases are thus precursors of much added discovery.

The Biomass Atlas to be published soon is only the first of a series on this subject. In the last several years the problems of arriving at a meaningful measure of zooplankton have been resolved. The zooplankton samples from the patterned cruises are being sorted into functional groups and their volumes measured. The fluctuations of the various groups between years represents the changes in available food for the small pelagic fishes.

Investigations of the oceanographic changes in the California Current prior to the MLR Program can give an insight into the time scales and ranges. One entree is the historical record in post-Columbian times. The records of the explorers along the west coast of North America may give some evidence of past oceanographic conditions. An example of unpublished material is a group of drawings of identifiable fish drawn in the latter quarter of the 18th century by Spanish biologists during the Malaspina Expedition. Another source are data from the rare, highly stratified (varved) sediments that occur in some ocean basins. MLRG studies have found varved sediments at six locations along the Pacific Coast from southern California to central Peru. These sediments are apparently laid down in annual layers subsequently un-



Deep-sea free vehicle photography system developed by Marine Life Research Group takes photos of ocean bottom.

disturbed. The initial finding from the preserved fish scales are that the sardine was abundant for about 70 years during the recent period and for a similar period about 800 years ago. The scales of the anchovy and the hake are in high abundance throughout the entire period except for short periods of time. Anchovies were rare in the recent period. From the associated organisms, the recent period appears to be typified by a weak California Current.

The causes of some of the oceanographic and marine biological changes have only begun to be investigated. North Pacific sea surface temperature anomalies have shown that changes in the California Current System are also changes involving the entire North Pacific Ocean, if not the entire planet. It is now known that non-periodic

departures from normal sea surface temperatures are common throughout the oceans. In the North Pacific these anomalous conditions are often large scale (ca. $\frac{1}{4}$ to $\frac{1}{2}$ the Pacific) and long persistence (ca. $\frac{1}{4}$ to 3 years). In addition, the first long term records from unmanned moored stations have shown several important features including astronomic periodicities of temperature fluctuations.

MLRG has recently begun investigations into the deep waters of the eastern North Pacific where oceanographic and marine biological changes are very small and little explored. This has required the development of new instruments. The new Isaacs-Brown opening and closing mid-water trawl and the Brown-McGowan opening and closing plankton nets are yielding much needed data on the vertical distribution of marine organisms. Autonomous instruments released from a ship have been developed to measure the near-bottom deep currents, view the benthic and epibenthic marine population in deep water, and measure the rate of sedimentation near the coast.

Deep currents in the eastern North Pacific have been found to be slow but of somewhat higher velocity than other evidence anticipated (ca. 3cm/sec), and the fluctuating component has been found to result principally from the lunar semi-diurnal surface tide. The presence of unexpectedly large fish populations, including very large climax predators, whose presence on the deep ocean bottom is an environmental condition of importance, has been demonstrated. The few data from the sediment collector have made possible the first direct estimates of the generation time of some planktonic marine organisms. It may be that this approach can yield much fundamental understanding of the economy of the sea that has avoided other efforts.

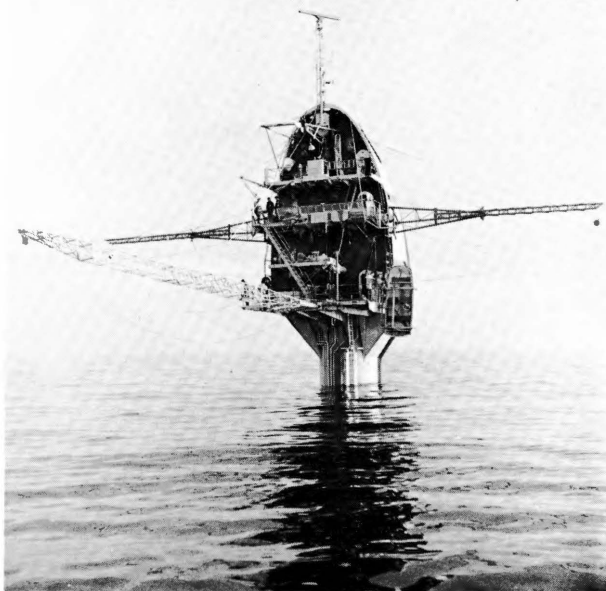
The entire Marine Life Research Program is contributing to a broad-scale understanding of the California Current from the surface to the abyssal deeps of the ocean and is developing four areas of research:

1. The analysis of Scripps data from the patterned cruises, since 1949, continues to improve our basic understanding of the ecology of the California Current System.
2. Investigation of the historical records and the varved sediments holds much promise for understanding the time scale, range, and nature of fluctuations of the California Current.
3. Extension of MLRG research into the spatial and temporal fluctuations of the North Pacific is resulting in better insight into North Pacific oceanographic, biological and meteorological processes and ultimately will enhance weather prediction.
4. Research into the deep waters is surprisingly providing understanding into some subsurface processes that have avoided other approaches.

Marine Physical Laboratory

Since its establishment in 1946 the Marine Physical Laboratory (MPL) of Scripps Institution has been carrying out (primarily with support of the Office of Naval Research) a program of investigation having four closely correlated facets. Interest has centered on underwater acoustics—the study of the manner in which sound travels through the sea and the nature of the noises which occur within it. Such studies bring one quickly into contact with the physical, chemical, and biological nature of the sea itself as well as to a broader look into two related fields—marine geophysics, in which sound signals provide a major tool, and signal processing, in which the goal is to understand the principles which provide the basis for design of sonar systems. Pursuit of knowledge in these three fields requires a technological base beyond that now available for exploitation of the sea, thus an interest in learning new ways of doing things in the ocean has been developed. As a result, it is possible to subdivide the Laboratory's work into four major areas of interest: underwater acoustics, marine geophysics, signal processing, and marine technology.

In ocean acoustics, continuing programs are directed at understanding propagation, background noise, and reverberation as well as toward related investigations of the physical (and to some extent biological) nature of water. Dr. F. H. Fisher's group has been working with FLIP to measure propagation fluctuations (of phase and amplitude). Deep-water experiments had been conducted (1963, 1964, 1965) off San Diego and during the last year these were extended to a mid-ocean location south of Hawaii. Phase fluctuations were small in both areas, leading to plans to conduct additional observations at



FLIP, which worked at sea 198 days on M.P.L. projects, features vertical position and sophisticated instrumentation.

short range, with fine-scale documentation of the environment to determine the validity of existing theory. William Whitney and Dr. Fred N. Spiess have been carrying out (again using FLIP in the San Diego and Hawaiian areas) a continuing investigation of long-range acoustic propagation and related studies of the directional nature of background noise in the sea. During this last year, Dr. Victor C. Anderson's reverberation-measuring equipment has been improved in frequency coverage, resolution, and data-handling capability and has begun to produce significant new information on the statistical distribution of biological sound scatterers.

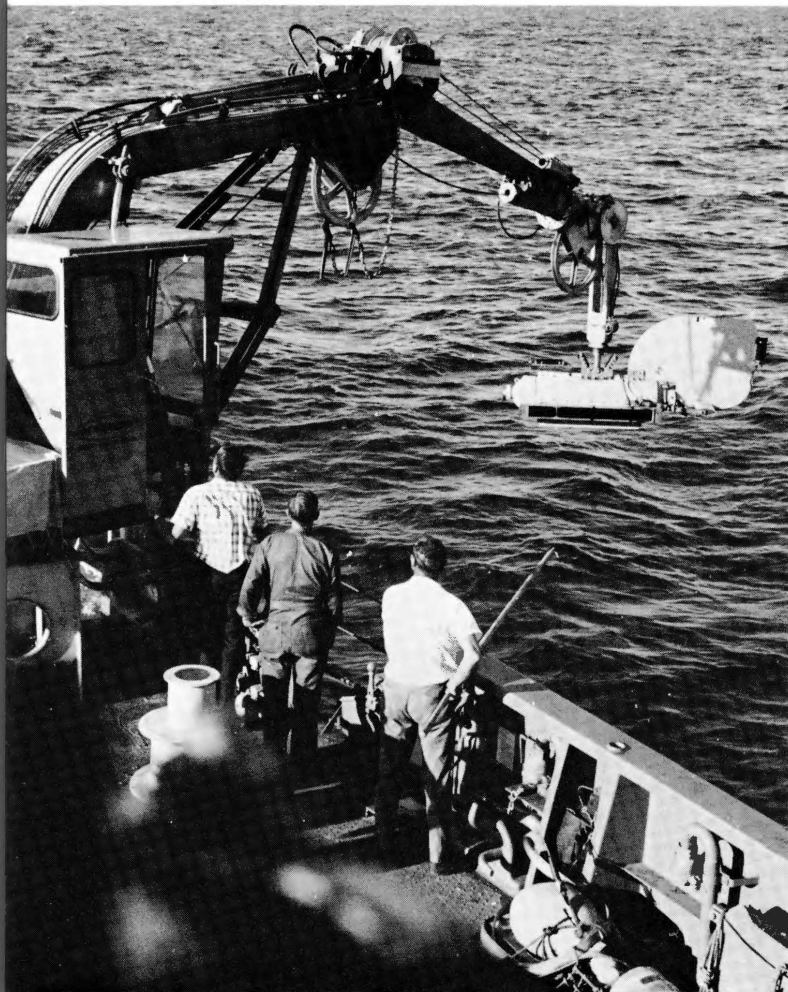
Sea-floor properties continue to dominate many of the problems of understanding and utilizing the sea. In this context, Drs. George Shor, Jr., and R. W. Raitt have continued their geophysical studies of the earth's crust beneath the sea, primarily using acoustic techniques, and have most recently been developing methods (very long receiving arrays) which will allow direct determination of sound velocity in the upper crustal layers. Major efforts of the recent past year were devoted by Dr. Shor to the mapping of the Mohorovicic discontinuity in the region just north of the Hawaiian Islands and by Dr. Raitt to determination of variation in speed of sound travelling horizontally through the crust of the earth in different azimuthal directions. Both of these programs were included in the multi-ship expedition (SHOW) directed by Dr. Shor and involving scientific groups from the University of Wisconsin, Oregon State University and the University of Hawaii, as well as from Scripps, in the summer of 1966.

Geomagnetic studies of the nature of seamounts and related structures are continuing under Prof. Victor Vacquier. In addition it is expected that this group will soon make its first extensive use of sea-floor magnetometers (under development and test for several years) to observe temporal fluctuations of the magnetic field at the deep-sea floor.

The largest of the sea-floor-study efforts in the Laboratory is that of Drs. Spiess, Carl Lowenstein, and John Mudie, using deeply towed instruments. During the last year, the transponders developed previously have been extensively used to support detailed observations in the northeast Pacific of sea-floor topography, roughness, and magnetic properties, and instrumentation has been added to allow determination of shallow layering and outcropping in the sea floor and to give a bottom photographic capability. Of particular interest is that these observations have shown for the first time the extensive existence of large amplitude (1000 gamma) magnetic anomalies, each having horizontal dimensions of only a kilometer or so.

The principal signal-processing activity in the Laboratory at this time is that of Dr. Victor C. Anderson on the development and testing of the steerable null system. Hydrophones for the sensing array have been procured

and tested, as have several of the major electronic components. Initial trials of the system will be made during 1968 at sea either from FLIP or from a specially configured research barge now under construction for support of our ocean technology activities. A second activity is being started by Dr. Carl Lowenstein in the deep-tow group to investigate a new high-resolution technique for searching the sea floor and examining its roughness in a manner similar to that of conventional side-looking sonar but with much more rapid area coverage.



Marine Physical Laboratory-developed instrumentation with top-, bottom-, and side-looking sonar is lowered into sea.

In addition to MPL research, various staff members have provided extensive advisory service to the Navy and Navy-related activities. This is one of the principal ways in which information and ideas arising from research are passed into places in which they can be used and by which the staff keeps in touch with the problems of marine science and technology. Examples of involvement are provided by participation in the Navy's Long Range Undersea Surveillance Coordinating Council, Naval Oceanographic Office Consultants Board, Mohole Site Selection Panel, Navy Marine Geophysical Survey Coun-

cil, Naval Postgraduate School Marine Science Review Committee, and participation in studies conducted during the summer of 1966 for the Navy by the National Academy of Sciences - National Research Council.

Most of the activities above provide opportunities for appropriate involvement of students - undergraduate, graduate, and post-doctoral - in the field of marine physics. The present complement includes graduate students in the Departments of Oceanography, Earth Sciences, and Physics. All of these students are potential workers in marine physics and therefore these activities allow the integration of the function of providing new knowledge with that of providing new people in a manner appropriate to a university laboratory.

Physiological Research Laboratory

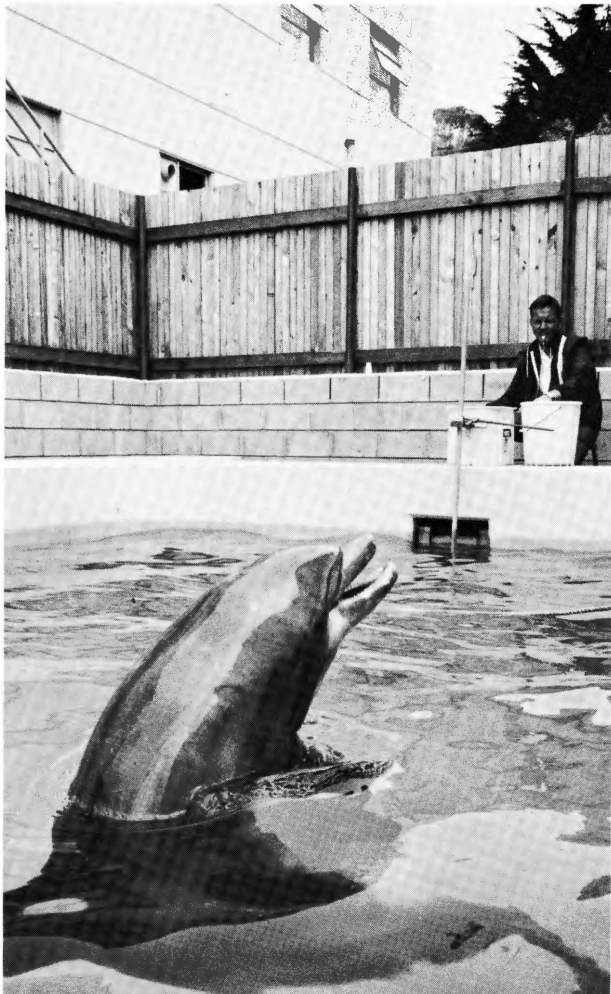
Much of the effort of the Physiological Research Laboratory during the past year has been devoted to the maiden voyage of the new biological laboratory ship, *Alpha Helix*, which left San Diego in March, 1966, and spent seven months at the Great Barrier Reef, off northeast Australia. The facilities of this "floating laboratory," the plans and design for which were initiated to a large extent by Dr. P. F. Scholander, attracted collaborating investigators from many American and foreign institutions. Their investigations spanned a wide range of topics, including salt and water regulation of mangroves, neurophysiological studies of various marine invertebrates, photosynthesis of free and symbiotic plants, temperature regulation in certain reptiles, and some physiological studies on a sirenian, the dugong. Results of the expedition to the Reef appear elsewhere in this report.

Dr. Theodore Enns continued research on biological transport of metabolic solutes. His recent studies on the excretion of urea by sharks have indicated that there is probably an active urea-secreting mechanism in the kidneys. With his co-workers, Dr. Enns has also demonstrated that the gills of the fish *Heterodontus francisci*, are readily impervious to urea and sodium, and he has measured CO₂ transport in whole blood, carbonic anhydrase activity in alga, *Gyrodinium* sp., and CO₂ exchange in a fish, *Clinocottus* sp.

Dr. Susumu Hagiwara and his colleagues investigated action potentials and excitation-contraction coupling in barnacle muscle fibers. In the sea-hare, *Aplysia*, the visceral ganglion cell exhibits an overshoot in the action potential apparently dependent on both calcium and sodium ions, as physico-chemical theory would indicate. Intracellular recordings from the primitive eyes of barnacles (*Balanus* sp.) showed that the action potential is dependent upon sodium current. In the midbrain of a weakly electric fish, they found a main integrating center for the electro-sensory system.

Studies of the biology of asphyxia, for which diving

mammals have been used as biological models, have been continued by Dr. R. W. Elsner and his co-workers. The asphyxial episode of birth has been studied in the sheep fetus and it was found that the cardiovascular adaptations of the diving mammals are displayed in the asphyxial response of the fetus. A variety of studies have been undertaken on marine mammals by Dr. Elsner and his colleagues. Investigations of metabolism and temperature regulation of the porpoise, dugong, and pilot whale have been performed. The physiology of respiration and lung function has been studied in the pilot whale.



Echo-location studies and animal training of dolphins occur in behavioral pool of Physiological Research Laboratory.

Dr. E. A. Hemmingsen carried out studies of snow blindness in native animals in Antarctica and also did preliminary investigations of oxygen transport and metabolism in ice fish which do not possess hemoglobin in their blood.

Special Developments

This group has concerned itself with satellite navigation instrumentation procurement for the entire oceanographic community of the United States and has de-

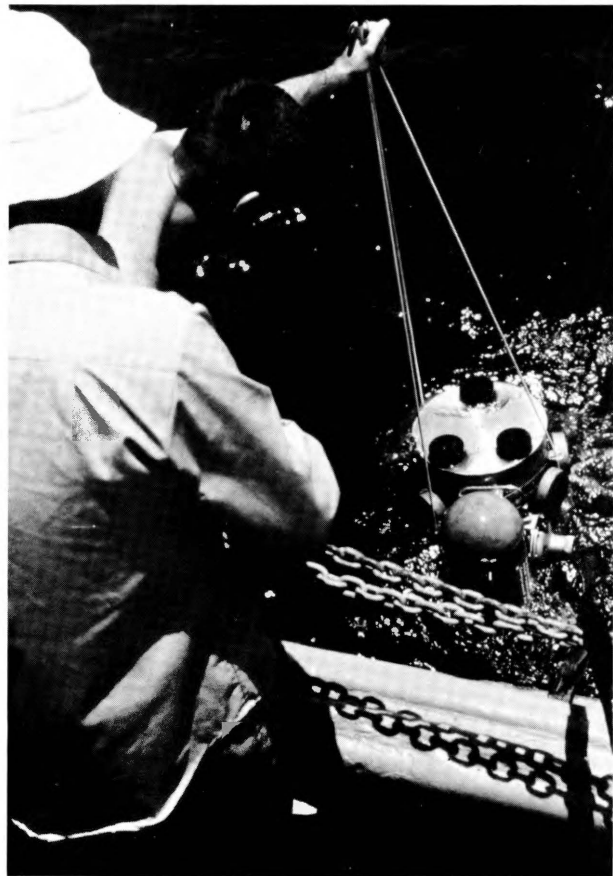
veloped standards and systems for telecommunications (allocation of radio frequencies, transmission of data, buoy coordination) on a global basis.

An interesting development was that of a shark bite meter, which for the first time has enabled scientists to really know how a shark bites and to measure its ability to inflict damage on people and structures. Such parameters as maximum force of bite and the forces of the individual teeth have also been determined.

Visibility Laboratory

Studies of the interaction of light with the ocean continued to be a major activity in the Visibility Laboratory. The National Science Foundation supports an investigation of the penetration of daylight into the sea and its utilization for photosynthesis. An underwater spectroradiometer is employed at appropriate depths to measure, wavelength-by-wavelength, the available light and its directional distribution. An understanding of the utilization of daylight within the sea and potential methods for a rapid assay of the standing crop of vital plankton are resulting from these studies.

Oceanic surveys of the optical properties of seawater were made in many parts of the Pacific Ocean. Data



Visibility Laboratory spectroradiometer is lowered into Gulf Stream to measure upwelling spectral irradiance throughout visible spectrum.

from shipboard submersible instruments were supplemented by aerial photography and measurements with airborne instruments in some cases. Studies of the outflow from rivers and other inshore phenomena are particularly aided by the aerial observations.

The Office of Naval Research has supported studies of the propagation of narrow beams of light from underwater lasers. Early experiments have been performed on a long underwater optical bench situated in a lake, but the research will be transferred to the ocean during the coming year. It has been found that the needle-like beam of green light produced by the laser is spread by water in a significantly different manner from spreading effects previously observed in the atmosphere. Because all light in the ocean, including any form of daylight, may be considered as the super position of many fine beams, distribution of underwater lighting can be usefully understood in a more detailed way on the basis of the knowledge gained through the studies of the propagation of light beams produced by underwater lasers.

Since man and marine animals see by means of underwater imagery, studies of the limitations imposed by seawater as well as by the atmosphere are being made. These investigations also make use of the knowledge gained from studies of the propagation of light from underwater lasers. Blurred imagery resulting from scattering and from random refractive processes within the water and within the atmosphere have been found to contain more information than can be appreciated or extracted by ordinary visual inspection.

A major research effort within the Visibility Laboratory is directed toward the extraction of information from poor quality imagery. This is accomplished by transforming the image into a frequency-space representation wherein it is possible to correct the distortions in terms of the amplitudes and phases of the separate spatial frequency components. After transformation back to its ordinary form, a vast improvement in image quality is observed.

Interactions between the atmosphere and the ocean are supported by light from the sun as a primary source of energy. Various optical aspects under study include airborne measurements of the manner in which sunlight is redistributed by the atmosphere before arriving at the ocean's surface under various measured meteorological circumstances. New techniques for measuring the distribution of the wind-field at the surface of the sea on the basis of airborne photographic radiometry have also been studied. This is one form of remote sensing of ocean and ocean-surface properties which may have eventual application in worldwide studies from research satellites.

Institute of Marine Resources

The Institute of Marine Resources is a Universitywide Institute established in 1954. Its terms of reference are to cooperate with the scientific and engineering departments of the several University of California campuses to find and define unsolved marine resources problems, to initiate research into the solution of these problems, and to support relevant investigations by University staff members.

Headquarters of the Institute are located on the Scripps Institution campus, where several staff members and students are supported whose researches are described elsewhere in this report. Some of the activities of other Institute staff members are outlined here.



California anchovy, Engraulis mordax. Closely related Peruvian anchoveta, E. ringens, supports world's largest fishery.
(Photo courtesy of U.S. Bureau of Commercial Fisheries)

Dr. H. W. Menard is studying the topography and structure of the sea floor and is interested, in particular, with the apparent spreading of the ocean floor by mantle convection. He has the overall direction of the Nova Expedition, which sailed from San Diego in early 1967 to study the geophysics of the southwestern Pacific.

The United Nations Food and Agricultural Organization has sponsored an evaluation of existing scientific data on the Arabian Sea for use as a guide to fisheries. Dr. W. S. Wooster, Dr. M. B. Schaefer, and Margaret Robinson have produced an atlas containing more than 140 charts of physical and biological properties.

Dr. Schaefer has also completed population dynamic studies of two important fisheries, the yellowfin tuna of the eastern Pacific and the enormous anchoveta stocks off the coast of Peru.

The Scripps Tuna Oceanographic Research project continues under Dr. Maurice Blackburn's direction. Studies are pointed toward establishing a scientific basis for improving the effectiveness of the tuna fisheries and

involves physical, chemical, and biological oceanography, much of it as part of Eastropac Expedition cruises.

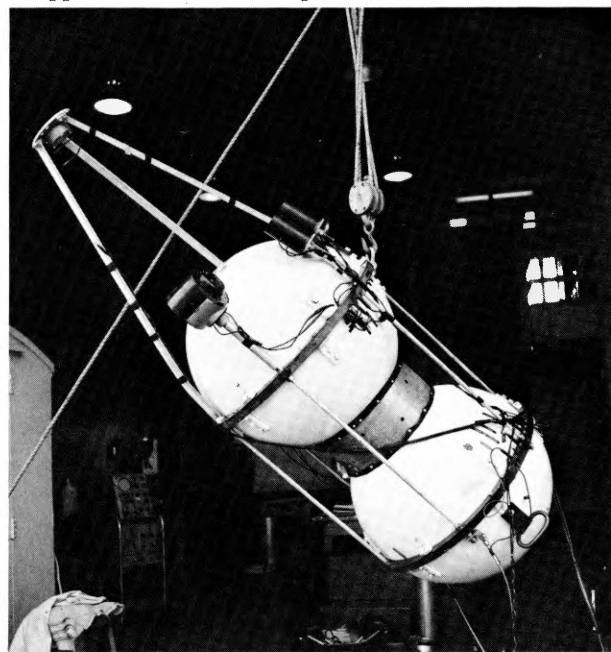
Under Dr. J. D. H. Strickland's leadership, a Food-Chain Research Group continues to make an interdisciplinary study of the early stages of the marine food web, particularly the rates and routes of transfer of matter. The work involves chemistry and all aspects of biology, with an ecological orientation. In particular this year, a sophisticated field program is under way to record the near-shore productivity of the sea adjacent to La Jolla and to attempt the documentation and explanation of the onset of a red-tide in these waters.

A complete account of the Institute's activities both at Scripps Institution and at other locations in the University system will be found in the IMR Annual Report for the year ending June 30, 1967.

Institute of Geophysics and Planetary Physics

The Institute of Geophysics and Planetary Physics (IGPP) is a Universitywide Institute with branches at La Jolla, Los Angeles, and Riverside. The Institute at La Jolla is intimately related to Scripps Institution, not only because of geographical proximity, but, more importantly, because of common scientific interests. As a matter of fact, Drs. G. E. Backus, J. F. Gilbert, R. A. Haubrich, and W. H. Munk hold joint appointments in IGPP and Scripps.

At least two IGPP programs depend ultimately on Scripps vessels for their implementation. Dr. Munk and



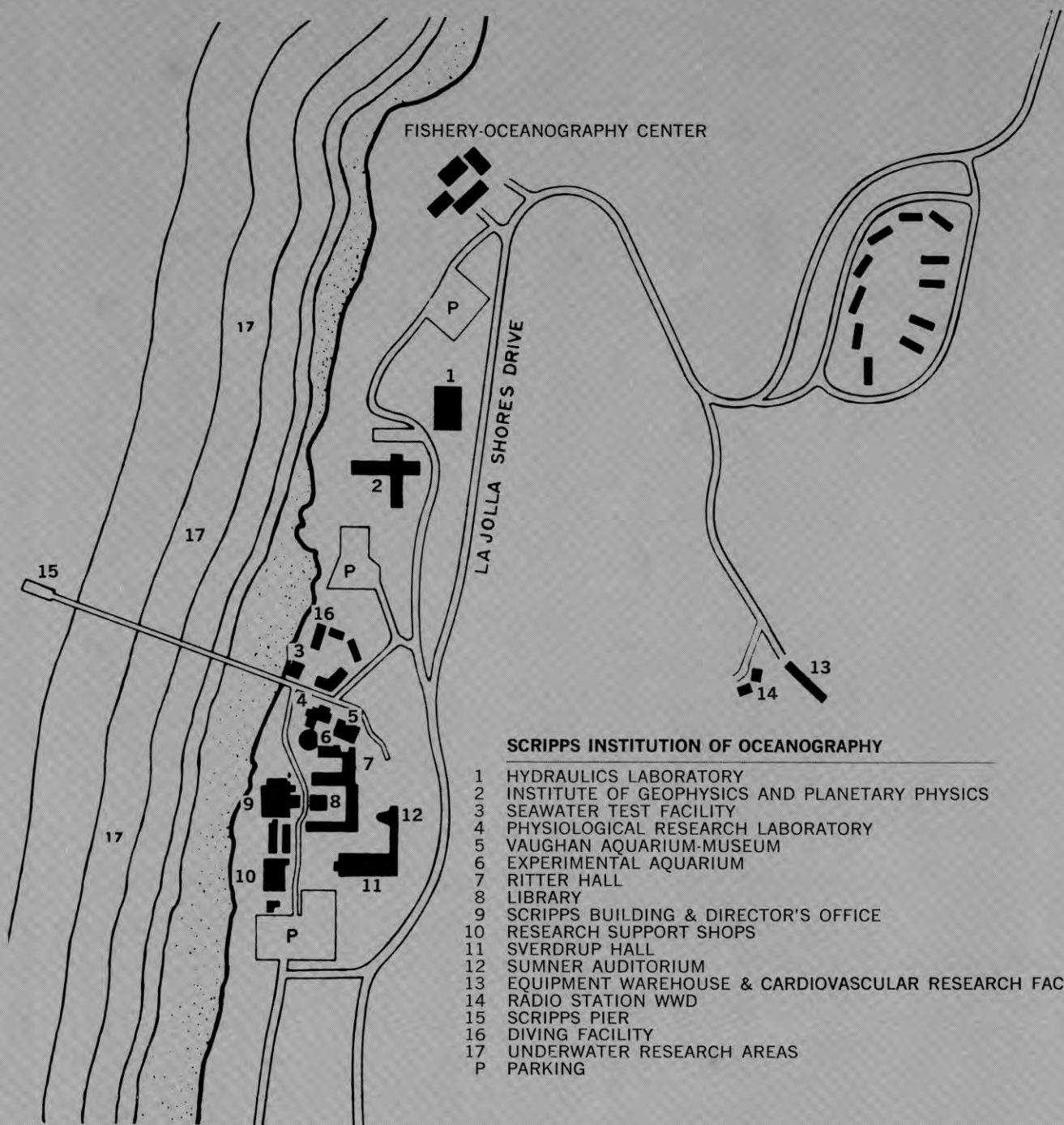
IGPP-developed free-falling instrument capsules record deep-sea tidal measurements and return to surface on command.

Frank E. Snodgrass have, over the past two years, developed self-contained instrument capsules for deep-sea tidal measurements. These capsules are dropped to the floor of the sea from a surface ship (the *Ellen B. Scripps* has been especially effective) and remain there for periods of up to several months, after which they are recalled to the surface by acoustical commands transmitted from the ship upon its return to the site. Data are recorded on computer-compatible magnetic tape. Pressure fluctuations associated with the tides are presently being measured by transducers capable of resolving changes equivalent to one-hundredth of an inch in sea level at a depth of three miles. Temperatures are being recorded with a resolution of a few millionths of a degree, and tidal currents as slow as ten feet per hour are being measured. This work has been sponsored by the Office of Naval Research (ONR) and the Environmental Science Services Administration.

Dr. Hugh Bradner has developed a seismometer capsule that also is dropped from, and ultimately recovered by, an oceanographic vessel. The capsule remains on the bottom for as long as two weeks and measures seismic background noise, especially the so-called *microseisms* with periods of the order of eight seconds. The source of these *microseisms* has been a scientific puzzle for more than 50 years, but now appears to be Rayleigh waves generated by the coastal reflection of ocean swell. This work has been sponsored principally by the U. S. Air Force.

Wind-generated waves, an ever-present feature of the oceans, are currently being studied both theoretically and experimentally in IGPP under Dr. John W. Miles, with support from both ONR and the National Science Foundation. Waves are generated by a wave-maker at one end of a wind-water tunnel, and the wave-induced disturbances in the airstream are measured by hot-wire anemometers in order to determine the energy transfer from wind to waves as a function of frequency for comparison with the corresponding theoretical predictions. This work ties in closely with earlier experimental and field work by Dr. C. S. Cox, of Scripps.

No attempt has been made to describe the complete spectrum of IGPP research, which also includes programs in tidal prediction; geophysical fluid dynamics; the free oscillation and internal constitution of the Earth; instrumentation for very low-frequency seismic phenomena (periods of one-hundred seconds up to one hour); observation of continuous oscillatory motion of the Earth by seismic arrays capable of resolving frequency, direction, and velocity; and magnetic anomalies in ocean-bottom sediments.



Shore Facilities and Collections



Thomas Wayland Vaughan Aquarium-Museum is focal point of campus and attracts more than 250,000 visitors annually.

No organization that conducts the amount and type of research that Scripps Institution does can function efficiently without special facilities and collections. Here, coded to an accompanying map, are brief descriptions of the principal shore facilities and collections at Scripps:

Facilities

Thomas Wayland Vaughan Aquarium-Museum (5). Open daily to the public at no charge, the Aquarium-Museum attracts between 250,000 and 300,000 visitors annually. It exhibits southern California and Baja California marine animals in 24 display tanks of from 75- to 2,000-gallon capacity. The Aquarium-Museum conducts an educational program for elementary, high school, and college students. As a marine specimen collecting facility, it provides Scripps scientists with 118 species of vertebrate and invertebrate animals.

Experimental Aquarium (6). Used by faculty and graduate students for various studies, such as fish culture, this aquarium is provided with seawater and is equipped with five rooms for controlled environmental studies, 17 tanks, and eight seawater tables.

Hydraulics Laboratory (1). This laboratory is equipped with a 50x65-foot wave basin provided with a wave maker and an adjustable simulated beach; a 131-foot-long, glass-walled, wave-and-current channel designed for wave motion studies; and an insulated cylindrical tank, 32 feet deep and 10 feet in diameter, with sampling and viewing ports at several levels. The latter is used for a variety of biological studies.

Scripps Library (8). The library houses a vast collection of oceanographic information, including 66,823 volumes, 20,611 reprints, 28,798 maps, 6,984 reports and documents, and 1,172 pieces of microcopy.

Seawater Test Facility (3). Scripps' seawater conversion study utilizes a 90-foot tower in a "multiple effect flash" evaporation system that produces 3,000 gallons of fresh water from seawater daily. The study is financed by the State of California through the University's Water Resources Center at UCLA.



Multiple-effect flash evaporator system utilizes 90-foot tower in desalination study financed by State of California.

Carbon-14 and Tritium Laboratories (7). The Carbon-14 laboratory provides equipment for the radio-carbon dating of specimens up to 40,000 years. It handles the measurement of C-14 in bicarbonate of ocean water in studies of movement of deep water masses and the downward mixing of surface water. Tritium measurements help solve various hydrological and oceanographic problems.

Research Support Shops (10). Functions in the development and fabrication of special equipment and instrumentation in support of the Scripps research fleet and for various laboratories at Scripps, UCSD, and other educational and governmental organizations.

Radio Station WWD (14). Operated jointly by Scripps and the U.S. Bureau of Commercial Fisheries, Station WWD affords ship-shore communication with ten to 12 daily contacts with an average of five ships at sea. The station is equipped with ten transmitters operating on various frequencies and maintains contact with Scripps and BCF ships operating anywhere at sea.

Scripps Pier (15). A familiar landmark is the 1,000-foot Scripps Pier, built in 1916 as a platform for serial observations, data gathering, and scientific work. Sea temperature and salinity observations have been made daily since August, 1916, from instruments housed at the pier's seaward end. Here also an automatic gauge records tidal fluctuations and pumps send salt water used in laboratories and aquaria of Scripps and the Fishery-Oceanography Center of the U.S. Bureau of Commercial Fisheries.

Salt-Water System (15). The system provides salt water to Scripps and the Fishery-Oceanography Center. It utilizes two sand filters and two concrete storage and settling tanks, each with a 53,000-gallon capacity. Maximum daily delivery capacity is 750 to 800 gallons per minute.

Electron Microprobe Laboratory (11). This laboratory permits the chemical analysis of areas as small as one square micron down to concentration levels varying between a few hundred parts per million. This is achieved by accurate spectrographic measurements of the x-radiation from the area to be analyzed, which is excited by a focused electron beam. The instrumentation is used primarily in studies of mineralogical, petrological, and solid-state physical problems.

Electron Microscope Laboratory (7). Two Siemens electron microscopes with accessory equipment provide high resolution in the study of ultrafine structure.

Diving Facility (16). This is equipped with men's and women's dressing and shower rooms. Scripps' diving training program, oldest and largest diver training and scientific diving program in the country, provides five SCUBA training classes annually that are limited to University personnel who have the need to work or study under water or to federal, state, or local government employees, by permission. Some 70 faculty and staff members and students are certified for underwater work; they make an average of 4,000 dives a year.

Mass Spectrographic Equipment (7 and 11). Six mass spectrographs are available, including two six-inch, Nier-type mass spectrometers for isotopic analysis of light elements; a 12-inch mass spectrometer for geochronology studies; an omegatron mass spectrometer for isotopic analysis of rare gases; and two units for respiratory gas analysis.

Underwater Research Areas (17). Located seaward off the campus is a biological research area set aside by the State of California and in which the taking of marine invertebrates and plants for research for scientific purposes is permitted. An adjoining ocean area is reserved by the Navy for research with bottom-mounted equipment.

Cardiovascular Research Facility (13). Established in 1965 as a joint enterprise of Scripps Institution's Physiological Research Laboratory and the Institute for Cardiopulmonary Diseases of the Scripps Clinic and Research Foundation, La Jolla, this facility consists of an experimental animal colony and equipment for physiological research involving measurements of blood flow and pressure in the heart and circulation.

Physiological Research Laboratory Pool Facility (4). This Physiological Research Laboratory facility consists of a holding pool for large marine mammals and other large marine vertebrates; a ring pool of 32-foot radius equipped with a variable speed-controlled trolley carrying instruments for various hydrodynamic biological studies of mammals and man; and a behavioral pool for echo-location 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 into the laboratory.

Wildlife Refuge (Mission Bay, San Diego). Twenty acres of marshland in Mission Bay belonging to the University constitute a wildlife refuge. Plans call for this land to be used for experimental biology research.



Hydrodynamic biological studies of mammals and man are conducted in Physiological Research Laboratory pools.

San Vicente Lake Calibration Facility (30 miles northeast of San Diego). 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 a 24x50-foot enclosed platform moored in 140 feet of water offering 4,500 feet of unobstructed range.

Special Collections

Echo-Sounding Records (7). Available are soundings from several hundred thousand miles of expedition tracks through all sectors of the Pacific Ocean and parts of the Indian and Arctic Oceans.

Marine Vertebrates (Fish Collection – 7). Here are some 250,000 specimens of 2,000 catalogued species of marine fishes. Added in 1966 were 548 collections.

Marine Invertebrates (Basements of Ritter Hall and Vaughan Aquarium-Museum and at Matthews Campus). In this collection are some 23,000 fully documented plankton samples, augmented by about 1,000 samples annually. Samples are supplemented by full meteorological, hydrographic, physical and chemical data.

Geological Samples (Storage locker adjoins Seawater Test Facility). This collection contains some 3,500 geological samples, including 2,500 cores, some dating back to the days of the expedition by the English oceanographic vessel *Challenger* (1872). Also available for study are dredge-haul samples and manganese nodules, taken mainly from the Pacific and Indian Oceans.

Oceanographic Data Archive (11). This collection includes more than 500,000 bathythermographic temperature observations, tide gauge records taken since 1925 at Scripps Pier, and daily temperature and salinity records from southern California shore stations taken since 1916. The latter records prior to 1949 are in bound volumes of *Oceanic Observations of the Pacific*.

Seawater Collection (7). Begun in 1959, this collection contains approximately 5,000 samples from all over the world. After analyses are made, the extra water may be obtained for scientific purposes.



Technicians examine geological cores taken from bottom of world's oceans and stored under refrigeration for study.

Staff

NAME	RESEARCH GROUP	FIELD
Angeles Alvariño de Leira	Marine Life Research Group	Marine Biology
Victor C. Anderson	Marine Physical Laboratory	Marine Physics
James L. Aronson	Earth Sciences Division	Geology
Gustaf Arrhenius	Earth Sciences Division	Marine Geology
Robert S. Arthur	Division of Oceanic Research	Physical Oceanography
Roswell W. Austin	Visibility Laboratory	Optical Physics
George E. Backus	Institute of Geophysics & Planetary Physics	Geophysics
Arnold E. Bainbridge	Division of Oceanic Research	Marine Chemistry
Manuel N. Bass	Earth Sciences Division	Geology
John R. Beers	Institute of Marine Resources	Marine Zoology
Andrew A. Benson	Division of Marine Biology	Marine Biology
George S. Bien	Division of Oceanic Research	Chemistry
Rudolf Bieri	Earth Sciences Division	Physics
Maurice Blackburn	Institute of Marine Resources	Biological Oceanography
Brian P. Boden	Division of Marine Biology	Marine Biology
Elizabeth Kampa Boden	Division of Marine Biology	Marine Biology
Almerian R. Boileau	Visibility Laboratory	Atmospheric Optics
Milton N. Bramlette	Division of Oceanic Research	Geology
Edward Brinton	Marine Life Research Group	Marine Biology
LeRoy A. Bromley	Seawater Test Facility	Chemical Engineering
Edward C. Bullard	Institute of Geophysics & Planetary Physics	Geophysics
Theodore H. Bullock	Neurosciences	Neurophysiology
Douglas R. Caldwell	Institute of Geophysics & Planetary Physics/ Division of Oceanic Research	Geophysics
Angelo F. Carlucci	Marine Life Research Group	Marine Biology
Thomas E. Chase	Earth Sciences Division	Marine Geology
Tsaihua J. Chow	Division of Oceanic Research	Chemistry
Charles S. Cox	Division of Oceanic Research	Physical Oceanography
Harmon B. Craig	Earth Sciences Division	Geochemistry
Joseph R. Curray	Division of Oceanic Research	Marine Geology
Seibert Q. Duntley	Visibility Laboratory	Physics
Carl Eckart	Non-Divisional Research	Marine Geophysics
Robert W. Elsner	Physiological Research Laboratory	Marine Physiology
A. E. J. Engel	Earth Sciences Division	Geology
Theodore Enns	Division of Marine Biology	Physiology
James T. Enright	Division of Oceanic Research	Biological Oceanography
Richard W. Eppley	Institute of Marine Resources	Biological Oceanography
E. W. Fager	Division of Oceanic Research	Biological Oceanography
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Robert L. Fisher	Division of Oceanic Research	Marine Geology
Arthur Flechsig	Division of Oceanic Research	Biological Oceanography
Abraham Fleminger	Marine Life Research Group	Marine Biology
Theodore Folsom	Division of Oceanic Research	Physical Oceanography
Denis L. Fox	Division of Marine Biology	Marine Biology
Dean L. Franklin	Physiological Research Laboratory	Physiology
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Walter F. Garey	Physiological Research Laboratory	Physiology
Donald Geduldig	Physiological Research Laboratory	Physiology
J. Freeman Gilbert	Institute of Geophysics & Planetary Physics	Geophysics
Edward D. Goldberg	Earth Sciences Division	Marine Chemistry

NAME	RESEARCH GROUP	FIELD
John J. Griffin	Earth Sciences Division	Marine Chemistry
Raphael P. Gruener	Physiological Research Laboratory	Physiology
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James L. Harris	Visibility Laboratory	Optical Physics
†Stanley R. Hart	Earth Sciences Division	Marine Chemistry
Richard A. Haubrich	Institute of Geophysics & Planetary Physics	Geophysics
James W. Hawkins	Earth Sciences Division	Geology
Francis T. Haxo	Division of Marine Biology	Marine Botany
Edvard Hemmingsen	Physiological Research Laboratory	Physiology
Myrl C. Hendershott	Division of Oceanic Research	Physical Oceanography
Nicholas D. Holland	Division of Marine Biology	Marine Biology
Robert W. Holmes	Institute of Marine Resources	Biological Oceanography
Osmund Holm-Hansen	Institute of Marine Resources	Biological Oceanography
*Carl L. Hubbs	Division of Marine Biology	Marine Biology
Douglas L. Inman	Division of Oceanic Research	Physical Oceanography
John D. Isaacs	Marine Life Research Group	Biological Oceanography
*Martin W. Johnson	Marine Life Research Group	Marine Biology
Charles D. Keeling	Division of Oceanic Research	Marine Chemistry
Hans T. Klein	Marine Life Research Group	Biological Oceanography
Margaret Knight	Marine Life Research Group	Biological Oceanography
Minoru Koide	Earth Sciences Division	Marine Chemistry
‡Devendra Lal	Earth Sciences Division	Nuclear Geophysics
Ralph Lewin	Division of Marine Biology	Marine Biology
Leonard N. Liebermann	Marine Physical Laboratory	Physics
Alan R. Longhurst	Institute of Marine Resources	Biological Oceanography
‡Michael Longuet-Higgins	Division of Oceanic Research	Physical Oceanography
C. Lorenzen	Institute of Marine Resources	Biological Oceanography
Michael S. Loughridge	Marine Physical Laboratory	Geology
Carl D. Lowenstein	Marine Physical Laboratory	Physics
Ferren MacIntyre	Division of Oceanic Research	Marine Chemistry
Edward D. McAlister	Applied Oceanography Group	Physics
*George F. McEwen	Division of Oceanic Research	Physical Oceanography
John A. McGowan	Marine Life Research Group	Biological Oceanography
William L. McLeish	Applied Oceanography Group	Physics
Gillian Maggert	Marine Life Research Group	Biological Oceanography
Tetsuo Matsui	Marine Life Research Group	Biological Oceanography
Henry W. Menard, Jr.	Earth Sciences Division/ Institute of Marine Resources	Marine Geology
Julian Miller	Marine Life Research Group	Biological Oceanography
James R. Moriarty	Division of Oceanic Research	Submarine Geology
John D. Mudie	Marine Physical Laboratory	Geophysics
Michael M. Mullin	Institute of Marine Resources	Biological Oceanography
Walter H. Munk	Institute of Geophysics & Planetary Physics	Geophysics
Tadashi Nakajima	Division of Marine Biology	Biochemistry
William A. Newman	Non-Divisional Research	Marine Biology
William A. Nierenberg	Director	Physics
John Northrop	Marine Physical Laboratory	Marine Geophysics
Benton B. Owen	Marine Physical Laboratory	Chemistry
Frances L. Parker	Division of Oceanic Research	Paleontology

NAME	RESEARCH GROUP	FIELD
M. N. A. Peterson	Division of Oceanic Research	Marine Geology
Fred B Phleger	Division of Oceanic Research	Marine Geology
Rudolph W. Preisendorfer	Visibility Laboratory	Mathematics
Arthur D. Raff	Marine Physical Laboratory	Marine Geophysics
Russell W. Raitt	Earth Sciences Division	Marine Geophysics
*Norris W. Rakestraw	Division of Oceanic Research	Marine Chemistry
Robert A. Rasmussen	Marine Physical Laboratory	Marine Physics
Archibald M. Reid	Earth Sciences Division	Mineralogy
Joseph L. Reid, Jr.	Marine Life Research Group	Physical Oceanography
*Roger R. Revelle	Non-Divisional Research	Marine Geology
†Sumner Richman	Institute of Marine Resources	Marine Biology
William R. Riedel	Division of Oceanic Research	Marine Geology
Margaret K. Robinson	Division of Oceanic Research	Physical Oceanography
Richard H. Rosenblatt	Division of Marine Biology	Marine Zoology
Andre M. Rosfelder	Earth Sciences Division	Geology
Philip Rudnick	Marine Physical Laboratory	Physics
Hideo Sakata	Physiological Research Laboratory	Physiology
Milner B. Schaefer	Institute of Marine Resources	Biological Oceanography
Walter R. Schmitt	Marine Life Research Group	Biological Oceanography
Per F. Scholander	Physiological Research Laboratory	Marine Physiology
Richard A. Schwartzlose	Marine Life Research Group	Biological Oceanography
John G. Sclater	Marine Physical Laboratory	Geophysics
*Francis P. Shepard	Division of Oceanic Research	Submarine Geology
George G. Shor, Jr.	Division of Oceanic Research/Marine Physical Laboratory	Marine Geophysics
Maxwell Silverman	Non-Divisional Research	Naval Engineering
John Sinkankas	Earth Sciences Division	Geology
Raymond C. Smith	Visibility Laboratory	Physics
Stuart M. Smith	Earth Sciences Division	Marine Geology
Frank Snodgrass	Institute of Geophysics & Planetary Physics	Geophysics
James M. Snodgrass	Special Developments	Instrumentation
Fred Noel Spiess	Marine Physical Laboratory	Marine Physics
John D. Strickland	Institute of Marine Resources	Biological Oceanography
Bruce A. Taft	Marine Life Research Group	Physical Oceanography
John H. Taylor	Visibility Laboratory	Psychology
William H. Thomas	Institute of Marine Resources	Biological Oceanography
John E. Tyler	Visibility Laboratory	Physics
Victor Vacquier	Earth Sciences Division	Geophysics
Tj. H. van Andel	Division of Oceanic Research	Marine Geology
William G. Van Dorn	Division of Oceanic Research	Physical Oceanography
Benjamin E. Volcani	Division of Marine Biology	Marine Microbiology
Theodore Walker	Division of Oceanic Research	Marine Biology
*Charles D. Wheelock	Non-Divisional Research	Naval Architecture
Donald W. Wilkie	Aquarium-Museum	Marine Biology
Peter M. Williams	Institute of Marine Resources	Biological Oceanography
Edward L. Winterer	Division of Oceanic Research	Marine Geology
Jacqueline Winterer	Earth Sciences Division	Marine Geology
Robert L. Wisner	Division of Marine Biology	Marine Geology
Warren S. Wooster	Division of Oceanic Research	Physical Oceanography
Claude E. Zobell	Division of Marine Biology	Marine Microbiology

*Emeritus

†Visiting

‡One-quarter/year



Publications

Scripps Institution of Oceanography issues a number of publications series and internal reports, in addition to the papers written by faculty and staff members which appear in scientific journals.

Among the various publications and reports, identified further in the section devoted to them, are the *SIO Contributions*, New Series; the *Bulletin*; the Reference Series; *Oceanic Observations of the Pacific*; Indian Ocean publications; and the CalCOFI Atlas Series.

Other published works include abstracts, books, and non-technical papers. Scripps Institution also has contributed maps and patents to the scientific community.

Contributions

The faculty of Scripps Institution of Oceanography is responsible for many papers appearing in scientific publications in the United States and abroad. These papers are collected annually in the volume, *Scripps Institution of Oceanography Contributions*, which the library exchanges with more than 900 educational and governmental institutions throughout the world. Information concerning exchanges is available from Gifts and Exchanges Department, Library, University of California, San Diego, P.O. Box 109, La Jolla, Calif. 92037.

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Scripps Institution of Oceanography Reference Series

This series consists of reports of research in more detail than would normally be appropriate in scientific publications or reports that are of interest only to a restricted audience. The Director of Scripps Institution usually

serves as editor and approving authority for these reports. Information concerning their availability may be obtained from Technical Publications, Director's Office, Scripps Institution of Oceanography, P. O. Box 109, La Jolla, California 92037. Reports in series for 1966 are listed below. The number of pages given below is the total number, including title pages and charts.

- 66-1 Physical, chemical, current measurement and biological data; Swan Song Expedition; 21 August-1 December 1961. September 1965. 143 p.
- 66-2 Physical and chemical data; Gulf Cal; 18 October-10 November 1961. October 1965. 22 p.
- 66-3 ANDERSON, Victor C., Michael S. LOUGHRIDGE and John D. MUDIE. MPL participation in Sealab II. Marine Physical Laboratory. February 1966. 42 p.
- 66-4 Physical and chemical data; CCOFI Cruise 6501; 6 January-18 February 1965. December 1965. 163 p.
- 66-5 Progress report; ONR, oceanic research. June 1965-July 1966. March 1967. 97 p.
- 66-6 Cancelled.
- 66-7 BLACKBURN, Maurice. Scripps Tuna Oceanography Research (STOR) Program. Report for the half-year July 1, 1965-December 31, 1965. (Also issued as IMR Reference Number 66-6) March 1966. 23 p.
- 66-8 Surface water temperatures at shore stations, United States West Coast, 1965, including surface *salinities* from several stations and *five-meter temperatures* and *salinities* at Scripps Pier. April 1966. Marine Research Committee. 24 p.
- 66-9 GORDON, Jacqueline I. Determination by Computer of the Radiance "Red Light" of waves due to a submerged body. Confidential. The title is unclassified.
- 66-10 McGLAMERY, Benjamin L. An image restoration experiment on turbulence-degraded images. Visibility Laboratory. July 1966. 17 p.
- 66-11 VAN DORN, William G. Theoretical and experimental study of wave enhancement and runup on uniformly sloping impermeable beaches. Final Report. May 1966. 125 p.
- 66-12 SQUIER, Earl D. FLIP, acoustical self-noise. Marine Physical Laboratory. July 1966. 9 p.
- 66-13 BAILEY, J. C. Visual search in complex fields, progress report. Visibility Laboratory. June 1966. 21 p.
- 66-14 FRAZER, J. Z., R. W. FITZGERALD and A. M. REID. Computer programs BMX and BMX2 for electron microprobe data processing. (With the Institute for the Study of Matter) June 1966. 70 p.
- 66-15 MILLER, Julian K. Biomass determinations of selected zooplankters found in the California Cooperative Oceanic Fisheries Investigations. Marine Life Research. June 1966. 16 p.
- 66-16 Physical and chemical data. Risepac Expedition; 7-23 December 1961; Proa Expedition; 12 April-6 July 1962; and Zephyrus Expedition; 12 July-26 September 1962. 46 p.
- 66-17 DUNTLEY, S. Q., R. W. AUSTIN, J. H. TAYLOR and J. L. HARRIS. Visual acuity and astronaut visibility; manned space flight experiment S-8/D-13; Gemini V and Gemini VII missions. Visibility Laboratory. July 1966. 44 p.
- 66-18 ISAACS, John D. and Daniel M. BROWN. Isaacs-Brown opening, closing trawl. July 1966. 39 p.

- 66-19 PAULLING, J. R., Jr. and Maxwell SILVERMAN. Model studies for an oceanographic ship derived from an offshore supply vessel. August 1966. 42 p.
- 66-20 Physical and chemical data. California Cooperative Oceanic Fisheries Investigations Cruise 6404; 10 April-1 May 1964 and CCOFI Cruise 6407; 15 June-4 August 1964. September 1966. 130 p.
- 66-21 Unavailable for distribution.
- 66-22 BLACKBURN, Maurice. Scripps Tuna Oceanography Research (STOR) Program, report for the year; July 1, 1965-June 30, 1966. (Also issued as IMR Reference Number 66-13) November 1966. 30 p.
- 66-23 MCGOWAN, John A. and Daniel M. BROWN. A new opening-closing paired zooplankton net. Marine Life Research Program. November 1966. 63 p.
- 66-24 Physical and chemical data. Boreas Expedition; 27 January-1 April 1966 (with some data from other parts of the Zetes Expedition). 185 p.
- 66-25 ANDERSON, Victor C. Final report; Contract Nonr-2216(07); 1 November, 1958-30 September 1963. Marine Physical Laboratory. December 1966. 11 p.
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- 66-9 OLCOTT, H. S. Oxidative deterioration of fish and fishery products. Progress report for the period March 6, 1966 to June 5, 1966.
- 66-10 OLCOTT, H. S. and D. B. MENZEL. Toxic residue in marine foods. Final report for year 1966.
- 66-11 BROWN, W. D. and H. S. OLCOTT. Final report on tuna quality. July 1, 1965 through June 30, 1966.
- 66-12 OLCOTT, H. S. and W. D. BROWN. Comparative biochemical studies of muscle proteins. Progress report for the period May 1, 1966-April 30, 1967.
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- 67-2 BROWN, W. D. and H. S. OLCOTT. Investigations into tuna quality. Progress report for the period July 1, 1966 through September 30, 1966.
- 67-3. FOLSOM, T. R. Studies of background radioactivity levels in marine environment near Southern California. Final report.
- 67-4 PILLAI, K. C., R. C. SMITH and T. R. FOLSOM. The separation and determination of plutonium in sea water and marine organisms.
- 67-5 PILLAI, K. C., A. W. YOUNG, T. R. FOLSOM, and R. C. SMITH. Analytical steps using silicotungstic acid and "duolite C-3" resin effective in purification following concentration of cesium from sea water by the "Conite" method.
- 67-6 STRICKLAND, J. D. H. Artificial ecosystems in marine research.
- 67-7 OLCOTT, H. S. Oxidative deterioration of fish and fishery products. Progress report for the period September 6 through December 5, 1966.
- 67-8 BROWN, W. D. and H. S. OLCOTT. Investigations into tuna quality. Progress report for the period October 1 through December 31, 1966.
- 67-9 Marine Food Chain Group progress report for the period January-December, 1966. Part I, Introduction and account of work in progress; part II, Manuscript reports of work concluded; part III, Data record and comments cruise. FGG 66/1.

- 67-10 BROWN, W. D. and H. S. OLCOTT. Investigations into tuna quality. Progress report for the period January 1 through March 31, 1967.
- 67-11 OLCOTT, H. S. Oxidative deterioration of fish and fishery products. Progress report for the period December 6, 1966 through March 5, 1967.
- 67-12 WOOSTER, Warren S., Milner B. SCHAEFER and Margaret K. ROBINSON. Atlas of the Arabian Sea for fishery oceanography.
- 67-13 SCHAEFER, M. B. A planning study of marine resources. State Standard Agreement P/135-SA-2. Final report.
- 67-14 OLCOTT, H. S. Lipid composition of fish protein concentrate. Progress report for the period ending April 1967.
- 67-15 BLACKBURN, Maurice. Physical, chemical and biological data, Cruise Tempo (TO-62-1), August 1962.

The CalCOFI Atlas Series

This is a series of atlases containing hydrographic and plankton data from the region of the California Current. The field work was carried out by the California Cooperative Oceanic Fisheries Investigations¹, a program sponsored by the State of California under the direction of the State's Marine Research Committee. The cooperating agencies in the program are the California Department of Fish and Game; the California Academy of Sciences; Stanford University, Hopkins Marine Station; U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries; and the Scripps Institution of Oceanography, University of California, San Diego.

CalCOFI atlases² are issued as individual units since they provide processed physical, chemical, and biological measurements of the California Current region. Each atlas may contain one or more contributions. A general description of the CalCOFI program with its objectives appears in the preface of Atlas No. 2.

CalCOFI atlases are prepared by the Data Collection and Processing Group for the Marine Life Research Program of Scripps Institution. The CalCOFI atlas editorial staff comprises Dr. Abraham Fleminger and Hans T. Klein as editors, and John G. Wyllie, principal analyst for physical-chemical oceanographic data.

CalCOFI Atlas No. 4, by J. G. Wyllie, entitled "Geostrophic flow of the California Current at the Surface and at 200 Meters," was published during 1966.

¹ Usually abbreviated *CalCOFI*, sometimes *CALCOFI* or *COFI*.

² For citations an issue in the series should be referred to as *CalCOFI Atlas No.* . . .

Bulletin

Published by the University of California Press, the *Bulletin* is a vehicle for printing lengthy research works in oceanography which have been written by specialists in a given field. Eight volumes of the *Bulletin* have been published since its inception in 1927.

Three volumes are in press. They are:

Volume 9. TAFT, Bruce A. and John A. KNAUSS. Equatorial undercurrent of the Indian Ocean as observed by the Lusiad Expedition.

Volume 10. HUBBS, Carl L., Tamotsu IWAI and Kiyomatsu MATSUBARA. External and internal characters, horizontal and vertical distribution, luminescence, and food of the dwarf pelagic shark (*Euprotomicrus bispinatus*).

Volume 11. Radiolaria in pelagic sediments from the Indian and Atlantic Oceans.

A list of available publications in the *Bulletin* series is available from the University of California Press, 2223 Fulton Street, Berkeley, California 94720.

Technical Memoranda

Information concerning the eligibility of requestors for the following technical memoranda is available from Technical Publications, Director's Office, Scripps Institution:

Dredging	DOR TM-1/65
Proton Magnetometer	DOR TM-2/65
Gravity Coring	DOR TM-3/65
The Sonar Pinger	DOR TM-4/65
Navigation for Preparation of Charts	DOR TM-5/65
Shipboard Sampling of CO ₂	DOR TM-6/65
Echo Sounding	DOR TM-7/65
Wire Rope and Winches	DOR TM-8/65
Piston Coring	DOR TM-9/65
Deep-Sea Camera	DOR TM-10/65
Collection and Care of Submarine Sediment and Rock Samples	DOR TM-11/65
Slack Wire Mooring	DOR TM-12/65
Taut Wire Mooring	DOR TM-13/65
Oriented Coring	DOR TM-14/65
Nansen Bottle Casts	DOR TM-15/65
Seismic Refraction and Reflection Work	DOR TM-16/65
Explosives Handling and Storage	DOR TM-17/65
Arcing	DOR TM-18/65
Air Gun	DOR TM-19/65
Drogues-Parachute	DOR TM-20/65
Net Hauls	DOR TM-22/65
Midwater Trawls (I); Leavitt Plankton Nets (II)	
Heat Flow	DOR TM-23/65
Box Sampler	DOR TM-24/65
Recording Weather at Sea	DOR TM-25/65
Chemistry Sampling	DOR TM-26/65
Large Water Samples for C ¹⁴	DOR TM-27/65
Scuba Diving at Sea	DOR TM-28/65
Microscopy at Sea	DOR TM-29/65
Preservation of Marine Biological Specimens	DOR TM-30/65
Bathothermograph Observations	DOR TM-31/65
Current Meters	DOR TM-32/65

Marine Physical Laboratory Technical Memoranda

Information concerning the Marine Physical Laboratory (MPL) technical memoranda is available from Reports and Drafting, Marine Physical Laboratory, Scripps Institution.

- 177 Final report, reflection studies of sea floor structure along the Alaskan coast, May, 1966.
- 178 The paleomagnetism of deep sea cores, September, 1966.
- 179 Deep sea magnetometer calibration, September, 1966.
- 180 Heat flow instruction manual, February, 1967.
- 181 MPL two-man submarine propulsion controller, October, 1966.
- 182 Operating instructions for MPL proton magnetometer (model #1), January, 1967.

NAGA Reports

From 1959 to 1961, Scripps Institution cooperated with the governments of South Vietnam and Thailand and the U.S. International Cooperation Administration in conducting an oceanographic study of the South China Sea and the Gulf of Thailand.

Certain reports from this Expedition appeared in the SIO Reference Series: Handbook of the food fishes of the Gulf of Thailand, Robert Rofen; SIO Reference 63-18; and final report of the NAGA Expedition, SIO Reference 63-11. In addition, a Scripps Publications Series was established in February, 1964, to provide a medium for publishing the larger papers resulting from this study.

The first report, NAGA Report, v. 2, "Physical Oceanography of the Southeast Asian Waters," by Klaus Wyrski, serves as a background report for the other volumes of the series. Two of these volumes are now in press. Information concerning them is available from Technical Publications, Director's Office, Scripps Institution.

Indian Ocean Program

The Scripps Institution Indian Ocean Program, with Dr. Robert L. Fisher as Director, was established in 1960 to direct and coordinate Scripps field and laboratory-participation in the International Indian Ocean Expedition 1960-65. That Expedition, under the overall sponsorship of SCOR (Scientific Committee on Oceanic Research of the International Council of Scientific Unions), grew out of the international, interagency and inter-laboratory cooperation effected during the International Geophysical Year. In all, ships and scientists of more than 20 countries participated; major participants in the pelagic aspects were the United Kingdom, the U.S.S.R., Australia, and the United States.

Scripps field participation, supported primarily by the

Office of Naval Research and the National Science Foundation, consisted of three expeditions: Monsoon (*Argo*), 1960-61; Lusiad (*Argo-Horizon*), 1962-63; Dodo (*Argo*), 1964.

The first and third cruises were primarily multi-phase geological-geophysical investigations of the central, southern and northeast Indian Ocean and Indonesia, although Dodo did include a cooperative study of the Somali Current with R.R.S. *Discovery* of the United Kingdom. Lusiad included (1) two three-months' studies of the equatorial undercurrent in the two monsoons, a single-ship program in cooperation with scientists of the Narragansett Marine Laboratory of the University of Rhode Island and (2) two-ship geological-geophysical exploration of the western, central, southern, and northeast Indian Ocean. Scripps vessels spent 22 ship-months in the Indian Ocean and steamed 117,000 miles there. Twenty-three foreign scientists representing ten countries took part in shipboard operations.

The Scripps Indian Ocean Program terminated formally in July, 1965, but data reduction and publication of results will continue for a number of years. A 1968-69 geological-geophysical expedition on *Argo* will spend six months in the Indian Ocean, detailing and extending the 1960-64 investigations and applying newly-developed techniques.

Narratives and preliminary results of Monsoon and Lusiad Expeditions were distributed as SIO Reference 64-19, Preliminary results of SIO investigations in the Indian Ocean 1960-63 (Robert L. Fisher, ed.), 237 p. Some published papers have been collected and will be reprinted in the "Collected reprints of the International Indian Ocean Expedition," prepared and distributed by the Office of Oceanography, UNESCO, Paris, France.

Publications during calendar year 1966 resulting wholly or in part from observations made within the Indian Ocean on Expeditions Monsoon, Lusiad or Dodo of Scripps Institution follow:

FISHER, R. L., The median ridge in the South Central Indian Ocean. In Irvine, T. N. (ed.), *The World Rift System: Geological Survey of Canada Paper 66-14*, 1966. pp. 135-147.

FRANCIS, T. J. G. and G. G. SHOR, Jr. Seismic refraction measurements in the Northwest Indian Ocean: *Jour. Geophys. Res.*, v. 71, no. 2, 1966. pp. 427-449.

TAYLOR, P. T. Geothermal and magnetic survey off the coast of Sumatra; 2. Interpretation and discussion of the results: *Bulletin*, Earthquake Research Institute, v. 44, 1966. pp. 541-550.

VACQUIER, V. and P. T. TAYLOR. Geothermal and magnetic survey off the coast of Sumatra; 1. Presentation of data: *Bulletin*, Earthquake Research Institute, v. 44, 1966. pp. 531-540.

VON HERZEN, R. P. and V. VACQUIER. Heat flow and magnetic profiles on the Mid-Indian Ocean Ridge: *Philosophical Transactions*, Royal Society of London, A, v. 259, no. 1099, 1966. pp. 262-270.

VON HERZEN, R. P. and M. G. LANGSETH. Present status of oceanic heat-flow measurements. In *Physics and Chemistry of the Earth*, v. 6, K. Runcorn, ed., Pergamon Press, N. Y., 1966.

Oceanic Observations of the Pacific

Oceanic Observations of the Pacific is a series containing physical and chemical oceanographic data from the Pacific Ocean, collected by Scripps Institution and cooperating agencies for the period 1949 through 1959. Information concerning the series can be obtained from Technical Publications, Director's Office, Scripps Institution.

Volumes:

Oceanic Observations of the Pacific: Pre-1949. W. Wooster, ed., published, 1961.

Oceanic Observations of the Pacific: 1949. N. Rakestraw, ed., published, 1957.

Oceanic Observations of the Pacific: 1950. N. Rakestraw, ed., published, 1960.

Oceanic Observations of the Pacific: 1951. J. Reid, Jr., ed., published, 1963.

Oceanic Observations of the Pacific: 1952. J. Reid, Jr., ed., published, 1965.

Oceanic Observations of the Pacific: 1953. J. Reid, Jr., ed., published, 1965.

Oceanic Observations of the Pacific: 1954. J. Reid, Jr., ed., published, 1965.

Oceanic Observations of the Pacific: 1955. (NORPAC Atlas and Data) N. Rakestraw, ed., published, 1960.

Oceanic Observations of the Pacific: 1955. J. Reid, Jr., ed., published, 1962.

Oceanic Observations of the Pacific: 1956. J. Reid, Jr., ed., published, 1963.

Oceanic Observations of the Pacific: 1957. J. Reid, Jr., ed., published, 1965.

Oceanic Observations of the Pacific: 1958. J. Reid, Jr., ed., published, 1965.

Oceanic Observations of the Pacific: 1959. J. Reid, Jr., ed., published, 1965.

Patents

Information concerning government-owned patents may be obtained from the U.S. Commissioner of Patents, Washington, D.C.

Patents issued during 1965-66 to members of the Scripps staff:

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| T. R. Folsom, et al: | Computing Apparatus
3,275,804 (1966) |
| P. Rudnick | Vertically Compensated Spar Buoy
3,218,655 (1965) |
| J. E. Tyler | Optical Filter
(Patent pending) |
| G. W. Harvey | Surface Collector
(Patent pending) |



Expenditures—1966-67

	CURRENT FUNDS			DISTRIBUTION		
	Total	General ⁻¹	Restricted ⁻²	Salaries and Wages	Other Expenditures	Less: Transfers
Organized Activities—Other—						
Service to Industry	\$ -1,111	\$	\$ -1,111	\$ -2,345	\$ 1,234	\$
Organized Research—						
Administration	116,595	106,213	10,382	101,867	14,728	....
Applied Oceanography Laboratory	214,935	....	214,935	111,802	103,133	....
Deep-Sea Drilling Project	68,490	....	68,490	36,349	32,141	....
Earth Sciences	441,695	94,831	346,864	290,973	150,722	....
Marine Biology	585,685	214,958	370,727	439,410	146,275	....
Marine Facilities—Ship Operations	-20,515	....	-20,515	1,217,340	1,749,972	2,987,827
Marine Facilities—Shops	....	....	....	193,149	97,136	290,285
Marine Life Research—General	815,246	549,922	265,324	602,591	212,655	....
Marine Life Research—Use of Ships	265,993	265,993	....	....	265,993	....
Marine Physical Laboratory	2,164,192	21,856	2,142,336	1,138,265	1,025,927	....
Non-Divisional Research	267,397	140,095	127,302	173,674	93,723	....
Oceanic Research	1,569,376	213,439	1,355,937	918,743	650,633	....
Physiological Research Laboratory	501,674	12,100	489,574	212,388	289,286	....
Ship Conversion and Commissioning	74,405	....	74,405	....	74,405	....
Special Developments	107,394	....	107,394	69,826	37,568	....
Use of Ships	2,418,744	127,589	2,291,155	....	2,418,744	....
Visibility Laboratory	1,113,882	14,807	1,099,075	728,761	385,121	....
Sub-Total	10,705,188	1,761,803	8,943,385	6,235,138	7,748,162	3,278,112
Total	\$10,704,077⁻³	\$1,761,803	\$8,942,274	\$6,232,793	\$7,749,396	\$3,278,112

⁻¹ Funds available for any operating purpose upon designation by The Regents. Primary components of the General Fund are state support, non-resident tuition, and a portion of overhead allocations received from federal grants and contracts.

⁻² Funds subject to restrictions established by the donors, outside agencies, or The Regents. All contracts and grants and private donations constitute Restricted Funds.

⁻³ Does not include \$1,315,074 received from overhead allocations based on federal contracts and grants.



Appendix A

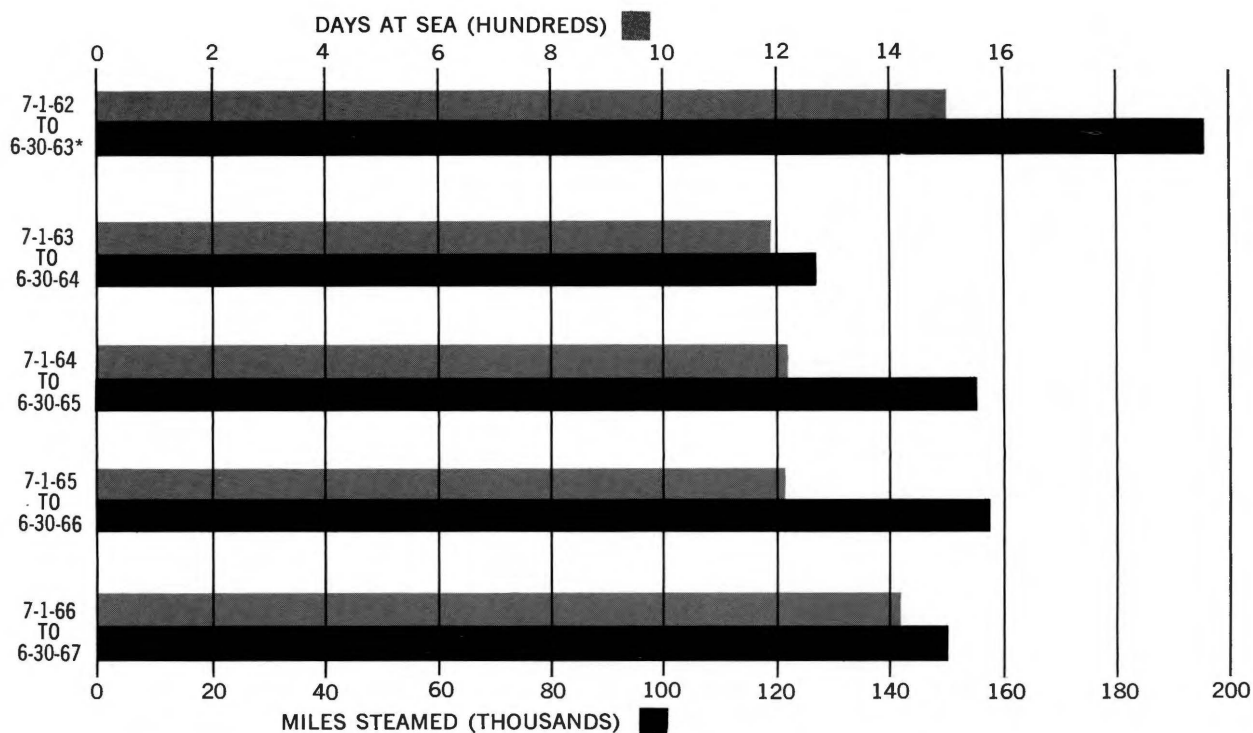
Major Awards and Honors

Among the major awards and honors bestowed upon faculty and staff members of the Institution since July 1, 1965, have been these:

- Dr. Milton M. Bramlette Awarded honorary Doctor of Laws degree by the University of California.
- Thomas A. Clarke Recipient, U.S. Navy's Citation of Meritorious Public Service for participation as scientist-diver in Sealab II program.
- Arthur O. Flechsig Recipient, U.S. Navy's Citation of Meritorious Public Service for participation as scientist-diver in Sealab II program.
- Richard Grigg Recipient, U.S. Navy's Citation of Meritorious Public Service for participation as scientist-diver in Sealab II program.
- Dr. Carl L. Hubbs Recipient, Fellows Medal of the California Academy of Sciences.
- Dr. Martin W. Johnson Recipient, Distinguished Alumnus Award, Pacific Lutheran University, Tacoma, Wash.
- Dr. Walter H. Munk Elected Member, American Philosophical Society; Recipient, Arthur L. Day Medal of the Geological Society of America; Recipient, Harald

- Ulrik Sverdrup Gold Medal of the American Meteorological Society; Recipient, Alumni Distinguished Service Award, California Institute of Technology.
- Earl Murray Recipient, U.S. Navy's Citation of Meritorious Public Service for participation as scientist-diver in Sealab II program.
- Dr. Francis P. Shepard Recipient, Wollaston Medal, highest award of the Geological Society of London. Honored by the naming of the Francis P. Shepard Award for Excellence in Marine Geology, by the Society of Economic Paleontologists and Mineralogists.
- James M. Snodgrass Named Telemetering Man of the Year (1966), by National Telemetering Conference.
- Dr. Fred N. Spiess Recipient, John Price Wetherill Medal of the Franklin Institute of Philadelphia.
- J. Morgan Wells Recipient, U.S. Navy's Citation of Meritorious Public Service for participation as scientist-diver in Sealab II program.
- Dr. Claude E. ZoBell Elected associate founding member of the Surtesy Research Foundation.





*Includes extensive operations during International Indian Ocean Expedition.

Appendix B

Research Vessels of Scripps Institution of Oceanography

	Alexander Agassiz	Argo	Alpha Helix	Horizon	Oconostota	Ellen B. Scripps	Thomas Washington	T-441	FLIP
Type:	light freight	rescue and salvage	oceanographic research (biological)	tug	tug	off-shore supply	oceanographic research	cargo and passenger	floating instrument platform
Hull:	steel	steel	steel	steel	steel	steel	steel	steel	steel
Year built:	1944	1944	1965-1966	1944	1944	1964-65	1965	1953	1962
Year acquired by SIO:	1961	1959	1966	1948	1962	1965	1965	1955	1962
From whom acquired:	State Educational Agency for Surplus Property	U.S. Navy	National Science Foundation	U.S. Navy	U.S. Navy	Dantzer Boat and Barge Co.	U.S. Navy	U.S. Navy	Gunderson Bros. Shipbuilding, Portland, Ore.
Owner:	University of California	U.S. Navy	University of California	University of California	U.S. Navy	University of California	U.S. Navy	U.S. Navy	U.S. Navy
Length:	180'	213'	133'	143'	102'	95'	209'	65'	355'
Beam:	32'	40'	31'	33'	25'	24'	40'	18'	20/12'
Draft:	10'	15' 1"	10' 5½"	13' 6"	10'	6'	14'	6'	10'
Displacement tons (full):	825	2,079	512	900	206	115	1,362	99	2,100 (vertical)
Cruising speed:	11	13	11	11½	12	11	11	10½	varies ⁻¹
Maximum speed:	12	14	12	12½	12	12	12	11	varies ⁻¹
Minimum speed:	3	½	3	½	½	3	½	3	varies ⁻¹
Range (miles):	7,700	8,000	6,200	6,800	6,000	4,700	8,000	1,830	varies ⁻¹
Endurance (days):	27	60	24	48	25	17	48	5	varies ⁻¹
Crew:	17	32	12	19	8	5	25	5	6
Scientific party:	14	24	10	16	6	8	16	9-2	8

⁻¹ Depends on towing vessel

⁻² Including crew

1966 TOTAL DAYS AT SEA: 1,683

1966 NAUTICAL MILES STEAMED: 178,373

Appendix C

Doctor of Philosophy Degrees Awarded in 1965-66 and 1966-67, with Titles of Dissertations

EARTH SCIENCES – 1965-66

- Lewis H. Cohen, "Melting and Phase Relations in an Anhydrous Basalt to 45 Kilobars."
Kent C. Condie, "Petrology and Geochemistry of the Late Precambrian Rocks of the Northeastern Great Basin."
Paul DeMitro Pushkar, "The Isotopic Composition of Strontium in Volcanic Rocks from Island Arcs."

MARINE BIOLOGY – 1965-66

- David James Chapman, "Studies on the Carotenoids of the Flagellate Cryptophyceae, and the Chloroplast Pigments of the Endosymbiotic Algae in *Cyanophora paradoxa* and *Glaucocystis nostochinearum*."
Roger Wolcott Lewis, "Studies of Marine Lipids I. Fatty Acid Composition of Marine Animals from Various Depths II. The Glyceryl Ethers of Some Marine Animals."

OCEANOGRAPHY – 1965-66

- Calvin Crowell Daetwyler, Jr., "Marine Geology of Tomales Bay, Central California."
Jack R. Dymond, "Potassium-Argon Geochronology of Deep-Sea Sedimentary Materials."
Richard Fiske Ford, "Distribution, Population Dynamics and Behavior of Bothid Flatfish, *Citharichthys stigmaeus*."
Brent Sherman Gallagher, "Generation of Surf Beat by a Non-Linear Mechanism."
Ronald John Gibbs, "The Geochemistry of the Amazon River Basin."
Abraham Golik, "Foraminiferal Ecology and Holocene History, Gulf of Panama."
William R. Holland, "Wind-Driven Circulation in an Ocean with Bottom Topography."
Hans Herbert Veeh, " Th^{230}/U^{238} and $U^{234}/^{238}$ Ages of elevated Pleistocene Coral Reefs and Their Geological Implications."

EARTH SCIENCES – 1966-67

- Donald V. Helmberger, "Head Waves from the Oceanic Mohorovicic Discontinuity."

- Albert M. Kudo, "A Study of the Phase Equilibrium of Granitic Melts."

MARINE BIOLOGY – 1966-67

- William Fisher Busby, "Studies on the Identification and Metabolism of the Sulfonic Acids, Systeinoic Acid and Sulfoopropanediol, in the Ciatom, *Navicula pelliculosa*, and their Distribution in the Major Algal Groups."
George Frederick Crozier, "Features of Carotenoid Metabolism in Growth and Sexual Maturation of the Labrid Fish, *Pimelometopon pulchrum* (Ayres)."
Thomas Sterling Hopkins, "Carotenoid Pigment Fractionation and Skin Color Varieties in the Henricia Specion Complex (ECHINODERMATA; Asteroidea)."

OCEANOGRAPHY – 1966-67

- Tim P. Barnett, "On the Generation, Dissipation and Prediction of Ocean Wind Waves."
Abner Blackman, "Pleistocene Stratigraphy of Cores from the Southeast Pacific Ocean."
Anthony J. Bowen, "Rip Currents."
Jean Henri Filloux, "Oceanic Electric Currents, Geomagnetic Variations and the Deep Electrical Conductivity Structure of the Ocean-Continent Transition of Central California."
Kern Kenyon, "Wave-wave Scattering for Gravity Waves and Rossby Waves."
Stanley A. Kling, "Castanellid and Circoporida Radiolarians: Systematics and Zoogeography in the Eastern North Pacific."
Jimmy C. Larsen, "Electric and Magnetic Fields Induced by Oceanic Tidal Motion."
Keith Brian Macdonald, "Quantitative Studies of Salt Marsh Mollusc Faunas from the North American Pacific Coast."
Erk Reimnitz, "Late Quaternary History and Sedimentation of the Copper River Delta and Vicinity, Alaska."
Helmuth Sandstrom, "The Importance of Topography on Generation and Propagation of Internal Waves."

Appendix D

Principal Administrative Officers of the University

President of the University
Charles J. Hitch

Vice President of the University for Administration
Harry R. Wellman

Vice President – Academic Affairs
Angus Taylor

Vice President – Business and Finance
G. C. Bannerman

Vice President – Educational Relations
Frank L. Kidner

Vice President – Executive Assistant
Earl C. Bolton

Vice President – Governmental Relations
Earl C. Bolton

Vice President – Physical Planning and Construction
Robert J. Evans (Acting)

Vice President – University Relations
Thomas C. Sorensen

University Dean of Agriculture
Clarence F. Kelly (Acting)

Dean of University Extension
Paul H. Sheats

University Officers Emeriti

Robert Gordon Sproul
President of the University, Emeritus

Claude B. Hutchison
Vice President of the University Emeritus, and Dean
of the College of Agriculture, Emeritus

Robert M. Underhill
Vice President and Treasurer of The Regents, Emeritus

James H. Corley
Vice President – Governmental Relations
and Projects, Emeritus

University Chancellors

Roger W. Heyns
Chancellor at Berkeley

Emil M. Mrak
Chancellor at Davis

Daniel G. Aldrich, Jr.
Chancellor at Irvine

Franklin D. Murphy
Chancellor at Los Angeles

Ivan H. Hinderaker
Chancellor at Riverside

John S. Galbraith (To resign before beginning
of 1968-1969 academic year)
Chancellor at San Diego

Willard C. Fleming
Chancellor at San Francisco

Vernon I. Cheadle
Chancellor at Santa Barbara

Dean E. McHenry
Chancellor at Santa Cruz

The Regents of the University of California

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Lieutenant Governor of California

Jesse M. Unruh
Speaker of the Assembly

Max Rafferty
State Superintendent of Public Instruction

Allan Grant
President of the State Board of Agriculture

Theodore R. Meyer
President of the Mechanics' Institute

William U. Hudson
President of the Alumni Association
of the University of California

Charles J. Hitch
President of the University

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The term of the appointed Regents is sixteen years,
and terms expire March 1 of the year indicated
in parentheses.

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Samuel B. Mosher (1972)

John E. Canaday (1974)

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Norton Simon (1976)

William E. Forbes (1978)

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Vice Chairman

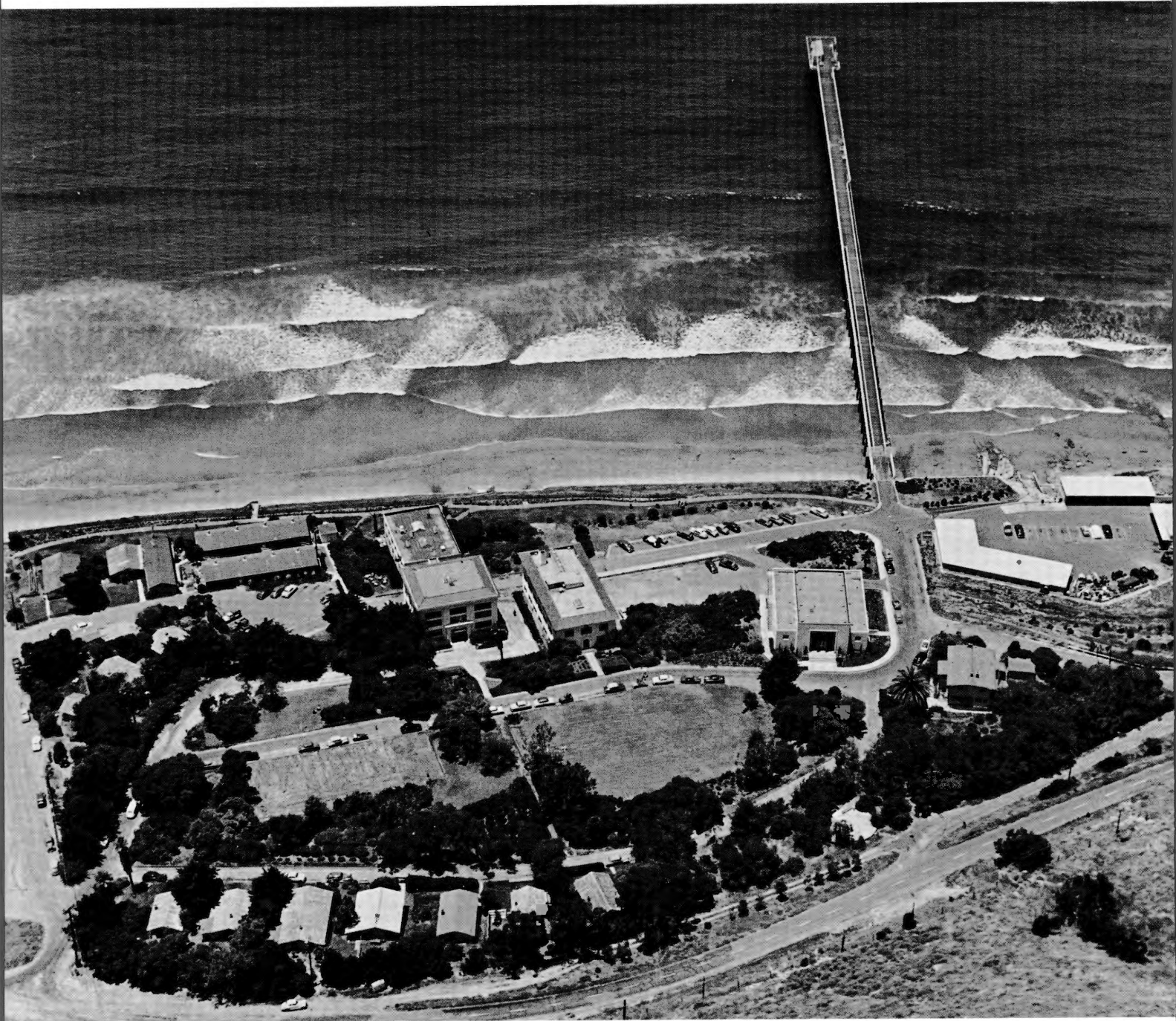
Thomas J. Cunningham
General Counsel

Robert M. Underhill
Treasurer, Emeritus

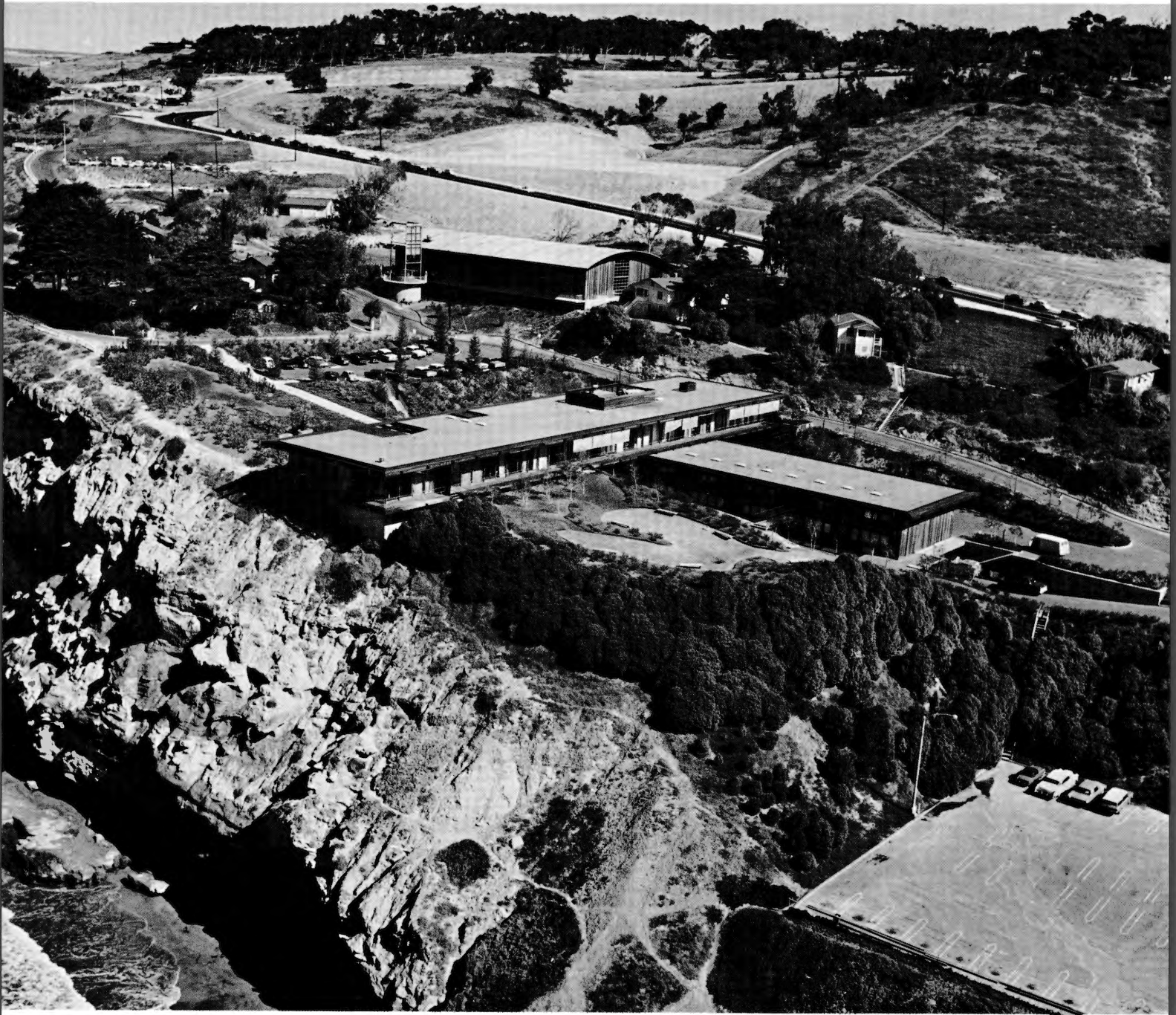
Owsley B. Hammond
Treasurer

Miss Marjorie J. Woolman
Secretary





View in 1952 shows Vaughan Aquarium at right; library, center, with Ritter Hall to its right, Scripps Building to rear.



La Jolla Laboratories of IGPP, foreground, and Scripps' Hydraulics Laboratory, top, overlook rugged shoreline.







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